PU Europe

FIRE SAFETY HANDBOOK

August 2026

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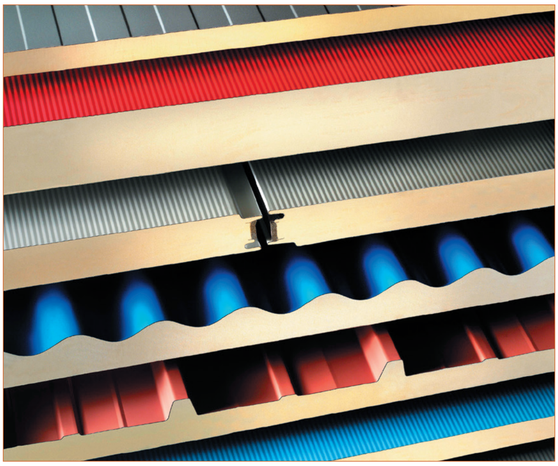
SUSTAINABLE CONSTRUCTION WITH RIGID POLYURETHANE INSULATION

Rigid polyurethane (PU – PUR/PIR) is widely used in all kinds of applications. One of its main uses is as a high-performance thermal insulation material in both residential and non-residential buildings. The term PU is used to denote both PUR (polyurethane) and PIR (polyisocyanurate) building insulation products (a definition of each is given in the harmonised European product standard hEN 13165). PIR was developed to give inherently higher fire performance required by certain applications. Actual fire performance test data shall be obtained where required for each specific product and application. PU insulation products take many different forms, without facings or with a variety of facings from steel to thin foils suited to their end-use application. Key characteristics of PU include its versatility for use in a wide range of applications, durability, and, above all, its outstanding thermal insulation capacity.

The need to cut energy demand and carbon emissions through the provision of energy efficient buildings (see the national implementation of the Energy Performance of Buildings Directive EPBD – latest Directive version EU/2024/1275) has led to an increased demand for PU insulation products. This is due in particular to their very high levels of performance without excessive thickness or weight, minimising any impact on the overall building structure. Quantification of overall environmental performance and economic costs of using PU



insulation in low energy buildings has proven that material selection for sustainability cannot be disconnected from the building context [1]. Knock-on effects of insulation product choices and resulting component thicknesses and fixing systems can become significant in terms of environmental and cost-efficiency performance. It is positive that the latest iteration of the EPB Directive will mandate Whole Life Carbon (WLC) assessment of buildings. In that context, Member States will set limit values and targets, ensuring progressive alignment with climate-neutral ambitions.

Regarding sustainability, the Construction Products Regulation (CPR) 2024 introduces new obligations on environmental performance declaration (EPD) which becomes part of the Declaration of Performance and Conformity (DoPC).

[1] PU Europe factsheet n° 15: *Life Cycle Environmental and Economic analysis of polyurethane insulation in low energy buildings* (2014)

In addition, it is important to understand other aspects that need to be considered in the design and specification of sustainable buildings, such as fire safety.

Enactment of fire safety regulations has always been and remains the responsibility of EU Member States. However, fire test standards and classification systems – on which the regulations are based – are harmonised throughout the EU thanks to efforts pursued under the 1989 directive CPD and the Regulation CPR 2011 (305/2011). Fire safety standards will be further developed under the revised version of the CPR, Regulation (EU) 2024/3110, which is currently being implemented.

Individual Member States, public and private sector procurers are free to set their own requirements on the performance of buildings and construction works and therefore the performance levels of products. The CPR is relied on by the EU Member States to set the building performance itself or its parts, via various European classifications which are applicable to the construction product as placed on the market, e.g. for reaction to fire. Interpretation (of national/local building codes) is almost in every case necessary to make the link between the construction product and the building performance, with regards to fire safety performance. Interestingly, the CPR and country legislations also allow, in some cases, the application of fire safety engineering (FSE) principles and system- or application-related testing to ensure that the most suitable insulation product to achieve optimum overall performance can be specified.

Due to the electrification of buildings other additional ignition sources and fire risks need to be taken into account to assess fire safety. This has to be done on a national level, but is supported by new guidance documents from the EU.

An example is the EU guidance of fire safety for electric vehicles parked and charging infrastructure in covered parking spaces. Further guidelines are under preparation.

PU insulation products meet a wide range of requirements of both national fire regulations and insurance backed standards.

WHAT IS PU?

PU insulation stands for a group of thermoset insulation products based on PUR (polyurethane) or PIR (polyisocyanurate). Their closed-cell structure and high cross-linking density leads to characteristics such as excellent thermal performance, good dimensional stability and high compressive strength. PU insulation has a very low thermal conductivity, starting from as low as 0.019 W/mK, making it one of the most effective insulants available today for a wide range of applications.

PU is also widely used in applications outside the construction industry. This includes clothes, footwear, furniture and mattresses, car parts, fridges and even medical devices.

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FIRE SAFETY IN BUILDINGS

FIRE SAFETY OBJECTIVES

When considering the fire safety of buildings, there are a number of key objectives to be achieved. The primary objective is clearly to prevent loss of life of occupants and fire fighters. A secondary objective is the limitation of damage to property and the protection of the environment.

HOW TO ASSESS FIRE SAFETY?

A fire safety assessment identifies the conditions needed to meet these fire safety objectives and looks at the balance of risk. However, to do the assessment, it is necessary to understand the different factors that will influence the outcome in case of fire. As such it can be decided whether the assessment should focus on the products themselves or the system including the product or a combination of products.

Test methods can help to determine product behaviour in the case of a fire. For the assessment to be valid, it is necessary that the outcome of the fire test gives a valid estimate with regards to the specified fire scenario(s).

FIRE SCENARIOS

Fires can be initiated and can develop in numerous ways, dependent on a number of factors, including:

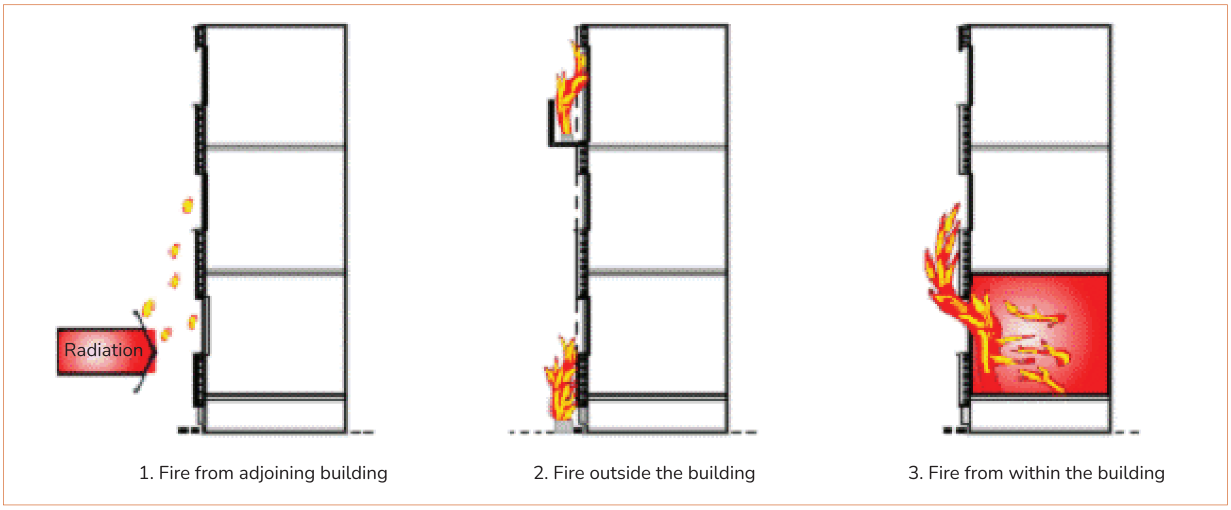


Figure 1: External fire spread mechanisms for façades (Kothoff, 2004)

- Type, intensity and location of the ignition source (see example in Figure 1)
- Primary and secondary ignited items
- Location of the fire
- Fire load density
- Building/room type and size
- Ventilation conditions
- Availability of passive (compartmentation, fire walls/doors, and natural ventings) and active (smoke extraction devices, sprinkler systems) protection measures and provisions for easy access and intervention of fire brigades

Understanding how a particular construction is likely to behave in a fire scenario is an important aspect of fire safety assessment. Eight different fire scenarios have been identified in an EU pre-normative research programme which was finalised in 1995 [2]: a small and large room, a vertical and horizontal cavity, a façade, a corridor, a staircase and a roof. All these scenarios presume that a larger secondary ignited item is present to grow the fire.

RISK ASSESSMENT

- Is the product likely to be the source of ignition?
- Is the product likely to be the secondary ignited item?
- Is the product a potential significant fuel source, even if it is not the first or secondary ignited item?
- What is the potential route to contribution to the risk (and hazard)?
- How close are occupants and/or critical equipment to the origin of a fire?

Whether the assessment focuses on a material, product or system is determined by an investigation of the risk.

[2] A. Pinney, *Update on the European Construction Harmonisation Programme*, Conference "Flame Retardants 96" (1996), p. 23-33

Source: Currenta Fire Technology

Figure 2: Test according to DIN 18234-1 in Germany with PIR insulation board on trapezoidal steel roof deck steel roof deck

The concept of fire scenarios is used extensively in fire safety engineering. The choice of the appropriate fire scenario is vital for the correct assessment of fire risks and fire hazards. Scenario testing is application-related testing and follows the development of the fire until a late stage, possibly until an uncontrollable stage of fire spread. The use of specific application-related tests is increasing in European countries in order to confirm that the product performance determined is in accordance with the level of fire safety applicable in specific countries (including in end-use applications). An example is façade testing where large-scale system testing is the preferred option. System testing should be conducted replicating the intended system for installation (Figures 4 and 5). Another example is testing of large industrial lightweight flat roofs according to DIN 18234 in Germany (Figure 2).

In the sections underneath the specific fire scenarios of internal and external fires are described.

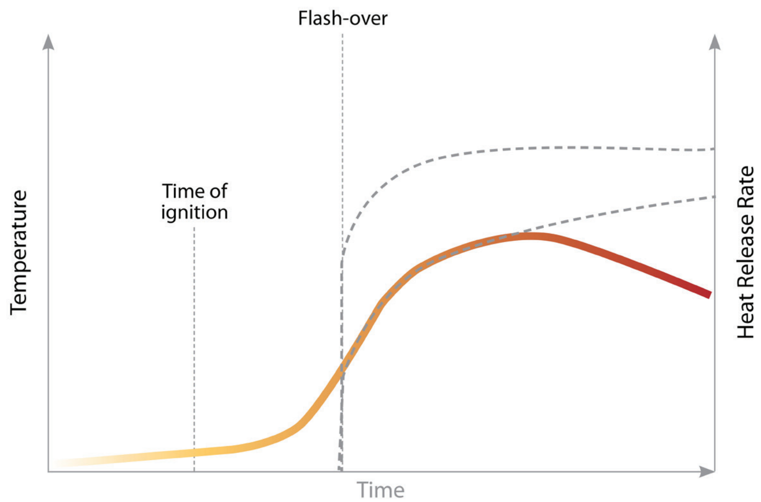
INTERNAL FIRE DEVELOPMENT

There are four key stages of fire development within a building:

- Ignition
- Growth
- Fully developed fire
- Decay

Initially, a source of heat, fuel, and oxygen is needed for ignition to take place. As flames spread and hot gases develop, the temperature of the room or compartment increases. Provided there is sufficient oxygen the fire starts to grow, and other sources of fuel become involved. With additional fuel, the level of heat released increases, and a layer of hot gas will form from the ceiling down. Towards the floor, a cooler layer of gas will be found, and unless the compartment is sealed, the lower pressure of this cooler layer allows an exchange of air from outside, providing the oxygen required for the fire to continue to grow. It is at the growth stage that the reaction to fire of exposed materials is crucial in determining whether or not they will contribute to the fire development, with factors such as ignitability, heat release, and flame spread coming into play.

The transition from a growing to a fully developed fire can be extremely rapid depending on the fire load and the size of the compartment. The International Fire Training Centre gives the following definition of this mechanism: *"In a compartment fire, there can come a stage where the total thermal radiation from the fire plume, hot gases and hot compartment boundaries causes the generation of flammable products of pyrolysis from all exposed combustible surfaces within the compartment. Given a source of ignition, this will result in the sudden and sustained transition of a growing fire to a fully developed fire. This is called a Flashover."* [4]



<table>
<tr><td>Pre-ignition</td><td>Fire growth</td><td>Fully developed fire and fire decay</td></tr>
</table>

<table>
<tr><td rowspan="2">Ignitability</td><td>Flame spread</td><td>Fire penetration</td></tr>
<tr><td colspan="2">Heat development</td></tr>
<tr><td colspan="3">Smoke (loss of visibility, generation of gases, toxicity, corrosivity)</td></tr>
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Figure 3: Development of fires in enclosures [3]

It is generally recognised that if a fire reaches flashover, the chance of escape for occupants in the vicinity becomes considerably less, since heat and smoke are released in significantly greater quantities after flashover. Once a fire is fully developed, fire resistance of building

[3] ISO/TS 3814:2014, Standard tests for measuring reaction to fire of products and materials – Their development and application

[4] International Fire Training Centre, *Firefighter Initial, Working in Smoke*, Issue 1 (January 2003)

Figures 4 and 5: Façade fire test set-ups for EU research project on an inert façade (large and medium exposure) [5]

components (walls, doors, etc.) becomes of the utmost importance by having the load-bearing, insulation and integrity capacity upon which the stability of the building and prevention of further spread of fire and smoke may depend.

A fully developed fire in a room releases the maximum amount of energy, but is generally limited by the amount of oxygen left available to it, and if oxygen remains in short supply and/or the available fuel is consumed the fire will fall into decay.

The Room Corner test ISO 9705 has been developed as a fire test scenario to simulate a fire in a small room, ignited by a burning waste paper basket in one corner. This test was used to help in the development of the 'European classification system' in order to standardise the classification and testing of construction products, especially in relation to flashover. However, the Room Corner test (later published as EN 14390) was developed for internal wall and ceiling lining products, which are directly exposed to a fire. This has led to some inconsistency when it comes to insulation, as the latter is rarely used as an internal lining product, but is almost always installed in a building element behind a thermal barrier lining (see section: European fire standards and national legislation). This aspect is taken into account in the mounting and fixing standard for reaction to fire testing of thermal insulation products (EN 15715), which allows for reaction to fire testing in simulated end-use applications.

EXTERNAL FIRE DEVELOPMENT

Fires develop differently on external horizontal or external vertical surfaces of buildings. Various factors influence the fire development such as wind, the surroundings, e.g. proximity of other buildings, design of the walls or roof, including type and design of the external cladding. Regulations take into account external fire scenarios and specific test standards exist, for example for façades and for roofs. Vertical and horizontal flame spread and break through into the building or to other levels or compartments is considered important. Flashover is not

[5] Source Figure 4: *Comparative document on the analysis of large-scale Round Robin tests on inert façade* (August 2024), p. 23
Source Figure 5: *Comparative document on the analysis of medium-scale Round Robin tests on inert façade* (August 2024), p. 27

relevant as there cannot be formation of a hot layer of fire effluents under the ceiling or roof, and the decay phase will not be triggered by lack of oxygen.

For roofs, system testing has been introduced regarding external fire exposure. In CEN/TS 1187 parts 1-4 and the related classification standard EN 13501-5 the complete roof build-up (for example the combination of the vapour barrier, insulation layer and the waterproofing layer(s)) has to be assessed regarding its fire performance.

For façades, a proposal for a new large-scale and medium-scale test methods (called large exposure test and medium exposure test), based on the German DIN 4102 part 20 and the British BS 8414, was developed in an EU research project finalised in 2025. It is foreseen to develop on this basis a European standard for a reference scenario for façade systems (Figure 6).

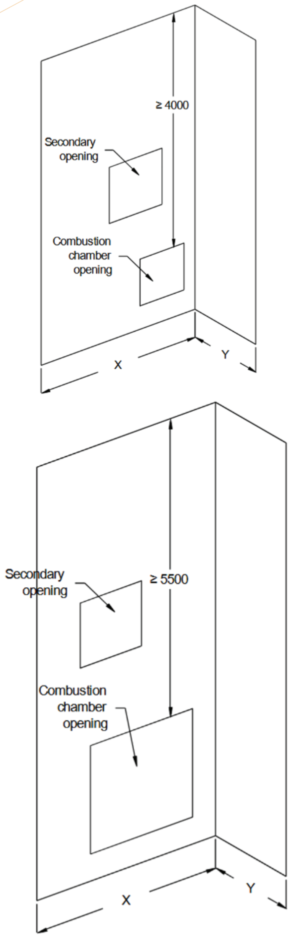


Figure 6: Drawing of the proposed fire test set-up in the EU approach to assess the fire performance of façades. Medium fire exposure is represented above and large fire exposure below [5]

SMOKE AND SMOKE TOXICITY

THE RELEVANCE OF SMOKE

Smoke is a significant hazard. UK and USA statistics have shown that the most common cause of death in a fire is to be overcome by smoke and gases. Smoke can originate from any burning object, and usually initially results from building contents (rather than building structure) combustion [6, 7].

Inhalation of smoke can lead to narcotic effects and irritation and can result in incapacitation or death. There are two key hazard aspects about smoke, namely loss of visibility during escape and intoxication after inhalation of a certain dose of asphyxiant gases (concentration of effluents multiplied by the exposure time) and/or exposure to a certain concentration and dose of irritant gases. Reduction or loss of visibility leads to delays in escape, disorientation and longer exposure times. The control of smoke in buildings is therefore considered an important aspect.

Correctly installed insulation products will not contribute to fire and

[6] Weghorst et al., *An investigation into the relevance of the contribution to toxicity of different construction products in a furnished room fire*
[7] PU Europe factsheet n° 24D: *Fire performance of thermal insulation products in end-use conditions - Building envelope vs buiding content* (2019)

HOW TO CONTROL SMOKE HAZARD [8]

Smoke is always toxic, irrespective of the material that is burning, and impedes escape by reducing visibility. The main steps to control smoke hazard are:

- to make sure fires remain small, by avoiding propagation and ensuring early detection and extinction;
- to limit development and spread of smoke to allow safe evacuation of occupants;
- to avoid exposure and inhalation of smoke to allow safe evacuation and avoid injury.

smoke development in the early phase of a room fire, as there will always be a barrier (e.g. gypsum plasterboard) between the room and the insulation product installed at or in the wall. Tests performed at Exova Gent [6] demonstrated clearly that in a fire in a furnished room untenable conditions in the room are reached long before the insulation products installed behind a layer of gypsum plasterboard start to contribute to fire and smoke development. Therefore, it would not improve the safety level of occupants if the insulation products were tested and classified for the toxicity of their combustion gases.

SMOKE AND REGULATIONS

The prime objective of fire related regulations is to prevent loss of life. In the building sector, limitation of smoke generation and exposure of occupants is achieved by preventing ignition and limiting growth of fire and spread of smoke and by ensuring early alerting of occupants and adequate means of escape through appropriate building design (e.g. provision of exit routes).

One of the most important measures which is used increasingly in many countries is the mandatory installation of smoke detectors in dwellings and in some cases of sprinklers alongside provisions for smoke evacuation especially in escape ways, e.g. in large commercial buildings. In addition, compartmentation is one of the key measures for limiting spread of fire and smoke in a building.

[8] S Levchik, M Hirschler, E Weil, *Practical guide to smoke and combustion products from burning polymers – Generation, assessment and control*, Smithers Rapra (2011)

Depending on the country, for certain building applications, there may be a requirement for the visible smoke performance of construction products, applying mainly for internal fire situations. For external fire situations, smoke is not considered a life hazard and in general there are no or low requirements. Smoke obscuration classification is part of the European reaction to fire standards.

To date, there are no relevant smoke toxicity standards for construction products in the EU Member States. Prevention of exposure is mostly achieved nationally via the above measures and, in some cases, via fire safety engineering (FSE). Nevertheless, some national regulations may include specific requirements. France, for example, has a regulation for combustible insulation that is applied to the internal side of a publicly accessible building without a thermal barrier lining.

LATEST INSIGHTS ON SMOKE TOXICITY OF CONSTRUCTION PRODUCTS FROM THE EU AND FROM THE UK

In 2018, a study was published on behalf of the European Commission [9], with the goal to evaluate the need to regulate within the Framework of the CPR on the toxicity of smoke produced by construction products in fires. The results of this study are based on contributions from European regulators, scientists and industry stakeholders.

A general conclusion of the study is that most of the interviewees did not agree that regulation of toxicity of smoke from construction products is required. The study confirmed that only seven EU Member States referenced regulations on the toxicity of smoke from construction products, but in each case their application is defined and limited in scope.

There were many comments questioning the usefulness of singling out construction products and emphasising that if legislation related to the toxicity of smoke from construction products were considered to be appropriate, it would need to be part of a holistic approach to fire and effectiveness of measures and would need to address the issues associated with the toxicity of smoke produced by building contents.

[9] *Study to evaluate the need to regulate within the Framework of Regulation (EU) 305/2011 on the toxicity of smoke produced by construction products in fires* (15/10/2017, published 18/01/2018)

In addition, recent publications have shown that currently no meaningful laboratory scale test method is available, which can be used for measuring and classifying the toxicity of smoke from all types of construction products taking into account different fire scenarios.

Based on the results of this study the European Commission did not introduce requirements to test, classify or regulate smoke toxicity of construction products.

A similar study has been commissioned by the UK government and was finalised and published in 2025 [10]. The conclusion of this study is similar to the outcome of the EU project: *"The primary conclusion from this work is that it is not necessary to explicitly regulate the toxicity of the smoke produced from burning construction materials".* It is also stated: *"As a consequence, while it may be appropriate to consider regulation of the toxicity of smoke from construction products, the fundamental understanding and the large range of potential variability that may be introduced as a result poses a significant technical challenge to generate robust, repeatable testing framework that allows clear and straightforward interpretation".* Instead alternative measures are proposed concerning reaction to fire of materials, suppression of fire growth, escape ways and smoke management measures.

SMOKE RISKS – ASSESSMENT AND MITIGATION

Smoke is the consequence of a fire and its generation is always dependent on the fire scenario. Smoke can come from a number of ignited sources, and the building contents are likely to be important contributors to smoke emissions. The involvement of the building envelope, including insulation, in smoke production will vary significantly depending on the construction and the conditions under which the fire develops. Each of the distinct stages of a developing and developed fire carries a specific smoke hazard, which may be at its greatest during a non-flaming combustion stage. The stages and scenarios described below are important and are distinctly different in terms of smoke generation:

[10] R Hadden and M Spearpoint, *Fire safety: smoke and toxicity, final report*, University of Edinburgh, OFR, UCL, Efectis (December 2025)

- Smouldering fires or non-flaming fires
- Well ventilated fires or developing flaming fires
- Poorly ventilated fires
- Post-flashover fires

The evaluation of the smoke performance of construction products and determination of the resulting hazard in a building should take into account the relevant fire scenarios (= risk assessment) [11]. Smoke is an integral part of the fire risk assessment. Such an assessment looks at the complete building design and not just at the smoke performance of a building product in a bench scale smoke test. FSE is considered the most effective approach to identify and manage potential risk from smoke, regardless of the type of insulation being used (see also chapter on The role of fire safety engineering).

EXAMPLES OF SMOKE HAZARDS

- A smouldering fire in the room of origin may be a hazard to a sleeping person who does not wake up in time;
- A ventilated, developing fire is not a great hazard for vigilant occupants who are in the room of origin of the fire or in the vicinity of it, as they can escape before the fire grows to a threatening size. However, it could be problematic in spaces from which no escape is possible, e.g. prisons or in occupancies with disabled people who need assistance for evacuation;
- Poorly ventilated fires are characterised by a low oxygen content and higher toxicity of the smoke. Often the size of the fire remains small, however it can grow large instantaneously when oxygen becomes available and then surprise remote occupants or rescue teams;
- One of the greatest smoke hazards is to occupants who are remote from the fire source and who are overcome by smoke from an unnoticed fire that has grown large or that is in post-flashover stage;
- Lack of availability of escape ways which are protected from fire and smoke is one of the biggest hazards in all cases.

[11] Fire risk is defined as a combination of the probability of a fire and a quantified measure or its consequence. Fire hazard is the physical object or condition with a potential for an undesirable consequence from fire (ref.: ISO 13943:2018, *Fire Safety – Vocabulary*)

SMOKE HAZARD POSED BY MATERIALS AND PRODUCTS

All organic materials produce smoke (visible and toxic) when burning. Smoke toxicity, to a certain degree, is not a material property. Depending on the environment, availability of oxygen, thermal attack, ventilation conditions and surface areas available for combustion, the chemistry of the combustion of a given material can proceed along various routes and produce species in very different quantities [12].

Smoke from fire is always highly toxic, irrespective of the materials that are burning. Combustion products of all materials include carbon monoxide (CO), carbon dioxide (CO_2) and water. Nitrogen containing materials, such as wool, silk, nylon and PU, can also produce hydrogen cyanide (HCN) or nitrogen oxides. Halogen-containing materials such as PVC and some flame retarded materials can produce hydrogen chloride (HCl) or hydrogen bromide (HBr). Wood and cellulosic materials produce acrolein, which is one of the most toxic components in smoke.

Asphyxiants such as CO and HCN can cause narcotic effects or can even lead to incapacitation or death. A reduced level or lack of oxygen also causes asphyxiant effects. Irritants, such as halogen chlorides and acrolein, can cause pain during breathing or irritation of the eyes and skin, and can hamper escape or can also add to the overall intoxication.

The dominant toxicant in fires is carbon monoxide (CO), which is produced from any burning organic material. Organic materials give off about 10 to 20 % of their weight in the form of CO when they are involved in a fully developed fire.

Therefore, the chemical composition of the fire load is not the single decisive factor regarding tenability conditions (visibility, heat, toxic hazard) for occupants.

[12] ISO/TR 13571-2:2016, *Life-threatening components of fire – Part 2: Methodology and examples of tenability assessment*

FIRE SAFETY ASPECTS TO CONSIDER

The below list needs to be considered by anyone involved in the construction sector (please also look at the EU Fire safety guide from the www.modernbuildingalliance.eu):

- Fire safety assessments need to take into account a wide range of factors, including occupancy and use, not just building construction;
- Compartmentation can greatly increase the chances of controlling the spread and magnitude of a fire, but it is also quite possible to have a number of compartments involved, each at different stages of fire development;
- Smoke detectors significantly increase the likelihood of the fire being discovered early, allowing a safe evacuation and also increasing the chances of the fire remaining smaller and being contained;
- Sprinkler systems ensure early suppression during the developing stage of a fire;
- The time required to evacuate depends on the size and design of the building, and the purpose to which it is put. For example, a nursing home would need to allow for a longer period of evacuation than an office building, and a multi-storey building would need longer than a single-storey one;
- The European reaction to fire classification of insulation materials is based on tests developed for internal lining products. A broader perspective is needed on insulation fire performance taking into account the context in which it is being used. This approach is gradually being developed, e.g. for façades.

Based on all the above, PU insulation can meet the required fire safety provisions for many applications.

IMPACT OF INSULATION ON FIRE SAFETY IN BUILDINGS

COMMON BUILDING PRACTICE

The way buildings are constructed has changed considerably over the last four decades.

Shopping malls, industrial buildings or cold stores are larger, and high amounts of goods are processed, stored and traded. In today's food industry, hot processing to produce ready-made meals for distribution is common. In general, the fire load of the building contents by far exceeds that of the construction products (see fire load densities of residential houses – Table 1 – and of the insulation – Table 2). Furthermore, the building contents are most likely to contribute first to a fire.

Finally, envelopes of all types of buildings, being residential, commercial, industrial and cold-chain, are becoming increasingly insulated. Thermal bridges are avoided and ventilation is controlled.

These changes in the ways of construction result in different fire risks and hazards.

ESTIMATED FIRE LOAD DENSITIES

Type of room	According to Bwalya et al.		Eurocode
	Average floor area [m²]	Fire load density [MJ/m²]	Average fire load density for residences [MJ/m²]
Kitchen	14.9 ± 4.9	807	780
Bedroom	18.8 ± 7.0	564	
Living room	23.2 ± 9.0	412	

Table 1: Assessment of fire load densities in residential houses according to the study by Bwalya et al. and Eurocode, based on literature published between 1970 and 1983. The Eurocode value is overly conservative compared to conducted surveys [13]

Material	Density [kg/m³]	Thermal conductivity [W/(m·K)]	Thickness [(mm) for U=0.21 W/m²K]	Calorific value [MJ/kg]	Fire load density [MJ/m²]
PIR/PUR	30	0.022	105	30	95
Stone wool (European classification A2)	120	0.040	200	3	72
	160	0.037	185	3	89
EPS	20	0.035	170	40	136
Bituminous roofing membrane 2 layers (8 mm)	1050	0.200	N/A	27	227
PVC roofing membrane 1 layer (1.5 mm)	1300	0.170	N/A	18	35.1

Table 2: Examples of calorific value and fire load density for different insulation materials and different types of roofing membranes (NEN 6090)

[13] *Fire load and fire growth characteristics in modern high-rise buildings*, Fire Safety Journal, Volume 135, Article 103710 (February 2023)

THE NEW BUILDING PRACTICE: HIGHLY ENERGY EFFICIENT BUILDINGS

By 2050, the energy efficiency of buildings needs to be significantly improved [14] in order to achieve a climate-neutral building stock. Key elements to improve the energy efficiency of buildings include the use of more and thicker insulation in the floor, walls and roof, the installation of double- or triple-glazed windows and the use of airtight building envelopes. At the same time a controlled ventilation system is needed. Solar panels may be installed to produce the remaining energy required. Finally, traditional heating sources, which may have been a cause of fire in the past, are less or no longer present in low energy buildings.

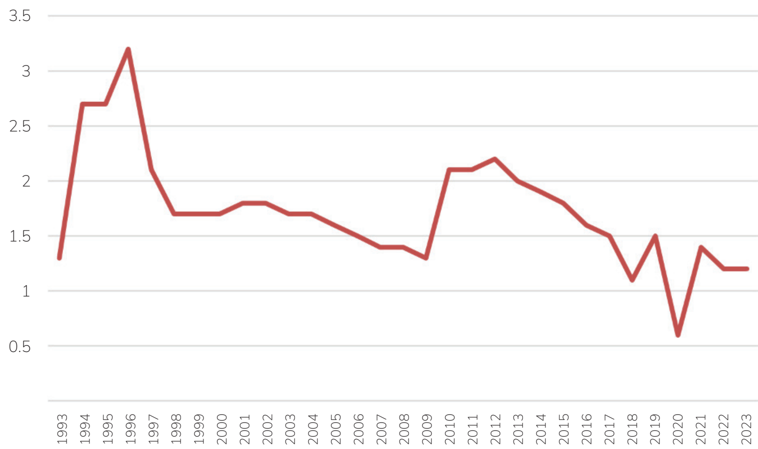
Some media have reported that fires in highly energy-efficient buildings attain flashover more easily [15]. The higher incidence of flashovers has been linked in the media to better insulated houses. A typical question is: are there more intense fires in highly insulated buildings?. The response is not necessarily yes. A fire in a highly insulated building may grow faster compared to an un-insulated building because the heat is retained in the building. This happens irrespective of the type of insulation. However, it is also possible that through controlled ventilation and tighter windows/doors fires may stay smaller. Furthermore, triple-glazed windows may not break or may do so only at a later stage of the fire. Together with air-tightness, this leads to a quick reduction in oxygen in case of fire. When a door opens, this can cause instantaneous revival of the fire as oxygen is rapidly introduced into an enclosed, oxygen-depleted, and fuel-rich space where the temperature inside is still high (backdraft).

In addition, solar installations on roofs or façades may become a source of ignition or contribute to fire spread and can have a significant impact on the fire performance of the building envelope.

Despite the increasing use of insulation and other energy saving measures, the number of fatalities per number of inhabitants has decreased over the years and is approximately constant in Europe since 2018. There are still significant differences between the countries. A

[14] See the revised EPBD issued in July 2018 and the European Green Deal issued end of 2019
[15] The point of flashover is the temperature at which suddenly all combustibles in the premise start to burn so that the fire suddenly changes from a local to an all involving fire

Figure 7: Average number of fire deaths per 100 000 inhabitants, reported by countries [16]



common approach on fire safety in the EU may lead to further reduction of fatalities.

A Dutch national study on the fire safety of combustible insulation materials concluded that when using current and correct applications in the building envelope these products neither significantly contribute to the severity of the fire nor to an increase of fire victims [17]. This conclusion is confirmed by official statistics (see Table 3 and Figure 7). The market share of non-combustible mineral wool insulation in Scandinavia is as high as 85 %, whereas combustible organic insulation materials including PU account for almost half of the insulation market in Western and Central Europe. However, the number of casualties per capita is not lower, and even tends to be higher in Scandinavian residential buildings than in western European countries.

More specifically, a simulation study on fire safety in passive houses, commissioned by the Hoge Raad voor Brandveiligheid (High Council for Fire Safety in Belgium), did not give rise to great concern. The conclusion was that the early phase of the fire is quite similar to traditional buildings and that a passive house does not constitute a higher risk for the escape of occupants. In the later phase, the simulated fire in the passive house resulted in lower temperatures because of lower oxygen levels. The report further determined that there may be a higher risk of backdraft when a door is opened in this phase [18].

[16] World Fire Statistics, International Association of Fire and Rescue Services, Center for Fire Statistics, CTIF report 30 (2025), table 1.1
[17] 2009-Efectis-R0824, *Brandveiligheid van isolatiematerialen*, for Ministerie VROM (February 2010)
[18] S Brohez et al., *Passive House and fire = Inferno?*, Final report financed by SPF Interieur, Direction générale Sécurité Intégrale, Issep, Belgium (2009-2010)

Table 3: Average number of fire deaths per 100 000 inhabitants for major European countries (2019-2023) [19]

Country	Population [x thousand inhabitants]	Average number of fatalities 2019-2023 per 100 000 capita per year
Austria	9 104	0.55
Belgium	11 697	0.44
Bulgaria	6 520	2.20
Denmark	5 944	0.89
Finland	5 565	0.90
France	67 244	0.43
Germany	83 020	0.46
Great Britain	65 185	0.48
Greece	10 788	0.52
Hungary	9 856	1.06
Netherlands	17 591	0.16
Norway	5 109	0.84
Poland	37 366	1.33
Portugal	9 857	0.45
Romania	19 053	1.39
Serbia	6 787	1.50
Slovakia	5 042	1.00
Spain	47 486	0.40
Sweden	10 552	0.85
Switzerland	8 703	0.20

From the above, it may be concluded that fire growth may be different in highly insulated buildings compared to traditional ones, and that, in most cases, this is due to the different building physics and not to the choice of the insulation material.

The changes in building design due to increasing energy efficiency need to be taken into account. When the causes and dynamics of fire are understood, effective recommendations can be formulated when and where needed.

[19] *World Fire Statistics*, tables 1.2 to 1.12

EUROPEAN FIRE STANDARDS AND NATIONAL LEGISLATION

INTRODUCTION

CURRENT TESTING AND STANDARDS

In the past, manufacturers, designers and specifiers operating in the European single market had to cope with a lack of pan-European standardisation for the assessment of the fire performance of construction products. Countries had each developed their own national standards [20], new products continuously arrived on the market, and there was the further complication of the range of applications; for example, is a test assessing the behaviour of a product in a house fire equally applicable to how a product in a large warehouse fire might behave?

The European reaction to fire classification system was introduced in support of the Construction Products Directive (CPD) with the aim of achieving harmonisation and eventually replacing the different national standard tests and classifications. Some correlations could indeed be drawn between the 7 European classes and elements of the pre-existing standards. Although the CPD has now been replaced by the CPR, the European harmonised test methods and classifications remain the same.

Harmonised test and classification standards are describing fire tests and performance criteria for all European construction products allowing to define simple unified levels of performance. In order to ensure that these classifications can be applied correctly to all applications in all types of buildings, the direct application of the test results (DIAP) as well as the extended field of application (EXAP) are defined partly in fire standards and partly in harmonised product standards.

Both DIAP and EXAP rules exist more widely for resistance to fire test standards than for reaction to fire test standards. Whereas DIAP rules are limited to the particular product tested, with only minor variations permissible, EXAP rules allow for greater variations, within the parameters of accepted knowledge and experience. Discussions continue in Europe on EXAP rules to develop new and revise existing EXAP standards. In many Member States national EXAP rules also exist, e.g. for external fire performance of roofs, which continuously are replaced by European standards. A number of EXAP rules are published, e.g. CEN/TS 15117 “Guidance on direct and extended application” and EN 15725 “Extended Application reports on the fire performance of construction products and building elements, principle of EXAP standards and EXAP reports”. Further specific EXAP standards also exist for various applications.

Essentially, the harmonised tests and standards are in place, but it is still for the responsibility of

[20] E.g. UK: BS 476; France: NF P 92-50x; Germany: DIN 4102-x

each Member State to decide for itself what level of classification for fire safety is considered acceptable for each type of application.

FIRE STANDARD CATEGORIES

Fire regulations historically refer to three basic categories of fire standards: reaction to fire, resistance to fire and external fire performance of roofs. A fourth category is used increasingly and a European research project was performed for setting a European approach to "asses the fire performance on façades". The next step will be the introduction of a European standard. This was triggered by the introduction of new façade systems in buildings and an increasing number of high-rise buildings.

Each of these categories is expanded upon in the following sections.

REACTION TO FIRE

A reaction to fire test assesses how easily a product can be ignited and contribute to fire growth. It relates mostly to the early stages of a fire development and is arguably mostly relevant to those products directly exposed to the fire source, i.e. wall linings, ceiling linings and external wall surfaces. It is also relevant for assessing the performance of construction products during construction or during building maintenance, e.g. welding of the building elements.

EUROPEAN CLASSIFICATION

Under the European classification system for reaction to fire as defined in the standard EN 13501 part 1, construction products are tested for reaction to fire and divided into seven European classes:

- A1 and A2;
- B, C, D, E;
- F for materials which fail European class E criteria.

No performance determined (NPD) exists where no test has been performed. The classification of PU insulation can range from B to F depending on a variety of factors, including types of facings, the formulation used and the end-use conditions.

Further classifications are used to indicate smoke production (s1, s2 and s3), and burning droplets (d0, d1 and d2). PU can achieve any class between s1 and s3 for smoke development, again depending on formulation, facings and end-use conditions, but as a thermoset material it does not produce droplets and therefore always achieves d0.

Alongside the European classification system there is a European test method to assess a building product's propensity to undergo continuous smouldering (EN 16733). Smouldering or continuous glowing represents slow, internal combustion processes that can lead to fires breaking out some distance and time away from the original source of ignition. This characteristic is considered a risk, regarding hidden spread of fire and persistence of ignition sources after fire brigades have assumed that a fire is completely extinguished.

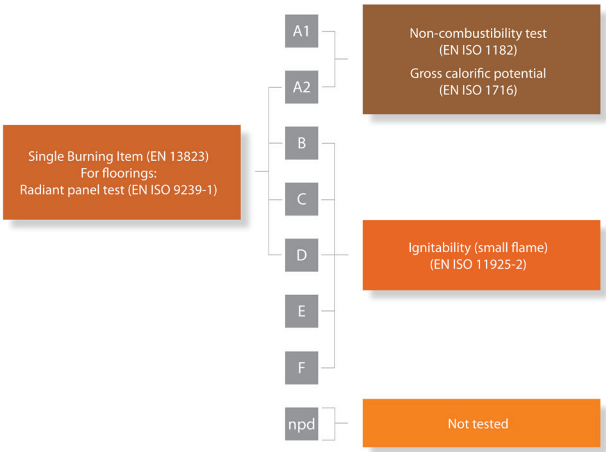
Other parts of EN 13501 cover classification for resistance to fire (parts 2, 3 and 4), external fire performance of roofs (part 5) and cables (part 6).

EUROPEAN FIRE STANDARDS TO DETERMINE EUROPEAN REACTION TO FIRE CLASSES

The following tests are used to determine the European reaction to fire classes for all construction products except floor coverings and cables:

EN ISO 1182	Non-combustibility test
EN ISO 1716	Determination of the heat of combustion
EN ISO 13823	Single Burning Item (SBI)
EN ISO 11925-2	Ignitability of products subjected to direct impingement of a small flame

The first stage of testing for combustible products is EN ISO 11925-2, which simulates a small flame ignition such as a cigarette lighter or a match being applied for a short time (15 seconds) to the edge



Reaction to fire classes (European classes) CEN standards

Contribution to fire	Smoke production	Burning droplets
A1	Not applicable	Not applicable
A2	s1, s2, s3	d0, d1, d2
B	s1, s2, s3	d0, d1, d2
C	s1, s2, s3	d0, d1, d2
D	s1, s2, s3	d0, d1, d2
E	Not tested	None or d2
F	Not tested	Not tested

Figure 8 (left): Tests needed for classification of reaction to fire

Table 4 (right): Possibilities for reaction to fire classes

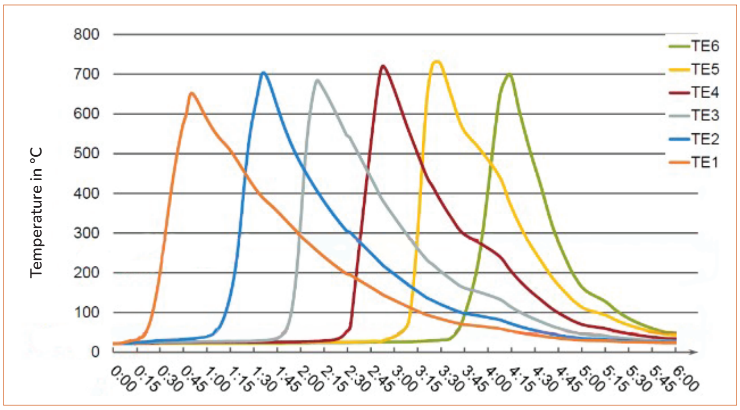
or surface of the product being tested. This can result in an E or F classification. A 30 s exposure is a prerequisite for the SBI test, when the aim is to achieve classes B, C or D.

In the SBI test method according to EN 13823, a specimen is exposed to a gas flame of 30 kW simulating a single burning item in a corner (i.e. waste paper basket).

The exhaust gases are analysed. From the amount of oxygen consumed and the amount of CO released, the heat released by the burning specimen can be calculated. The main classification is based on the criteria FIGRA (Fire Growth Rate) and THR (Total Heat Release within 10 minutes), and for the higher classes lateral flame spread is also taken into account.

In the exhaust duct, smoke obscuration is also measured resulting in the parameters SMOGRA (Smoke Growth Rate) and TSP (Total Smoke Production – measured over 10 minutes) which form the basis for the smoke classification of the product.

The third parameter for classification is based on the visual observation of whether burning droplets (outside the burner area) are observed during the test.



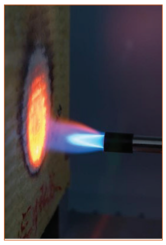



Figure 9: Test and example for results for a product showing smouldering combustion

Smouldering is a criterion alongside the reaction to fire classification for products classified C or better, introduced on request of some national regulators. PU products currently do not need to be tested for smouldering, as PU rigid foam is generally considered as a product which cannot undergo smouldering combustion, based on the initial tests when the standard EN 16733 was developed and introduced. At the time of publication of this handbook the future approach following the new version of the CPR is still under discussion. To avoid unnecessary testing it might become necessary that for a classification for PU rigid foam as product which does not smoulder a CWFT (Classification Without Further Testing) will be requested.

For floor coverings, an existing horizontal flame spread test allowing also a smoke classification, EN ISO 9239-1, has been adopted for the classes $A2_{fl}$ to D_{fl}, instead of the SBI.

BACKGROUND TO THE REACTION TO FIRE CLASSIFICATION OF PRODUCTS

The European classification for a product is determined via small- and medium-scale test methods.

In some cases, and for some products, the proposed European classification system was not considered acceptable. This was the case for linear products. For cables, pipe insulation and pipes, a different classification system for reaction to fire has been developed and adopted and included in EN 13501-1 (linear products). For cables, special tests have been developed which allow a classification according to EN 13501-6 (cables).

The reaction to fire classification of a product should not be confused with fire safety performance in a building. It should not be assumed that by using an A2-rated product a building will always be fire-safe or that with an E-rated product the building will be less fire-safe. Fire safety in a building strongly depends on how the products have been installed/applied. For other than wall and ceiling lining products, there may not be an easy link between the reaction to fire class of the product and its actual performance in the building.

The interpretation of the safe use of construction products is made via the national (Member State) building fire regulations.

REACTION TO FIRE CLASSIFICATION IN END-USE

Testing insulation boards as such does not take into account the context in which they are used, e.g. behind a covering such as plasterboard or bricks.

It is written in the scope of the classification standard for reaction to fire, EN 13501 part 1, that testing is supposed to be in relation to the end-use conditions of the construction product. The SBI standard EN 13823 gives some basic rules for mounting and fixing, but that may not be sufficient. Specific mounting and fixing conditions can be used provided the manufacturer communicates the boundary conditions of the declared European class clearly. Therefore, product specifications (harmonised product standards and EADs) may contain additional mounting and fixing rules.

The first version of the insulation product standards did not have additional mounting and fixing rules. It soon became clear that the classification of the insulation product as such does not reflect the behaviour of the product in its real end-use application. A mounting and fixing standard (EN 15715) was developed and adopted to be used with the product standards. This allows the manufacturer to classify their product tested in the SBI in a number of specific set-ups simulating end-use conditions, as well as the product as placed on the market. In some Member States, an end-use classification is needed for the interpretation of the national regulations.

RESISTANCE TO FIRE

One definition of fire resistance is "the ability of a structural element to sustain the performance of its structural duty, whilst being exposed to the temperatures likely to be encountered in a developed fire for specified periods of time" [21].

Consequently, resistance to fire relates to the structure, which mostly is a combination of products, including fixing methods. However it could consist of a single or a composite product. Classification and certification are therefore awarded to that particular construction or product as a whole, and not to the individual materials it is made of.

With this kind of testing, there are many possible different combinations of products and fixings making up the overall structure, and it is impractical to test every permutation. Because of the huge amount of variations that are possible, harmonised standards are accompanied by direct and extended field of application rules.

The most relevant test standards are EN 1363, EN 1364, EN 1365 and EN 1366. The main parameters are:

R = the load bearing capacity of the element, looking at strength and stability;

E = the integrity of the element, the ability of the element to contain flames;

I = insulation; the ability of the element to limit the heat transfer to the side facing away from the fire.

The results are expressed as the number of minutes all three aspects resisted under the effects of a fire, so an element fulfilling all of these criteria for 30 minutes would be classified as REI 30. The classifications for resistance to fire are described in EN 13501-2, -3 and -4.

[21] PU Europe factsheet n° 1: *Fire resistance of different insulation materials in pitched roofs and timber frame walls*

Because the test sample has to represent the complete element (roof or wall, etc.), determining REI requires testing on a large scale and is expensive. For example, a flat roof test would need to include the supporting roof deck, the waterproofing layer, as well as the insulation respecting the method of fixing intended in the building.

Naturally, the degree to which the insulation has an opportunity to play a role in fire resistance depends on the construction. For instance, if a flat roof with a concrete slab base were being tested, it would give several hours of fire resistance, regardless of what other products were placed on top, and when it does fail, the performance of the other products would be irrelevant, as the structure itself would already be compromised.

Regarding the insulation criterion (I), experience and testing have shown that structures insulated with rigid polyurethane insulation (PU) products show excellent fire performance in real fire scenarios due to their thermosetting character and high thermal stability. This is especially so with PIR insulation, which is formulated for improved fire resistance. The char generated on the surface of the insulation protects the core from decomposition, so the integrity of the structure is maintained for a long time even if heavily attacked by the fire. Structures insulated with PUR/PIR insulation can perform better than or give performance equivalent to structures insulated with other mainstream insulation materials. PUR/PIR insulation performs better than the European classification system for 'reaction to fire' might indicate. PU insulation does not melt or drip when heated. Evidence is provided through the tests described in the examples in the section Combustibility behaviour of insulation products (Performance in application-related tests).

EXTERNAL FIRE PERFORMANCE OF ROOFS

In many countries, regulators want to avoid that a fire is spreading across the entire roof or into the building if the roof is exposed to radiation, burning debris or brands from a fire on a neighbouring building, a chimney or roofing works.

EXAMPLE OF DIFFERENT COUNTRIES APPROACHES TO CEN/TS 1187

Scenario according to CEN/TS 1187	Origin	Exposure	Criteria
1187-1	Germany	Burning brand	External and internal fire spread, burn through, droplets, glowing
1187-2	Nordic countries	Burning brand, wind	External and internal fire spread
1187-3	France	Burning brand, wind and radiation	Time of external fire spread to a defined limit and to penetration
1187-4	UK	Gas flame, wind and radiation (as in BS 476 part 3)	Penetration, flame spread and duration of burning

Table 5: Example of different countries approaches to CEN/TS 1187

In this context a number of tests and classification criteria had been developed in different EU Member States. It was not possible to agree on a single harmonised test and classification method in Europe. Therefore, a technical specification (CEN/TS 1187) and the classification standard EN 13501-5 were developed, allowing for four different test methods and classifications, which enable the member countries to choose for their regulations.

CEN/TS 1187 is a system test, where all the components are taken into account. These are normally the supporting roof deck, insulation layers, vapour barriers and waterproofing layers on top. More layers may be present. If every variation of one of these components had to be tested, costs would be extremely high. Based on the experience with national tests, rules for direct and extended application of test results for the different tests have been developed in CEN/TS 16459. For a number of roof systems, experience shows that the covering layer is able to protect the layers below from any impact of a fire from outside. This is why the European Commission took a decision in 2000 to allow a deemed-to-satisfy list for a number of roof coverings. This includes products like stone, fibre cement and steel, and covers also steel-faced sandwich panels with PUR or PIR core material which are CWFT (Classified Without Further Testing) classified B_{ROOF}(t1, t2 or t3) if certain conditions are met (thickness of covering layer, etc.).

Towards a single harmonised test scenario? There was some discussion at the European level to only get one test; however, this was very difficult and complex due to a high number of parameters. As a result, the discussion has stalled and is currently no longer active.

Incidents and research testing have shown that the impact of a fire on a roof below PV panels is different from the external fire scenarios as defined in CEN/TS 1187. Currently a discussion is ongoing within CEN/TC 127 on how the impact of PV panels mounted above a roof can be assessed – it is expected that a project will be started in 2026 to define a test and classification method for roofs with PV panels mounted above.

FIRE PERFORMANCE OF FAÇADES

With increasing requirements for energy saving, more and more houses are insulated, notably by applying thermal insulation systems on the outside of the building walls. Also increasingly medium- and high-rise buildings are constructed. During recent years, regulations regarding fire safety of these insulation systems have been introduced in most European countries. For other applications in buildings, these requirements are mainly based on the results of laboratory tests, but for façades, full-scale tests have been developed to show the behaviour of the whole façade, including insulation and cladding.

WHAT ARE THE RELEVANT FIRE SOURCES AND HOW DOES A FIRE DEVELOP ALONG A FAÇADE?

A fire on a façade can be initiated either by a burning house near the façade, or by a burning item close to the façade (burning car or waste container). The most frequent and in many cases the most severe fire source for a façade is a fire resulting from a flashover situation in a room. In this situation a fire starts in a room and after some time the window breaks and then flames are soon so high on the façade that they reach the window of the floor above the initial fire. After some further time, this window is also destroyed and the fire ignites the items in this room. When flashover is then reached in the room on the next floor, the same process starts again. Such a fire will always spread upwards, but that takes some time. If the façade is insulated, it is important that the façade cladding and insulation system do not contribute to a fast fire spread upwards.

As there have been some fires in recent years where, for example, burning waste containers or vehicles in front of buildings have caused serious façade fires, some countries (i.e. Germany) are now applying additional tests and requirements regarding the performance of façade systems when exposed to a severe external fire source.

FIRE TESTS FOR FAÇADES

In the past, most countries set requirements for outer façade insulation based on the classifications obtained from the usual laboratory tests. Experience has shown that, in some cases, these tests do not give sufficient information about the performance of the complete insulation and cladding system in a real fire. Therefore, full-scale tests have been developed in several European countries. Most of these tests are based on the scenario of a fire in a room breaking through a window. In most cases, the parameters measured include the observation of flame spread (visual observation and temperature measurements), the assessment of damage on the outside of and within the insulation system after the test, and burning droplets and parts or debris falling down.

There are significant differences between the tests depending on the country. The main parameters that differ include the following:

- Type of fire source (some tests use wood cribs, others gas burners or liquid fuels)
- Size of fire source
- Specimen configuration (corner or flat wall, additional openings/windows)
- Height of test rig

In UK, for example, a test method according to BS 8414 (parts 1 and 2) has been introduced which is one of the most severe full-scale façade fire tests in Europe.

The specimen is 9.7 m high and around 4 m wide and has a 2 m x 2 m opening at the bottom for the burn chamber. Around 400 kg of wood is placed in the burn chamber, which produces a heat output around 3 MW intended to represent a room in flashover, with flames venting out a window and attacking the façade. Criteria for passing the test are defined in BR 135. Currently this method can be used to support the approval of residential buildings up to 18 m and of higher non-residential buildings in GB. It is also applied for higher buildings in some other countries and other parts of the UK.

In Germany the fire load during the test according to DIN 4102-20 is lower, and a general limit for the use of combustible products within a façade cladding system has been set such that above a height of 22 m (highest occupied floor), independent from the use of the building, combustible products are not allowed. In addition, a further test for façades has been introduced with a fire load similar to the BS 8414 test to simulate a fire from the outside of the façade (for example, burning waste container).

In France, a large-scale façade fire test called LEPIR 2 has been developed. The test, required by French fire regulations for certain residential and public buildings, evaluates vertical fire spread from floor R to R+2. A fire load of two 300 kg wood cribs is placed in two rooms with window openings.

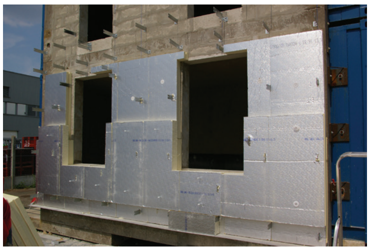


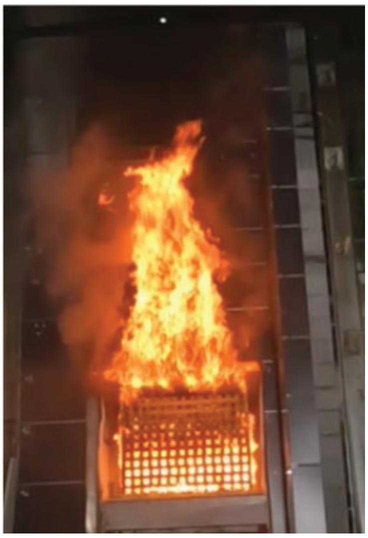
Figure 10: Construction of the façade with PIR insulation for LEPIR 2 test

Figure 11: Photos illustrating the test stages of the LEPIR 2 test on a façade with PIR insulation

8 min and 20 sec

12 min and 55 sec

25 min and 50 sec



Figures 12 and 13: Proposed large exposure test method – European research project [22]

A test carried out by CSTB on behalf of SNPU in July 2013 is an example for the performance of a well-constructed façade system with PU insulation. 240 mm of PU insulation were used and it was demonstrated that there was no vertical or lateral fire spread, no ignition or melting at upper levels, and that effective fire compartmentation was achieved through a fire separation between levels R+1 and R+2 ensured by a full-width steel sheet across the façade, providing continuous fire stopping through all insulation layers and the cladding, as well as a non-combustible cladding skin – confirming the critical role of façade design in fire safety performance.

Various further large- and medium-scale façade test methods with different fire sources, specimen configurations and performance criteria are currently used in Europe for approval of façades for different types of buildings and different height limits are set in the specific regulatory requirements. In view of the variety of test and assessment methods in the EU Member States, the European Commission commissioned two follow-up research projects with the aim to develop a European approach for assessing the fire performance of façades and the definition of all relevant details and classifications to be used for harmonised products standards (in CEN) and for European Assessment Documents (in EOTA) for the relevant construction products (kits) within the framework of the Construction Products Regulation (CPR). In 2024 the final report was published, which defines two test methods which can be used by national regulations for different levels of performance (needed for example for different building heights).

The two different methods are called the large-fire exposure test and the medium-fire exposure test (Figure 5 and the upper part of Figure 6). The large exposure test is similar to the BS 8414 test from the UK (lower part of Figure 6 and Figures 12 and 13), while the medium exposure test is similar to the German method according to DIN 4102-20. Both methods use a corner configuration for the test wall and a wood crib as the ignition source. A difference compared to these older national tests is the introduction of a 'secondary opening' in the test wall, simulating a window opening.

[22] Source: https://www.ri.se/sites/default/files/2024-06/Comparative%20document%20aluminium%20Draft12_c.pdf

In addition, a classification scheme has been proposed, which includes a main classification, based on temperature measurements to assess the vertical and horizontal fire spread and additional classifications for falling parts and burning parts.

For particular elements and/or exposure, additional assessments may be performed:

- Occurrence of smouldering
- Integrity and thermal insulation at the façade-floor junction

The EU group of fire regulators (Horizontal Group Fire) started in 2026 to work on a standardisation request for CEN/TC 127 to develop new test standards and a related classification standard. In parallel, CEN has already started work on the standardisation of the proposed new test method(s). The resulting test and classification standards might not be identical in all details to the methods proposed in the EU research project. For example, there is a strong tendency to replace the wood cribs by gas burners as a fire source. The classification system will be adjusted according to the needs of regulators from EU member countries.

When the harmonised test and classification standards are published, their application will be mandatory only for harmonised products, which, in case of façade systems, means kits (for example, ETICS). In addition, Member States are free to apply the new methods in their building regulations for façade systems that do not rely on harmonised product standards.

PUR AND PIR FOR FAÇADE INSULATION

Wherever combustible products are allowed, it is possible to pass the requirements for fire safety of façade insulation systems with PU insulation. However, the insulant used is not the only factor deciding on fire safety. If an ETICS (External Thermal Insulation Composite System) is produced, the quality and stability of the outer covering (reinforcement layers and mortar) is also important for the performance of the insulation system in a fire. For curtain walls (wall covering systems with a ventilated gap between the outer cladding and the insulation layer or the wall), special precautions always have to be taken. The reaction to fire of the outer cladding is important, and the fire will be able to spread upwards through the gap if appropriate fire barriers have not been installed. This is the same even if non-combustible insulation products are used. Therefore, from a point of view of fire safety, PU products can be applied in façade systems for all heights and types of buildings, whenever national regulations do not require Euroclass A1 or A2 insulation products, provided they can fulfil the relevant full-scale testing requirements.

THE ROLE OF INSURANCE STANDARDS

While the primary objective of national legislation is to reduce risk to life, insurers have a secondary objective, which is the protection of property in conjunction with promoting fire safety measures. Consequently, there are a number of insurer-led fire standards and guidelines which look at different aspects of fire performance. Three widely recognised examples are the UK-based Loss Prevention Certification Board (LPCB), the American FM Global (formally known as Factory Mutual), and the German Insurance Association (GDV).

LPCB (LOSS PREVENTION CERTIFICATION BOARD)

LPCB is a globally recognised certification body, whereby their LPC insurance tests assess various levels of fire performance based on the reaction to fire and resistance to fire principles. LCPB series of test standards include the following: LPS 1181 part 1 (external panels), LPS 1181 part 2 (internal panels), LPS 1208 (fire resistance). The LPC's LPS 1181 involves large-scale insurer approved 'end-use application' tests that combine assessments of reaction and resistance to fire in real life situations. The test itself is sometimes referred to as a 'garage test' or occasionally 'room corner test' and is intended to assess the reaction of products or an assembly of products in the developing stages of a fire. LPS 1181-1 carries two primary grades of performance. Grade EXT-B confirms the system tested conforms to the requirements of the standard and in accordance with external building envelope performance. Grade EXT-A additionally indicates a level of fire resistance that can be compared to BS 476-22 resistance rating in minutes for insulation. It is useful in assessing the performance of elements such as roofs and walls in the developing stages of a fire. However, as it is a system test, it cannot be used to assess the performance of generic products.

These standards not only test the actual reaction to fire but are specific about the method and type of fastening, orientation of the panel, maximum permissible height of use and impose requirements on securement at panel joints to maintain fire integrity.

A key reference is the LPCB RedBook. Access to the most up-to-date RedBook listings is crucial to enable quick and easy verification of LPCB-approved products and services. The listings can be accessed via the RedBook online search (RedBookLive).

FM (FACTORY MUTUAL)

FM is a major global insurance company with its own rigorous test procedures for building systems including insulated panel systems and constructions incorporating insulation boards.

FM approval encompasses a range of tests specified in Approval Standards. Namely FM Approvals Standards including FM 4880 (insulated wall/roof/ceiling panels), FM 4881 (exterior wall systems), FM 4882 (smoke-sensitive occupancies), FM 4471 (external roof panels) and FM 4470 (roof covers). FM 4880 assesses the fire performance of insulated panel systems for internal and external wall, roof and ceiling systems, ensuring the system will not significantly contribute to the fire's spread, helping contain the fire to its area of origin, whilst FM approvals Standard 4881 looks specifically at the impact of fire and natural hazards on wall panel systems, ensuring structural and thermal integrity even when exposed to harsh environmental forces. FM 4882 ensures that the wall and ceiling systems will produce minimal smoke and non-toxic fumes, protecting sensitive products and ensuring safe evacuation. FM 4471 and FM 4470 include the testing of specific characteristics such as wind uplift and foot traffic, in addition to fire characteristics. For example, a Class 1 insulated steel roof deck is one which meets the criteria of FM 4470 for internal fire, external fire, wind uplift, live load resistances, corrosion of metal parts and fatigue of plastic parts. The standard applies to all components assembled in the system. Panel roofs are tested in accordance with FM Approval Standard 4471.

All FM approved products and assemblies worldwide are listed in FM Approval database, which is publicly accessible. This allows one to search not only for individual FM Approved products, but also for complete assembly compositions made up of multiple FM-certified components. Useful links:

- FM Approval guide
- FM Roofnav
- FM Data sheets

GDV AND VDS (GESAMTVERBAND DER DEUTSCHEN VERSICHERUNGSWIRTSCHAFT AND VERBAND DER SACHVERSICHERER)

The Berlin-based German Insurance Association (GDV) is the federation of insurers active in Germany. Its about 470 member companies provide comprehensive risk protection and provision to private house-holds, trade, industry and public institutions, through 470 million insurance contracts (status 2025).

VdS, a GDV subsidiary, offers fire protection concepts for industry, planners and contractors. The organisation owns a technical laboratory for type and system tests. The services include certification and recognition schemes for products (fire extinction systems, smoke detectors) and specialised installers. At an international level, VdS closely co-operates with the certification bodies and test laboratories in Europe and the US. The testing and certification of insulation products and insulated building elements is currently not included in the range of activities of VdS.

With strict standards and regulations for fire safety of buildings in place in Germany, the German insurance industry does not see a need, at the time of writing, to introduce additional tests and classifications. The requirements set for insurance purposes are mainly based on existing regulations, and the insurance industry is actively taking part in the further development of standards (e.g. DIN 18234 “Fire safety of large roofs for buildings – Fire exposure from below”), guidelines and regulations for the assessment of the fire safety of products and constructions. Special focus is on the further development of the “Industriebaurichtlinie” (code for industrial buildings).

Since 2023, VdS is also focusing on the topic of photovoltaic installations and the requirements for roofs beneath these installations.

Several guidelines (Richtlinien) have been published, providing complementary guidance and recommendations, based on official tests results and classifications for products and constructions. Special recommendations are given, in particular for the use of combustible insulation products (i.e. installation and type of joints for sandwich panels).

The following VdS publications are noteworthy:

- VdS 2035 – Stahltrapezprofildächer, Planungshinweise für den Brandschutz
- VdS 2216 – Brandschutzmaßnahmen für Dächer, Merkblatt für die Planung und Ausführung
- VdS 2244 – Sandwichelemente als raumabschließende Wand- und Dachbauteile, Brandschutz-Hinweise für die Planung, Ausführung und Instandhaltung
- VdS 2827 – Bemessungsbrände für Brandsimulationen und Brandschutzkonzepte
- VdS 3461 – Wärmedämmverbundsystem

In 2026 the following revised guideline has been published:

- VdS 6023: 2026-05 (02), "Photovoltaik-Anlagen auf Dächern mit brennbaren Baustoffen"

The VdS guidelines are not mandatory and most insurers have developed their own guidelines in addition to the VdS guidelines. Based on test results from regulators and industry, a revised version of this guideline has been published in 2026.

RELEVANT EUROPEAN BODIES

There is a European association of insurances, which is CEA, the European insurance and reinsurance federation. In addition, insurance companies work closely with a number of European bodies engaged in fire safety and participate in the European fire safety standardisation work.

FUTURE TRENDS

System-based tests are important and are expected to become increasingly important. However, there are voices in certain countries calling for façades made out of non-combustible materials, thereby stifling the development of new façade system tests.

For roof covering systems below PV installations, there have also been calls to use only non-combustible insulation. Here too, a holistic approach should be taken.

There is a need for further scientific development in order to address innovation regarding energy efficiency and renovation, to improve confidence in the fire safety of future building and construction systems with high performance insulation products.

PU Europe FIRE SAFETY HANDBOOK

THE ROLE OF FIRE SAFETY ENGINEERING

WHAT IS FIRE SAFETY ENGINEERING?

Fire Safety Engineering (FSE) has been defined as: "the application of scientific and engineering principles to the protection of people, property and the environment from fire" [23]. The key point here is that FSE takes a holistic approach to fire safety, rather than specifiers relying purely on complying with prescriptive regulatory requirements to achieve a particular level of fire safety. It also allows for the assessment of the fire performance of very complex buildings, where the standard methods do not provide the required answers. Simulation models may incorporate various active and passive fire protection measures, such as sprinkler systems, automated technical safeguards like smoke curtains, and smoke extraction concepts. They can also account for smoke propagation, the potential consequences of smouldering fires, and even human behaviour during escape and evacuation scenarios. In addition to life safety, simulations may also be extended to address property protection, which requires consideration of different parameters and objectives.

The occupancy and use of a building have a significant impact on the fire risk. The contents strongly affect the likely rate of fire growth and the intensity of the fire and its impact is generally greater than that of the building construction itself. Using the FSE approach takes these issues into account. FSE methodology can assess the most effective solution to manage the risks rather than presenting a standard fire performance specification for all constructions which may not deal with the particular vulnerabilities of individual projects or lead to the best option in terms of other building design considerations.

The FSE model approach uses proven methods but still allows room for innovation and takes budget and other design constraints into consideration without compromising on levels of safety.

FSE has been applied to individual projects, mostly large and complex ones; however, in some countries it can also be applied on a more general basis within a regulatory context.

With the increasing use of performance-based fire safety design, there is a growing need for standardised and comparable verification methods to ensure consistent quality and a reliable level of safety. Standardisation supports transparency, facilitates communication among stakeholders, and helps align safety expectations across different jurisdictions. ISO/TC 92/SC 4, the subcommittee on Fire Safety Engineering, addresses this need by developing international standards that support the application of fire safety engineering in the built environment. This includes areas such as

[23] BS 7974, *Application of fire safety engineering principles to the design of buildings. Code of practice*, The British Standards Institution (2019)

EXAMPLE FOR FIRE PREVENTION MEASURES [24]

- "Do not store highly combustible materials against external façades or steel-faced composite panels or do not allow rubbish to collect against façades.
- Have damaged walls or sealed joints repaired immediately and make sure that jointing compounds or gaskets used around the edges of panels are in good order.
- Check where openings have been made for doors, windows, ducts and cables to ensure that these have been sealed or closed with flashings and the inner core has not been exposed.
- Check that there has been no mechanical damage e.g. by mobile equipment such as fork lift trucks. Repair any damage that has occurred".

performance-based design and assessment, implementation of fire safety strategies, and fire safety management.

FSE OPTIONS IN REGULATIONS

In many European countries (e.g. UK, Sweden, Germany), authorities increasingly recognise the advantages of performance-based and objective-based fire safety codes. This trend is driven by the need for greater flexibility in designing cost-efficient buildings and transport systems that incorporate innovative construction materials while maintaining high levels of fire safety. Design approaches based on fire safety engineering principles are central to meeting these demands.

In several countries, including France, Germany, and Scotland, approval of construction products – such as insulation systems – can be granted based on demonstrated performance in large-scale fire tests, especially for certain types of buildings.

A notable example of risk-based regulation is the UK Regulatory Reform (Fire Safety) Order 2005, which has been in effect since October 2006. It requires a designated 'responsible person' to carry out a fire risk assessment for non-domestic premises. This assessment

[24] *Insulated Panels, The Fire Safety Order (2005): Advice and guidance on insulated panels for responsible persons and enforcers implementing the Regulatory Reform (Fire Safety) Order 2005*, EPIC (February 2007), p. 14
N.B.: EPIC is the UK association of producers of factory-engineered steel faced composite panels. Brochure downloadable from: www.epic.uk.com

identifies potential fire hazards, evaluates risks, and determines the necessary precautions to protect occupants.

Following the Hackett Review, the UK introduced the Building Safety Act 2022, which strengthens the regulatory framework by:

- establishing a Building Safety Regulator;
- introducing a duty-holder regime for all phases of building design and operation;
- requiring a 'golden thread' of building safety information throughout the life-cycle [25].

These reforms emphasise the importance of early integration of fire safety expertise and the use of FSE to ensure compliance and resilience.

At the European level, the revised Construction Products Regulation (EU) 2024/3110, adopted on 27 November 2024 and in force since 18 December 2024, replaces Regulation (EU) No 305/2011 [26]. It introduces harmonised rules for the marketing of construction products and explicitly strengthens the role of fire safety performance and life-cycle-based assessments.

In parallel, the European Commission, through DG GROW and in collaboration with the Joint Research Centre (JRC), is actively exploring the feasibility of a European Fire Safety Code based on FSE principles, analogous to the Eurocodes. This initiative aims to promote consistent application of FSE across Member States, provide guidance and training for engineers, and support innovation while maintaining safety levels.

A key reference in this context is the JRC Technical Report "The status and needs for implementation of Fire Safety Engineering approach in Europe" [27]. The report highlights that while FSE is increasingly acknowledged, its implementation across EU/EFTA countries remains uneven. It identifies regulatory, educational, and infrastructural gaps and proposes harmonisation strategies to support fire safety authorities and professionals. The initiative targets the built environment and aims to foster a unified approach to performance-based fire safety design across Europe.

[25] Building Safety Act 2022 and Hackitt Review implementation, UK Government
[26] Regulation (EU) 2024/3110 of the European Parliament and of the Council of 27 November 2024, Official Journal of the European Union, L series, 18 December 2024 (EUR-Lex)
[27] European Commission, Joint Research Centre, *The status and needs for implementation of Fire Safety Engineering approach in Europe* (2023)

System-based fire testing remains a valuable tool, especially when designed to reflect realistic fire scenarios. The scope of such tests must be meaningful and aligned with the base principles of Fire Safety Engineering, which include:

- Life safety and safe evacuation
- Property and environmental protection
- Continuity of operations
- Quantitative risk assessment
- Integration of passive and active fire protection systems [28]

The scale of testing should be appropriate to the objective. For large-scale tests – which are often complex and costly – consideration of extrapolation and deemed-to-satisfy approaches is essential. FSE provides the analytical framework to interpret these tests and support performance-based approvals.

Based on current developments, it is expected that FSE will continue to gain importance across Europe, offering a robust and flexible foundation for future fire safety regulation and innovation.

POSSIBILITY OF TRADE-OFFS IN FIRE SAFETY ENGINEERING

Good building design weighs up all the different construction demands to find the optimum balance between safety and performance, functionality and aesthetics, cost and longevity. If the focus concentrates too heavily on a single aspect, there is a danger of over-specification in some areas and neglect in others. The possibility of a 'trade-off' helps to mitigate this. For example, installing sprinklers as a fire safety measure could allow for a greater open internal space, or the specification of a thermally higher-performing insulation in the walls and roof, while remaining safely within the balance of risk.

[28] SFPE Engineering guide to performance based fire protection and relevant NFPA codes, such as NFPA 550: *Guide to the Fire Safety Concepts Tree*. Based on this work it can be expected that, in future, FSE will be applied to a greater extent than now in all European countries

COMBUSTIBILITY BEHAVIOUR OF INSULATION PRODUCTS

COMBUSTIBILITY BEHAVIOUR OF PU (PUR/PIR) INSULATION

PU rigid insulation products can reach different fire and smoke classifications up to class B, depending from the formulation, including the type and amount of flame retardants and the facing. They do not show either burning or non-burning dripping in fire tests and real fires.

There is no evidence that rigid PU insulation smoulders or shows continuous glowing. For this to occur, an open porous material is necessary, which is not the case for PU insulation, but it is for many natural and synthetic materials, e.g. wood shavings, cotton, wool, etc. and a number of mineral wool products.

Structures insulated with PU products show excellent fire performance in real fire scenarios due to their thermosetting character and high thermal stability. PU insulation neither melts nor drips when heated. The char emerging on the surface of the insulation protects the core from decomposition, so the integrity of the structure is maintained for a long time even if heavily attacked by the fire. Structures insulated with PU insulation can perform better than or give performance equivalent to structures insulated with other mainstream non-combustible insulation materials.

Although PUR products can perform well in a fire, PIR insulation products offer reduced combustibility, greater working temperature ranges, increased char formation and increased heat stability, and are therefore generally more suitable for higher risk applications.

PERFORMANCE IN APPLICATION-RELATED TESTS

EXAMPLE 1: FAÇADE FIRE TEST ON PU EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM (ETICS) [29]

An ETICS system was tested in 2002 in accordance with the German proposed standard prDIN 4102-20 “Besonderer Nachweis für das Brandverhalten von Außenwandbekleidungen”. This is now a full standard (DIN 4102-20) and has been proposed to be used as part of the future harmonised European test procedure with small adaptions.

[29] Isopa factsheet: *Façade fire test on PUR External Thermal Insulation Composite System (ETICS)*

Figure 14: Build-up according to prDIN 4102 -20

Figure 15: Damage of the test sample: render finishing

EXECUTION OF TESTS:
FMPA Leipzig (Germany)

The test façade was arranged in a corner configuration with an opening (simulating a window) at the bottom. The flames from a wooden crib located in the opening attacked the cladding of the façade. A crib of 25 kg was used as the fire load.

Temperature measurements were carried out at the surface and behind the rendering and within the PUR boards in different levels of height of the façade. The test and observation time were a total of 60 minutes.

After ignition of the wooden crib the flames impinged on the surface of the PU ETICS system. The wooden crib was almost totally consumed after 14 minutes. However, further fire exposure was generated by the burning wooden window frame and the burning rolling shutter box. After 50 minutes the fire had extinguished totally and all flaming had stopped by self-extinguishment.

The temperatures reached 1 000 °C in the opening and even 800-600 °C between 1 m to 3 m above the opening. At the 4-5 m level the temperatures decreased to 200 °C, which corresponded to the maximum observed flame height which reached almost to the top of the façade at 5 m level. However, the measured temperatures within the PU foam (75 mm to 150 mm from the outside surface) remained quite low and did not exceed 25 °C to 60 °C compared to the temperatures at the outside surface of 600 °C to 800 °C.

After the test the rendering was removed from the PU. No breaking of the rendering had occurred. The foam was only discoloured and partially destroyed within the surface layer and in a limited area, where the temperature from the fire exposure

Figure 16: Damage of the test sample: PU insulation layer

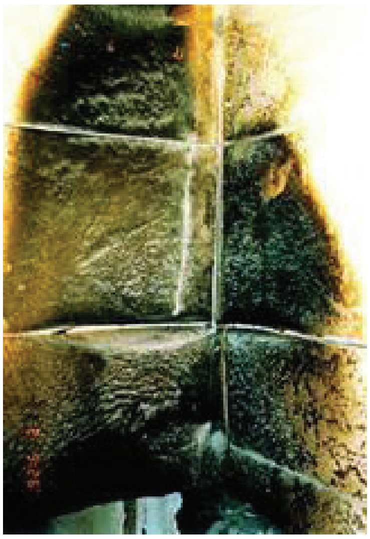


Figure 17: Damage of the test sample: PU insulation layer close to fire room

exceeded 200 °C. There was no spread of fire within the PU itself or outside the region of direct flame exposure.

DISCUSSION OF RESULTS:

The fire exposure was increased by the installation of a wooden window frame and a combustible rolling shutter box. Despite this increased fire loading, the PU ETICS façade showed very limited response to the fire exposure and then only where a high enough flame temperature occurred. No further flame spread was initiated by the PU rigid foam itself. All the flaming stopped by self-extinguishment.

MORE DETAILS:

Isopa factsheet: *Façade fire test on PU External Thermal Insulation Composite System (ETICS)* (https://www.isopa.org/wp-content/uploads/2022/09/facade61.pdf)

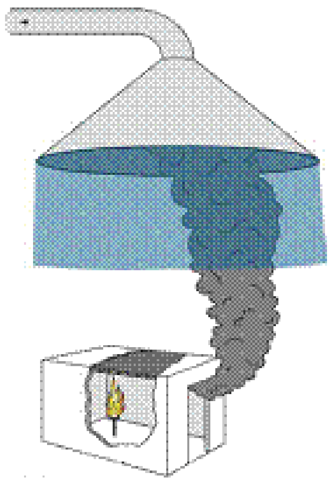


Figure 18: Schematic drawing of the test set-up under a large calorimeter hood

EXAMPLE 2: ASSESSMENT OF THE FIRE BEHAVIOUR OF INSULATED STEEL DECK FLAT ROOFS

Europe has no harmonised test standard designed to simulate the performance of an insulated steel deck flat roof above a developing internal fire, neither for regulatory nor insurance purposes.

A test programme was therefore initiated in 2004 with the objective of developing a small room scale test method for this purpose.

In order to use the test method as a basis for a classification system for steel deck flat roof assemblies insulated with different insulation materials, clear pass/fail criteria were developed.

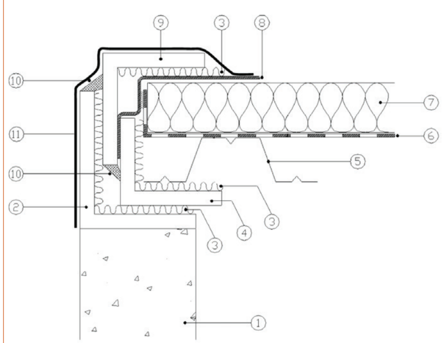
EXECUTION OF TESTS:

SP (Sweden)

Test configuration

The geometry of the test apparatus is the same as for the room corner test. The floors and walls are made of lightweight concrete, while the roof is constructed and tested simulating the end-use application (Figure 18).

Figure 19: Schematic of the edge detail



1. Non-combustible lightweight concrete wall
2. Frame permanently attached to the room
3. Ceramic wool
4. Bottom frame
5. Steel deck
6. Vapour control layer
7. Thermal insulation
8. Waterproofing membrane
9. Top frame
10. Welds, at two points on each side
11. Bituminous waterproofing membrane strip to seal the deck

The complete roof assembly was mounted in a closed frame on top of the test room. The frame is set at a slope of 2 %, with the lower side above the back wall. The channels in the steel deck are laid parallel to the length of the building. The thickness of insulation material is varied according to its declared thermal conductivity so as to achieve the same R-value.

DISCUSSION OF RESULTS:
The research programme demonstrated the repeatability of results, which makes it suitable for the assessment of the full-scale fire behaviour of steel deck flat roof assemblies.

The results obtained with the non-combustible fibrous product and PIR insulation show acceptable performance. Flashover is not observed, the temperature on the outside of the insulation stayed well below 20 °C and there was no venting. The insulation remained in place over the entire roof. PIR insulation gave some contribution to the rate of heat release while the non-combustible fibrous product showed some onset of glowing after the test. Some other insulation products failed.

The PIR insulation product used in the tests also achieves FM 4450 **[30]** class I. This is an indication of a possible correlation between this test method and FM 4450.

MORE DETAILS:
PU Europe factsheet: *Assessment of the fire behaviour of insulated steel deck flat roofs* (https://www.pu-europe.eu/wp-content/uploads/2023/06/Factsheet_2_Assessment_of_the_Fire_Behaviour_of_Insulated_Steel_Deck_Flat_Roofs.pdf)

[30] Currently FM 4470

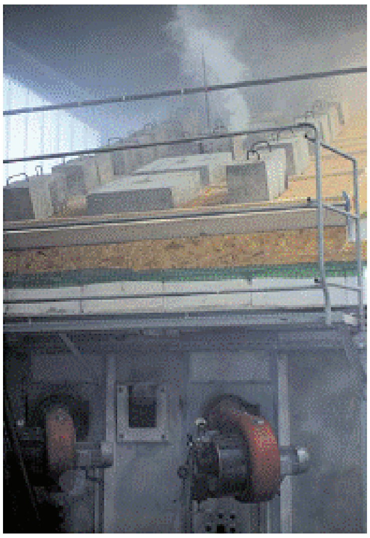


Figure 20: Test rig at the end of the test

EXAMPLE 3: FIRE RESISTANCE TEST ACCORDING TO EN 1365-2 OF A PITCHED ROOF INSULATED FOR PU BOARDS

A pitched roof structure insulated with PU insulation was tested in 2004 in accordance with the European Standard EN 1365-2: 1999 “Fire resistance tests for load bearing elements – Part 2: floors, roofs”.

The tested assembly consisted of rafters, 19 mm thick tongue and groove timber boards above the rafters, bituminous felt, 100 mm PU insulation boards covered with 22 mm oriented strand board (OSB).

EXECUTION OF TESTS:

FMPA Leipzig (Germany)

Observations during the test:

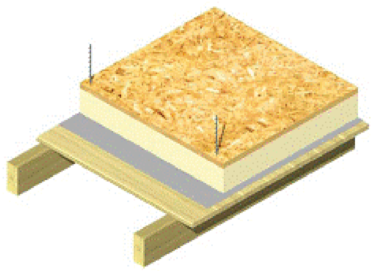


Figure 21: Test assembly

- 21 minutes after the start of the test, the timber boarding burned through and the PU insulation boards were exposed to the fire.
- Only after 37 minutes a slight increase in temperature was observed on the upper surface of the test rig but the limiting temperature rise of 180 K was never reached during the duration of the test.
- After 41 minutes some smoke was released through a joint but the structure was still not visibly damaged.
- In the 46th minute the test had to be stopped to prevent the structure from collapsing because the rafters had

been weakened by the fire.

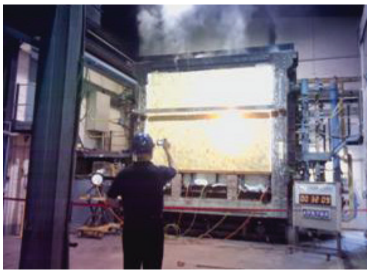
- At the end of the test, the PU insulation boards were partially charred but had prevented the fire from reaching the upper layers of the test rig.

DISCUSSION OF RESULTS:

The roof structure was classified REI 45. This means that three critical criteria were met for a minimum of 45 minutes: stability or mechanical resistance (R), room enclosure (E) and thermal insulation (I). Pitched roof constructions containing non-combustible non-cellular insulation materials hold REI 30 and REI 45 certification. Pitched roof constructions containing PU insulation boards can therefore demonstrate equivalent performance to, or better performance than, similar constructions containing non-combustible non-cellular insulation materials.

MORE DETAILS:

PU Europe factsheet: *Fire resistance of different insulation materials in pitched roofs and timber frame walls* (https://www.pu-europe.eu/wp-content/uploads/2023/06/Factsheet_1_Fire_resistance_of_different_insulation_materials_in_pitched_roofs_and_timber_frame_walls.pdf)



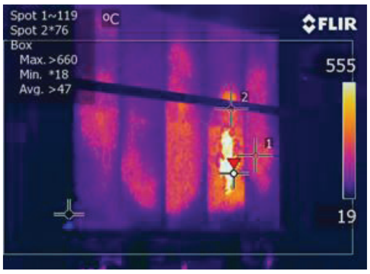


Figure 22 (above): Test build-up according to EN 1365-1: the unexposed face of the specimen

Figure 23 (below): Test build-up according to EN 1365-1: thermographic image during test

EXAMPLE 4: FIRE RESISTANCE OF TIMBER FRAME CLOSED PANEL SYSTEMS USING POLYURETHANE AND MINERAL WOOL WITH EN 1365-1

This test was conducted in 2011 with a view to comparing typical timber frame closed panel systems using PU and mineral wool with EN 1365-1 “Fire resistance tests for load-bearing elements – Walls”. The build-ups were agreed with the UKTFA (UK Timber Frame Association) and Exova (Warrington Fire UK) and used exactly the same materials and fixings. The internal exposed (to fire) face was covered by a 12.5 mm standard gypsum wallboard. For the unexposed face cladding, a 11 mm OSB (Orientated Strand Board) was used. Both build-ups used C16 grade softwood 140 x 38 mm studs (at 600 mm ctrs), headbinder and soleplate. The insulation was fitted between the studs.

- (Test 1) 140 mm FrameTherm Slab 35 (mineral wool)
- (Test 2) 80 mm foil faced PIR

Both tests were loaded to 11 kN per meter.

EXECUTION OF TESTS:
Exova (Warrington Fire UK): WF Report N° 306703

Test 1 (140 mm FrameTherm 35 Mineral Wool)

The load-bearing capacity was maintained for 32 minutes (test stopped at 32 minutes). The insulation lost its integrity after 31 minutes.

Test 2 (80 mm foil faced PIR)

The load-bearing capacity was maintained for 39 minutes (test stopped at 39 minutes). The insulation lost its integrity after 38 minutes.

DISCUSSION OF RESULTS:

All external timber frame walls in the UK require a minimum of 30 minutes fire resistance. The mineral wool build-up (T1) achieved 32 minutes and met this requirement. Test 2 (PIR build-up) used the same materials, same fixings, same U-value (0.27 W/m²K) with 60 % of the insulation thickness thanks to a lower thermal conductivity. With 39 minutes, the level of fire resistance was approximately the same and the regulatory requirements were also clearly met.

MORE DETAILS:

PU Europe factsheet: *Fire Resistance of timber frame wall constructions* (https://www.pu-europe.eu/wp-content/uploads/2023/06/Factsheet_20_Fire_resistance_of_timber_frame_wall_constructions.pdf)

EXAMPLE 5: COMPARATIVE TESTS OF FULLY FURNISHED ROOMS, INSULATED WITH NON-COMBUSTIBLE MINERAL WOOL AND WITH PU FOAM

Tests were done in 2016 in order to find out whether the contribution of the building envelope to smoke toxicity in a building fire starting in a furnished room is relevant.

The tests were performed in two identically furnished rooms with a different envelope construction: insulated with non- combustible mineral wool and with PU foam.

EXECUTION OF TESTS:

Exova (Warrington Fire Belgium)

A test room according to ISO 9705 with door opening was used. The wall build-up (insulation products and internal lining) was mounted inside this room. The wall of the test room was insulated with PIR in the first test and with mineral wool in the second test. Details for the insulation products are given in Table 6. In order to achieve a fair comparison, the insulation thicknesses differed (80 mm vs.140 mm) so that the walls U-values in both tests were the same, however leaving the inner volume of the room identical. The insulation layer was lined with 12.5 mm plasterboard. A power socket was placed near to the main fire-load to create a realistic weak spot in the plasterboard lining.

	Test 1 PIR	Test 2 MW
Reaction to fire classification	E	A1
Thermal conductivity *(W/m·K)*	0.022	0.035
Thickness *(mm)*	80	140

Table 6: Insulation products in test 1 and test 2

Both rooms were identically furnished, with a curtain (fabric), an armchair, a small table, a TV cabinet, a TV and a bookcase.

The fire scenario was chosen in order to simulate a waste bin fire in a room. A gas burner was used to simulate a waste bin fire underneath the curtain and initiate the fire.

The time of ignition of the armchair was chosen to be the starting point of the analysis, to minimise variations in fire development in the early stages of the fire.

DISCUSSION OF RESULTS:

- In the early stage of a fire, when people still could escape, the contents of a room are far more important for fire development, smoke obscuration and toxicity than the contribution of the envelope;

- Contribution of the building envelope to the development of heat and smoke starts only in a later phase of a fire and is not significant compared to the effects from burning building contents;
- Performance of the complete build-up is much more relevant compared to the individual construction products only;
- Toxicity is only to a certain degree a material property. It is strongly influenced by the environment, availability of oxygen, thermal attack, airflow and surfaces available for combustion;
- As smoke inhalation often contributes in case of occupant fatalities;
  - Early detection is key;
  - Other measures like early detection, extinction and safe egress are key for safety.

MORE DETAILS:

Contribution to toxicity of different construction products in a furnished room fire, Roy Weghorst and al., Fire and materials (2017)

PU Europe factsheet: *Fire performance of thermal insulation products in end-use conditions – Building envelope vs building content* (https://www.pu-europe.eu/wp-content/uploads/2023/06/Factsheet_24D_Fire_performance_of_thermal_insulation_products_in_end-use_conditions_-_Building_envelope_vs_building_content.pdf)

Figure 24: Arrangement of PV system on the roof assemblies

EXAMPLE 6: EXPERIMENTAL SIMULATION OF AN EXTERNAL FIRE ON A FLAT ROOF WITH PV PANELS MOUNTED ABOVE

Study on the influence of the type of insulation and the importance of end-use testing.

ABSTRACT:

There is a global increasing attention in the building industry regarding fire safety on the one hand, and reduction of Green House Gas emissions on the other hand. The first aspect leading to the promotion of non-combustible insulation materials, the latter resulting in an increased number of PV installations on flat roofs and the growing interest in highly insulating, combustible synthetic foams such as PIR. This raises the question: is non-combustible insulation necessary beneath PV panels on flat roofs, or can combustible materials such as PIR offer a comparable fire performance in such configurations?

There remains considerable uncertainty regarding how to assess the fire safety of flat roof assemblies with PV installations. Concerns are raised because a fire below panels is intensified due to re-radiation by the PV panels. Even more, they might be an extra ignition source, complicate firefighting and add an extra fire load to the roof. Reason enough for PU Europe to simulate this application in an end-use configuration, rather than to focus on the reaction to fire of some components of the roof parts as such.

EXECUTION OF TESTS:

KIWA BDA Testing

Test set-up [31]

Two test rigs, 6 m x 6 m each, were tested on their behaviour in case a fire ignited between the PV panels and the waterproofing membrane. The build-up of both roof systems was identical,

[31] PU Europe factsheet n° 24E: *Fire behaviour in end-use conditions – PIR & MW under PV systems* (June 2022)

apart from the insulation layer. To achieve equivalent thermal insulation performance (R = 6.45 m²K/W), one rig used a single layer of 142 mm PIR, while the other employed two layers of 130 mm Mineral Wool (totalling 260 mm). The insulation was covered with a PVC waterproofing membrane and supported by a steel deck structure. A PE vapour barrier was installed between the insulation and the steel deck. Both build-ups were FM approved [32].

A common East-West configuration of PV panels was installed by mounting four panels (3.2 m x 1.84 m in total) back-to-back with an inclination of 13° relative to the roof surface. The panels had a foil back sheet and were rated fire class C according to IEC 61730-2 [33].

In order to simulate an external fire starting below a PV array on top of a flat roof, an ignition was forced by means of a gas burner, as suggested by CENELEC CLC/TR 50670:2016 [34]. The burner provided a heat output of 15 kW for 10 minutes, resulting in a fire exposure comparable to what is achieved in a CEN/TS 1187 t1-test [35]. Opposed to the aforementioned standardised t1-test, the test under consideration took place outdoors, consequently being submitted to the outdoor climate conditions such as temperature, relative humidity and wind at the moment of testing. As the rigs were tested one after the other, these conditions varied slightly. The most significant change was observed in terms of wind direction.

DISCUSSION OF RESULTS:

Observations

The analysis of the burned test rigs was based on visual observations and temperature loggings.

The area which was attacked by flames was not confined to

[32] FM 4470, Single-ply, polymer-modified bitumen sheet, built-up roof (BUR) and liquid applied roof assemblies for use in Class 1 and non-combustible roof deck construction (2020)
[33] IEC 61730-2:2016, Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing
[34] CLC/TR 50670:2016, External fire exposure to roofs in combination with photovoltaic (PV) arrays – Test method(s)
[35] CEN TS 1187:2012, Test methods for external fire exposure to roofs

the perimeter of the PV panels. The total area of flame spread was comparable for both test rigs, reaching the outer periphery of the test set-up in the test with the PIR insulation, due to the wind direction, but, in both cases, without covering the complete area. As the wind direction changed between both tests, its influence could be clearly observed. The type of insulation seemed to have little influence on this flame spread, nor in the time until the flames self-extinguished (32 minutes in the case of PIR, 28 minutes in the case of Mineral Wool).

Temperatures were measured below and in the middle of the insulation layer (within and outside the perimeter of the PV panel configuration). The temperatures were registered and clearly showed a different tendency regarding the temperature in the middle of the insulation layer within the perimeter of the PV configuration. A peak temperature of 155 °C was reached after 23 minutes in case of the PIR build-up, after which the temperature started to decrease again. At about 80 minutes after the start of the test, the complete test rig, including the steel deck, started to cool down. This fast increase and decrease of the internal temperature could not be detected in case of the Mineral Wool build-up. A steady increase in temperature was observed after the start of the test, leading to 35 °C after 30 minutes, 290 °C after 80 minutes and 440 °C after 4 hours. Continuous temperature monitoring indicated that the steel deck with the Mineral Wool insulation at some points retained a temperature of approximately 190 °C overnight.

The overall visual extent of damage of the surface of the burned test rigs appeared to be similar for both set-ups.

Both test rigs were dismantled to enable the analysis of the damage of the different layers of the build-up. No burn-through of the PIR insulation layer was observed. Only a maximum of 25 % of the thickness of the PIR insulation was charred. The

PE foil underneath remained undamaged. On the other hand, the high temperatures in the Mineral Wool layers caused the underlaying PE foil to melt away.

Conclusions

A comparative fire test was set up by PU Europe in order to gain insights in the fire behaviour of a flat roof below PV panels, on the one hand, and to evaluate the impact of the type of insulation layer, on the other hand. A large-scale non-standard end-use test set-up was tested with a PIR (combustible) and with a Mineral Wool (non-combustible) insulation layer. Both roof assemblies were FM approved. An external fire was simulated by adding an ignition source between the PV panels and the waterproofing membrane.

By testing the insulation materials in an end-use configuration, it was shown that the fire performance of the insulation boards as such did not have a significant influence on the overall fire behaviour of this specific tested roof set-up. The fire spread to the same extent in both situations, mainly determined by the presence and direction of the wind. Both test assemblies self-extinguished after about half an hour and for none of the test rigs the fire spread over the complete roof.

A difference was observed in temperature profiles inside the insulation layer. Whereas there was a rather fast increase, moderate peak (155 °C) and constant cool down of the PIR insulation, the temperature curve increased steadily up to 440 °C (4 hours after the start of the test) in the Mineral Wool layers. This high temperature caused a part of the PE foil underneath the insulation to melt away, whereas this layer remained undamaged for the PIR build-up.

Under the specific test conditions described, the tested PIR insulation product did not cause inferior fire performance of the roof compared to the tested Mineral Wool product in terms of flame spread, burn through and self-extinguishing behaviour.

MORE DETAILS:
PU Europe factsheet: *Fire performance of thermal insulation products in end-use conditions – Comparative fire tests to investigate the contribution of PIR & MW thermal insulation products to the fire performance of flat roofs under PV systems* (https://www.pu-europe.eu/wp-content/uploads/2023/08/Factsheet-24E-Fire-performance-of-thermal-insulation-products-in-end-use-conditions_Comparative-fire-tests-PIR-MW-under-PV-systems.pdf)