

FIREPROOFING BIPV: OVERVIEW AND COMPARISON OF BUILDING FIRE SAFETY REGULATIONS IN INCREASE DEMONSTRATION SITE COUNTRIES

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ABSTRACT: This paper presents a comparative analysis of fire safety regulations governing building integrated photovoltaics (BIPV) across Belgium, Estonia, France, Spain and Switzerland, the countries hosting INCREASE demonstration sites. BIPV systems face unique regulatory challenges, as they must comply with both electrical safety and building fire safety standards. The study focuses on the impact of national building codes and the Euroclass system defined by EN 13501, which classifies construction products according to their reaction to fire. Building height is identified as the principal determinant of facade fire safety requirements, with stricter standards for mid- and high-rise buildings often restricting BIPV deployment. The absence of harmonised European standards and the limitations of current fire testing methodologies, including those specified in EN 13501, contribute to regulatory uncertainty and hinder widespread adoption. The paper discusses alternative compliance pathways, such as large-scale fire testing and the implementation of national guidelines, which provide project-specific routes for demonstrating fire safety and facilitating BIPV integration. Policy recommendations include the harmonisation of BIPV standards at European level, the development of BIPV-specific fire testing methods, performance-based compliance options, clear national guidelines and enhanced research and data sharing to support safe and effective BIPV deployment in buildings.

Keywords: BIPV (Building-Integrated PV) ; Fire safety ; Codes and regulations ; BIPV facades ; BIPV roofs.

1 INTRODUCTION

Fire safety is a critical consideration in the design and construction of buildings, underpinning the protection of lives, property and the continuity of essential services. As the built environment evolves to incorporate innovative technologies such as building integrated photovoltaics (BIPV), ensuring robust fire safety standards becomes increasingly complex. BIPV modules uniquely serve dual functions, they generate renewable electricity while simultaneously acting as construction elements. This dual role introduces new challenges in fire risk management, as BIPV systems must comply with both electrical safety requirements and building fire safety regulations.

The integration of BIPV into building envelopes presents specific fire safety challenges. Notably, the materials used in photovoltaic modules often prevent them from achieving the highest non-combustible classifications required by certain building codes. Furthermore, existing fire testing methods, such as the Single Burning Item (SBI) test, may not adequately capture the fire behaviour of BIPV products, prompting the need for more representative assessment techniques. The absence of a harmonised European standard tailored specifically to BIPV compounds regulatory uncertainty, with national and local variations in fire safety requirements potentially hindering broader adoption of BIPV.

This paper addresses the importance of fire safety in relation to BIPV systems, focusing on the regulatory frameworks that govern their deployment in buildings. The scope encompasses a comparative analysis of national fire safety regulations in INCREASE demonstration site countries, namely Belgium, Estonia, France, Spain and Switzerland, with particular attention to the Euroclass system defined by EN 13501-1 and EN 13501-5. Although fire testing and classification standards for construction products are unified across the EU, each Member State is responsible for its own building regulations and sets its own fire safety requirements. In practice, EN 13501-1 entails that BIPV products, due to their combustibility, are not able to

classified A1 or A2.

The paper first provides an overview of the regulatory framework for construction products in Europe, including the Construction Products Regulation (CPR) and EN 13501, and how they impact BIPV deployment in buildings. Secondly, the paper delves into a description of the regulatory requirements in the INCREASE demonstration site countries. The section considers building classification and fire safety requirements for facade and roof elements in each country. Thirdly, a comparative analysis of the national regulations is done, highlighting commonalities and differences. Based on the analysis, a typology of BIPV projects is proposed based on fire safety requirements for construction elements. Finally, the paper includes a discussion of the limitations in existing fire testing approaches and an exploration of ongoing efforts to develop more effective fire safety assessments for BIPV products.

Fire safety rules for building facades differ across Belgium, Estonia, France, Spain and Switzerland, with requirements tightening as building height increases. Low-rise buildings usually allow more combustible facades, making BIPV installation easier, while mid-rise structures encounter stricter standards but BIPV is often still possible. High-rise buildings require non-combustible facades classified A1 or A2, significantly limiting BIPV options. Each country has its own nuances but, overall, building height is the main factor affecting facade fire safety and BIPV feasibility in Europe. Alternative pathways exist in a few countries, such as Belgium, France and Switzerland to allow for BIPV deployment in high-rise buildings with large-scale testing. In the absence of harmonised standards for BIPV, alternative routes, while currently costly, location dependent and time consuming, appear as the most suitable pathway to unlock BIPV deployment in high-rise buildings.

Overall, to support safe and widespread BIPV adoption, there is an urgent need for harmonised European standards, performance-based compliance options, BIPV-specific fire testing methodologies, clear

national guidelines and enhanced research and data sharing across stakeholders.

2 EUROPEAN FRAMEWORK FOR CONSTRUCTION PRODUCTS

The essential feature of BIPV modules lies in their ability to both produce electricity and function as a fundamental part of the building structure. Hence, BIPV elements must comply with two different standards and regulations derived from building requirements and from PV electrical requirements (Low Voltage Directive, LVD). This dual regulatory approach ensures that modules generate clean electricity while integrating seamlessly into the design and functionalities of the built environment. This dual framework also present certain challenges, which can hinder BIPV deployment. In this paper, the focus is on building requirements and fire safety standards.

The Construction Products Regulation (CPR) provides a harmonised European framework for product performance and fire safety [1]. In turn, each Member State sets up its own minimal fire safety requirements in buildings. As construction elements, BIPV systems are classified using EN 13501-1, but due to their materials, they cannot achieve the highest fire safety categories (A1 and A2). This limitation restricts BIPV use where non-combustible classifications are required. Furthermore, the current testing approach, based on the Single Burning Item (SBI) test, does not fully reflect BIPV-specific fire risks. Some countries are developing larger-scale fire tests and alternative methods to address these gaps and support BIPV deployment.

2.1 Regulatory framework for construction products

The unification of the regulatory framework for construction products in the European Union began with the introduction of the Construction Products Directive (CPD 89/106/EEC) [1]. The CPD aimed to harmonise national regulatory systems, establish essential requirements for construction materials and components, and create conditions for the free circulation of products within the internal market.

This framework was later replaced by the Construction Products Regulation (CPR 305/2011), which simplified procedures for assessing and verifying the performance of construction products. The CPR sets out harmonised rules for expressing product performance in relation to essential characteristics and governs the use of CE marking. It also defines the “Basic Requirements for Construction Works” (Annex I), including “safety in case of fire”. The CPR was updated in 2024 (Regulation (EU) 2024/3110), reinforcing the regulatory framework. All BIPV systems fall under the scope of the CPR, as they meet the definition of construction products [1].

Fire safety requirements for construction products are determined by national and local building regulations. As such, they differ in each Member State. Nonetheless, they have to follow the harmonised Euroclass system of fire safety standards as defined in EN 13501-1 (reaction to fire) and EN 13501-5 (external fire exposure to roofs). Fire safety requirements are usually defined based on building height or use.

The classification system under EN 13501-1 ranges from A1 (non-combustible) to F (highly combustible) and includes sometimes additional classifications for smoke production (s1, s2, s3) and flaming droplets (d0, d1, d2).

The standard includes various tests to evaluate the combustibility, flame spread, heat release, smoke production, and occurrence of flaming droplets when materials are exposed to fire.

Furthermore, the EN 50583 standard on ‘Photovoltaics in buildings’ applies to photovoltaic modules used as construction products and refers to the CPR. However, it is not a harmonised standard and therefore does not provide a basis for manufacturers to issue a Declaration of Performance or affix the CE marking. In the absence of a harmonised standard specific to BIPV, national or local regulations apply, particularly regarding fire safety. Hence, the only common reference at EU level remains the classification scheme defined in EN 13501.

2.2 Implication of EN 13501-1 and EN 13501-5 for BIPV products

Whilst fire testing and classification methods for individual construction products are harmonised at EU level, building regulations, including fire safety requirements, remain the responsibility of individual Member States. Each Member State determines its own fire safety level. As such, the same building types might have different minimal fire safety requirements in different Member States. As EN 13501 is the harmonised standard in the EU for construction products, BIPV elements are subject to the required test and classification. Table I details BIPV elements and their corresponding construction products in legislations.

In practice, EN 13501-1 entails that BIPV products, due to their combustibility, are not able to be classified A1 or A2. Indeed, the classification defined in EN 13501 is based on the Single Burning Item (SBI) test. Based on the SBI test, BIPV elements can only achieve B to F classification. This is mainly due to the combustibility of the encapsulant. As part of the Increase project, heat of combustion of different encapsulant materials used in PV modules were collected in Ollagnon *et al.* [2]. As a result, if a national building code requires A2 or higher classification for building elements, BIPV cannot be installed.

Table I: Correlation between BIPV products and construction elements

BIPV product	Construction element
Ventilated façade	External walls
Rainscreen cladding	Ventilated façade
Double-skin façade	
Curtain walls	
Roofing (discontinuous or continuous)	Roof
Skylight	
Balustrade	Barriers
Parapet	
Greenhouse window	Window
Winter garden window	
Pergola	Ancillary elements
Shading	
Canopy	

Besides the regulatory limitation on BIPV deployment that SBI and EN 13501 pose, these test methods are not entirely adequate to assess fire behaviour of façades overall and BIPV elements in particular. The SBI test is a small-scale test that has been developed to allow for easier and less costly study of the fire reaction of

building materials. In practice the test is undertaken to simulate a scenario of combustion of an isolated object in a bin burner in a corner of a room. There are currently discussions on the suitability of such test to assess a façade, as the fire scenario of a fire occurring in a façade is different from a small item in terms of heat power or sample size, measurement parameters and observations.

Thus, some countries have developed mid- and large-scale fire tests to palliate for these shortcomings. At European level, the harmonisation of large-scale testing methods are also being investigated. Such method would be more suitable for BIPV testing and thus support BIPV deployment. Indeed, Belgium and the Netherlands, for example, are permitting other alternatives to justify safety in case of fire, through other type of tests.

Regarding BIPV elements, the standard does not address BIPV particularities. Notably, there is no specification regarding where the junction boxes or cables should be added. Furthermore, SBI and EN 13501 assumes passive materials, whereas BIPV can generate heat and electrical faults. More details on these shortcomings are provided in the discussion section.

3 OVERVIEW OF FIRE SAFETY REGULATIONS IN INCREASE DEMONSTRATION SITE COUNTRIES

3.1 Belgium

Belgium has a multi-layered approach to fire safety, with responsibilities shared between federal, community, regional and municipal authorities.

The Arrêté royal du 7 juillet 1994 (Royal Decree of 7 July 1994) and its amendments set the basic fire prevention standards for new buildings and extensions, including fire resistance of structural elements, reaction to fire of materials, fire compartmentation and evacuation and specific rules for façades, roofs and technical installations. The Decree provides general provisions and detailed ones in its annexes (Annex 1 Terminology, Annex 2 Low-rise buildings, Annex 3 Mid-rise buildings, Annex 4 High-rise buildings) [3].

The 2022 amendment to the Decree introduced explicit fire safety requirements for façades, which apply to BIPV when integrated into the external wall system. One major change affecting BIPV is the introduction of a minimum requirements of A2 class for high-rise buildings. However, the Belgian legislation offers an alternative compliance route to allow for materials not meeting the A2 requirements with large-scale testing of the façade.

3.1.1 Building classification

The Decree details a building classification based on height (distance between the finished floor level of the highest floor and the lowest level of the roads surrounding the building) [4]:

- High-rise building (*bâtiments élevés* - BE): above 25m
- Mid-rise building (*bâtiments moyens* - BM): between 10m and 25m
- Low-rise building (*bâtiments bas* - BB): lower than 10m

3.1.2 Minimum fire safety classification requirements for façades

Fire safety requirements are outlined in Annex 5 of

the Decree (§6.1.1). Requirements for external surfaces of façades are as follows:

- High-rise buildings: A2-s3, d0 or large-scale testing
- Mid-rise buildings: B-s3, d1
- Low-rise buildings: C-s3, d1 for single-wall façade and D-s3, d1 for double-wall ventilated façade

Section 6.2 “*Essai à grande échelle*” of Annex 5/1 in the Belgian Arrêté royal du 7 juillet 1994 introduces a complementary testing method for façades [4]. The large-scale test is designed to evaluate the global fire behaviour of a façade system under realistic conditions, beyond what small-scale Euroclass tests EN 13501-1 can show. It addresses fire spread via the external envelope, including vertical and lateral propagation and the risk of flames reaching upper storeys. If a façade system passes a recognised large-scale fire test (BS 8414-1 and LPS 1581, BS 8414-2 and LPS 1582 and LEPiR 2 with the related Decree of 10 September 1970) and meets the performance criteria defined in the referenced documents, then the A2 requirement does not apply to that façade.

As such, Belgium has an alternative compliance route, in which a high-rise façade does not need to meet Euroclass A2 if the entire system is successfully tested at large scale and satisfies the prescribed performance limits. This applies only if the test is done according to the listed standards and the criteria in the annex are met, the system must demonstrate controlled fire spread and integrity under severe conditions.

3.1.3 Minimum fire safety classification requirements for roofs

Roofing products must be classified as B_{ROOF} (t1) as stated in §8.1 of Annex 5 of the Decree [4]. Furthermore, balconies and walkways must also have a B_{ROOF} (t1) class.

3.2 Estonia

In Estonia, the Building Code aims to ensure the safety, purposeful functionality and usability of the built environment, as well as to promote sustainable development [5]. Fire safety is mentioned among the requirements for construction works (§11(2)). The Fire Safety Act provides general requirements, obligations, rights and liabilities related to ensuring fire safety of legal persons and governmental entities [6].

Fire safety requirements for buildings are detailed in a dedicated regulation from 2021 [7]. This document notably outlines the fire safety classes of buildings, from TP1 to TP3 (§5), building classifications based on usage (Annex 1), fire safety requirements for roof and roof coverings (§16), balconies (§17) and external walls (§21 and Annex 7).

3.2.1 Building classification

Buildings are classified based on their usage and described in Annex 1 of the Fire safety requirements for buildings regulation [7]. Seven categories of use exist, based on the occupants’ familiarity with the building and able to ensure their own safety in case of fire and whether or not the occupants are expected to sleep in the building. Building categories, based on use are summarised below.

- Use I: Residential buildings
- Use II: Accommodation buildings
- Use III: Welfare and detention buildings

- Use IV: Assembly buildings
- Use V: Offices
- Use VI: Industrial and warehousing buildings
- Use VII: Garages

Buildings are also divided into classes according to their fire safety, TP1 fire-resistant (*tulekindel*), TP2 fire-retardant (*tuldtakistav*), TP3 fire-sensitive (*tuldkartev*) (§5) and detailed in Table II. This classification is determined by use of the building, the purpose of the premises, the number and area of floors, the height of the building, the number of users, the specific fire load density and the fire hazard of the activities taking place in the building (§5(1)). Different part of a building can have different fire safety classes in so far as there a fire protection structures and that the lower floor has a higher safety class than the upper levels.

Table II: Overview of building fire safety classes in Estonia

Fire safety designation	Description
TP1 fire-resistant	The building's load-bearing structure must not collapse during the specified time in the event of a fire; generally, such a structure does not collapse during a fire.
TP2 fire-retardant	The building's load-bearing structure must not collapse during the specified time in the event of a fire; however, the specified time is shorter than that required for a fire-resistant building.
TP3 fire-sensitive	The fire resistance of the building's load-bearing structure is not specified, provided it does not affect the fire resistance of fire compartments.

Building classifications come with specific restrictions on the number of storeys, height and number of users of the building and enclosed area of the building. TP1 buildings do not have specific restrictions as their fire safety is higher. However, TP2 and TP3 buildings have restrictions, which are specified in Annex 2 of the legislation. TP2 buildings can be up to 2 storey and 9 m high, except residential and office buildings which can go up to 8 storey and 14 m for 3-4 storey and 28 m for 3-8 storey. TP3 buildings should be up to 2 storey and 9 m high. Essentially, bigger or riskier buildings must be TP1 and smaller, lower-risk ones can be TP3.

3.2.2 Minimum fire safety classification requirements for façades

Fire safety requirements for building elements are detailed in the Fire safety requirements for buildings regulation, including fire safety requirements for roof and roof coverings (§16), balconies (§17) and external walls (§21 and Annex 7) [7]. Table III provides an overview of the fire safety requirements for façade elements based on building classification, use and related restrictions on height and number of storey.

Estonia requires B, d0 for external walls for high-rise buildings and specific uses, such as welfare and educational buildings, and mid-rise office and residential buildings. As a results, BIPV is challenging to install on these buildings. It is worth noting that A2 requirements for insulation system do not pose an issue for BIPV

installation.

The requirement for a B-s1, d0 fire classification on the outer surface of the ventilation cavity facing the external cladding is also challenging. This surface often contains combustible materials, including plastic backsheets, junction boxes and electrical connectors. Standard fire tests may struggle to achieve the required classification when these components are present and the actual installation may involve even greater quantities of combustible material not fully represented in laboratory samples. In contrast, the fire classification for the cavity surface opposite the supporting wall or insulation is contingent upon the insulation material selected, specifying an insulation product that meets the necessary fire rating can facilitate compliance for this interface.

The fire performance requirement for balconies, loggias and terraces is D-s2 for buildings up to two storeys, B-s1 for buildings between 3 and 8 storeys and A2-s1 for buildings with a height of over 28m (§17(2)). Surface layers of balconies are also restricted in terms of fire safety requirements, with a minimum of D_{fl}-s2 for buildings up to five storeys and B_{fl}-s1 for buildings above five storeys (§17(2)).

Table III: Overview of fire safety requirements for façade elements in Estonia

Building class and use	External wall	Outer surface of the ventilation gap	Inner surface of the ventilation gap
TP1 Generally	B, d0	B, d0	B-s1, d0
TP1 For medical and welfare institutions (Use III) of more than 2 storey, kindergarden (Use IV) of more than 2 storey and school buildings (Use IV) of more than 3 storey	B, d0	B, d0	B-s1, d0
TP2 Generally	D, d2	D, d2	D-s2, d2
TP2 Buildings in use III (welfare, detention)	B, d0	B, d0	B-s1, d0
TP2 Use I (residential buildings) and V (offices) use with 3-8 storey	B, d0	B, d0	B-s1, d0
TP3 Generally	D, d2	D, d2	-

3.2.3 Minimum fire safety classification requirements for roofs

External fire resistance for roofing materials should be B_{ROOF}(t₂-t₄) (§16(3)) or lower if the building does not possess any fire source or if it is located at least more than 40 m away from other constructions (§16(4)) [7].

3.3 France

In France, the Building and Housing Code (*Code de la construction et de l'habitation*, CCH) is the Code that brings together the legislative and regulatory provisions

relating to construction, property development, social housing and other property-related matters [8]. In addition, certain building regulations are contained in other codes or are not included in any code.

3.3.1 Building classification

France separates building types into residential and non-residential buildings (called in French *établissement recevant du public* (ERP)). Residential buildings are classified into four “families” or groups, as specified in Article 3 of the “Arrêté du 31 janvier 1986 relatif à la protection contre l'incendie des bâtiments d'habitation” [9]. Residential buildings are classified depending on height, number of storey and disposition (in a row or independent). The four “families” can be summarised as follows:

- Family 1 and 2: low-rise houses and low-rise buildings (up to 3 stories),
- Family 3: mid-rise buildings, 4-8 stories or up to 28 m,
- Family 4: high-rise buildings, between 28 and 50 m.

The rules of non-residential buildings (ERP), are specified in the CCH from Articles R 143-1 to R 143-47. ERP are defined as premises and buildings in which persons are admitted, either freely or for a fee or contribution of any kind, or in which meetings open to the general public or by invitation, whether paid or free of charge, are held [8]. General rules regarding fire safety apply to all non-residential buildings and particular rules apply to specific types of buildings.

Non-residential buildings are classified doubly, depending on the use of the building (type) and the number of people the building can accommodate (category). Whatever their type, non-residential buildings fall into five categories depending on the number of people they can accommodate, as follows:

- 1st category: more than 1500 people
- 2nd category: from 701 to 1500 people
- 3rd category: from 301 to 700 people
- 4th category: less than 300 people, except for buildings included into the 5th category
- 5th category: small buildings, the number of people does not reach the minimum number set by the safety regulations for each type of building usage.

The types of building, depending on use, are outlined in Article GN1 §1 of the “Arrêté du 25 juin 1980” [10].

Other types of non-residential buildings have specific conditions set by different ministries, such as establishments dependent on public law entities, buildings necessary for the functioning of public railways, prisons, military establishments and administrative detention centres.

3.3.2 Minimum fire safety classification requirements for façades

Before Euroclasses, France used a M classification based on combustibility and flammability of the materials. The M classification tends to disappear and is not used in practice but still present in the legislation. The M classification was translated into Euroclass with the Arrêté du 21 novembre 2002 [11]. Regarding façades, minimum fire safety requirements are outlined in Euroclasses, however for roofs, they are described using the M classification.

Fire safety requirements for residential buildings façades are outlined in Euroclass, in Articles 12 and 13 of the Arrêté du 31 janvier 1986 and are as follows [9]:

- 1st family: at least D-s3, d0
- 2nd family: at least D-s3, d0
- 3rd family: at least A2-s3, d0
- 4th family: at least A2-s3, d0

General fire safety requirement for non-residential buildings (ERP) are outlined in the “Arrêté du 25 juin 1980 portant approbation des dispositions générales du règlement de sécurité contre les risques d'incendie et de panique dans les établissements recevant du public (ERP)”, more specifically in Livre II, Titre Ier, Chapitre II [10].

Article CO 20 from the Arrêté du 25 juin 1980 sets fire safety rules for façades. For most cases, the façade components must be made of M3 materials or have a European fire classification of D-s3, d0 [10]. There are stricter requirements if the C+D rule from Article CO 21 §3 is not applied to the entire façade (i.e. no vertical fire barrier between floors), then external cladding and shutters and blinds must meet higher fire performance M2 materials or classified as C-s3, d0.

In addition, laboratory assessments are possible following Technical Instruction 249 (IT 249) [12]. IT 249 supplements the fire safety regulations for ERP buildings, residential buildings and high-rise buildings. It outlines provisions relating to façades and their connection with floors. Its role is to limit the risk of fire spread to the levels above or laterally via the façades. Laboratory assessments of the fire performance of an innovative process are also possible with a Technical Experimentation Assessment (ATEX). However, in this case, the fire performance of the tested solution is project specific and cannot be replicated and the process is timely and costly. The administrative burden is further exacerbated by the fact that there is no validation ensured and that the tests might have to be undertaken again.

3.3.3 Minimum fire safety classification requirements for roofs

For roofs, the French legislation uses its own classification system, from M0 to M4. The French fire classification for roofing includes two components, the T/x (e.g. T/5, T/15, T/30) indicates how long the roof resists fire penetration from the outside (in minutes) and the Indice de propagation (1, 2, 3) shows how well the roof limits fire spread to nearby buildings. Indice 1 is the best (low spread risk), Indice 3 is the least protective. The Arrêté du 14 février 2003 relatif à la performance des toitures et couvertures de toiture exposées à un incendie extérieur translated the French system into the Euroclasses, as outlined in Table IV below. In France, only Test 3 (t3) is recognised for regulatory use.

Table IV: Overview of the correlation between the French classification for roofing materials and the Euroclasses

French classification	Euroclasses
T30	B _{ROOF} (t3)
Indice 1	
T15	C _{ROOF} (t3)
Indice 2	
T 5	D _{ROOF} (t3)
Indice 3	

Construction elements from M0 to M3 (corresponding to B_{ROOF}) can be used without restrictions if built on continuous incombustible material. Roofs with M0 to M3 materials are automatically considered Indice 1.

Roof coverings in category M4 must meet two fire safety criteria regarding resistance to fire penetration (T/x) and control of fire spread to neighbouring buildings. Resistance to fire penetration must meet the below requirements depending on the building family:

- 1st family: T/5, T/15 or T/30
- 2nd family: T/15 or T/30
- 3rd and 4th families: T/30

The control of fire spread to neighbouring buildings (*Indice de propagation*) depends on the distance to the neighbouring building or property line and the Indice of the neighbour's roof. The propagation index (1 to 3) is not directly included in CEN TS 1187 but is partially reflected in flame spread criteria.

Overall, the French roofing fire protection requirements by housing family for residential buildings can be summarised as follows in Table V.

Table V: Summary of fire rating requirements for roofing materials for residential buildings in France based on building families

Building family	French fire penetration class	Euroclass equivalent	Propagation index required
1 st family	T/5, T/15 or T/30	D _{ROOF} (t3), C _{ROOF} (t3), B _{ROOF} (t3)	Depends on distance (Indice 1 to 3)
2 nd family	T/15 or T/30	C _{ROOF} (t3), B _{ROOF} (t3)	Depends on distance (Indice 1 to 3)
3 rd and 4 th family	T/30	B _{ROOF} (t3)	Depends on distance (Indice 1 to 3)

Fire safety requirements for roofing in ERP aims to protect the roof from fire originating from a neighbouring building. If buildings are contiguous, the roof must also comply with isolation rules in Article CO 7 (§2 and §3) of the 25 June 1980 Arrêté [10].

Table VI: Summary of fire rating requirements for roofing materials for non-residential buildings in France based on building families

Category and purpose of the ERP	Distance to neighbour			
	Less than 8 m		Between 8 and 12 m	
1 st family, or 2 nd , 3 rd and 4 th with sleeping areas	T 30 Indice 1	B _{ROOF} (t3)	T 15 Indice 1	C _{ROOF}
2 nd , 3 rd and 4 th family without sleeping areas	T30 Indice 2	B _{ROOF}	T 15 Indice 2	C _{ROOF} (t3)

Requirements depends on the distance to other buildings. If the ERP is more than 12 metres from the neighbouring building or property line, no fire protection requirement applies to the roof. If another building is located less than 12 metres from the ERP, the roof must meet one of the following:

- Made of M0 materials (non-combustible),
- Made of M1 to M3 materials, installed on continuous support in M0 material or continuous support in wood or equivalent,
- Made of M1 to M3 materials not installed as above, or M4 materials with minimum class and propagation index based on building category and distance (described in the Table VI).

3.4 Montenegro

Montenegro is an EU candidate country. Accession negotiations with Montenegro started in June 2012 and EU candidate countries must meet a set of criteria (*acquis*) before joining the Union. The European Commission supports these countries in implementing reforms during the accession process and comply with the EU *acquis*. When the accession negotiations and the reforms have been completed the country can join the EU, if all current Member States agree.

Future EU countries need to be able to join the EU Single Market. For Montenegro and the Western Balkans, this area of integration is supported by the launch of the Western Balkans Common Regional Market structured around free movement of goods, services, capital and people. The aim is to integrate the region before accession to the Single Market. As an essential element of the free circulation of construction products in the EU, the CPR must also be implemented in Montenegro to align its standards with EU requirements.

As such, Montenegro has adopted a Law on Construction Products that partially transposes the EU Construction Products Regulation. This law and its bylaws are the legal basis for the use of harmonised European standards, including those related to fire safety and Euroclass. A Rulebook on Construction Products was published in 2017, it regulates construction products in Montenegro [13]. However, the publicly available summary does not specify if it directly references Euroclass or EN 13501-1. The full text would need to be checked for explicit mention.

In addition, Montenegro generally accepts building materials with certificates from the country of origin, especially if they are CE-marked and compliant with EU standards. There is no mention of local testing or additional national standards for fire classification, suggesting that Euroclass (EN 13501-1) is accepted in practice for CE-marked products [14].

Given the difficulty to find relevant information about the regulation, Montenegro will not be analysed in the rest of the document.

3.5 Spain

The Spanish Building Code or *Código Técnico de la Edificación* (CTE) provides the regulatory framework governing the basic quality requirements that buildings, including their installations, must meet in order to satisfy basic safety and habitability requirements. It is organised in two parts, with the first one containing the general provisions and conditions of application of the CTE and the basic requirements that buildings must comply with [15]. The second part is composed of "Basic Documents" for the fulfilment of the basic requirements of the CTE. These Basic Documents provide the technical characterisations and procedures to meet the requirements.

The Basic Documents cover structural security, fire safety, safety in use, hygiene, health and environmental protection, noise protection and energy saving and thermal insulation. The relevant one for fire safety is the *Documento Básico Seguridad en caso de incendio* (DB-SI), it specifies parameters and procedures to comply with the fire safety requirements of the Building Code, except for industrial buildings, which are covered in another document.

It is worth noting that the Spanish Ministry of Housing and Urban Agenda has initiated the public consultation process for a draft Royal Decree amending the Building Technical Code (*Real Decreto* 314/2006), with the consultation period open until 9 December 2025, which includes updated fire safety requirements for building envelopes, among other key revisions. Once the Decree is released, an updated version of this paper will be published.

3.5.1 Building classification

Building classification are determined by the use of the building and spelt out in Annex SI A “Terminology” [16]. Building usage include: administrative, warehouse, parking, commercial, educational, hospital, public residential and residential uses. Buildings across various sectors serve distinct purposes, each defined by their primary function and the nature of activities conducted within them.

3.5.2 Minimum fire safety classification requirements for façades

In Spain, the facade fire reaction class requirements do not vary by occupancy, they are set by the height of the facade.

The fire classification for façade “construction system” occupying more than 10% of the surface area depend on the total height of the façade and are the following (SI 2 §4 [16]):

- D-s3, d0 for façades up to 10 m high;
- C-s3, d0 for façades up to 18 m high;
- B-s3, d0 for façades over 18 m high.

Insulation systems inside ventilated chambers must have at least the following reaction to fire classification depending on the total height of the façade (SI 2 §5 [16]):

- D-s3, d0 in façades up to 10 m high;
- B-s3, d0 for façades up to 28 m high;
- A2-s3, d0 for façades higher than 28 m.

Spain also has a special rule to prevent fire spread at ground level (SI 2 §6 [16]). For buildings up to 18 m, if the facade is accessible to the public (ground floor or roof terraces), the first 3.5 m of facade from the ground must be at least Class B-s3, d0, even if the rest of the facade can be C or D. This is to mitigate arson or fire exposure where people can reach the facade.

3.5.3 Minimum fire safety classification requirements for roofs

With regards to roof, materials, products or systems covering more than 10% of the roof surface should have a B_{ROOF} (t1) classification.

3.6 Switzerland

Switzerland is not an EU Member State, however it signed a Mutual Recognition Agreement (MRA) with the European Community (now the EU), which entered into force in 2002. The MRA aims to promote trade in goods between the EU and Switzerland by removing technical

barriers, via the recognition of conformity assessments for several products, including construction products.

At the Swiss level, the fire protection regulations are issued by the Association of Cantonal Fire Insurance Institutions (VKG/AEAI). They include the fire standard (*norme de protection incendie*) and the directives (*directives de protection incendie*) together with explanatory notes on fire protection, as well as thematic support publications and references to specific sectors of use [17]. The fire protection standard establishes the framework for fire safety, covering general duties, construction, fire protection equipment, organisation and related fire defence measures. It sets the applicable safety standards and is supplemented by fire protection guidelines, which detail the specific requirements and implementation measures.

Fire protection requirements for buildings and other structures are determined in particular by [18]:

- a) the type of construction, location, risks in relation to neighbouring properties, size and intended use;
- b) the geometry of the building and the number of storeys;
- c) the number of occupants;
- d) the thermal load and fire behaviour of materials, as well as the risk of smoke emission;
- e) the activation hazard inherent to the building’s use and the activities carried out within it;
- f) the intervention capabilities of the fire brigade.

3.6.1 Building classification

Buildings are classified according to their “geometry”, that is to say, their size, according to Article 13 (3) of the “Norme de protection incendie” [18]. The classification is summarised as follows:

- Low-rise building: up to 11 m
- Medium-rise building: up to 30 m
- High-rise building: above 30 m
- Small-scale building: up to 2 levels above ground and up to 1 underground
- Annex building: single-storey

Article 13 (1) also outlines building classification according to their intended use [18]. Uses include accommodation establishments, large shops, premises accommodating large numbers of people, car parks, high-bay warehouses and temporary structures.

The fire protection directive, “Directive de protection incendie: Matériaux et éléments de construction”, defines the classification of materials and construction elements according to both the EN and VKG/AEAI systems and sets the required EN fire resistance classes for different construction elements in Switzerland [19]. Indeed, construction materials can be classified according to the EN 13501-1 standard or according to the VKG/AEAI classification.

Construction materials are classified into the following groups according to their fire behaviour (RF), as described in 2.1 (1) of the “Directive de protection incendie: Matériaux et éléments de construction” [19]:

- RF1: no contribution to fire
- RF2: low contribution to fire
- RF3: acceptable contribution to fire
- RF4: unacceptable contribution to fire

The legislation also considers materials that have critical fire behaviour (cr). That is to say, materials that may have unacceptable effects in the event of a fire, due

to smoke production, the formation of burning droplets or particles, or corrosion.

The legislation also propose a correlation table between the EN 13501-1 classification and the VKG/AEAI classification for construction products and for roofing materials.

3.6.2 Minimum fire safety classification requirements for façades

The fire protection directive on use of construction materials (Directive de protection incendie: Utilisation des matériaux de construction) sets out the requirements that building materials must meet in terms of their reaction to fire [20]. Detached houses must meet the requirements for ‘low-rise buildings’, regardless of the geometry of the building (§12(1)). For medium-rise buildings, if the exterior wall cladding and/or thermal insulation consists of combustible building materials, it must be ensured that the fire brigade can access the affected façade to fight the fire (§3.1.1(1)). The external wall and the external wall cladding system of high-rise buildings (*bâtiments élevés*) must be made of RF1 category materials (§3.1.2(1)). Table VII provides a detailed overview of minimum fire safety requirements for façades using both the Swiss and Euroclass classifications.

Translucent elements made of combustible materials may only be used for limited areas (§6). Window frames and essential elements with a negligible surface area (connectors, joints, insulating crossbars, edge strips, etc.) must be made of materials that at least meet the requirements of category RF3 (cr). They may be used regardless of the specifications concerning the choice of materials (§7).

Ventilated facades (§3.2.3) used on medium-rise buildings must be of a design recognised by the AEAI or equivalent if the cladding and/or insulation on either side of the air gap, or the solid layers, are made of combustible building materials. Cladding on low and medium-rise buildings may be fixed to laths made of RF3 (cr) materials. Fixings and point anchors that hold the cladding of ventilated façades and are located in the thermal insulation must be made of materials that are at least RF3 (cr), regardless of the height of the building (including high-rise buildings).

Double-skin façades (§3.2.4) extending over several storeys must be made of RF1 materials. However, linear window profiles made of combustible materials are permitted. The use of combustible building materials is possible, subject to additional measures.

The regulation outlines two complementary concepts for fire protection in buildings. The construction-based concept (concept de construction) relies on passive measures such as fire-resistant materials and structural design to meet safety objectives. Depending on the building’s use, additional fire protection equipment may be required. The extinguishing system concept (*concept d’installation d’extinction*) integrates certified fixed fire suppression systems (e.g. sprinklers) into the building’s fire safety strategy, particularly in cases where passive measures alone are insufficient. Depending on which concept is used, fire safety requirements may differ.

Furthermore, accommodation establishments [a], that is to say hospitals, care homes and medico-social facilities accommodating 20 or more people, either permanently or temporarily, who require assistance from others, require higher fire safety protection, mostly RF1.

In addition to the requirements set out in the legislation, Swissolar developed a transitional guide for planning and demonstrating fire protection in ventilated PV façade installations, valid until 31 December 2026 [21]. The guide aims to address the lack of a definitive technical standard for fire safety in PV façades and complements existing VKG/AEAI and Swissolar guidelines.

The guide explains which façades, under what conditions and with what fire protection verification procedures, BIPV installations can be planned and, if authorised, implemented. It also outlines technical principles specific to façades, supplementing the VKG/AEAI fire protection guidelines for solar panels. This document simplifies planning and justification for fire protection specialists, and makes evaluation easier for fire protection authorities. However, it does not grant automatic approval, each project must be individually assessed. The guide is not a definitive technical standard, but serves as a transitional document until such a standard is available.

Fire risks are detailed and different BIPV ventilated façade systems are described. PV façade systems are classified into three categories: System 0, with no verification required (mainly for low-rise buildings), System 1 with verification by argumentation/report and System 2 with verification by fire testing. The procedure for fire protection verification defines protection objectives that must be submitted to the fire protection authority for approval. Since there is no established technical standard, compliance with these protection objectives for system category 2 must be demonstrated through fire tests.

In the case of mid-rise buildings (up to 30 m), bi-glass with minimum thickness BIPV modules with a B-s3, d1 classification according to EN 13501-1 are allowed with further fire safety measures (System 1) or testing showcasing fire safety protection is achieved (System 2). BIPV can be allowed for mid-rise and high-rise buildings if strict fire protection measures are implemented and, where necessary, compliance is demonstrated through fire tests and detailed verification reports, all subject to approval by the fire protection authority. For high-rise buildings, up to 100 m, bi-glass BIPV modules with a B-s3, d1 classification can be installed with several requirements. The façade and cladding (excluding PV modules) must be made of RF1 materials or encapsulated systems, horizontal fire protection measures must be implemented at each floor in the ventilated cavity and cable ducts and no inverters are allowed in the rear ventilation space. In this case as well, fire tests are required.

3.6.3 Minimum fire safety classification requirements for roofs

Minimum fire safety requirements for roofing materials are RF3 (cr), corresponding to C_{ROOF} (t3), C_{ROOF} (t4), D_{ROOF} (t3), D_{ROOF} (t4), except for specific roof structures such as warm roofs with single or double ventilation (*toiture chaude à ventilation simple et double*) and flat roofs (*toiture plate*), which require RF1 materials. In addition, surface limitations apply to insulated roof types (*toiture isolée*) classified under roof categories 6, 7, 8, and 9, with 600 m² for categories 6 and 7 and 1200 m² for categories 8 and 9 [20].

Table VII: Overview of minimum fire safety requirements for façade elements depending on building geometry and specified EN 13501-1 classification and the VKG/AEAI classification (in bold)

	Construction-based concept	Extinguishing system concept	
Low-rise buildings	Overall façade	D-s1,d2 ; D-s2,d2 ; D-s3,d0 ; D-s3,d1 ; D-s3,d2 ; E ; E-d2 (RF3 (cr))	D-s1,d2 ; D-s2,d2 ; D-s3,d0 ; D-s3,d1 ; D-s3,d2 ; E ; E-d2 (RF3 (cr))
	Exterior wall cladding	D-s1,d2 ; D-s2,d2 ; D-s3,d0 ; D-s3,d1 ; D-s3,d2 ; E ; E-d2 (RF3 (cr))	D-s1,d2 ; D-s2,d2 ; D-s3,d0 ; D-s3,d1 ; D-s3,d2 ; E ; E-d2 (RF3 (cr))
	Thermal insulation layers	D-s1,d2 ; D-s2,d2 ; D-s3,d0 ; D-s3,d1 ; D-s3,d2 ; E ; E-d2 (RF3 (cr))	D-s1,d2 ; D-s2,d2 ; D-s3,d0 ; D-s3,d1 ; D-s3,d2 ; E ; E-d2 (RF3 (cr))
	Semi-transparent panels	D-s1,d0 ; D-s1,d1 ; D-s2,d0 ; D-s2,d1 (RF3)	D-s1,d0 ; D-s1,d1 ; D-s2,d0 ; D-s2,d1 (RF3)
Medium-rise buildings	Overall façade	A2-s1,d2 ; A2-s2,d2 ; A2-s3,d0 ; A2-s3,d1 ; A2-s3,d2 ; B-s1,d2 ; B-s2,d2 ; B-s3,d0 ; B-s3,d1 ; B-s3,d2 ; C-s1,d2 ; C-s2,d2 ; C-s3,d0 ; C-s3,d1 ; C-s3,d2 (RF2 (cr))	D-s1,d2 ; D-s2,d2 ; D-s3,d0 ; D-s3,d1 ; D-s3,d2 ; E ; E-d2 (RF3 (cr))
	Exterior wall cladding	A2-s1,d2 ; A2-s2,d2 ; A2-s3,d0 ; A2-s3,d1 ; A2-s3,d2 ; B-s1,d2 ; B-s2,d2 ; B-s3,d0 ; B-s3,d1 ; B-s3,d2 ; C-s1,d2 ; C-s2,d2 ; C-s3,d0 ; C-s3,d1 ; C-s3,d2 (RF2 (cr))	D-s1,d2 ; D-s2,d2 ; D-s3,d0 ; D-s3,d1 ; D-s3,d2 ; E ; E-d2 (RF3 (cr))
	Thermal insulation layers	D-s1,d2 ; D-s2,d2 ; D-s3,d0 ; D-s3,d1 ; D-s3,d2 ; E ; E-d2 (RF3 (cr))	D-s1,d2 ; D-s2,d2 ; D-s3,d0 ; D-s3,d1 ; D-s3,d2 ; E ; E-d2 (RF3 (cr))
	Semi-transparent panels	A2-s1,d1 ; A2-s2,d0 ; A2-s2,d1 ; B-s1,d0 ; B-s1,d1 ; B-s2,d0 ; B-s2,d1 ; C-s1,d0 ; C-s1,d1 ; C-s2,d0 ; C-s2,d1 (RF2)	D-s1,d0 ; D-s1,d1 ; D-s2,d0 ; D-s2,d1 (RF3)
High-rise buildings	Overall façade	A1 ; A2-s1,d0 (RF1)	A1 ; A2-s1,d0 (RF1)
	Exterior wall cladding	A1 ; A2-s1,d0 (RF1)	A1 ; A2-s1,d0 (RF1)
	Thermal insulation layers	A1 ; A2-s1,d0 (RF1)	A1 ; A2-s1,d0 (RF1)
	Semi-transparent panels	A1 ; A2-s1,d0 (RF1)	A2-s1,d1 ; A2-s2,d0 ; A2-s2,d1 ; B-s1,d0 ; B-s1,d1 ; B-s2,d0 ; B-s2,d1 ; C-s1,d0 ; C-s1,d1 ; C-s2,d0 ; C-s2,d1 (RF2)

Translucent roof coverings are permitted under Swiss fire regulations provided they are made of materials classified at least RF3, cover no more than 30% of the total roof surface, and do not exceed 40 m² above evacuation routes or 120 m² above other areas. Individual sections of translucent roofing must be spaced at least 2 metres apart. If the materials used are classified RF1, these surface limits do not apply (§3.3.1(4)).

4 COMPARATIVE ANALYSIS OF FIRE SAFETY REGULATIONS IN INCREASE DEMONSTRATION SITE COUNTRIES

This section presents a comparative analysis of fire safety regulations in the countries hosting Increase demonstration sites, namely Belgium, Estonia, France, Spain and Switzerland. It aims to investigate how national building classification systems, fire rating requirements and regulatory approaches shape the requirements for both façade and roofing materials, with particular focus on their implications for the deployment of BIPV across a range of building types and heights. The analysis highlights common trends, distinctive national practices and specific challenges encountered when integrating BIPV into construction. A typology of buildings and their suitability for BIPV installation is also proposed. By systematically examining the minimum fire safety standards and the feasibility of BIPV installation in residential and non-residential contexts, this section provides a foundation for understanding the regulatory landscape and identifying opportunities for solar integration in European buildings. Figure 1 provides an overview of commonalities and differences in regulatory approaches.



Figure 1: Overview of commonalities and differences in regulatory approaches for fire safety in buildings in Belgium, Estonia, France, Spain and Switzerland

4.1 Building classification and fire rating

Building classification systems across Belgium, Estonia, France, Spain and Switzerland vary in structure but converge in their role of shaping fire safety requirements. **Belgium, Spain and Switzerland** primarily classify buildings by height, with thresholds triggering progressively stricter fire safety measures. **Spain** classifies buildings by use, though fire safety obligations ultimately depend on height. **Estonia** adopts a dual system based on building use and fire resistance class, which directly governs permissible height, number of storeys and occupancy. **France** distinguishes between residential and non-residential buildings. The former including categories (“families”) depending on height,

number of storeys and disposition (in a row or independent), and the latter being categorised by both use and capacity, with fire safety rules tailored accordingly in dedicated regulations. Overall, these systems reflect national priorities, whether structural resilience, occupant vulnerability or building function, and determine the scope of fire protection measures, evacuation planning and material standards.

Additionally, **France and Switzerland** have their own classification system for fire rating with corresponding Euroclasses. **France** historically used its own “M” combustibility ratings from M0 incombustible and M1 non-flammable, down to M4. In practice, the use of the M classification is phasing out but still present in the legislation and for products certified before 2022. These have been translated into Euroclasses. France uses a unique system for roof fire performance: classifications like T30, T15, T5 coupled with “Indice de propagation” 1-3 (spread index). **Switzerland’s** classification system is based on the fire behaviour of the materials with a ranking from RF1 (no contribution to fire) to RF3 (acceptable contribution to fire), with RF4 representing an unacceptable contribution to fire. Critical fire behaviour of the materials are represented with (cr). This classification has been translated into Euroclass terms in the Swiss legislation.

4.2 Commonalities and differences in regulatory approaches

Overall, the Grenfell Tower fire (June 2017) has led to stronger fire safety requirements in buildings in Europe, including stricter rules for high-rise buildings. The studied countries also witnessed this effect, with changes and updates in regulations in **Belgium** in 2022, in **Estonia** in 2021, in **France** in 2019 and upcoming in **Spain**.

In terms of regulatory approaches, the analysis of the regulations in the five countries showcases two approaches, one with fire safety requirements based on building height only (**Belgium, Spain and Switzerland**) and a dual approach based on height and use of the building (**Estonia, France**). **Estonia’s** approach also stands out with its fire safety classes for the overall building (TP1-TP3), with TP2 and TP3 inducing restrictions on height, number of storeys and number of users. In effect, TP3 and TP2 are allowed for low-rise buildings, up to 9 m and TP2 is allowed for mid-rise buildings for residential (Use I) and office buildings (Use V). TP1 is therefore mandatory for high-rise buildings. **Switzerland** also have higher requirements for welfare buildings (accommodation establishments [a]).

Furthermore, **Swiss** regulations also present another particularity, they define two complementary approaches to fire protection in buildings. The construction-based approach (*concept de construction*) relies on passive measures, including fire-resistant materials and structural design, to achieve safety objectives. Depending on the building’s function, additional fire protection equipment may be necessary. The extinguishing system approach (*concept d’installation d’extinction*) incorporates certified fixed fire suppression systems, such as sprinklers, into the building’s fire safety strategy, particularly where passive measures alone are inadequate. Fire safety requirements vary depending on the approach adopted.

France adopts a distinct regulatory approach by maintaining separate fire safety regimes for residential

and non-residential buildings (ERP). The requirements for ERP are somewhat less stringent than those for residential buildings. For instance, facades must achieve at least D-s3, d0, with an upgrade to C-s3, d0 mandated in the absence of fire-stops between floors. As such, a mid-rise office building in France may employ a BIPV system rated as Class C, whereas a residential building of comparable height would be required to meet the higher A2 standard. In contrast, most other countries apply a single set of facade classification rules across building types, with only limited exceptions for particular cases. As a result, France's regulatory framework imposes greater constraints on BIPV deployment in residential settings than in offices.

Finally, Belgium, France and Switzerland allow large-scale testing for façades to be installed on mid- and high-rise buildings. In **Belgium**, large-scale fire testing is permitted, allowing for the evaluation of the overall fire behaviour of façade systems in realistic scenarios, offering a more comprehensive assessment than smaller Euroclass tests. **France** provides performance-based routes for BIPV façades, enabling laboratory assessments to demonstrate fire safety compliance. Products typically require a ATEEx from CSTB, certifying fire performance when installed. However, ATEEx are project specific, lengthy, difficult and very costly processes, in practice limiting BIPV adoption to a few prestige projects. In addition, insurance challenges remain limiting the use of innovative BIPV installation in buildings in France [22]. In **Switzerland**, Swisssolar has introduced a transitional guide for planning and verifying fire protection in ventilated PV façade installations, supplementing existing guidelines and facilitating BIPV deployment in mid- and high-rise buildings, provided strict fire measures and thorough testing are undertaken, subject to approval by the fire protection authority.

4.3 Fire safety requirements

This section analyses fire safety requirements in each country for residential and non-residential buildings, from low- to high-rise buildings. Table VIII summarises these requirements.

4.3.1 Residential buildings overview: façade requirements

For **low-rise residential buildings** (single-family homes or 1-3 story apartments), all five countries allow relatively combustible facades (Euroclass D or similar). As a result, BIPV deployment on houses and small-rise residential buildings faces minimal fire code barriers.

Belgium requires C-s3, d1 for single-wall façade and D-s3, d1 for double-wall ventilated façade for buildings lower than 10 m. **Estonia** requires D-s2, d2 for TP2 and TP3 buildings up to 9 m and B, d0 for TP1 buildings and residential buildings with less than 3 storeys require D, d0. In **France**, low-rise residential buildings (up to 3 stories and 8 m from the ground to the floor of the highest level), which are equivalent to family 1 and, require D-s3, d0. **Spain** require D-s3, d0 for buildings up to 10 m. **Switzerland** requires D or E classes for low-rise buildings.

Mid-rise residential buildings have a wide range of requirements from Class B to D, with the notable exception of France, which requires A2. As a result, BIPV is possible in most cases.

Belgium requires B-s3, d1 for buildings between 10 and 25 m. **Estonia** requires B, d0 for residential buildings

with 3-8 storeys (up to 14 m for 3-4 levels and up to 28 m for 3-8 levels). In **France**, A2-s3, d0 is required for the 3rd family of residential buildings (4-8 stories or up to 28 m). **Spain** require C-s3, d0 for buildings up to 18 m. **Switzerland** requires Class C or Class D if fire extinguishing systems are in place in mid-rise buildings.

Regarding **high-rise residential buildings**, all countries converge on very stringent requirements. Typically non-combustible facades (Euroclass A2 or RF1) are mandated, reflecting the high risk. A such, BIPV installation is nearly impossible in some countries for high-rise buildings.

Table VIII: Comparison of fire safety requirements for facades and roofs in Belgium, Estonia, France, Spain and Switzerland

Country	Facade fire rating requirements (for typical buildings)	Roof fire requirements
BE	High-rise (>25 m): A2-s3, d0 Medium-rise (10-25 m): B-s3, d1 Low-rise (<10 m): C or D (depending on system)	B _{ROOF} (t1)
EE	Tall facades (>22 m): B, d0 and A2 thermal insulation Mid-rise buildings: facade outer layer can be D or B depending on building class and use Low-rise buildings: B or D	B _{ROOF} (t2-t4) generally required, unless very isolated situation.
FR	Residential: Low (Fam. 1-2) D-s3, d01 Mid (Fam. 3 ≤ 28 m) A2-s3, d0 or approved test High (Fam. 4 ≤ 50 m) A2-s3, d0 (minor parts allowed if protected). Non-residential (ERP): D-s3,d0 C-s3,d0 if no fire-stops between floors	Residential: B _{ROOF} (t3) With exceptions for individual houses and less than 2 storey buildings (Fam. 1 & 2) Non-residential: B _{ROOF} (t3) C _{ROOF} (t3) if neighbouring buildings over 8 m away
ES	to 10 m: D-s3, d0 Up to 18 m: C-s3, d0 Over 18 m: B-s3, d0 Additionally insulation ≥A2 for >28 m facades. Ground-level 3.5 m of facade to B if accessible public area.	B _{ROOF} (t1) minimum for >10% roof area.
CH	High-rise (>30 m): A2-s1 Medium-rise (11-30 m): B/C class Low-rise: D/E class	C _{ROOF} /D _{ROOF} certain roof types require RF1

Belgium requires A2-s3, d0 for buildings higher than 25 m. In **Estonia**, high-rise buildings would fall into TP1, requiring B, d0. In **France**, A2-s3, d0 is required for the 4th family of residential buildings (between 28 and 50 m). **Spain** require B-s3, d0 for buildings over 18 m, with B-s3, d0 insulation for façade up to 28 m and A2-s3, d0 above 28 m. **Switzerland** requires A2-s1, d0 for high-rise buildings.

Fire safety requirements for residential building facades vary by height across Belgium, Estonia, France, Spain and Switzerland. Low-rise residential buildings in

all five countries permit relatively combustible facades (Euroclass D or similar), posing minimal barriers to BIPV deployment. Mid-rise buildings generally require stricter standards, ranging from Class B to D, except in France, which mandates non-combustible A2 facades. For high-rise residential buildings, all countries enforce stringent, typically non-combustible (Euroclass A2 or equivalent) facade requirements, significantly restricting BIPV options in tall buildings.

4.3.2 Non-residential buildings overview: façade requirements

For **low-rise non-residential buildings**, all five countries allow relatively combustible facades (Euroclass D or similar), except for specific buildings linked to care and welfare activities. As a result, BIPV on houses and small-rise buildings faces minimal fire code barriers.

Similarly to residential, **Belgium** requires C-s3, d1 for single-wall façade and D-s3, d1 for double-wall ventilated façade for buildings lower than 10 m. **Estonia** requires D-s2, d2 for TP2 and TP3 buildings up to 9 m and B, d0 for TP1 buildings and for welfare and detention buildings up to 9 m. Office buildings with less than 3 storeys require D, d0. In **France**, low-rise non-residential (except specific buildings) require C-s3, d0 if no fire barriers exist between floors or D-s3, d0. **Spain** require D-s3, d0 for buildings up to 10 m. **Switzerland** requires D or E classes for low-rise buildings, with the exception of medical buildings, which require A2-s1, d0.

Mid-rise non-residential buildings have a wide range of requirements from Class B to D, making BIPV deployment possible.

Belgium requires B-s3, d1 for buildings between 10 and 25 m. **Estonia** requires B, d0 for office buildings with 3-8 storeys (up to 14 m for 3-4 levels and up to 28 m for 3-8 levels) and B, d0 in general for mid-rise buildings (TP1). In **France**, mid-rise non-residential (except specific buildings) require C-s3, d0 if no fire barriers exist between floors or D-s3, d0. **Spain** require C-s3, d0 for buildings up to 18 m. **Switzerland** requires Class C or Class D if fire extinguishing systems are in place.

Similarly to residential buildings, **high-rise non-residential buildings** require higher safety standards, with A2 in most cases. Here France stands out with lower requirements.

Belgium requires A2-s3, d0 for buildings higher than 25 m. In **Estonia**, high-rise buildings would fall into TP1, requiring B, d0. In **France**, high-rise non-residential (except specific buildings) require C-s3, d0 if no fire barriers exist between floors or D-s3, d0. **Spain** require B-s3, d0 for buildings over 18 m, with B-s3, d0 insulation for façade up to 28 m and A2-s3, d0 above 28 m. **Switzerland** requires A2-s1, d0 for high-rise buildings.

In Estonia and Switzerland, rules are more stringent for specific non-residential buildings, which are deemed higher risk. In **Estonia**, for TP2 class, welfare and medical institutions (Use III) buildings and residential buildings (Use I) and offices (Use V) use with 3-8 storeys require B, d0 for external walls, instead of D, d2 for other buildings. In **Switzerland**, accommodation establishments class [a], that is to say hospitals, care homes and medico-social facilities accommodating 20 or more people, either permanently or temporarily, who require assistance from others, require higher fire safety protection compared to other building uses, mostly RF1 (A1 ; A2-s1,d0). While these A2 requirements represent an issue for BIPV deployment in these buildings, these

specific uses are rather limited and are not as impactful as other challenges. In **France**, specific non-residential buildings (ERP) also have dedicated rules.

Fire safety requirements for non-residential buildings also tighten with height, but some occupancy or use-based nuances exist. **France** stands out by separating them into a distinctive category with slightly relaxed facade criteria (balanced by other requirements like alarms, compartmentation for ERPs), and dedicated requirements in separate regulations. **Switzerland** allows fire engineering (sprinklers, fire curtains) more in commercial projects, which can indirectly ease BIPV integration by compensating for combustibility with safety systems. Meanwhile, critical facilities such as hospitals tend to face stricter rules, effectively narrowing BIPV options unless those are low-rise. Both **Switzerland** and **Estonia** have specific requirements for welfare buildings.

In summary, fire safety requirements for building facades vary significantly by height, building type and country, with low-rise structures in Belgium, Estonia, France, Spain and Switzerland generally permitting more combustible materials and thus facilitating BIPV deployment. Mid-rise buildings face stricter regulations, but BIPV remains feasible in many scenarios. For high-rise constructions, stringent non-combustible standards typically restrict BIPV integration, especially in residential towers, while some non-residential occupancies such as hospitals and care homes face additional limitations. National nuances, such as France's differentiated approach for non-residential buildings and Switzerland's allowance for fire safety engineering solutions, influence BIPV possibilities, but the overarching trend is that height is the major determinants of facade fire safety and consequently, the viability of BIPV across Europe.

4.3.3 Requirements for roofs

Regarding roofing fire safety requirements, most countries have requirements regardless of building use. France and Estonia allow for lower requirements if buildings are isolated. Only France has detailed roofing requirements based on building classification.

For roofing products, **Belgium** requires B_{ROOF} (t1). **Estonia** requires B_{ROOF} (t2-t4) or lower for isolated buildings. **France** defined requirements for residential buildings depending on building families, Family 1 allows Classes D, C and B, Family 2 requires Classes C and B with and Family 3 and 4 require B_{ROOF}. All roofs must follow Test 3 (t3). Roof requirements for non-residential buildings in France depend on the number of users and whether they sleep in the building, as well as the distance to a neighbouring building. For non-residential buildings, France requires B_{ROOF} (t3) for the 1st family or 2nd, 3rd and 4th with sleeping areas if the next building is less than 8 m and C_{ROOF} if the building is located between 8 and 12 m away. For the 2nd, 3rd and 4th family without sleeping areas, the legislation requires B_{ROOF} if the next building is located less than 8 m away and C_{ROOF} (t3) if it is located over 8 m away. **Spain** requires B_{ROOF} (t1) if the roof materials or systems are covering more than 10% of the total roof surface. In **Switzerland**, minimum safety requirements for roofing materials are RF3 (cr), that is to say C_{ROOF} (t3), C_{ROOF} (t4), D_{ROOF} (t3), D_{ROOF} (t4). Translucent roof covering up to 30% of the total roof area require RF3.

In practice, minimum fire safety requirements for roofing materials outlined in the different legislations do not prevent the deployment of BIPV elements on roofs. However, PV presents a different characteristic, PV and IPV can act as a source of fire [23]. For roofs, EN 13501-5 applies, using CEN/TS 1187 test methods (B_{ROOF}(t1-t4)) to assess external fire exposure scenarios, propagation and penetration. These tests were designed for conventional roofing materials, focusing on flame spread and resistance under conditions like burning brands, wind and radiant heat.

CEN/TS 1187 tests do not account for electrical ignition sources, such as DC arcs, or the interaction between PV components and roofing membranes. EN 13501 assumes passive materials, whereas BIPV can generate heat and electrical faults. Complementary standards, such as EN 50583, and research initiatives are trying to bridge the gap.

Regardless of use, high-rise structures have the most demanding fire safety provisions, which makes high-rise BIPV the most challenging sub-sector. A common principle across all five countries is that external fire spread must be minimised in tall buildings, lessons from past high-rise fires are reflected in rigorous facade rules. All countries studied require facades on high-rises to be of limited or no combustibility.

4.4 Typology of IPV projects and associated fire safety considerations

Fire safety regulations apply different requirements depending on building type (residential and non-residential) and building height (low-, mid-, high-rise). Hence, BIPV feasibility is strongly influenced by these factors. While thresholds for low-, mid- and high-rise buildings varies in each country, categories can be made based on the building height.

A common trend is visible for all categories of buildings in Figure 2, as building height and risk increase, regulators either raise the bar on material fire class or demand compensating measures. For BIPV, this typology analysis reveals a clear pattern: the lower and smaller the project, the easier the fire approval (virtually no issues for single-family homes or small public buildings), mid-sized projects are feasible with careful product selection (often needing Class B or C products), high-rise demand higher fire safety requirements. All five countries share this gradient of difficulty, what differs is exactly where they draw the lines (height thresholds) and whether they allow flexibility (testing, sprinklers) to accommodate BIPV. In addition, extra safeguards are required for certain high-risk occupancies, such as hospitals and educational buildings, sometimes independent of height.

Hence, based only on fire safety requirements, a typology of buildings and their impact on BIPV is possible and illustrated in Figure 2. Buildings can be classified into four groups: low-rise, mid-rise, high-rise and high-risk buildings. In the typology, fire safety requirements increase with height, with BIPV elements being easier to integrate in low-rise buildings and less feasible on high-rise and high-risk buildings.

An additional layer should be added to the typology, which has a major impact on the feasibility of BIPV project via alternative routes, that is to say the possibility of large-scale fire testing of facade in the legislation. Such alternative routes in mid- and high-rise buildings are essential to support BIPV deployment. Indeed, in

cases where BIPV elements cannot comply with the fire safety requirements set out in the building codes for construction products, BIPV facades can prove their safety with adapted test following proven standards. In that case, BIPV feasibility in mid- and high-rise buildings would increase. Given the specificities of high-risk buildings, they are not considered in the large-scale testing section.

Figure 2: Typology of buildings and their impact on BIPV elements, based on fire safety requirements in building codes

	Low-rise building	Mid-rise building	High-rise building	High-risk building
Height	< 10-11 m	11-30 m	> 30 m	Variable
Fire safety requirements	D-C classes	C-B classes	B-A classes	B-A classes
BIPV feasibility	High - Moderate	Moderate - Low	Low - Impossible	Low - Impossible
BIPV feasibility with large-scale testing	High - Moderate	Moderate - High	Moderate	-

5. DISCUSSION AND POLICY RECOMMENDATIONS

5.1 Discussion

The lack of harmonised standards for BIPV has been widely documented in the literature, the IEA PVPS Task 15 report on “Advancing BIPV Standardization: Addressing Regulatory Gaps and Performance Challenges” provides an overview of the challenges in this domain [24]. The current lack of harmonisation leads to increased costs and delays for manufacturers, ultimately impeding the broader adoption of BIPV in the market. Establishing clear and comprehensive standards is therefore critical. Achieving this requires coordinated action among all relevant stakeholders, in order to avoid unnecessary duplication and overlap in testing arising from both building and electrical regulations.

Nonetheless, until BIPV standards are harmonised at European level, BIPV products have to comply separately with both construction and electrotechnical regulations. This paper is only focusing on fire safety requirements for construction products, which are determined at national level, and how they affect BIPV deployment in selected European countries. Fire safety requirements are primarily determined by the height and use and a building with national differences. Based on regulatory requirements, the feasibility of BIPV project is highest in low-rise buildings and moderate in mid-rise buildings. High-rise buildings represent the most challenging type of building, with in most cases the impossibility to deploy BIPV.

Current regulatory frameworks in many European countries restrict the use of combustible elements by requiring Euroclass A materials notably in high-rise buildings, which hinders BIPV deployment in those buildings. However, alternative routes with large-scale fire testing can allow for BIPV deployment on a case-by-case basis. These tests need to be made possible in the legislation, as it is the case in Belgium and France, as well as, in Switzerland with the transitional guidelines by SwissSolar. While these large-scale testing are costly,

allowed in a few Member States and must be repeated for every product and project variation, they allow for alternative routes to deploy BIPV.

In the **Belgian** regulation large-scale fire testing are allowed to evaluate the global fire behaviour of a façade system under realistic conditions, beyond what small-scale Euroclass tests (EN 13501-1) can show.

France's regulations also offer performance-based pathways in which a BIPV façade can be subjected to an assessment by a laboratory to demonstrate that the system limits fire spread as required. In practice, France relies on its Technical Assessment system for novel facade products. BIPV modules often require a DTA (Document Technique d'Application) or ATec (Avis Technique) from CSTB to be used, which includes fire performance evaluation. Several BIPV products have obtained such approvals, typically certifying that when installed per certain methods, they meet the facade fire regulation (often via large-scale tests). In practice, these assessment are project specific, lengthy, very costly and other issues can arise even with a large-scale test due to insurance coverage challenges [22]. Hence, performance-based pathways in France are limited to a few prestigious projects able to absorb cost, time and administrative burden.

In **Switzerland**, Swissolar developed a transitional guide for planning and demonstrating fire protection in ventilated PV façade installations, valid until 31 December 2026 [21]. The guide aims to address the lack of a definitive technical standard for fire safety in PV façades and complements existing AEAI and Swissolar guidelines, thus supporting BIPV deployment in mid- and high-rise buildings, when strict fire protection measures are implemented and, where necessary, compliance is demonstrated through fire tests and detailed verification reports, all subject to approval by the fire protection authority.

Furthermore, current construction products standards often misalign with BIPV needs and applications and there is a gap in testing methodologies for BIPV to accurately assess risks. BIPV present unique fire safety challenges that are not accounted for in current fire safety regulations for buildings.

Currently, fire risks associated with BIPV are predominantly covered under electrical codes for PV modules, which focus on module electrical safety and associated testing procedures. However, these standards do not take into account the possibility that the fire performance of PV modules may change when the modules are both heated and electrically active during normal operation. To properly address the hazards of fire propagation across BIPV façades, it is essential to evaluate both vertical and horizontal fire spread, whether the fire originates from the PV system itself or is introduced from an external source. Presently, neither PV-specific nor general building codes set out explicit fire safety requirements for BIPV cladding, curtain wall assemblies, double-skin façades, or integrated glazing systems.

Euroclass roofing fire tests (EN 13501-5, CEN/TS 1187) are not fully adapted to BIPV because they ignore active electrical risks and integration-specific factors. While they remain mandatory for CE marking, complementary standards (EN 50583) and research initiatives are trying to bridge the gap. For now, compliance often requires dual certification and sometimes bespoke testing. Codes and standards fall

short in adequately addressing the fire risks posed by BIPV roof covers integrated within roofing systems, particularly where combustible or flammable materials are present. Laboratory fire tests currently in use, which measure the fire resistance of roof coverings in response to external ignition sources, fail to accurately replicate the real fire conditions encountered with PV roofs. Owing to the rapid fire propagation across extensive PV installations and the potential for significant fire damage and penetration to roof structures. There is a need to establish new testing methodologies specifically for BIPV roofs [25].

Another critical fire hazard associated with BIPV modules arises from the fact that these systems may remain electrically active during a fire event. Assessing the fire resistance of BIPV modules must therefore go beyond evaluating material performance and reaction to fire, it should also account for the risks presented by an operational system under fire conditions. Currently, only a limited number of tests consider this operational aspect, as BIPV modules are not consistently kept active during fire testing procedures. This gap indicates a clear need for further research and the development of testing methodologies that ensure BIPV modules remain operational during relevant fire tests, enabling a more accurate assessment of real-world hazards [26].

5.2 Policy recommendations

Harmonise BIPV standards at European level

There is an urgent need to harmonise standards for BIPV across Europe. At present, BIPV products must comply separately with construction and electrotechnical regulations, which hinders widespread deployment and creates uncertainty for manufacturers and developers. A unified European approach would streamline compliance, reduce duplication and provide greater clarity for all stakeholders. Complementary standards, such as EN 50583 should be integrated and their testing protocols updated to reflect BIPV-specific risks.

Introduce performance-based compliance pathways with large-scale fire testing

National regulations should allow for performance-based compliance options, including large-scale fire testing of BIPV systems. Countries such as Belgium and France have already introduced such pathways, enabling BIPV deployment in mid- and high-rise buildings where Euroclass requirements are incompatible with BIPV elements and small-scale tests are insufficient. While these alternative routes are still challenging, especially in France, they should be formalised in legislation across Europe to facilitate BIPV deployment while ensuring safety.

Develop BIPV-specific fire testing methodologies

Existing fire testing standards, such as Euroclass tests and roofing fire tests (EN 13501-5, CEN/TS 1187), are not fully adapted to the specific risks posed by BIPV, particularly the combination of electrical activity and integration with building materials. There is a clear need for new, BIPV-specific fire testing methodologies that accurately assess both vertical and horizontal fire spread, and account for operational electrical risks during fire events.

Establish national guidelines until harmonisation

Until harmonised European standards are adopted, national authorities should issue clear guidelines to address the current regulatory gaps. For example, Switzerland's Swissolar guidelines provide a practical

framework for demonstrating fire protection in ventilated PV façades, supporting safe BIPV deployment in mid- and high-rise buildings. Other countries should develop similar interim measures to bridge the gap and facilitate safe BIPV adoption. All relevant BIPV stakeholders should be involved in the development of such guidelines.

Support further research and data sharing

There remains a significant need for research into the fire behaviour of BIPV systems, especially under operational conditions. Data sharing between Member States, testing laboratories and industry stakeholders will be essential to build a robust evidence base, inform future standardisation, and support the development of effective fire safety solutions for BIPV.

6. CONCLUSION

A comparative analysis of fire safety regulations for BIPV in Belgium, Estonia, France, Spain and Switzerland reveals that building height is the primary factor influencing facade fire safety requirements and BIPV feasibility. Low-rise buildings generally permit more combustible facades, enabling straightforward BIPV integration. Mid-rise structures face stricter standards but remain accessible for BIPV deployment. High-rise buildings are subject to stringent non-combustible requirements, which significantly restrict BIPV options. National differences exist, yet the overall trend is consistent across countries.

Roof requirements also play a crucial role in BIPV deployment. Most countries set minimum fire safety standards for roofing materials, typically requiring B_{ROOF} or equivalent classifications. These standards are generally less restrictive than those for façades, meaning BIPV integration on roofs is widely feasible, regardless of building height or use.

The absence of harmonised European standards for BIPV creates regulatory uncertainty, increases costs and impedes widespread adoption. Current fire testing methods for construction products do not fully capture the fire behaviour of BIPV products and existing standards fail to address the unique risks posed by electrically active modules.

Alternative compliance pathways, such as large-scale fire testing, offer a practical solution in several jurisdictions. Belgium, France and Switzerland have introduced performance-based routes that allow BIPV systems to be assessed through comprehensive fire tests simulating real-world conditions. These pathways enable the deployment of BIPV in mid- and high-rise buildings where standard Euroclass requirements would otherwise prohibit their use. Although large-scale testing is more costly and time-consuming, it provides a robust means of demonstrating fire safety for innovative facade systems. In Switzerland, transitional guidelines further support BIPV integration by outlining technical principles and verification procedures, subject to approval by fire protection authorities. Such approaches facilitate flexibility and innovation, but their adoption remains limited and project-specific.

Policy recommendations are as follows:

1. Harmonise BIPV standards at European level to streamline compliance and reduce duplication.

2. Introduce performance-based compliance pathways, including large-scale fire testing, in national regulations.
3. Develop BIPV-specific fire testing methodologies that address both material and operational risks.
4. Establish clear national guidelines to bridge regulatory gaps until harmonisation is achieved.
5. Support further research and data sharing to inform future standardisation and improve fire safety solutions.

Harmonised standards, adapted testing methods and coordinated policy action are essential to unlock the full potential of BIPV in European buildings while ensuring robust fire safety in buildings. Realising these measures will enable BIPV to play a central role in decarbonising the built environment and advancing the energy transition.

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9 LOGO SPACE

