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International Energy Agency
Photovoltaic Power Systems Programme



Task 15 Enabling Framework for the Development of BIPV

PVPS

Critical Review of International Fire Safety Requirements of Building-Integrated Photovoltaic Cladding Systems

2026

Report IEA-PVPS T15-28:2026

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The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems." In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas.

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What is IEA PVPS Task 15?

The objective of Task 15 of the IEA Photovoltaic Power Systems Programme is to create an enabling framework to accelerate the penetration and deployment of BIPV products in the global market of renewable energies and in the construction sector, resulting in a level playing field for BIPV products, BAPV products, and conventional building envelope components, while addressing mandatory, aesthetic, reliability, and financial considerations.

Subtask B of Task 15 aims to harmonise BIPV standards by bridging gaps between PV and construction regulations. By coordinating with international standardisation bodies such as ISO, IEC, and CENELEC, Subtask B seeks to align BIPV standards with both PV and construction requirements, ensuring a more integrated and widely accepted regulatory framework to support the market adoption of BIPV systems.

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COVER PICTURE

BIPV Façade Testing. Credit: Onyx Solar.

INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Critical Review of International Fire Safety Requirements of Building Integrated Photovoltaic Cladding Systems

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Task 15
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IMPORTANT NOTES

This report is based on information collected through a survey of participating countries. As such, the content reflects the data provided by respondents and may not represent a complete or fully verified account of all national regulatory frameworks.

While some details may be incomplete or may not fully reflect the most recent developments, this does not affect the overall intent of the report. The analysis is designed to capture key trends, highlight common approaches, and identify critical technical gaps in the regulatory landscape for BIPV systems. It is not intended to provide a comprehensive country-by-country assessment or a detailed understanding of individual national regulatory systems.

LIST OF ABBREVIATIONS

AC	Alternating Current
AICAA	Associazione degli istituti cantonali di assicurazione antincendio
BAL	Bushfire Attack Level
BAPV	Building Applied/Attached Photovoltaics
BIPV	Building Integrated Photovoltaics
CdTe	Cadmium telluride
CENELEC	European Electrotechnical Committee for Standardization
CI(G)S	copper indium gallium selenide
CPR	Construction Products Regulation (European normative)
CTE	Spanish Building Code (Código Técnico de la Edificación)
DC	Direct current
EL	Elastic
EPE	EVA-POE-EVA
ETFE	Ethylene tetrafluoroethylene
EU	European Union
EVA	Ethylene vinyl acetate
FIGRA	Fire Growth Rate Index
FM	Factory Mutual
G/B	Glass/Backsheet
G/G	Glass/Glass
IBC	International Building Code
IEA	International Energy Agency
NABERS	National Australian Built Environment Rating System
NBCC	National Building Code of Canada
NCC	National Construction Code (Australia)
OPV	Organic photovoltaics
PA	Polyamide
PDMS	Polydimethylsiloxane
PET	Polyethylene terephthalate
POE	Polyolefin elastomer
PV	Photovoltaic

PVB	Polyvinyl butyrate
PVDF	Polyvinylidene fluoride
PVF	Polyvinyl fluoride
PVPS-IEA	Photovoltaic Power Systems Program of the International Energy Agency
SBI	Single Burning Item
TP	Thermoplastic
TPO	Thermoplastic polyolefin (polyethylene-acrylate)
US	United States
UV	Ultraviolet
VOC	Volatile Organic Compound

EXECUTIVE SUMMARY

This study reviews fire safety provisions in codes, regulations, and standards applicable to BIPV façade cladding systems, focusing on material- and system-level requirements. The review is based on a structured survey of experts from Australia, Austria, Canada, Japan, Norway, Singapore, South Korea, Spain, Switzerland, and the United States, complemented by a comparative analysis of applicable codes, standards, and test methods. As reflected in the disclaimer, the survey captures the information provided by respondents and is intended to identify key trends, common approaches, and critical technical gaps rather than provide a complete or fully verified country-by-country account of every national regulatory framework.

The analysis shows that BIPV façade systems are currently assessed largely within existing façade regulatory frameworks and compliance pathways. While this provides a valuable foundation for demonstrating fire safety, these frameworks do not fully reflect the specific characteristics of BIPV systems, particularly their electrically active nature and system-level behaviour in fire scenarios. At the same time, the analysis highlights the importance of incorporating system-level design and risk-based regulatory approaches to support safe and flexible implementation. Key findings include:

- Reliance on existing façade regulatory frameworks

BIPV systems are generally assessed using requirements developed for conventional façade materials. While this enables compliance within established regulatory structures, these provisions do not fully capture the distinctive behaviour of BIPV systems. At present, most countries have not established comprehensive, dedicated codes or standardised testing methodologies specifically tailored to BIPV. However, some jurisdictions are introducing adapted compliance approaches, such as stricter material classifications or alternative large-scale fire propagation tests (e.g., Singapore).

- Material- and system-level regulatory considerations

Established fire performance tests (e.g., combustibility, ignitability, heat release, and smoke production) remain part of the current regulatory framework and provide a baseline for material classification. However, their application to BIPV systems may require adaptation within standards to better reflect typical PV configurations, including module dimensions and integrated electrical components.

At the system level, existing façade fire test methods provide a recognised basis for compliance, but further development is needed within standards to account for realistic operating conditions, such as energized states, thermal loading, and representative installation details. A system-level regulatory perspective is essential to enable multiple compliant design solutions for BIPV systems.

- Unaddressed fire scenarios within current provisions

Certain fire scenarios are not explicitly covered by existing codes and standards, including PV-induced ignition, fire spread within façade cavities, and the behaviour of systems under electrically active conditions. In addition, the interaction between PV systems and fire detection or suppression measures, including water application, remains insufficiently addressed. These gaps indicate a need for provisions that consider both component-level performance and overall building fire safety within the regulatory framework.

- Firefighting and emergency response provisions

Regulatory requirements addressing firefighting, emergency response, and occupant safety for BIPV systems remain limited. Emerging provisions in some standards—such as rapid shutdown requirements, system labelling, documentation, and access for firefighting—reflect an increasing recognition of operational safety. These aspects are critical for integrating BIPV into broader building fire safety strategies and codes.

- System-level risk assessment within regulatory frameworks

A key insight from this review is the importance of incorporating system-level, risk-based approaches into codes and standards. Such approaches enable BIPV systems to be assessed within the context of the overall building fire strategy. This allows greater flexibility in design for non-combustible construction (e.g., concrete buildings), while for combustible construction types, additional regulatory measures—such as restrictions on application, enhanced detection, or sprinkler requirements—may be necessary. This highlights the need for regulatory frameworks that link façade requirements with overall building fire risk assessment.

- Opportunities for harmonisation and regulatory development

The evolving nature of BIPV regulations presents strong opportunities for further development and international harmonisation. Aligning test methods, classification systems, and performance criteria—particularly at the European level and across IEA member countries—could improve consistency, support innovation, and facilitate clearer compliance pathways for industry.

Overall, while BIPV-specific fire safety provisions within codes and standards are still developing, the current regulatory landscape provides a robust foundation upon which targeted improvements can be built. Continued research, alongside the integration of system-level and risk-based considerations into regulatory frameworks, will be essential to enhance fire safety while enabling the broader and more flexible adoption of BIPV systems in the built environment.

1 INTRODUCTION

Building-Integrated Photovoltaics (BIPV) represent a pivotal innovation in the transition to sustainable energy, enabling the dual function of energy generation and building envelope performance [1], [2]. However, they pose challenges since, as multi-functional components, BIPV modules and systems have to meet requirements from both construction and electrical standards, such as EN50583 [3] and IEC 63092 [4], [5]. Among the various BIPV applications, façade cladding systems (see Figure 1) are gaining increasing attention due to their architectural integration potential and large surface area availability, and potential energy production.

However, the adoption of BIPV façade systems is significantly constrained by the heterogeneous and often misaligned nature of fire safety regulations across countries. To effectively evaluate fire performance, it is crucial to understand the interplay between standards (which establish fire safety criteria), test methods (which outline procedures for compliance assessment), and local regulations (which, shape the interpretation and implementation). However, there is a disconnection between BIPV standards and local building codes, since current standards refer to local building codes that may not explicitly address the unique fire characteristics of photovoltaic, energy-generating building components.

Applying existing fire testing standards, originally conceived and developed to determine the fire reaction performance of conventional construction materials, to solar products such as BIPV systems has raised concerns as additional components and potential risks derived from the inherent use of photovoltaic solutions are not yet appropriately considered in current testing methods. In general, construction materials are required to be evaluated for their fire behaviour. This concept covers both reaction to fire (response of a test specimen when it is exposed to fire under specified conditions in a fire test) and fire resistance (ability of a test specimen to withstand fire or give protection from it for a period of time, being the typical criteria used to assess the fire integrity, fire stability, and thermal insulation material). In the case of fire performance of façade systems, cladding materials are required to be evaluated for their reaction to fire behaviour at the material level while the resistance to fire propagation is evaluated at the system level (e.g., fire spread over façade cladding). The specific concerns related to BIPV elements and cladding systems focus on reaction to fire and fire propagation provisions, in light of the current absence of a dedicated regulatory framework for these applications.

Current regulations and standards at both levels do not comprehensively address the distinct fire behaviour associated with photovoltaic (PV) systems. This includes burning behaviour linked to PV modules that are heated and electrically active under normal operating conditions, the characteristics of fire spread, in particular when originating from the PV system itself, as well as concerns related to smoke toxicity and firefighting challenges.

Previous studies, including international reviews and recent academic publications, have provided valuable overviews of the regulatory landscape [6], [7], [8]. However, these studies have been limited in offering detailed, system-specific discussion, particularly concerning BIPV façade cladding systems. As a result, there remains a critical need for a focused analysis that addresses the unique fire safety challenges and compliance requirements associated with these systems.

This report aims to fill that gap by conducting a targeted review and analysis of fire safety regulations, performance criteria, and test methods specifically for BIPV façade cladding

systems. The goal is to reduce market adoption barriers while clearly identifying fire performance requirements of these materials and systems, which will eventually also help in managing insurance requirements.

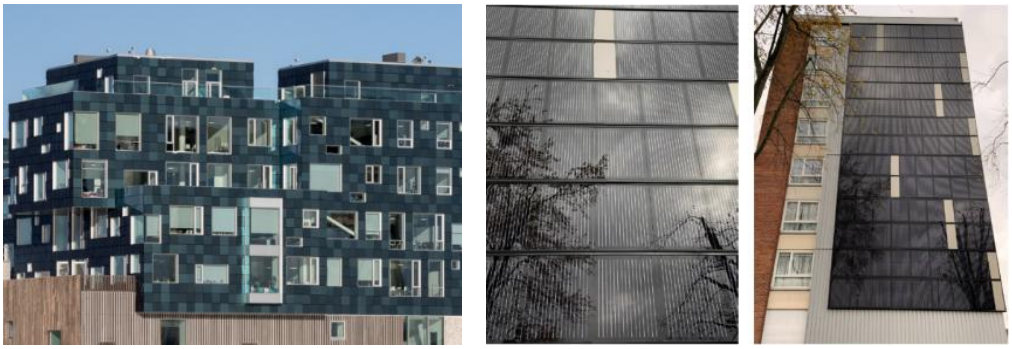


Figure 1. Examples of BIPV Cladding systems: Copenhagen International School (left) and BIPV ventilated façade of apartment buildings in France (right) [9]

1.1 Objectives

Key objectives of this study are to:

- Identify the prerequisites for fire safety compliance specific to BIPV façade cladding systems and support safer and more efficient market integration.
- Review and compare international regulations and test procedures related to fire performance of BIPV façades, highlighting regional differences and commonalities.
- Compile current building code fire safety requirements relevant to façade systems, including:
    - Reaction to fire
    - System-level resistance to fire propagation
    - Code objectives and intents
    - Types of fire hazards addressed
    - Standard fire test provisions
- Identify gaps in existing codes and standards that may hinder the safe deployment of BIPV façade systems, such as:
    - Unaddressed fire hazards unique to BIPV
    - Inadequate test protocols or pass/fail criteria
    - Missing regulatory coverage in key countries or regions
    - Lack of alignment between electrical and building codes
- Contribute to the development of harmonized international standards by providing a detailed baseline analysis to inform future standardization efforts and by formulating recommendations.

This focused approach will provide stakeholders, including regulators, manufacturers, and designers, with actionable insights to advance the safe and widespread adoption of BIPV façade cladding systems.

1.2 Document structure and chapter overview

Chapter 2 provides an overall understanding how BIPV cladding systems influence fire behaviour and associated hazards. It introduces component materials and system integration details, which govern the fire behaviour of PV claddings. Chapter 2 examines potential fire scenarios relevant to PV cladding, which are essential for understanding where and how hazards may arise, enabling a structured approach to later evaluate compliance with codes, standards, and performance requirements. Hazards are classified as material, system, and electrical risks, providing a foundation for understanding the topics discussed in subsequent chapters.

Chapter 3 provides a summary of fire safety electrical requirements.

The detailed examination and comparative analysis of various standards and test methods as they relate to fire safety compliance are thoroughly surveyed and discussed in **Chapters 4 and 5**.

Chapter 4 discusses the material level, '*reaction to fire*' requirements, focusing on properties such as combustibility, ignitability, flame spread, and heat release.

Chapter 5 covers the requirements at the system level for resistance to fire propagation. It assesses how well the entire façade assembly, as an example, can resist fire spreading over the surface and prevent fire penetration into different building elements.

Chapter 6 identifies critical gaps by evaluating the different standards and test methods outlined in Chapters 4 and 5 in relation to the hazards and fire scenarios described in Chapter 2. **Chapter 6** highlights unaddressed fire hazards, shortcomings in current testing protocols, and missing regulatory provisions that could impede the safe deployment of BIPV façade systems. This chapter also proposes pathways for harmonisation by offering practical insights and recommendations, thereby supporting regulators, manufacturers, and designers in promoting the safe and widespread adoption of these systems.

1.3 Survey participants

The survey gathered insights from a diverse group of international experts, ensuring a wide range of perspectives on BIPV cladding fire safety. The review was based on a structured expert survey supported by contributors from **Australia, Austria, Canada, Japan, Norway, Singapore, South Korea, Spain, Switzerland, and the United States (US)**, followed by a comparative examination of the codes, standards, and test methods identified through those responses. The survey focused on capturing current regulatory practices, perceived gaps, and technical considerations relevant to BIPV façade fire safety. As noted in the Disclaimer, the findings reflect the information provided by respondents and may not represent a complete or fully verified account of all national regulatory frameworks or the most recent developments. Nevertheless, the survey provides a robust basis for identifying common approaches, highlighting key trends, and analysing critical technical gaps, rather than delivering a fully comprehensive country-by-country assessment.

Please refer to the Appendix for the survey questions.

2 FIRE HAZARDS OF BUILDING INTEGRATED PHOTOVOLTAIC CLADDING SYSTEMS

Façade cladding systems form the exterior protective layer of the building envelope and are commonly constructed as ventilated rainscreen façades, double skin façades, or curtain wall assemblies. These systems control rain penetration, facilitate drainage and drying, and improve thermal and acoustic performance. Their ventilated cavities, however, can promote chimney-driven flame spread and increase the severity of exterior fire exposure. Within the IEA-PVPS Task 15 classification of BIPV applications (see Figure 2) [2], BIPV used as ventilated rainscreen cladding is identified as a distinct façade category because the PV element replaces the conventional cladding panel while simultaneously generating electricity. This dual function, combined with the presence of cavity ventilation and combustible substrates, makes this configuration particularly relevant for detailed fire-hazard analysis.

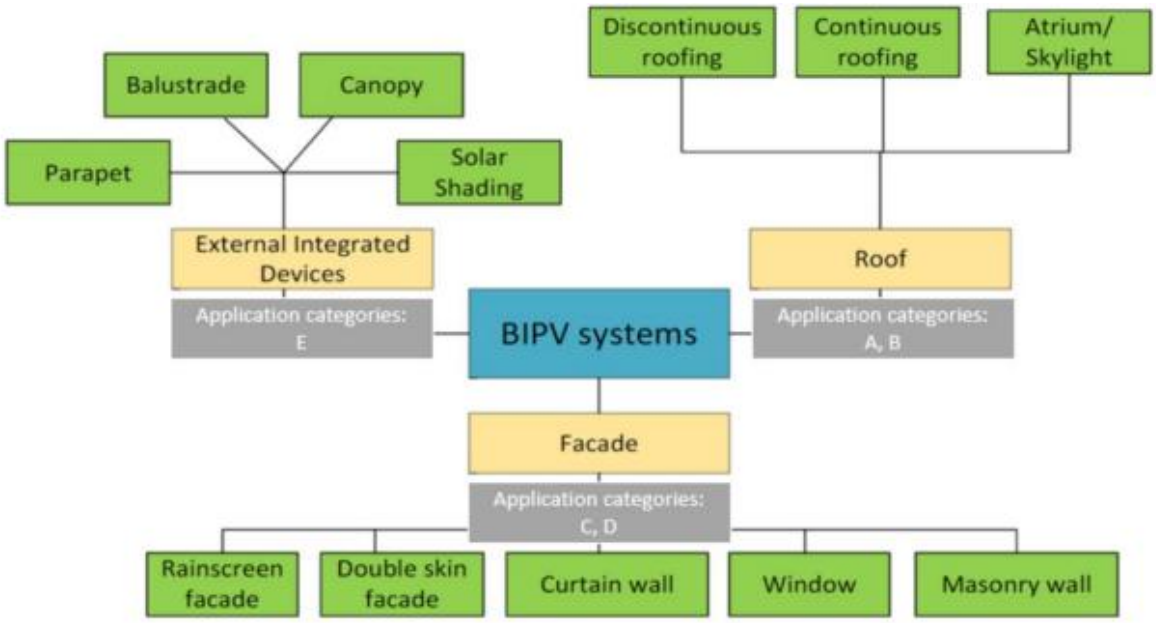


Figure 2. BIPV classification system according to IEA PVPS Task 15 [2]. The primary scope of this report is BIPV rainscreen façade cladding systems.

2.1 Photovoltaic façade cladding systems

2.1.1 PV façade cladding materials

Photovoltaic (PV) modules consist of multilayer laminates of various materials that serve to generate energy and influence fire behaviour [10]. The heart of these systems is the solar cell. Crystalline silicon is the most commonly used material (IEA PVPS Trends 2023 [11] indicates that about 98% of modules are sc-Si, with mc-Si and thin-film now marginal). Other materials, such as thin-film CI(G)S (copper indium gallium selenide), CdTe (Cadmium telluride), OPV (Organic photovoltaics), and amorphous silicon, are niche technologies. Metallic busbars or wires interconnect these cells, and these active cell layers are embedded in and protected by polymer films (elastic encapsulation). This laminate is covered on the front with a protective

layer (usually glass) and on the back with either a second glass layer or a backsheet. Two main module configurations dominate the market: glass-glass modules (G/G) and glass-polymer backsheet modules (G/B), with G/G being by far the dominant module design for BIPV façades. A typical PV module design is shown in Figure 3, while Figure 4 and Figure 5 show typical BIPV cladding system installations and BIPV curtain system installation, respectively.

- G/G modules incorporate low-iron tempered glass on both sides, G/G modules use glass as both the front and rear protective layers of the laminate. Compared with conventional G/B modules, the rear glass replaces the polymer backsheet and provides a more robust protective barrier [12]. However, once the glass fails or breaks, the combustible encapsulant may become exposed and available for ignition.
- All G/G modules contain combustible encapsulant materials such as ethylene-vinyl acetate (EVA) or polyolefin elastomers (POE), typically 1-2 mm thickness depending on the product. Although these polymers account for only about 6-8% of the module mass, they possess high heats of combustion and contribute significantly to the fire load.

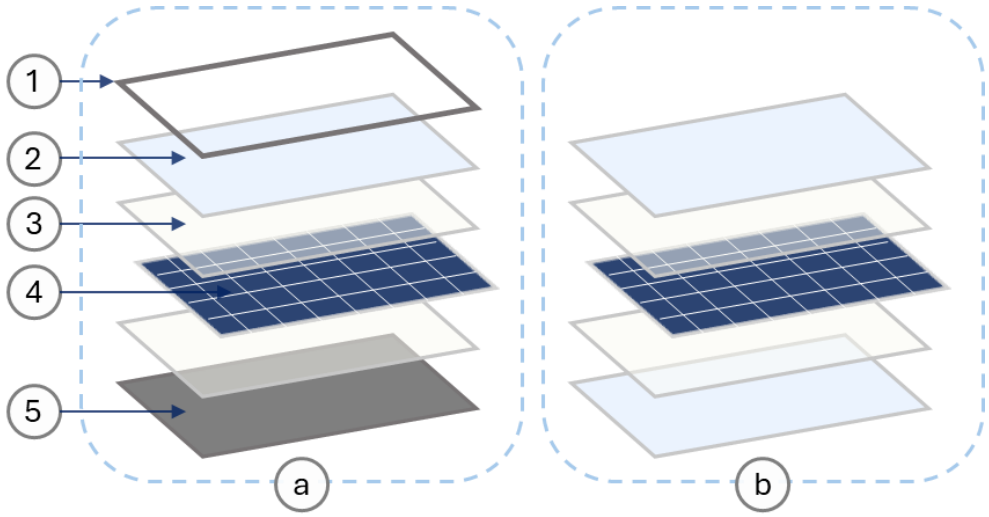


Figure 3. Schematic representation of G/B (a) and G/G (b) modules, where 1) Frame; 2) Glass; 3) EVA or POE; 4) Solar cell; 5) Backsheet.

- G/B aluminium-framed modules typically use a 3 mm or 6 mm tempered glass front, combined with a 1-2 mm encapsulant layer (e.g., EVA or POE) and a multilayer polymer backsheet. These backsheets commonly consist of polyethylene terephthalate (PET) core with thinner outer layers of polyvinyl fluoride (PVF), polyvinylidene fluoride (PVDF), or polyamide (PA), and may also include reinforced variants incorporating metal sheets (steel or aluminium), mortar layers, or polyolefin/polypropylene composites. Although relatively thin (0.3-0.4 mm), these polymeric backsheets reduce weight but are more flammable and have lower thermal degradation temperatures than glass. The selection of materials, ranging from tempered glass and aluminium composite to fluoropolymer- and PET-based backsheet, directly influences aesthetics, mechanical performance, and fire safety in PV cladding systems, where the module's location, external exposure, and combustible mass further shape its fire behaviour. During fire exposure, the encapsulant layer (EVA or POE) makes both G/G and G/B modules combustible; however, their protective layers behave differently. Polymer

backsheets can soften, melt, or ignite, while glass layers do not burn but may crack or fail, eventually exposing the encapsulant beneath.

2.1.2 PV façade cladding integration/installation details

A precise understanding of how BIPV systems are installed on façades is essential for any fire-performance assessment, since the configuration of the assembly governs how heat, smoke, and flames can develop and spread along the exterior wall. These configurations, used in both new construction and retrofit projects, were selected because they capture the geometric and material features that influence the fire behaviour, including the way the PV laminate is fixed to the support structure, the detailing of ventilation cavities, and the arrangement of combustible and non-combustible layers. Two types of BIPV cladding installation are described below, because they represent the approaches widely adopted in the current BIPV practice and therefore provide the most relevant basis for assessing fire behaviour: Rainscreen façade and Pressure controlled cladding.

- **Rainscreen Façade Cladding (Ventilated or Non-Ventilated)**

PV modules are typically integrated as ventilated cladding or rainscreen systems (Figure 4), which is the most widely used installation method. In this configuration, an air cavity is created between the structural wall and the outer PV cladding layer. For BIPV rainscreen façades, the cavity is typically designed with a depth of 20-50 mm; however, a thickness of 100 mm is recommended to ensure adequate natural airflow, which helps limit module overheating, regulate moisture, and support drainage performance (IEA-PVPS BIPV Technical Guidebook, sec. 5.3.1 [1]). An insulation layer is also normally included between the cavity and the supporting wall. Some products are frameless and feature hidden mounting systems, allowing them to blend seamlessly with various architectural finishes such as stone, wood, or metal. Structurally, some products are reinforced, for example, with an aluminium honeycomb composite core, providing both strength and reduced weight.

Compartmented cladding involves dividing the cladding cavity into isolated sections. Each compartment is sealed to improve the building's airtightness and to limit moisture penetration. When applied to PV cladding, this method requires careful planning of the electrical layout, as wiring and junction boxes must be routed in a way that respects the compartment boundaries. Specific examples of this method are not common, yet it remains a viable strategy for projects. Due to the lack of experiments and experiences, it is not yet clear whether the compartmented cladding system details would also enhance fire safety by limiting flame and smoke.

- **Pressure-Controlled Cladding**

Pressure-controlled rainscreen systems are designed to moderate the pressure difference between the exterior and the cavity behind the cladding, reducing the risk of wind-driven rain penetration and minimizing moisture transport through the façade assembly. Unlike ventilated rainscreens, where continuous airflow equalizes pressure rapidly, pressure-controlled systems use restricted vent openings and local compartmentation to dampen the rate of pressure change within the cavity. The objective is not to eliminate airflow, but to create a more stable internal pressure field under variable wind conditions. In the context of BIPV integration, this approach is relevant where the façade design prioritizes weather resistance or where architectural constraints limit the use of ventilation gaps. Here, the PV modules function as the external weathering surface, while the cavity and substructure are configured to maintain the required hygrothermal performance. Pressure control is therefore a façade-engineering strategy that may be combined with BIPV but is not a primary driver of PV integration and is applied only in projects with specific environmental control requirements.

The PV modules are installed on an adjustable sub-framing system that is anchored directly to the building's primary structure. Installation typically involves fastening continuous steel angles to the wall framing, followed by the attachment of galvanized steel angles over a layer of semi-rigid insulation and a continuous air- and weather-resistive barrier. Each PV panel is then clamped onto the angles using specialized clips, which allow for fine vertical and horizontal adjustments.

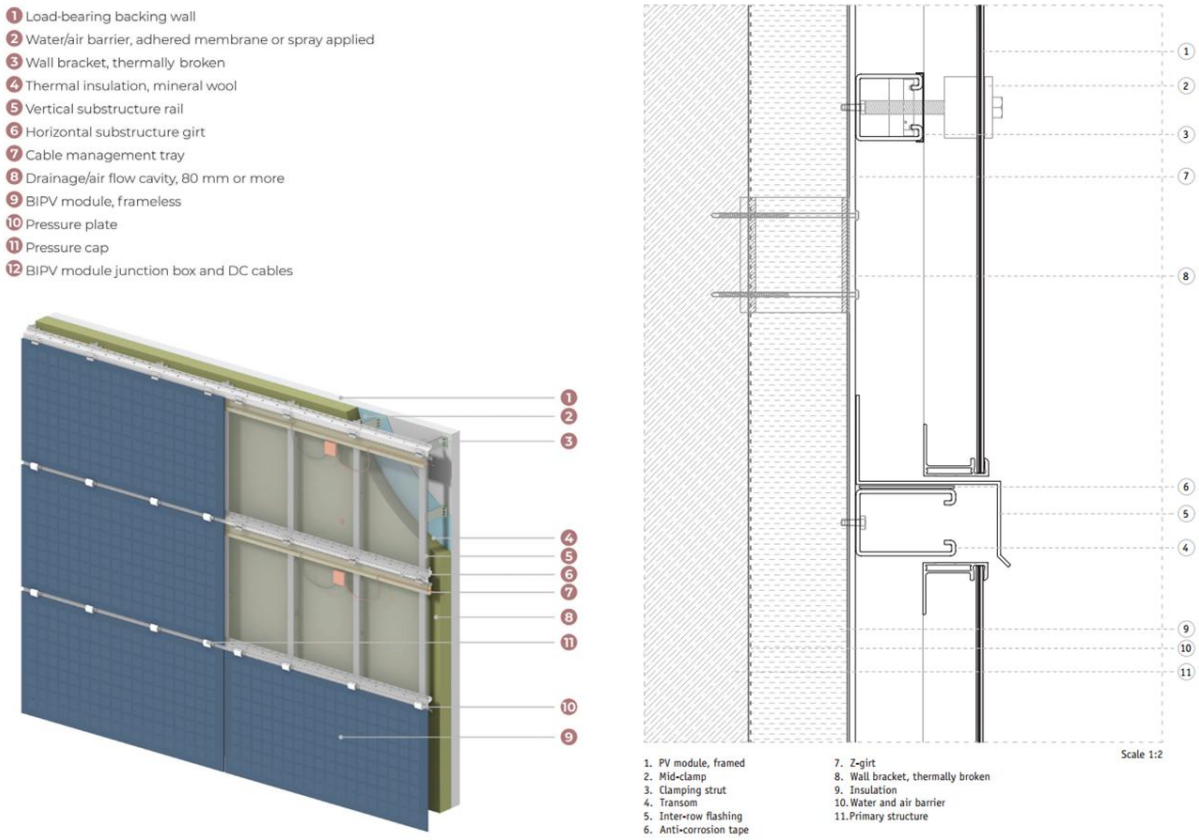


Figure 4. A typical BIPV rainscreen system (left) and cross-sectional installation details of façade cladding systems (right) [1]

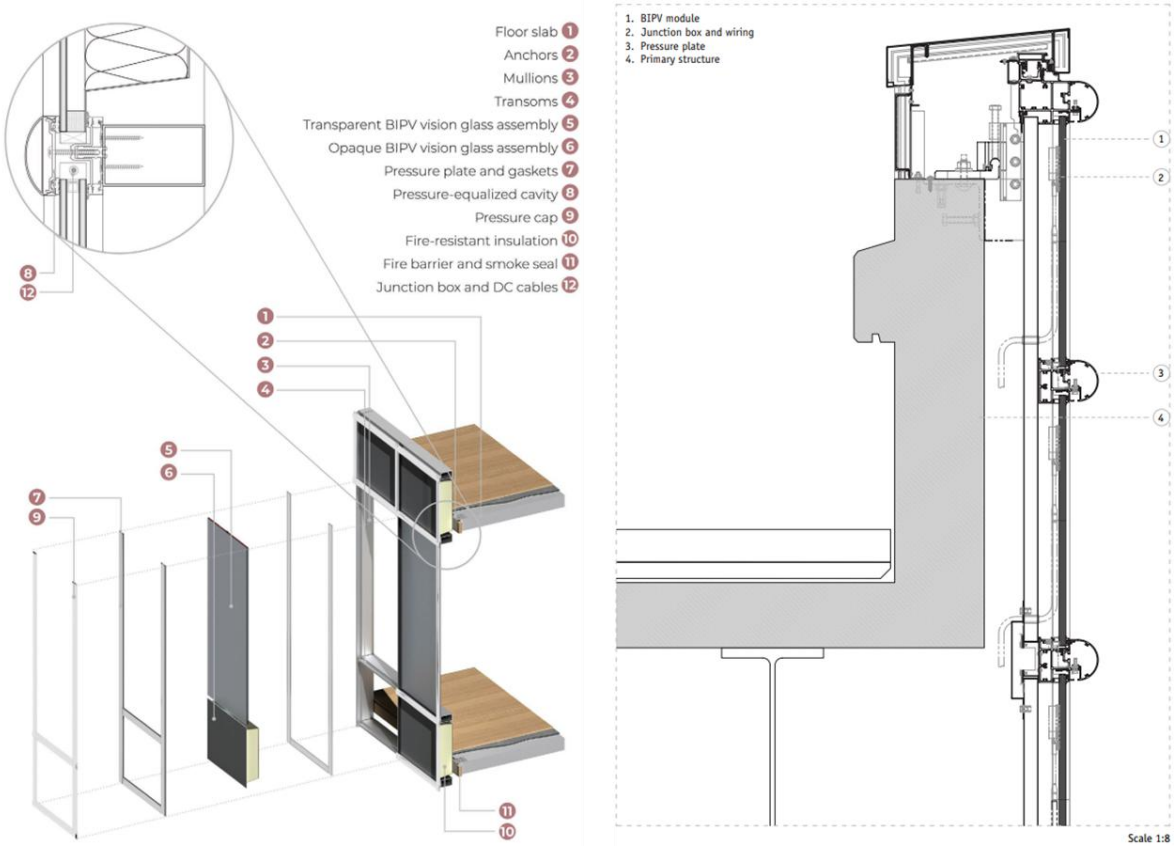


Figure 5. Exploded view of a typical BIPV curtain wall (left) and corresponding cross-section (right), shown as an example of a pressure-controlled cladding system [1].

2.1.3 PV façade electrical design

Electrical integration in BIPV façades can be carried out through junction boxes mounted on the back of the panels or through dedicated connection points incorporated into the façade build-up. Cabling may be routed within the cavity or passed through the insulation layer to reach the building's internal wiring management system. These penetrations must be detailed so that the continuity of the air- and weather-resistive layers is preserved, and the routing must comply with the electrical-safety requirements set by the relevant national and international standards. Local sealing components or infill elements are often needed to close small gaps around cable paths, ensuring thermal continuity and maintaining the performance of the façade system. The exposed conductive parts and support elements are specified with corrosion-resistant materials, and care is taken to ensure that the electrical layout does not introduce shading or obstruct airflow within the cavity.

In current façade-grade products, electrical performance typically ranges from 50 to 200 W/m^2, with higher outputs emerging as cell efficiencies improve and large-format modules become more common. Industry trends already indicate the availability of modules in the 500-600 W range (i.e., up to about 250 W/m^2), reflecting the gradual convergence with utility-scale formats. System voltages for BIPV installations generally fall within 1000-1500 V DC, consistent with the limits specified in IEC 61730 [13].

2.2 Cladding Fire scenarios

A major classification of fire scenarios in PV panels, as suggested by [15], [16], distinguishes between **internal fire scenarios** and **external fire scenarios**. Internal fire scenarios refer to ignition phenomena originating within the PV system boundaries, typically driven by electrical faults—such as hotspots, cell mismatch[1], arc faults, or ground faults—or by operating conditions (e.g., partial shading) that induce localized overheating and subsequent accelerated material degradation mechanisms. In contrast, external fire scenarios refer to situations where PV panels are ignited by external fire sources, not directly related to the BIPV system itself. The external ignition sources are equally relevant to BIPV façades and other cladding materials, while the internal ignition sources are mostly relevant for electrically active construction materials like BIPV façades. Recognising and differentiating between internal and external fire scenarios is essential for accurately assessing the fire risk associated with BIPV cladding. BIPV cladding systems present distinctive ignition scenarios not seen in conventional cladding systems, resulting in additional fire hazards compared to equally combustible traditional claddings. Consequently, it is essential to comprehensively understand these unique fire scenarios when assessing fire safety for façades that incorporate PV technologies.

In short, emphasizing the dual role of BIPV systems as both potential fire initiators and combustibles in a building fire, the following ignition scenarios are summarized, as shown in the figure below. Figure 6 provides an overview of the fire scenarios classified into internal fire scenarios and external fire scenarios.

[1] Mismatch means the interconnection of solar cells or modules having different properties or conditions from one another.

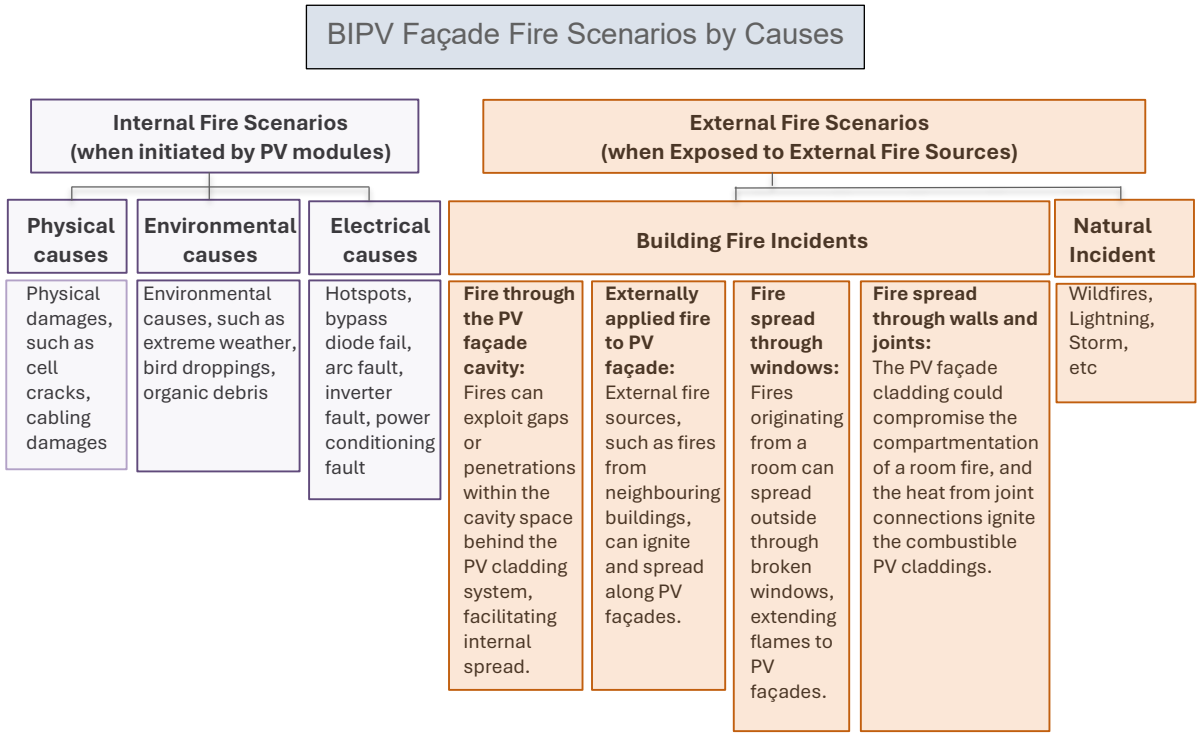


Figure 6. BIPV façade cladding fire scenarios by causes (Note: Environmental causes such as shading and dusting induce localized heating and hotspot, which may or may not directly cause internal fire.)

When triggered by specific internal or external causes, fire propagation may occur across combustible façade cladding systems, either along the cladding surface or within the cavity space. These scenarios are illustrated in Figure 7. Generally, cladding designs account for ignition and flame spread originating from window flames (originating from a room fire), heat or flame transmission caused by failure of the wall behind (cracks or joint issues), as well as external sources (like fires in adjacent buildings, vehicular accidents, dumpster fires, or intentional arson). Fire can readily penetrate and involve the cavity, which is particularly concerning as certain cavity conditions (e.g., presence of combustible insulation materials) can accelerate fire spread, requiring mitigation solutions to limit the spread.

Additionally, BIPV cladding surfaces may themselves ignite due to module failure, and the cavity fire spread may be started by electrical faults (inverter, cable, connector, etc.). Comprehensive analyses of PV fires resulting from electrical faults have been published in [17], [18], [19]. However, most of these studies focus on roof-mounted PV systems, and there is a lack of analyses specific to BIPV façade systems.

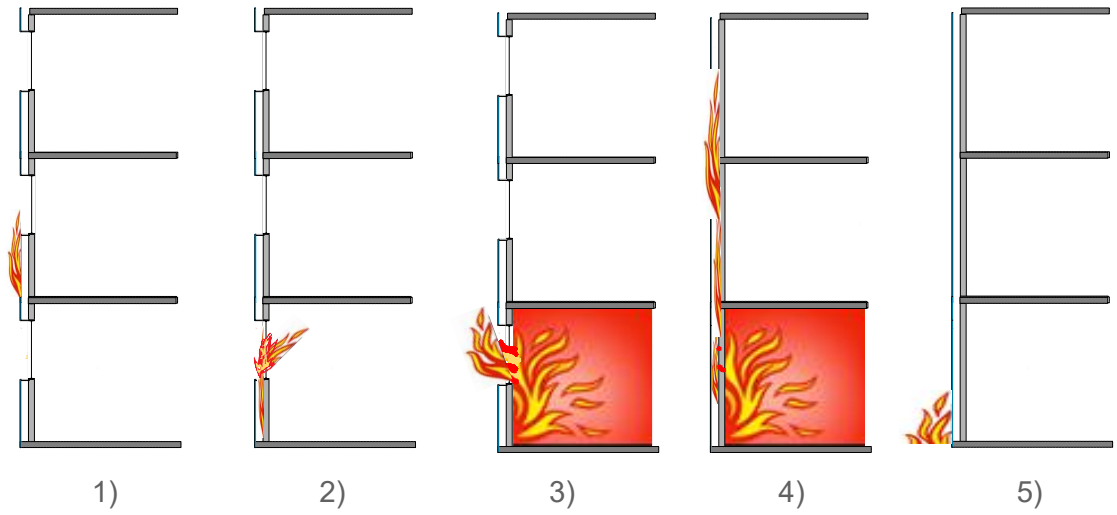


Figure 7. BIPV Façade Fire Scenarios: 1) BIPV cladding surface ignition due to module failure; 2) the cavity fire spread started by electrical faults (inverter, cable, connector); 3) cladding exposed to window flames (originating from a room fire); 4) heat or flame transmission caused by failure of the wall behind (cracks or joint issues); 5) the cladding exposed to external fire sources (like fires in adjacent buildings, vehicular accidents, dumpster fires, or intentional arson).

2.3 PV cladding fire hazards

This section introduces key concepts related to the various hazards of BIPV façade systems, covering material, system, and electrical levels. For clarity, material-level hazards concern reaction-to-fire characteristics; electrical hazards concern ignition or shock risks associated with faults and energized components; and system-level hazards concern fire propagation through the façade assembly. It also provides an overview of occupant evacuation and firefighting hazards to ensure proper hazard scoping. Furthermore, this introduction is designed to help readers better understand the detailed discussions presented in the subsequent Chapters 3, 4, and 5, by establishing a foundational context for the analysis that follows.

2.3.1 Material level hazards

BIPV façades and roofing systems should be evaluated as integrated assemblies. This requires testing not only the complete system, but also its constituent materials and components, in order to identify inherent fire hazards and ensure that the overall assembly can be reliably validated. In general, the fire behaviour of a construction material is characterized by combustibility, ignitability, heat and smoke generation, and flame spread. Furthermore, in evaluating these characteristics of the material layers incorporated in PV modules, it should be taken into consideration that the module's electrical activity could alter these burning behaviours and pose new fire risks. The energized state of PV panels may result in an accelerated ignition and flame spread behaviour of the PV panels. Thus, to fully understand the material level fire hazards specific to PV modules, the following characteristics are considered:

- Combustibility
- Ignitability

- Heat and smoke generation
- Flame spread
- Smoke toxicity
- Suppression challenges of electrically active materials
- The performance of the above characteristics, when the module is electrically active

Both G/G (glass/glass) and G/B (glass/backsheet) PV modules include combustible polymer components/layers, that can ignite when heated. The junction box and cables also represent a fire load.

The polymer encapsulant can be thermoplastic (TP) or, after a crosslinking step, elastic (EL). The most commonly used encapsulating materials are summarized in Table 1 . EVA has been the most widely used material in recent decades, while POE is currently the dominant encapsulation material. As can be seen from the table, both are elastic, and do not exhibit true melting/liquefaction upon increasing temperature but rather soften only. EVA melts at 60 – 105°C but only ignites above 340°C [20]. The heat of combustion ranges from 26.5 kJ/g (for silicone) to 46.5 kJ/g for the pure hydrocarbon polyolefin POE [21]. The heat of combustion of EVA is 40 - 41.6 kJ/g, depending on the vinyl acetate content [22], which is in good accordance with the range of 37 - 43 kJ/g [23] reported as the heat of combustion for G/G and G/B modules.

Table 1 Compilation of polymer encapsulation materials used to embed the solar cells in PV-modules [21], [24], [25]

Abbreviation	Material	Polymer characteristics
TPO	Thermoplastic polyolefin (polyethylene-acrylate)	Thermoplastic elastomer
POE	Polyolefin Elastomer	Elastomer
EPE	EVA-POE-EVA	Elastomer
EVA	Ethylene–vinyl- acetate	Initially thermoplastic and after crosslinking, elastomer
PVB	Polyvinyl butyrate (contains softeners)	Thermoplastic
Silicone-based	Poly-dimethyl siloxane (PDMS)	Elastomer

With G/B modules, the multilayer polymer backing must also be considered. This consists primarily of PET, a thermoplastic and flammable material that initially melts between 240 and 260°C and then pyrolyses at temperatures above 350°C [26] . The glass in G/G and G/B modules is not combustible and provides fire protection for the polymer layers inside the modules. However, upon strong temperature differences it is prone to break at high temperatures, 400–550°C [23] affecting the façade integrity, and allowing the fire to ignite the underlying interlayer.

Fire spreads rapidly once the glass breaks in G/B and G/G modules, and a flame spread rates reaching 30 mm/s is reported from small-scale roof panel tests [27]. For G/B façade claddings, flame spread rates up to 28 – 47 mm/s are reported when the ventilated cavity space is involved in fire [28]. It should be also noted that some tests report accelerated ignition and flame spread due to the energized state of PV panels [28], [29]. In general for G/B modules, fire spread could be accelerated in the cavity due to the combustible backsheet. Thus, G/G module design is highly recommended for BIPV façade applications, particularly for BIPV façades installed in high rise buildings.

The risk of toxic smoke from BIPV systems under fire should not be underestimated, especially in PV- glazing applications. Generally, smoke migration into the building can be a concern for any combustible glazing systems. Recent small-scale fire tests have detected hazardous gases such as hydrogen fluoride, hydrogen cyanide, and volatile organic compounds (VOCs) from PET-laminated PV fires [30]. These toxic emissions can present notable risks to life safety and should be carefully considered in fire safety assessments.

2.3.2 System level hazards

The fire performance of PV cladding systems is not only governed by the BIPV module material fire characteristics but also significantly influenced by their manufacturing and installation details and system designs. Ventilated cladding systems have been known to promote flame spread, particularly within the rear ventilated cavity, where the stack (chimney) effect can enhance vertical fire propagation. Consequently, system details should incorporate measures to limit both vertical and horizontal fire spread and to restrict flame penetration into the cavity. For roof-mounted solar panels, it has been reported [31] that actual roof fires involving PV systems have resulted in fire spread areas ranging from 1,000 ft² to 183,000 ft² (≈93–17,000 m²), far exceeding the fire spread observed in standard small-scale roof-fire tests. In the largest case, the fire penetrated the structure and destroyed the building. As such, real-world PV system fire spread can scale far beyond what is captured in controlled standard tests, making fire spread in vertical façade applications an even more critical concern that must be addressed. Consequently, to mitigate this rapid system-level fire spread, joints, interfaces, and perimeter details—especially around openings such as windows and doors—must be carefully designed and protected (e.g., through cavity barriers, fire stops, or intumescent seals) to prevent fire ingress and uncontrolled propagation within the cavity space.

In assessing façade fires, it is essential to consider not only flame spread over the façade surface but also the flame propagation through the cavity space usually in the façade cladding systems. The flame propagation in the cavity is generally enhanced depending on the cavity's depth and design as well as materials in the cavity, such as insulation materials [32].

As explained above, cavity-related fire hazards are an important consideration in BIPV façade cladding systems, as the cavity environment may experience elevated temperatures due to solar exposure and module operation. In cases where ignition originates within the PV assembly, such as from electrical faults in G/B modules, fire development may be facilitated by the confined and thermally active cavity conditions. This underscores the need to adequately address such scenarios in fire safety assessments of BIPV façades.

Additionally, fire-induced material responses (such as glass cracking, softening or deformation of aluminium frames, and potential glass fallout) can influence fire dynamics and façade performance [33]. These aspects should be systematically considered within comprehensive BIPV fire performance evaluations.

2.3.3 Electrical hazards

As discussed, BIPV claddings have additional ignition sources compared to conventional construction materials, primarily due to potential electrical faults. In this context, 'electrical hazards' refers to risks such as electrical arcing/arc faults, ground faults, and energized conductive parts that can lead to ignition, electric shock, or arc-flash. Consequently, fire involving PV systems may present additional pathways for occurrence than those associated with traditional claddings, and their electrical characteristics require additional considerations in the fire safety of a building and firefighting efforts, including the use of water, while also

accelerating ignition and flame spread. Studies reveal that two-thirds of reported PV fires are caused by internal electrical issues, with an estimated global annual frequency of 28.9 fires per GW for rooftop PV systems[2], suggesting an even higher risk for BIPV roofing and façade systems compared to normal materials [17].

This aspect is increasingly recognised in emerging regulatory frameworks, where the management of electrically active PV systems during fire events, including safe shutdown and firefighter protection, is explicitly addressed.

Rapid shutdown is a safety feature that quickly cuts off the DC (direct current) power from solar panels in the event of an emergency such as a fire, reducing the risk of electric shock when extinguishing a fire. While it is still mandatory in a few countries, it can reduce electrical hazards during firefighting operations. However, there are also concerns raised that adding shutdown devices, connectors, and wiring may introduce new failure points and increase the likelihood of PV system faults [34].

Overall, these fire hazards associated with electrical risks are manageable and are increasingly being addressed through improved system design, installation practices, and evolving regulatory requirements.

2.3.4 Occupant Evacuation and Firefighting Hazards

Potential electrical shocks and thermal hazards associated with BIPV cladding systems present safety concerns, as these hazards can ignite fires in adjacent spaces while also hindering occupant evacuation and firefighting efforts. Typical PV arrays generate direct current (DC) voltages ranging from 600 to 1500 V, far exceeding safe voltage thresholds. For instance, NFPA 70 [35] has defined 100 V as the DC shock threshold since its 2012 update, while UL has identified life-threatening "Electrocution" at 240 mA (120 V with a body resistance of 500 Ω), "Lock-on" at 40 mA, and 2 mA as a "Safe" threshold [36]. PV modules can produce "Lock-on" current even under dim lighting or darkness due to fire flames or artificial lighting. Fire suppression efforts also face potential risks; studies have shown that water streams aimed at PV modules with 1000 V can result in unsafe current levels, with a current of 2 mA reported at a distance of 6 metres[36], [37]. Thus, there is a growing need to rethink and tailor evacuation planning and firefighting strategies for BIPV fires [38].

[2] The study is based on historical data that may not fully reflect recent technological and regulatory developments.

3 FIRE SAFETY ELECTRICAL REQUIREMENTS

3.1 Electrical requirements for fire safety of PV modules

The electrical risks are addressed in the current PV standards' testing sequences intended to detect the potential breakdown of internal and external components of PV modules that would result in a fire. The standards address the following:

- The operating temperature of system components in ANSI/UL 1703 (section 19) [39], and IEC 61730-2 test MST 21 [40]
- Hot-spot condition potentially caused by a short circuit in ANSI/UL 1703 (section 39) [39], IEC 61730-2 test MST 22 [40], and IEC 61215-2 test MQT 09 [14]
- Bypass diode reliability and reverse current overload IEC/UL 61730-2 (test MST 25) [40], and IEC 61215-2 test MQT 18 [14]
- Current overload test and arc fault in ANSI/UL 1703 (section 28) [39], IEC 61730-2 (test MST 26) [40], UL 1699–standard for PV DC arc fault circuit protection [41], UL 4703–standard for PV wire [42]
- Electrical/fire safety tests such as water spray tests (ANSI/UL 1703 section 33), sudden impacts (ANSI/UL 1703 section 30) and fire tests (ANSI/UL 1703 section 31 [39] and IEC/UL 61730-2 MST 23) [40] and electrical system component safety (UL 6703 [43]).
- UL 3741 Photovoltaic Hazard Control [44]

Potential fire hazards typically exist in the heated PV modules due to the operation, failure of components or flows of high-voltage current through electrically conductive system components. Questions raised are whether or not these tests are suitable for large-scale PV claddings.

4 MATERIAL LEVEL REQUIREMENTS – REACTION TO FIRE

Previous literature reviews [6], [7], [8] indicated that the current PV standards refer to existing local building codes and standards that are developed for regular building materials and systems. And the current building codes practiced in many countries require construction materials to be evaluated for their fire behaviour (i.e., how the material responds to a fire) at the material level, such as combustibility, ignitability, heat and smoke production, flame spread rate, smoke toxicity, and water responsiveness. In this report 'BIPV materials' refers to the complete, manufactured PV module assembly, rather than individual constituent layers. This directly reflects standard practice within published fire testing literature and building codes, where an entire composite product is classified as a single construction material.

Thus, the present survey was conducted to first collect the existing provisions and test standards for regular building materials/systems. In addition, the survey also addressed the existence of additional requirements specific to PV systems. The present survey also collected views from the participants on the sufficiency of applying the existing building codes and standards for regular façade cladding to BIPV cladding.

European countries share a common regulatory framework that applies across all EU member states, and non-member countries like Switzerland, thanks to a mutual recognition agreement. Nonetheless, national standards may differ in some specific areas. Many European countries (Austria, Spain, Switzerland, and Norway) reference the EN 13501-1 standard [45] for classifying the reaction to fire of construction materials. This standard, supported by tests such as the Single Burning Item (EN 13823 [46]) and ignitability test (according to EN ISO 11925-2 [47]), forms the basis for determining material classifications and their suitability for use in different building types and heights. Similarly, smoke production and heat release rate are common criteria in both European and non-European contexts (e.g., Canada, Australia, Japan, South Korea), but not to the extent to include smoke toxicity. Most countries also require material classification systems (e.g., Euroclass, material group numbers, or smoke indices) to guide compliance.

4.1 Combustibility

4.1.1 Requirements for general Façade cladding materials

Generally, in many countries, combustible materials are regulated to limit their application to buildings of certain occupancies and heights, etc.

- In Australia, combustible façade claddings are not allowed to be installed or attached to the external face of an external wall that is required to be non-combustible as per NCC 2022 C1.14 Ancillary elements [48].
- In Spain and Switzerland, the relevant standard is EN 13501-1 [45] as referenced by EN 50583 [3]. The test method is EN ISO 1182 [49] for determining non-combustibility performance, with pass–fail criteria based on EN 13501-1 and applicable only in classifications of noncombustible materials (e.g., Class A1 and A2). Nonetheless, Spanish national building codes allow the use of combustible façade claddings in some cases.
- In Canada, the National Building Code of Canada (NBCC) [50] regulates the use of combustible materials in non-combustible buildings by prescribing whether they may be used and by imposing limits based on building occupancies and conditions and fire performance criteria.

- In the US, the use of combustible cladding in non-combustible buildings is allowed under certain conditions.
- In Japan, the use of combustible materials for exterior walls is strictly restricted depending on the fire prevention designation of the building's location (fire prevention area, quasi-fire prevention area, etc.), as well as the size and structure of the building. In fire prevention and quasi-fire prevention areas, exterior walls in areas where there is a risk of fire spreading must use non-combustible materials specified by the Building Standards Act, or flammable materials must be covered with fireproof coverings that meet specifications recognized as fire-resistant structures.
- Similarly, South Korea has relevant codes: Building Act Article 52-4 (Quality Control of Building Materials) [51], and Standards for Quality Certification and Control of Building Materials Article 23 (Performance Standards for Non-combustible Materials) [52].
- Norway does not have any regulation that prohibits combustible materials in façade claddings.

Combustibility is usually determined by a standard test method, and general façade cladding materials are also required to be tested for combustibility.

- Various standard test methods for combustibility are available, which include AS 1530.1 [53] (Australia), ASTM E136 [54] (US), CAN/ULC-S114 [55] (Canada) and ISO 1182 [49] (Spain, Switzerland, EN13501-1 [45] as referenced by EN 50583 [3]), JIS A 1321 [56] (Japan) as well as KS F ISO 1182 [57] (South Korea). These test methods are similar in using a cylindrical furnace tube to expose materials to heat and observe their behavior, but they differ in their testing protocols and criteria for non-combustibility. Nonetheless, these standard test methods pass a material if it does not significantly ignite, burn, or release heat during the test, as defined by the temperature increase, mass loss, and sustained flaming criteria. For example, as per AS 1530.1 [53], a sample with sustained flaming for more than 5 seconds in a 30-minute test period is deemed combustible, and the material should not exhibit a temperature rise of more than 30°C above the furnace temperature. The test is very severe and designed to allow a maximum of 0.5% combustible content. A more onerous criterion is used in KS F ISO 1182 [57], with the maximum temperature rise limited to no more than 20°C in a 20-minute test.
- Canadian national building codes reference the cylindrical furnace test CAN/ULC-S114 [55] “Standard Method of Test for Determination of Non-Combustibility in Building Materials” which classifies building materials as either combustible or non-combustible. To be used in non-combustible construction, combustible materials must then be assessed by ULC-S135 [58] “Standard Test Method for the Determination of Combustibility Parameters of Building Materials Using an Oxygen Consumption Calorimeter (Cone Calorimeter)”, which tests a building material’s combustibility with all layers exposed. To be used in combustible construction, a large-scale system-level test is needed, which is further discussed in Chapter 5.

4.1.2 Requirements for BIPV Façade cladding materials

The present survey indicates that there is no country providing specific combustibility testing methods or requirements for PV materials. However, it is observed that PV materials should be tested following the existing combustibility testing method or requirements that are developed for general construction materials.

- In Australia, in order to satisfy the requirement in C1.14, every component of the PV module needs to achieve a result of “deemed non-combustible” when tested to AS 1530.1 [53], and consideration must be given to how the electrical components affect the test results.
- In Canada, all PV layers including encapsulation should be tested as per Canadian national building codes using the ULC-S135 [58] cone calorimeter tests for non-combustible construction or tested as a combustible cladding in CAN/ULC-S134 [59] exterior wall assembly test for both non-combustible and combustible constructions.
- In Switzerland, BIPV façade cladding is currently addressed through the general reaction-to-fire framework for construction products, mainly based on EN 13501-1 classification and the Swiss Fire Protection Directives. However, recent Swiss developments complement material-level classification with system-level considerations. An interim guidance document developed by Swissolar with the support of SwissEnergy [60] provides provisional guidance for ventilated photovoltaic façade systems, pending the publication of a consolidated state-of-the-art document. Within this framework, PV modules are classified as construction products in accordance with the applicable reaction-to-fire requirements, while the overall assessment of the façade system also considers system configuration, façade typology, building height, and applicable technical and constructional fire protection measures. This framework recognizes that material classification alone may not be sufficient to determine the acceptability of BIPV façade systems, particularly for medium-rise and high-rise buildings.

PV panels are classified as combustible composites if they use plastic backsheet and/or polymer encapsulation foils. Polymer encapsulant foils made of EVA, PVB, POE or TPO are reported to be the main combustible components.

The adequacy of the current test methods and code provisions should be reviewed, as individual tests may not be sufficient; representative intermediate or large-scale system testing may be required to evaluate fire performance. Section 5 further explores system level intermediate/large scale testing.

4.2 Ignitability

4.2.1 Requirements for general Façade cladding materials

In many European countries, building products and building materials are classified into 7 classes according to the EN 13501-1 [45], as referenced by EN 50583 [3], and their application as a system to the building will be limited by the class. Test methods include the flame spread/ignitability over the surface of a construction material in various set-ups and scales, such as EN ISO 11925-2 (bench-scale ignitability tests for small samples) [47].

- In Austria, Spain and Switzerland, the relevant standards are aligned, with the pass-fail criteria based on EN13501-1 [45]. Spanish pass-fail criteria are based on the Spanish Building Code (Código Técnico de la Edificación, CTE), in particular the Basic Document on fire safety (DB-SI) [61]. For façade systems that cover more than 10 % of the envelope, the required fire-reaction class is D-s3,d0 for façades up to 10 m high, C-s3,d0 for heights up to 18 m, and B-s3,d0 for heights above 18 m. Nevertheless, the CTE is undergoing an amendment; the public-consultation phase has just closed on 9 December 2025 [62], and the draft amendment proposes tighter fire-performance requirements for façades, introducing a classification that differentiates façade products not only by building height but also by their intended use.

- In the guidelines for the Norwegian building regulations, pre-accepted performance criteria B-s3,d0 or D-s3,d0 according to EN 13501-1 [45] for external wall claddings are listed for different fire classes. This classification implies testing of Ignitability according to EN-ISO 11925-2 [47] (single-flame source test) and reaction to fire according to EN 13823 (Single Burning Item, SBI) [46].
- In Australia, relevant standards include the National Construction Code 2022. Test methods include the AS 1530.3 [63] 'Methods for fire test on building materials, components and structure Part 3: Simultaneous determination of ignitability, flame propagation, heat release and smoke release', but it does not have fixed pass-fail criteria. Instead, it provides indices that quantify the fire performance of materials. The lower the indices (ignitability, spread of flame, heat evolved, smoke developed), the better the fire performance of the material. Building codes and project specifications dictate acceptable values based on the application, intended use, and fire safety objectives.
- In Japan, there are no regulations regarding the ignition properties of exterior wall materials, but JIS A 9523 [64] specifies ignition test methods for insulation materials, which are carried out as necessary when used in the exterior wall system.

There are no direct ignitability test specifications for Canada, South Korea, and Singapore; however, testing is conducted for combustibility and other burning behaviours. The National Building Code of Canada does not prescribe a stand-alone ignitability requirement; instead, ignition-related behaviour is addressed implicitly through surface flame spread, non-combustibility, and assembly-level fire performance tests.

4.2.2 Requirements for BIPV Façade cladding materials

In many European countries, testing PV module for ignitibility is needed for the reaction to fire classification of PV module. In Germany, the reaction to fire Class E (i.e., testing only ignitability is required according to ISO 11925-2 [47]) is required not just for BIPV but also for BAPV. Thus, the existing test methods for regular materials are currently considered and used in testing PV modules, such as EN13501-1 [45], and EN ISO 11925-2 [47] (bench-scale ignitability tests for small samples). However, the required specimen size (250 x 90 mm) in EN ISO 11925-2 [47] is difficult to make for some PV manufacturers.

There is an ignitability test method of MST 24 for PV modules in IEC 61730-2 [40], which is based on ISO 11925-2 (Reaction to fire tests — Ignitability of products subjected to direct impingement of flame) [47] with small modifications for PV for the apparatus set-ups and sample preparations. The modified IEC 61730-2 [40] requires a larger specimen, but most of the lab test benches are sized for EN ISO 11925-2, so it is not feasible to test a larger sample due to bench limitations.

In Canada, CSA C22.2 No. 61730-1:19 [65] Photovoltaic (PV) module safety qualification, an adoption of the IEC 61730-1:2016 standard [13] with Canadian deviations, also references the MST 24 ignitability test and requires adequate properties for resistance against ignition for "enclosed parts". CSA C22.2 63092-1 [66] and 63092-2 [67] also refer to Part 3 and Part 9 of NBCC for fire safety requirements.

In Japan, ignitability tests are conducted on railroad vehicle materials, building materials, and photovoltaic materials for BAPV modules (generally standardized PV modules). This refers to ignitability tests based on ISO 11925-2 [47]. This test was designed to evaluate the ignition behaviour of materials when directly exposed to flame, which is also a requirement for obtaining Euroclass in EN 13501-1 [45].

In Australia, Norway, South Korea, and Singapore, the building regulations do not specify any specific requirements for BIPV used as façade cladding, and the general requirements and pre-accepted requirements for cladding materials as mentioned above applies.

4.3 Heat and smoke production

4.3.1 Requirements for general Façade cladding materials

Smoke production and heat release rate are common criteria in both European and non-European contexts (e.g., Singapore, Canada, Australia, Japan and South Korea) for determining material classifications and their suitability for use in different building types and heights. General façade cladding materials are tested in many countries mainly for classifying the reaction to fire of construction materials for heat and smoke production to form the basis. In Austria, Spain, Switzerland, and Norway as well as Singapore, the EN 13501-1 [45] standard as referenced by EN 50583 [3] is used with standard testing methods using the Single Burning Item (EN 13823) [46] for smoke production and heat release rate.

While the standard and test methods are common, the pass-fail criteria vary across different countries. Spanish pass-fail criteria are based on the Spanish Building Code (CTE), in particular the Basic Document on fire safety (DB-SI) [61]. The reaction to fire testing and classification requirements are applicable to materials installed on building envelopes, insulation material systems, and façade systems. In Switzerland, the reaction-to-fire requirements for construction materials and building components installed on building envelopes are defined by the Swiss Fire Protection Directive "Construction Materials and Building Components" [68]. The Swiss fire classification system also includes an additional classification for smoke production. For external thermal insulation systems incorporating combustible components, prescriptive solutions or equivalent systems in accordance with the Swiss Fire Protection Directives are required. Norway uses EN 13501-1 [45] (Euroclass classification), as per the guidance of the Norwegian building regulations (TEK17 §11-9 [69]), and this applies to the classifications for external claddings and interior surfaces of cavities.

The test methods of using cone calorimeters are also used in Canada and the US, while the pass-fail criteria or classification methods vary.

Also, in Japan, building materials' heat generation and smoke standards are evaluated through fire performance tests (such as cone calorimeter tests), which provide criteria for heat release rate, total heat output, cracking, and penetration. These tests involve irradiating the material with radiant heat, measuring the heat release rate from the oxygen consumption during combustion, and checking for damage to the test specimen. Building materials used as fire-resistant materials must be tested individually and certified by the Minister of Land, Infrastructure, Transport and Tourism. This certification process evaluates whether they meet specified performance standards, including heat release and smoke generation.

The same cone calorimeter-based test methods (adopting ISO 5660-1 [70] Reaction-to-fire tests) are also required in South Korea, as per the Building Act Article 52-4 [51] (Quality Control of Building Materials) and Standards for Quality Certification and Control of Building Materials, and Article 25 [71] (Performance Standards for Fire-resistant Materials). The above mentioned test method using the cone calorimeter evaluates heat release, smoke production and mass loss rate. Notably, in South Korea the pass-fail criteria are not only based on the heat release rate but also fire induced cracks and deformations, which are regarded applicable to exterior façade materials.

Testing methods different from cone calorimeter or SBI tests are also used for the evaluation of construction materials. In Australia, the relevant tests include AS 1530.3 [63] using the building material radiant panel testing equipment, 'Methods for fire test on building materials, components and structure Part 3: Simultaneous determination of ignitability, flame propagation, heat release and smoke release'. AS 5637.1 test results could be used to derive a smoke growth rate index or smoke density, and the AS 1530.3 [63] test results could be used to derive a smoke release index. The pass-fail criteria are based on achieving a material group number, smoke growth rate index, and specific extinction area.

In the US, a room-corner test and a corner test are used for reaction-to-fire evaluation for some cladding materials, particularly containing foam plastics, although they are mainly developed for testing interior finishing materials. Test methods include the NFPA 286 [72] (Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth) also known as the room-corner test. The corner tests in FM 4880 [73], UL 1040 [74], or UL 1715 [75] also test exterior wall materials for their combustibility and fire propagation while the pass-fail criteria are based on the prevention of flashover in the room/corner tests and meeting the requirements for fire spread resistance and smoke generation.

4.3.2 Requirements for BIPV Façade cladding materials

The present survey identifies Singapore as the country that has specific requirements for BIPV. In Singapore, the relevant test methods include the EN 13501-1 [45], with the pass-fail criteria based on classification and fire growth rate index (FIGRA). The requirement of FIGRA ≤ 70 W/s disqualifies general glass-plastic PV panels at the material level so that only glass-glass systems are actually installed in current practice.

In other countries, specific BIPV requirements are not yet established. In this regard, the present survey participants indicate that BIPV façade cladding materials are regarded as being tested in the same way as other general façade cladding materials.

In Austria, EN13501-1 [45] is relevant to PV façade claddings because the combustible construction material flame spread rating/index and smoke generation rating also need to be evaluated not only for interior finish materials but also for exterior finish materials such as BIPV products. In Spain, unlike BAPV, PV façade claddings would be considered like any other cladding material because the PV modules are integrated in the building. In Switzerland, the provisions for general cladding materials are relevant to PV claddings because the PV modules are used as the building's cladding material.

The requirements for PV claddings can vary depending on whether the exterior walls where they are installed meet relevant compliance standards. When PV systems are added to compliant exterior walls, fire safety assessments may focus on the underlying walls rather than the PV modules themselves.

In Japan, currently, BIPV modules can be treated as general building cladding materials if they meet the building code requirements, yet in principle, the cladding surface must be made of non-combustible materials. Additionally, in practice, careful consideration is required in developing technical recommendations (guidelines) consulted with the Fire Department and other relevant organizations.

In South Korea, the Building Act Article 52-4 [51] (Quality Control of Building Materials), Standards for Quality Certification and Control of Building Materials, and Article 25 [71] (Performance Standards for Fire-resistant Materials) are relevant to PV façade claddings

because they apply to "composite exterior cladding materials". Since PV modules are made of more than one material, they are considered "composite materials", and when applied as façade cladding, they fall under the category of "composite exterior cladding materials". There are no modified requirements for PV.

As discussed above, while most jurisdictions apply the general reaction-to-fire framework for façade products to PV modules, the suitability of applying the existing regulations and standard test methods to PV materials is also raised.

For example, the SBI fire test method is commonly required, but not representative for a large fire potentially involving PV. Moreover, the sample size defined in EN 13823 SBI [46] is smaller than standard PV panels, so the real product must be cut or produced ad hoc. This could be a challenge for the manufacturers. Furthermore, there is no specific assembly protocol for testing PV façade cladding systems in SBI that defines the position and quantity of junction boxes, cables, connexions. Also, the burner heat release rate is also quite moderate with 30 kW exposure for 21 minutes.

4.4 Flame spread and smoke production

4.4.1 Requirements for general Façade cladding materials

Flame spread testing at the material level is required in the regulations of Spain and Switzerland, for the classification for reaction to fire, which is determined based on the degrees of the burning characteristics by EN13501-1 [45] as referenced by EN 50583 [3]. In Spain, as per the Spanish Building Code, known as Código Técnico de la Edificación or CTE, construction systems covering more than 10% of the façade surface, as well as “Insulation material systems” within ventilated cavities in façades should be tested for a Reaction to Fire classification, as explained above.

In the US and Canada, the flame spread tests use a tunnel testing device, where horizontal flame spread is mainly evaluated following the Standard Method of Test of Surface Burning Characteristics of Building Materials, ASTM E84 [76], ULC S102 [77], NFPA 255 [78], or UL 723 [79]. These test methods are mainly to test interior finishing materials, but the 2021 International Building Code (IBC) [80] sets flame spread and smoke development requirements for façade cladding materials particularly for foam plastic insulation within exterior wall systems. Additionally, plastic in exterior walls over 40 ft (12 m) in height is required to pass NFPA 285 [81] as a system, which will be further discussed in Chapter 5.

In Australia, there is no existing Australian Standard available to provide on the rate of flame spread. The alternative is to employ the test method from ASTM Standard E1321 [82] ‘Standard Test Method for Determining Material Ignition and Flame Spread Properties’, which is used only to evaluate lateral flame spread.

In addition to the flame spread testing at the material level, many countries also require the flame spread testing at the system level, which is further discussed in the next chapter for system level requirements.

In Switzerland, the Fire prevention directive, known as Direttiva Antincendio, under the classification of “Materiali da Costruzione e parti della costruzione” [68] has pass-fail criteria based on the classification of materials from the smoke formation. And this provision also applies to exterior cladding materials.

The 2021 IBC [80] requires for exterior wall assemblies containing foam plastic components a smoke developed index not exceeding 450, when tested as per ASTM E84 [76].

In Japan, testing methods involve measuring the characteristics of smoke generated by building materials in the event of a fire (amount, carbon monoxide concentration, etc.).

4.4.2 Requirements for BIPV Façade cladding materials

In many countries, if the PV modules are used as the building's cladding material, they are treated the same as any other cladding material, without any other specific consideration. This is the case in Spain. In Switzerland, EN 13501-1 is relevant to PV façade claddings because PV modules used as part of the building envelope are considered construction products and must be assessed in accordance with the applicable reaction-to-fire requirements. However, the acceptability of a BIPV façade system cannot be determined solely by the classification of the PV module, but also depends on the overall façade configuration, the supporting wall assembly, building height, and applicable constructional fire protection measures.

In Australia, there is currently no existing standard that provides material-level data on the rate of flame spread. Where multiple PV modules are attached to a building element and arranged in a configuration that could enable potential fire spread between two or multiple floors via the PV modules, a system level testing could be carried out to demonstrate the flame spread over the PV modules. Such system-level considerations are discussed in the next chapter.

There are no standards relevant to flame spread and smoke production tests at the material level of PV modules in Canada and Norway. In South Korea, flame spread testing is not reported at the material level but at the system level for roofing PV (adopting IEC 61730-2 [40]) and for BIPV façade (KS F 8414 adopting BS 8414 [83]).

The 2024 edition of the IBC [80] in the US requires façade BIPV systems to be listed to UL 1703 [39], which incorporates a PV fire classification test derived from the ASTM E108 [84] standard for roof coverings. This requirement also belongs to the fire resistance test specified in UL 61730-2 (i.e., harmonized with IEC 61730-2 [40]) MST 23 fire test, which is based on the UL 790 [85] standard for roof testing. However, adapting a roof-mounted fire test for façade-installed PV panels is not representative of façade fire exposure conditions. This reconfiguration limits the relevance of the test for façade applications and may create a misleading perception of fire safety when a roof-based test method is used to qualify façade-integrated systems.

More importantly, the assessment of the fire performance of BIPV modules should not be limited to the fire resistance level of the material and the reaction to fire of modules, and this should also be extended to estimate the hazard of a system under operation.

In the US, the standard Method of Test of Surface Burning Characteristics of Building Materials ASTM E84 [76], NFPA 255 [78] or UL 723 [79] are relevant to PV façade claddings because building materials, including BIPV cladding elements, are required to be tested for classification for reaction to fire. For a BIPV cladding/curtain wall system incorporating insulation foams, flame spread index (FSI) of 25 or less is required, and the 25 of FSI generally resulted from highly fire-resistant building materials (e.g., concrete). However, there are not yet any clear requirements for PV in these provisions.

In Singapore, IEC 61730-2 [40] is regarded as relevant to BIPV façade materials while it does not explicitly detail a vertical flame propagation test, and the small flame test of ISO 11925-2 (i.e., MST 24 ignitability tests) [47] is considered to evaluate the flame spread to a defined distance. The pass-fail criteria based on flame propagation provisions are relevant to PV façade claddings. Singapore's regulatory approach is mitigating the risk of vertical fire propagation from PV system components based on the material level testing results. In this

way, glass-plastic module configurations are likely to be disqualified from use at the material level, and only glass-glass materials are allowed.

4.5 Smoke toxicity

4.5.1 Requirements for general Façade cladding materials

There are no standards or tests relevant to smoke toxicity in Austria, Australia, Canada, Norway, Spain, or Singapore. In Switzerland, no relevant standards or tests currently exist, but they are under study by AICAA.

In South Korea, the relevant standards include the Building Act Article 52-4 [51] (Quality Control of Building Materials), Standards for Quality Certification and Control of Building Materials, Article 23 [52] (Performance Standards for Non-combustible Materials) and Article 25 [71] (Performance Standards for Fire-resistant Materials). Test methods include the KS F 2271 Testing method for gas toxicity of finish materials of buildings, which also includes exterior cladding materials. The pass-fail criteria are based on the time for behavioural cessation of experimental rats.

In Japan, there are no laws or standards regarding the smoke toxicity of building materials. However, the Building Standards Act sets out standards for smoke exhaust systems to prevent the amount of smoke generated and its spread in the event of a fire.

4.5.2 Requirements for BIPV Façade cladding materials

The smoke toxicity provision in South Korea is relevant to PV façade claddings because the requirement applies to "composite exterior cladding materials". No modified requirements or test methods specific to PV are given for the provisions.

In many other countries, e.g., Austria, Australia, Canada, Norway, Spain, or Singapore, there are no requirements, standards or tests relevant to PV smoke toxicity, as there is no provision for smoke toxicity for general façade cladding materials.

In Switzerland, no specific standards or test methods currently address smoke toxicity for BIPV façade systems.

4.6 Fire behaviour when electrically active

4.6.1 Requirements for general Façade cladding materials

At present, regulatory requirements do not address the fire behaviour of façade cladding materials under electrically active conditions. While these provisions are widely applied to general façade cladding systems, including BIPV, they do not capture the distinctive behaviour of electrically active systems. As a result, although the regulatory scope appears to cover all façade cladding, key aspects specific to BIPV remain unaddressed and require additional PV-specific consideration.

4.6.2 Requirements for BIPV Façade cladding materials

There are no provisions concerning fire behaviour of BIPV when electrically active in Austria, Australia, Canada, Norway, South Korea, Spain, or the US. In Switzerland, no specific standards or test methods currently address the fire behaviour of electrically active BIPV façade systems.

In Singapore, IEC 61730-2 [40] and MST 22 (hot spot endurance tests), MST 25 (bypass diode thermal tests to verify the thermal design and long-term reliability of bypass diode devices), and MST 26 (test methods for arc fault risk) are considered relevant to PV façade claddings because they minimise the risk of photovoltaic panel-induced fires resulting from module faults.

Although such electrical standards exist, incidents of PV-induced fires continue to be reported, often with rapid spread and significant damage, underscoring the need for further material studies that account for the actual fire behaviour of PV when energized and in normal operation.

4.7 Fire suppression (water responsiveness) when electrically active

4.7.1 Requirements for general Façade cladding materials

Current regulatory requirements for façade cladding materials do not address their interaction with fire suppression water under electrically active conditions, as this is not relevant for conventional façade systems. While these provisions are widely applied to general façade cladding, including BIPV, they do not capture the distinctive behaviour of electrically active systems.

As such, although the regulatory scope appears to cover all façade cladding materials, key aspects related to the interaction of energized components with suppression water remain unaddressed, indicating the need for additional PV-specific provisions.

4.7.2 Requirements for BIPV Façade cladding materials

Photovoltaic system components may influence the propagation of fire outside or inside the building, interfere with the smoke and venting system of combustion products, hinder fire-fighting operations or even introduce electrical shock hazards for firefighters and rescue operators due to energized electric circuits. In relation to the safety of firefighters, electric shock is the main potential fire hazard during firefighting operations, although the hazards identified for occupants in the previous Chapter are also relevant. If the fire brigade employs water-based extinguishing agents to fight fire while BIPV modules are active, the firefighters could receive electric shocks. Therefore, firefighters are likely to face the potential hazard of electric shock at the sites of fires. There are no standards or test methods relevant to fire suppression when electrically active in Austria, Australia, Canada, Japan, Norway, South Korea, Spain, Singapore or the US. While there are electrical tests such as water spray tests (ANSI/UL 1703 section 33 [39]), it does not assess PV modules under fire conditions or evaluate their reactivity with water.

There are currently no specific standards or test methods in Switzerland addressing fire suppression or water responsiveness of electrically active BIPV façade systems. However, IEC/TS 60479 (published in Germany as DIN IEC/TS 60479 [86]/ VDE V 0140-479 [87]), which provides guidance on the effects of electric current and associated safety considerations, may serve as a useful technical reference. The general danger in firefighting at electrical materials comes from the risk of arc flash from electrically conductive system parts or from the passage of the electrical current through water, and in particular from the quench water stream. Guideline distances normatively apply to live electrical materials in reference both to proximities and to extinguishing measures for ruling out the danger of electric shock. PV materials belong to the low-voltage materials as per VDE 0132 [88] (AC<1,000 V, DC<1,500 V). The relevant test methods include DIN VDE 0132 Measurement of leakage currents via the quench water stream and DIN VDE 0132 Firefighting in the vicinity of electrical systems. To

prevent hazardous currents from flowing through the water stream and into rescue workers' bodies while they are extinguishing live system parts, DIN VDE 0132 [88] – Firefighting and technical assistance in or near electrical installations – defines the recommended distances between the extinguishing agent outlet and the live system parts.

In Switzerland, the provision above is relevant to PV façade claddings because the presence of photovoltaic modules on buildings may increase or contribute to the pre-existing level of fire risk.

5 SYSTEM LEVEL REQUIREMENTS – RESISTANCE TO FIRE PROPAGATION

The current building codes regulating combustible cladding systems for fire safety vary significantly. A common provision across most codes is the requirement to resist fire spread along the exterior façade—primarily addressing scenarios such as flame propagation through windows. For the potential fire scenarios (discussed in Chapter 2.2), this review examines existing codes and standards to identify the provisions that may be applicable or necessary for BIPV cladding systems.

The survey indicates that, at the time of review, no country has established dedicated fire testing methods or prescriptive requirements specifically tailored to BIPV cladding systems. In practice, these systems are generally assessed using existing regulatory frameworks developed for conventional (often combustible) façade claddings. However, such approaches should be complemented by additional considerations that address the specific fire risks associated with BIPV systems, including the presence of electrical components and potential ignition sources.

For example, in Switzerland, the assessment considers building height, system configuration, and technical/constructional fire protection measures. Systems are assigned with risk levels based on design and integration; for medium- and high-rise buildings, additional measures or formal proof of compliance may be required. Where standard configurations are not met, fire performance must be demonstrated through appropriate system-level testing. Overall, this reflects a shift from prescriptive, material-based requirements to a performance- and system-based evaluation that supports safe BIPV façade integration while accommodating ongoing technological development.

The following sections (5.1 to 5.8) provide a detailed discussion on how the cladding system is assessed considering various fire scenarios (see Section 2.2. and Figure 6), as an example, if the system can resist fire spreading over the surface and prevent fire penetration to different building elements.

5.1 Resistance to fire spread on exterior façade (window flame)

5.1.1 Requirements for general façade cladding systems

The application of combustible façade cladding systems is regulated since they can cause rapid fire spread as reported from recent catastrophic high-rise building fires [89]. The façade fire spread is known to be attributed to the combustibility of materials (e.g., cladding materials, insulation layer and substrate materials) as well as the cavity space design, joint configuration, and fire barrier effectiveness. The present survey indicated that Canada, South Korea, Japan, Australia, Norway and the US require a multi-storey façade fire performance test to ensure the performance of façade cladding systems.

- The NBCC [50] requires testing of flame spread and heat flux on exterior wall assemblies following CAN/ULC-S134 [59] “Standard Method for Fire Test of Exterior Wall Assemblies” when combustible façade systems are used in either non-combustible or combustible construction.

- In South Korea, as per their Standards for Quality Certification and Control of Building Materials Article 27 [90], Standards for Quality Certification and Control of Building Materials, a full-scale model test for Exterior Wall Composite Finishing Materials is required following KS F 8414 Standard test method [91].
- In Japan, JIS A 1310 [92] specifies a “Test method for fire propagation over building façades” when exposed to flames ejected from an opening. This is a standard test method for measuring the spread of fire through organic exterior wall materials (e.g., insulation panels).
- Norway TEK 17 [93] §11-9 (2) guidance part D specifies that the use of combustible insulation requires testing of the complete wall assembly as per SP Fire 105 fire test [94] or similar.
- In Australia, the test method of AS 5113 [95] ‘Fire propagation testing and classification of external walls of buildings’ is required for testing façade claddings.
- In the US, IBC [80] Section 2603 requires testing as per NFPA 285 [81], while FM has the standard fire test method of FM 4880 [73].
- A new test standard ISO 3957 [96] large-scale façade test was published in July 2025. This provides for a consistent, repeatable façade fire test.

Since these exterior wall façade fire tests are not yet internationally harmonized, the required height of façade specimen, ignition method, and pass-fail criteria vary significantly across different countries. However, these tests fundamentally evaluate the fire performance of façade/cladding systems for the following:

- to evaluate the fire spread over the façade cladding system in case of fire
- to simulate exposure to a window flame scenario, as in CAN/ULC S134 [59], KS F 8414, SP 105 [94], AS 5113 [95] and NFPA 285 [81],
- to assess exposure of façade cladding system to a high heat flux resulting from propagating flame between the two façade cladding systems facing to each other, as in FM 4880 [73] and ISO 3957 [96].

5.1.2 Requirements for BIPV Façade cladding systems

The present survey indicated that there are currently no specific requirements that is enhanced or modified for PV façade cladding systems across the different countries analysed. The existing fire performance requirements for general façade cladding systems are deemed applicable to PV cladding systems.

In the present survey, input from Japan indicated that BIPV cladding is considered as other conventional organic exterior wall materials (i.e., façade systems that incorporate combustible, carbon-based components such as polymeric encapsulants, plastic backsheets, or resin-based layers), containing composite encapsulants and plastic backsheet. The same can be said for lightweight PV modules (resin based or ETFE (ethylene tetrafluoroethylene) sheets-laminated solar cells), which have been increasingly installed recently.

Inputs from South Korea noted that the fire spread performance of PV cladding façade systems varies depending on factors such as rear insulation and cavity depth, which should be tested as an exterior cladding system. For example, in Norway, using combustible insulation in external walls is pre-accepted for certain fire classes as long as the complete system of wall, insulation and external cladding is tested according to the large-scale test method SP 105 [94] or similar.

In Australia, it is observed that PV façade claddings would also be tested according to AS 5113 [95] because if there are multiple PV modules attached to a building element and arranged in a configuration that may create a pathway for fire spread between two or multiple floors.

In Canada, the NBCC [50] does not recognize the BIPV systems including PV cladding systems, and the scope of CAN/ULC S134 [59] does not specify that the test method is directly applicable to PV cladding systems. As such, CSA C22.2 No 63092-2 Photovoltaics in buildings - Part 2: Requirements for building-integrated photovoltaic systems [67] indicates that "requirements for fire safety specific to BIPV modules have not yet been established nationally."

FM is currently developing a new FM Approval standard, FM 4483 for wall-mounted BIPV systems [97].

Concerns have arisen regarding the direct application of current façade cladding standard test methods to photovoltaic (PV) claddings, particularly because PV systems are electrically active and may promote fire spread. It is recommended that these factors be incorporated into test protocols. Since system details, such as cavity design, significantly influence fire propagation, testing procedures should specifically require evaluation of realistic cavity designs during performance assessments. Furthermore, it is crucial to update pass/fail criteria, as PV modules exhibit distinct burning behaviours, including phenomena like glass breakage.

5.2 Resistance to fire spread through the cavity gap

5.2.1 Requirements for general façade cladding systems

Flame spread in façade fires is influenced not only by the fire performance of the external cladding materials but also significantly by the characteristics of the insulation materials used within the cavity, as well as the cavity's depth, geometry and design in general. However, current standard façade fire test methods discussed in Chapter 5.1 overlook the role of cavity configurations in fire propagation, primarily evaluate system-level fire propagation under prescribed configurations and may not explicitly isolate or parametrically assess the influence of cavity design variables. This oversight becomes particularly critical in the context of BIPV systems, where the cavity space is subject to elevated temperatures due to electrical activity and solar exposure. In cases where ignition originates within the PV assembly (e.g., due to electrical faults), the confined cavity conditions may influence subsequent fire development. These conditions increase the likelihood of fire propagation within the cavity itself [28], [29]. Even a minor ignition event can escalate rapidly in such thermally active and confined environments, highlighting a crucial gap in existing fire safety assessments for BIPV-integrated façades.

The current survey identifies a test method currently available for testing fire spread through the cavity gap, which is the FM Approval Standard 4411 [98]. This test method addresses the material burning characteristics of a fire in a cavity.

In Spain, vertical fire propagation within ventilated cavities in façades should be limited by placing a fire barrier in every fire compartmentation slab (E30 classification for Fire Resistance is considered as a valid measure for that purpose) while fire barrier performance should also be validated.

In Canada, NBCC [50] requires the installation of fire blocks at every floor level to divide concealed spaces within wall assemblies such that their maximum height is 3 m and maximum

horizontal dimension is 20 m. However, they would not be required if the thickness of the air cavity is not more than 25 mm.

5.2.2 Requirements for BIPV façade cladding systems

There is currently no requirement or specific standard for BIPV façade cladding systems. The FM 4411 could be considered in evaluating BIPV façade cavity fire performance, and FM is currently developing a new FM Approval standard, FM 4483, which might include the cavity test [97]. However, it should be noted that the sample size and ignition source used in the testing protocol are developed considering welding and cutting torches or electrical fires[3], rather than electrical ignition caused by PV modules or electrical PV components. Also, the pass-fail criteria[4] need to be updated specifically for BIPV to limit substained burning and upward fire propagation in the BIPV façade systems.

In Switzerland, the issue of fire spread through ventilated façade cavities in BIPV systems is explicitly addressed within the transitional framework [60] developed for photovoltaic façade applications. The approach considers typical fire scenarios such as vertical fire spread along the façade, horizontal propagation between compartments, and fire initiation due to electrical faults (e.g. arc faults). To mitigate these risks, specific construction measures are required at the system level, including the introduction of horizontal and vertical cavity barriers, the compartmentation of façade sections, and the controlled routing of electrical cables through fire-resistant layers. The continuity of the ventilation cavity is therefore intentionally interrupted to limit fire propagation, while maintaining the functional requirements of the façade system.
In addition, the need for system-level assessment is emphasized, as the fire behavior of the cavity cannot be reliably inferred from individual material classifications. As a result, for non-standard configurations, appropriate large-scale or representative testing may be required to demonstrate compliance with fire safety objectives.

5.3 Resistance to fire exposure from within the building and Protection from fire originating from external claddings

5.3.1 Requirements for general façade cladding systems

A fire resistance rating could be required for exterior walls (e.g., when the building is close to the property line triggering fire safety issues for neighbouring buildings). The resistance ratings are obtained through standard wall furnace tests, which expose the interior side of the exterior wall to the post-flashover fire condition of a typical room fire. The standard fire resistance tests (e.g. ULC S101 [99] Standard Methods of Fire Endurance Tests of Building, EN 1365 [100] Fire resistance tests for loadbearing elements or EN 1364-1 [101] Fire resistance tests for non-loadbearing elements, AS 1530.4 [102]) also require monitoring the temperature increase on the unexposed side of the exterior wall.

Façade claddings could be installed on exterior walls requiring fire resistance ratings, and this often forms the ventilated cladding systems, where there is a cavity space between the primary exterior wall (also called “back-up wall”) and the external facing panels, due to the design of

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[3] the ignition source sizes (i.e., propane sand burner imposing 40-45 kW/m^2 to sample surface, measured 6“ (0.15 m) above)

[4] Current criteria are the heat release rate of 100 kW and the maximum flame height of 6 ft (1.8 m) height; however, criteria for BIPV are under development and will be released by end of 2025.

the mounting mechanism. In this case, the fire resistance rating is generally required only for the primary wall behind the cladding system.

However, in Australia, the claddings that form part or all of the external wall are required to have a fire resistance rating (e.g., to achieve an FRL as the duration in minutes for structural adequacy, integrity, and insulation when tested to AS 1530.4 [102].

Also, the IBC [80] in the US requires any exterior cladding systems mounted on primary exterior walls to demonstrate that the installed claddings do not affect the fire resistance of the primary exterior walls. More importantly, when the cladding system contains an insulation layer, a thermal layer (that has passed the NFPA 275 [103] fire test with a 15-min exposure to a standard time-temperature curve similar to ASTM E119 [104]) should be added to separate the cladding from the interior of the building.

In Japan, the Building Standards Act [105] (article 2-9-2 fire resistance building) and its Enforcement Order provide provisions for exterior wall openings and windows (vision part in curtain walls) where there is a risk of fire spreading. For instance, flame protection is defined as a fire resistance rating of 20 minutes (exposed to ISO 834 [106] standard heating curve) in the event of both a "fire that breaks out indoors" (Enforcement Order Article 109-2) and a "fire that breaks out around the building" (Enforcement Order Article 136-2). Fire protection equipment must comply with specifications using a certified structure. Additionally, exterior wall openings and windows installed across fire compartments must meet the standards for specific fire protection equipment (Enforcement Order 112-1) under the Building Standards Act [105]. Specific fire protection equipment is required to have a 60-minute fire resistance rating against typical fires within or around a building.

5.3.2 Requirements for BIPV façade cladding systems

There are a few requirements related to PV claddings installed on exterior walls requiring fire resistance ratings. In Singapore, as per the Code of Practice for Fire Precautions in Buildings [107], wall-mounted PV claddings are required to be mounted on external walls with a fire resistance rating of at least 1 hour.

While there is no specific provision currently available for the fire resistance requirement of exterior walls with PV claddings, it is regarded that the impact of PV claddings on the fire resistance of the primary walls should be examined through the standard fire resistance furnace tests. When testing PV ventilated cladding systems, the current temperature pass-fail criteria should be carefully assessed particularly on the unexposed side and in the cavity space since they could be elevated not only due to the fire exposure but also due to the PV operation, in real scenarios.

The thermal barrier requirement in the US could be applied particularly to PV claddings with or without an insulation layer since a fire could be started from PV modules, which can affect the fire resistance of the primary wall behind.

5.4 Limiting installation areas

5.4.1 Requirements for general façade cladding systems

The result of this survey reveals that there are currently a few regulatory restrictions practiced across the different countries on limiting the application area of combustible façade cladding systems.

In Singapore, as per the Code of Practice for Fire Precautions in Buildings [107] Cl.2.3.3a.(3), there shall be no unprotected openings of occupancy area or combustible material/construction within 1.5 m horizontally or within 3 m vertically below any opening including final discharge openings located in the external walls of the internal exit staircase.

In Japan, the Building Standards Act [105] designates special areas such as "fire prevention areas" and "quasi-fire prevention areas." In these areas and in areas at risk of fire spread, the use of fire prevention equipment and non-combustible materials that can block flames for a certain period of time is mandatory. The exterior walls themselves must also be fireproof or semi-fireproof according to the area's designation. When using organic insulation for exterior walls, special measures are required, such as preventing the fire from spreading to upper floors.

5.4.2 Requirements for BIPV façade cladding systems

Likewise, limitations to the application area of PV façade cladding system have been observed in Singapore and Japan[5]:

- Prohibiting PV installation near openings/right above windows or requiring minimum distance from openings including windows.
- Regulating PV installation near exit doors
- Limiting the maximum installation area of a combustible cladding system over a building or requiring a separation distance: Currently there is no provision for façade application.

In Singapore, as per Cl.2.3.3a.(3) [107], PV shall be installed away from any unprotected openings, or combustible material/construction within 1.5 m horizontally or within 3 m vertically, or adjacent to or facing it. Alternatively, the 3 m vertical separation can be exempted if a 1-hour fire-rated horizontal projection that extends at least 600 mm from the building is installed between the PV installation and the unprotected opening.

In addition, PV installations located adjacent to exit staircases shall comply with the Cl.2.3.3a.(3) or Cl.2.3.3b.(2)(b). As per Cl.2.3.3b.(2)(b), an external exit staircase can be used as a required exit in-lieu of an internal exit staircase provided: (b) there is no unprotected opening, or combustible material/construction within 3 m horizontally or within 3 m vertically below, or adjacent or facing it." [102].

In Japan, the Tokyo Fire Department, in its guidelines for fire safety measures related to solar power generation facilities, requires the installation area and method of PV modules that ensure the safety of firefighting activities. This means that PV modules should not be installed around facilities used by firefighters in their firefighting activities to reduce the risk of electric shock. Specifically, for installation around facilities used by firefighters, the following requirements apply to exterior walls: (1) PV modules should not be installed around emergency entrances, exterior staircases, or within approximately 50 cm of these. However, this does not apply if the PV modules are protected by sufficiently strong building materials or metal frames, or if there is no risk of damage or electric shock if they come into contact with the modules. (2) DC wiring should not be installed around emergency entrances, alternative openings, exterior staircases, or within approximately 50 cm of these. However, this does not apply if the DC

[5] In Brazil, installation provisions also consider the layout of PV arrays from an operational safety perspective, including the need to maintain accessible pathways and adequate spacing to support firefighter intervention, particularly in rooftop applications.

wiring is protected by metal pipes, or if there is no risk of damage or electric shock if they come into contact with the DC wiring. (3) Window-type PV modules should not be installed in alternative openings. Furthermore, no PV modules should be installed within approximately 50 cm of the roof. However, this does not apply if an electric shock prevention module is installed within approximately 50 cm of the roof.

The survey shows that there is currently no regulation on limiting the maximum PV installation area on the façade. However, it should be noted that the NFPA 1 fire code [108] limits the BAPV roof rack system array size to 46 m by 46 m (150 ft by 150 ft), and includes walkway requirements allowing some separation distances.

5.5 Detection Suppression and requirements

5.5.1 Requirements for general façade cladding systems

The survey conducted in this study shows that there is currently no regulation requiring detection or suppression systems for general façade cladding systems.

In Japan, the Building Standards Act requires that exterior wall windows and fire compartment doors shall be equipped with fire prevention equipment to prevent the spread of fire, and drenchers are sometimes used. Drenchers are devices that create a water curtain to prevent the spread of flames in the event of a fire.

5.5.2 Requirements for BIPV façade cladding systems

The survey shows that, except in Singapore, there is currently no regulation requiring detection or suppression systems for PV façade cladding systems across the different countries. In Singapore, for wall-integrated PV installation, all spaces abutting/facing PV installations shall be fully protected by an automatic sprinkler system or automatic fire extinguishing system, as per the Code of Practice for Fire Precautions in Buildings.

5.6 Smoke hazards and other impacts on egress

No requirement related to smoke hazards at the system level exist either for general cladding or BIPV claddings.

5.7 Firefighting and emergency responses

PV materials and system designs may hinder firefighting and occupants' evacuation since they could cause electric shocks, crash damages, and toxic gas emissions from ignited BIPV. The requirements for firefighting and occupant evacuation are not covered in the current codes and standards (e.g., EN 50583 [3] and IEC/UL 61730 [13]). No requirement on this was collected from the survey for either general cladding or BIPV claddings.

While there is no related provision or guide for BIPV façade, the ISEP Section 5 (IFC (International Fire Code) [109] - Section 605 requires roof rack BAPV systems to provide firefighting access, pathways and smoke ventilation, which limit the maximum array size and minimum width for pathways as well as separation distances from heat vents. FM DS 1-15 [110] requires a maximum size of array of 150 ft (45.7 m) x 150 ft (45.7 m); aisles at least 4 ft (1.2 m) and a separation distance of 6 ft (1.8 m) from plastic skylights. Similarly, in Switzerland, access or a ladder to the roof shall be provided when a combustible PV roof is installed. IEC

Technical Report 63226 [111] offers a more holistic approach to fire safety in PV systems, while leaving room for inconsistency in application.

IEC 63226 [111] provides guidance on:

- Fire prevention during the design, installation, commissioning, and maintenance phases,
- Support measures for firefighters during active intervention, and
- Post-fire handling of PV systems to ensure safety and minimize further risks.

Emergency shutdown of PV systems is another key safety measure to reduce electrical hazards during firefighting operations. This aspect has been discussed earlier in Section 2.3.3 (Electrical Hazards), where its role in improving firefighter safety is highlighted.

In addition, provisions such as alert labelling, system documentation, and defined emergency procedures[6] are increasingly recognized as important for supporting safe and effective firefighter intervention.

Together, these insights highlight a growing recognition of fire safety in PV and BIPV systems, including firefighting and emergency management.

5.8 Other requirements

5.8.1 Resistance to fire exposure from external fire (Wildland fire, ember ignition)

Where applicable, cladding systems need to follow code provisions for wildfire protection, such as Part 7A of the California Building Code for buildings in wildland and urban interface [112], which mandates the use of fire-resistant materials for siding, windows, and other building elements.

In Australia, AS 3959–2009 [113], “Construction of buildings in bushfire-prone areas” is a mandatory standard under the National Construction Code (NCC). It outlines detailed construction requirements based on a site’s Bushfire Attack Level (BAL) to reduce risk across varying bushfire exposures. AS 3959 specifies materials and minimum thicknesses for external walls, such as non-combustible cladding or bushfire-resisting timber.

No requirement related to wildland fires exists for BIPV claddings.

[6] In Brazil, recent standardization efforts follow a similar operational-safety logic. ABNT NBR 17193, the Brazilian national standard developed with reference to IEC TR 63226, addresses photovoltaic systems applied to and integrated into buildings, with specific attention to emergency intervention. The approach includes provisions for rapid shutdown, alert labelling, documentation, and procedures before firefighting, while also considering access and layout conditions intended to support safer intervention by firefighters

6 CONCLUSIONS

This report examines the current landscape of fire safety provisions for BIPV cladding systems. The report first clarifies the scope of fire hazards by recognising and differentiating between internal and external fire scenarios, which is essential in assessing the fire risk associated with BIPV cladding. Under the hazard scope associated with the identified fire scenarios, international regulatory provisions are systematically analysed taking into account PV module electrical, material (reaction to fire), and system (resistance to fire spread) requirements. The systematic review analysis has enabled identification of critical gaps in the current provisions specific to BIPV claddings, as shown in Table 2, where blank cells denote an absence of specific regulatory provisions identified.

Table 2: A review of fire safety provisions for BIPV Claddings

		Internal Fire Scenarios (when initiated by PV modules)					**External Fire Scenarios (when exposed to external fire sources)**							
		Physical	**Environmental**	**Electrical causes**			**Manmade Incidents**						**Natural Incidents**	
Level of Requirement	**Performance Requirement**	Physical damages, such as cell cracks, cabling damages	Environmental causes, such as extreme weather, bird droppings, organic debris	Hotspots, bypass diode failure, arc fault, inverter fault, power conditioning fault	Fire through the PV façade cavity		Externally applied fire to PV façade		Fire spread through windows		Fire spread through walls and joints		Wildfires, Lightning, Storm, etc.	
		BIPV	BIPV	BIPV	General Façade	BIPV	General Façade	BIPV	General Façade	BIPV	General Façade	BIPV	General Façade	BIPV
Electrical	Operating Temperature		✓											
	Hotspot & Short Circuit		✓											
	Bypass Diode Reliability		✓											
	Current Overload Arc Fault		✓											
	Water Spray Test		✓											
	Sudden Impact		✓											
	Fire Test		✓											
	Electrical System Component Safety		✓											
Material (reaction to fire)	Combustibility						✓		✓					
	Ignitability						✓	Δ	✓	Δ			✓	Δ
	Heat and Smoke Production						✓	Δ	✓	Δ				
	Flame Spread and Smoke Production						✓		✓					
	Smoke Toxicity						Δ		Δ					
	Fire Behaviour When Electrically Active													
	Fire Suppression (Water Responsiveness) When Electrically Active													
System (resistance to fire/fire spread)	Resistance To Fire Spread on Exterior Façade (Window Flame)								✓					
	Resistance to Fire Spread Through Cavity Gap				Δ									
	Resistance To Fire Exposure From Within the Building and Protection From Fire Originating From External Claddings										✓	Δ		
	Limiting Installation Areas								✓	Δ				
	Detection/Suppression Requirements													
	Smoke Hazards and Other Impact on Egress													
	Firefighting and Emergency Response													
	Resistance to Fire Exposure From Exterior Fire (Wildland fire, ember Ignition)													

LEGEND

Δ = Has some provisions, but limited in adoption or feasibility

✓ = Has provisions with international adoption or many local provisions

blank cells denote an absence of specific regulatory provisions identified

6.1 Gaps and opportunities analysis

This review of international requirements concludes that while general façade standards and requirements are often directly applicable to BIPV systems, there is a lack of provisions addressing the specific nature of BIPV modules and systems such as theire electrically active nature, fire behaviour in air cavities, and emergency response challenges.

- **Lack of BIPV specific tests/provisional considerations**

The present survey indicates that there is no country currently providing a comprehensive and fully dedicated BIPV Fire-safety framework. Most countries apply provisions designed for general façades to BIPV cladding while treating the PV module as a combustible material. While many survey participants indicated concerns regarding applying the existing requirements and standards of conventional façade to BIPV cladding, Singapore imposes stricter material restrictions, disqualifying glass-backsheet PV modules and allowing only glass-glass systems. Generally, in Europe, the Euroclass systems based on material characterization tests may not accurately address key concerning fire scenarios of a PV façade system. In response, some countries are introducing intermediate or large-scale fire propagation tests as an alternative compliance route. While these alternative routes could be an option for BIPV systems to be compliant, there are still no specific test protocols tailored to the unique risks presented by BIPV claddings.

- **Material level requirement issues**

The present survey results indicate a general view that PV materials should be tested following the existing tests for material characterization, e.g., combustibility, ignitability, heat, and smoke production. However, adopting these test methods is not easy since these existing test methods are developed for general construction materials. For example, the SBI fire test method is unsuitable for BIPV cladding systems, as its sample size is smaller than standard PV panels, making it difficult for manufacturers to prepare appropriate samples. Additionally, it lacks protocols for testing PV façade systems, such as specifying junction box and cable placement.

- **System level requirement issues**

The most concerning fire scenario for BIPV cladding is the exposure to flames coming from a window, as for any combustible cladding, due to the risk of rapid fire spread through the air cavity. Given that PV systems are electrically active in normal operation, current façade test methods need to be updated to properly evaluate realistic system operation and designs, and the pass/fail criteria should address PV modules' unique burning behaviour, such as glass breakage and potential falling debris.

Resistance to fire exposure within the building should be required for BIPV façade claddings addressing the conditions introduced by PV claddings on exterior walls. For instance, Singapore mandates at least a one-hour fire resistance for back walls, which could serve as an example.

Currently, there are few regulations restricting the application area of PV façade cladding systems; Both Japan and Singapore have rules that restrict the use of combustible claddings near window openings. It may also be worthwhile to consider limits on total surface area.

- **Assessment of the fire performance of the BIPV cladding systems being electrically active**

The survey highlights that existing regulations fail to specifically address the unique challenges posed by the electrically active nature of PV façade cladding systems, unlike traditional façade

materials. Requirements and testing methods should be updated to reflect that PV panels operate in an energized, heated state, which increases ignition risk and flame spread.

- **Scenarios of fire ignition from PV and Cavity fire**

As shown in Table 2, two significant gaps can be identified: first, no global regulations address fire scenarios involving PV cladding cavities; second, internal fire scenarios caused by PV ignition are not considered at all regarding building applications, whether at the material or system level.

In particular, a cavity fire scenario initiated by a PV failure represents a unique intersection connecting internal fire scenarios (where the PV itself acts as the ignition source) and external fire scenarios (where the façade is exposed to an external fire source). Because of this intersection, Table 2 positions the column of fire propagating through the PV façade cavity directly between these two domains.

Assessments of the fire performance of the BIPV cladding systems when the fire source is created by the electrical components (connectors in the cavity, cables, damaged cells) may have significant implication in particular on the system level performance

of PV cladding. For example, regulatory provisions should address gaps related to fire spread within the air cavity behind a BIPV façade, with consideration that PV may serve as an ignition source.

- **Detection and Suppression**

There are no system level performance requirements for BIPV cladding in any provisions regarding detection/suppression of fire. In addition, there are no material/system level performance requirements in any provisions which address the water responsiveness of PV systems in fire.

- **Egress and firefighting**

Smoke hazards and other effects on egress, firefighting, and emergency response are risks uniquely associated with integrating PV systems in buildings, and these areas require further research.

- **Opportunities and outlook**

As BIPV cladding fire safety provisions are not yet fully developed worldwide, testing methods and performance criteria of reaction to fire and fire resistance of façades could be harmonised at EU level and potentially through IEA member countries. If standards and regulations are updated and potentially harmonized across countries, concerns related to diverse configurations of BIPV systems (glass thickness, encapsulant thickness, glass size, support/installation method, etc.) could be alleviated, paving the way for increased adoption.

In the absence of a consolidated state of the art, the transitional framework [60] provides a means to enable the safe implementation of photovoltaic façades through a structured, system-based assessment approach. Such approaches may represent a valuable intermediate step toward future standardization, providing practical guidance for designers, authorities, and industry stakeholders in a rapidly evolving technological context.

Limited knowledge of fire risks in this area may be one factor contributing to the lack of regulations. More research is needed to assess fire safety concerns related to BIPV. Potential mitigation strategies for PV façade fires, such as sprinkler systems and fire blocks, should be considered when developing provisions, which might be relaxed accordingly. Additional

concerns include the impact of aging effects like UV exposure and weathering on the fire performance of PV claddings.

Emerging regulatory approaches are not limited to material or façade fire-spread performance but increasingly address the operational safety of electrically active PV systems during fire events. In particular, requirements related to rapid shutdown, alert labelling, documentation, and firefighter access indicate a broader shift toward integrating emergency response considerations into PV fire-safety frameworks.

This code and standards review provides a structured starting point for identifying key gaps in current fire safety provisions for BIPV façade systems. Addressing these gaps will support the development of more appropriate performance requirements and associated test methods tailored to the specific characteristics of BIPV. At the same time, it enables the exploration and integration of a range of mitigation measures within regulatory frameworks. In particular, provisions should promote system-level fire risk assessment approaches that evaluate BIPV integration within the overall building fire safety design, allowing measures such as detection and suppression systems, thermal barriers, and other protective strategies to be effectively utilised and adapted to enhance overall building fire safety.

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APPENDIX

SURVEY
Fire Safety of Building Integrated Photovoltaic Systems: Focused review and analysis of Codes and Standards on BIPV Cladding systems

IEA PVPS Task 15 phase 3 Activity B1

1 Overview of fire safety requirements of BIPV

Safety in case of fire is discussed in IEC 63092, as the below:

> *It shall be noted that fundamental requirements for fire safety are not internationally harmonised. It is therefore not possible to define general requirements for fire safety of BIPV modules, as international recognition of specific test results is not well established. The BIPV module shall meet the fire safety requirements of the* ***local national, building code*** *(or similar) for the building function it provides.*
>
> *An example of such requirements can be found under the European Construction Product Regulation CPR 305/2011:*
>
> *The buildings must be designed and built in such a way that in the event of an outbreak of fire:*
>
> *a) the load-bearing capacity of the construction can be assumed for a specific period of time;*
> *b) the generation and spread of fire and smoke within the buildings are limited;*
> *c) the spread of fire to neighbouring buildings is limited;*
> *d) occupants can leave the buildings or be rescued by other means;*
> *e) the safety of rescue teams is taken into consideration.*

The safety of PV modules is also addressed in the following global standards:

- EN 50583 Photovoltaics in buildings [12,13]
- IEC 63092 Photovoltaics in buildings [14,15]
- ANSI/UL 1703 Standard for safety: Flat-Plate Photovoltaic Modules and Panels [16]
- ISO/TS 18178 Glass in building — Laminated solar photovoltaic glass for use in buildings [17]
- IEC/UL 61730 Photovoltaic module safety qualification [18,19]
- EN/IEC 61215 Terrestrial photovoltaic modules -Design qualification and type approval [20,21]
- IEC TR 63226 Managing fire risk related to photovoltaic systems on buildings [22]

2 Electrical requirement for fire safety of PV modules

Note:

- Provide any electrical requirements/provision **specific to PV façade cladding systems**, which are not in the following table-general Electrical requirement for fire safety of PV modules.
- Provide references, and attach any relevant materials.

COUNTRY:		**Input by:**				
electrical requirements/provision specific to PV façade cladding systems					**In application to PV façade cladding materials**	
Intent	**Risks**	**Related Codes/standards**	**Related Test Methods**	**Pass-Fail criteria**	**Why is this provision relevant to PV façade claddings?**	**Your inputs on the adequacy of current code provisions and standard fire tests Or other notes**

3 Material Requirements for fire behaviour: PV Reaction to Fire

Note:

- Previous reviews indicated that the current PV codes and standards refer to existing local building codes and standards that are developed for regular building materials and systems. And the current building codes require construction materials to be evaluated for their fire behaviour (i.e., how the material responds to a fire) at the material level. Thus, the table below is built to first collect the existing provisions/test standards for regular building materials/systems, and then then the table is also expanded to collect any enhanced/modified requirements specific to PV materials.

- Also, the current BIPV standards are quite limited in application to BIPV, and adherence to the current building codes and standard test methods is not sufficient to verify the fire safety of PV systems. In this regard, where possible, please provide your inputs.
- Provide references, and attach any relevant materials.
- An example table is provided, FYI.

COUNTRY:		Input by:					
Façade cladding materials in general					In application to PV façade cladding materials		
Intent	Material burning characteristics	Related Codes/standards	Related Test Methods	Pass-Fail criteria	Why is this provision relevant to PV façade claddings?	Are there enhanced/ modified requirements for PV?	Your inputs on the adequacy of current code provisions and standard fire tests Or other notes
3.1	***Fire behaviour evaluation (Reaction to Fire)***						
	Combustibility						
	ignitability						
	Heat and smoke production						
	Heat generation						
	Flame spread and smoke production						
	Smoke toxicity						
	Fire behaviour when electrically active						
	Fire suppression (water responsiveness) when electrically active						
3.2	***Is there any other provision/standard/ concerning fire behaviour/reaction to fire, that is relevant to PV claddings?***						

4 Provision/standard fire tests relevant to BIPV walls/claddings

Note:

- Previous reviews indicated that the current PV codes and standards refer to existing local building codes and standards that are developed for regular building materials and systems. Thus, the table below is built to first collect the existing provisions/test standards for regular building materials/systems, and then the table is also expanded to collect any enhanced/modified requirements specific to PV systems.
- Also, the current BIPV standards are quite limited in addressing the fire safety of BIPV since adherence to the current building codes and standard test methods is not sufficient to verify the fire safety of PV systems. In this regard, where possible, please provide your inputs.
- Provide references, and attach any relevant materials.
- An example table is provided, FYI.

COUNTRY:		Input by:					
Façade cladding system in general					In application to PV façade claddings		
Intent	Relevant cladding types and Performance requirements	Related Codes/standards	Related Test Methods	Pass-Fail criteria	Why is this provision relevant to PV facade claddings?	Are there enhanced/ modified requirements for PV?	Your inputs on the adequacy of current code provisions and standard fire tests Or other notes
4.1	***Resistance to fire exposure from within the building***						
	Fire containment within the fire compartment by fire resistance ratings of the exterior wall.						

4.2	***Resistance to fire exposure from exterior fire (adjacent building fire)***						
4.3	***Resistance to fire exposure from exterior fire (Wildland fire, amber ignition)***						
4.4	***Resistance to fire spread on exterior façade (window flame)***						
	Limiting fire spread over the façade system when exposed to a window flame						
4.5	***Resistance fire spread through the cavity gap***						
	Limiting fire spread with the cavity space of a ventilated cladding system						
4.6	***Protection from fire risks originating from external claddings***						
	Thermal barrier requirements						
4.7	***Limiting installation areas***						
	Limiting the total installation area of a combustible cladding system over a building.						
	Min. Distance requirement from openings (windows) or prohibiting the installation of combustible cladding right above a window						
4.8	***Detection Suppression requirements***						
	Any detection /suppression systems requirements concerning combustible cladding systems						
4.9	***Smoke hazards and other impact on egress***						
	Min. Distance requirement from egress routes and exist doors						
4.10	***Fire suppression/firefighting supports***						
4.11	***Is there any other provision/standard/ concerning combustible façade cladding systems or relevant to PV claddings?***						

