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Standardization, performance risks and identification of related gaps for a performance-based qualification in BIPV

BIPVBOOST

"Bringing down costs of BIPV multifunctional solutions and processes along the value chain, enabling widespread nZEBs implementation"

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1 EXECUTIVE SUMMARY

The growing demand for the use of photovoltaic (PV) systems integrated in buildings, having the need to be versatile, to provide design and multifunctional features beyond the bare energy production, is triggering a profound change in the sector of Building Integrated Photovoltaics (BIPV), with major challenges to be addressed in the coming years.

Supported by the increasing technological development, by digitization and process innovation, such systems will progressively have to be implemented in the ordinary construction market allowing the achievement of the demanding energy policies for nZEB buildings. These BIPV products are evolving from the only function of architectural integration, intended as an aesthetical element capable of producing energy, towards **multifunctional products** that can aggregate many features required for the **building skin** such as thermal and acoustic insulation, solar control, safety in case of fire, etc.

However, to effectively enter the building market, the BIPV products will necessarily have to respect the goal of **cost-effectiveness** on the entire production chain as well as the compliance with adequate **quality, safety and reliability** requirements. In addition to a technological development, it is essential to obtain a specific interconnection between product standards, industry standards and specific rules for the type of installation and use in buildings. The EN 50583-1:2016 and EN 50583-2:2016 standards made a first step in this direction by defining the properties and the applicable **regulatory framework** for photovoltaic modules used as construction products. Nevertheless, the current regulatory framework collects norms created for standard PV or, on the other hand, for "non-active" building products, without proposing new testing procedures specifically adapted to BIPV. Consequently, significant progress regarding BIPV systems qualification is still needed, which represents a current **barrier** for a mass market deployment.

From the current regulatory framework, very often not sufficient for addressing a proper BIPV performance assessment and validation, it arises the need to identify new "multi-disciplinary" reference requirements, performance levels and new test methodologies better suited to the use of PV in building skin. Therefore, a possible path for addressing these issues will be addressed within WP5 of the project by identifying the **gaps in the current standards** related to BIPV and by developing a new **performance-based approach** for the qualification of BIPV products. This deliverable will provide an overview on the current normative framework, including the definition of some relevant missing gaps in relation to reference requirements and a **roadmap** to define new reference procedures for BIPV products qualification, as the basic ground for next developments in the coming years.

1.1 Description of the deliverable content and purpose

The purpose of this document is to identify the **main routes** to contribute to a **cost reduction** in BIPV through an advanced standardization scheme supporting the qualification of BIPV systems for a massive and reliable implementation in the building skin. The general goal of WP5 is the development of an advanced, performance-based BIPV qualification framework, through the collection of failures in the current approach and identification of related gaps in the standards (T5.1). The development of specific, performance-based laboratory testing procedures for BIPV modules (T5.2) will allow defining reference procedures for the sector and they will be put in common, as a follow-up of the project, with the relevant IEC, ISO and International Energy Agency (IEA) Committees. The demonstration of compliance of the proposed results with the relevant tests and standards will be part of the process.

In the realization of a **new approach for products qualification**, it is fundamental to control the level of performance of different **BIPV product families** in order to guarantee the quality for the market: this is why

WP5 is addressed to focus on specific **technical requirements**, which will be object of investigation in T5.2. In particular, the next task, which is not object of this deliverable, starting from the framework and definitions here reported, will develop and define new specific BIPV performance assessment procedures, concerning safety and durability, including mechanical safety, electrical behavior in non-optimal and non-uniform exposure, glass energy performances and fire prevention.

As an essential preliminary investigation, the present deliverable starts identifying the **state of art** of the regulatory framework, detecting the current **missing gaps** of the most relevant BIPV performance and defining the **main routes** for the development of a new approach for qualification procedures to adopt in BIPV sector. The activity is also the joined result of the participation of SUPSI, TECNALIA and CSTB to other projects related to the standardization topic such as the most recent Task 15 IEA-PVPS Subtask C: International framework of BIPV specifications (www.iea-pvps.org), Construct-PV (www.constructpv.eu) (1) and PVSITES (www.pvsites.eu) (2).

The present document is structured in three main parts with the goal:

- To identify the **state-of-the-art** in BIPV standardization, with a basis on the progress made at European and international level by other EU research projects (Construct PV, PVSITES, etc.) and working groups (IEA Task 15, IEC and ISO committees, etc.).
- To detect the current **missing gaps** within the current standardization framework related to the most relevant BIPV performance with the identification of standardization needs, as it has been initiated at a more general level within IEA PVPS Subtask C and the new Project Team PT63092 integrated by IEC/TC82 and ISO/TC160 experts (including experts from SUPSI and TECNALIA).
- To define the **main routes for the development** of new qualification procedures in BIPV to support the market with a better-defined performance-based approach, aimed at creating the link with T5.2 concerning new qualification procedures as annexes or to be integrated in ongoing standardization.

1.2 Relation with other activities in the project

The relation with other activities in the project are shown as followed. Table 1.1 depicts the main links of this deliverable to other activities (work packages, tasks, deliverables, etc.) within BIPVBOOST project.

Table 1.1 Relation between current deliverable and other activities in the project

Project activity	Relation with current deliverable
T1.3	Archetypes defined in D1.3 will support the product family definition
T5.2	It will be the operative translation of this document in real testing procedures
T5.3, T5.4	They will put in practice the methodologies developed in T5.1 and T5.2
WP3, WP4	The testing methodologies developed are put in relation with the real product families and manufacturing/market needs (feedback from industries supported the deliverable)

1.3 Reference material

IEA-PVPS Task 15, *Compilation and Analysis of User Needs for BIPV and its Functions*, February 2019 (www.iea-pvps.org)

IEA-PVPS Task 15, *International definitions of "BIPV"*, August 2018 (www.iea-pvps.org)

IEA-PVPS Task 15, *Analysis of requirements, specifications and regulation of BIPV*, July 2019 (www.iea-pvps.org)

PVSITES, *European regulatory framework for BIPV*, project report, July 2016 (www.pvsites.eu)

PVSITES, *Standardization needs for BIPV*, project report, September 2016 (www.pvsites.eu)

ACTIVEINTERFACES, what is the long-term reliability of BIPV? Summary sheet of Project Report 1.3 Innovative Technologies (www.activeinterfaces.ch)

1.4 Abbreviation list

AEC	Architecture, Engineering and Construction
BAPV	Building applied Photo Voltaic
BIPV	Building Integrated Photo Voltaic
CPR	Construction Products Regulation
DoP	Declaration of performance
EADs	European Assessment Document
EDP	Early Design Phase
EOTA	European Organisation for Technical Assessment
EPBD	Energy Performance of Buildings Directive
ETAs	European Technical Assessment
ETAGs	European Technical Approval Guidelines
FEM	Finite Element Method
hEN	Harmonized standard
IEA	International Energy Agency
LS	Limit State
MG	Missing Gap
nZEB	Nearly Zero Emission Building
PEB	Plus Energy Building
PV	Photovoltaic
PVB	Polyvinyl Butyral
TABs	Technical Assessment Body
Tn	Task number
WPn	Work package number

2 STATE-OF-THE-ART IN BIPV NORMATIVE FRAMEWORK

2.1 Introduction

At the end of 2016, the European Commission released the Clean Energy for all Europeans package, where a comprehensive update of its energy policy strategy was presented to facilitate the transition from fossil fuels towards a cleaner energy and a drastic reduction of greenhouse gas emissions. In that framework, the Energy Performance of Buildings Directive (EPBD) (2010/31/EU) and Energy Efficiency Directive (2012/27/EU) were updated and amended, setting the basis for making possible the mass deployment of Near Zero Energy Buildings. Although no clear binding measures are specifically defined for BIPV technology, the framework of increasing building energy efficiency drawn by the new EPBD allows expecting a prominent role for BIPV, implicit in the low primary energy consumption allowed for nZEBs by most Member State's transposition of the Directive, requiring renewable on-site generation to comply with the regulation.

Today, solar PV technology has the potential to exploit existing buildings' surfaces instead of using landscape areas. Currently, the growing demand for the use of PV systems integrated in buildings, demands for versatility, flexibility in design and multifunctional features beyond the bare energy production. Supported by the increasing technological development, by digitization and process innovation, such systems will progressively have to be implemented in the ordinary construction market allowing the achievement of the demanding energy policies for nZEB buildings. BIPV solutions have experienced a constant evolution during the past decade, going from bare energy generation devices applied onto building surfaces (without any multifunctional performance being exploited), to multifunctional building products that besides fulfilling the same requirements demanded to a traditional construction product, are capable of generating renewable electricity on-site. After more than 20 years of R&D, a true market segment for BIPV has emerged with very interesting products for the building envelope and elegant showcase projects.

To understand the evolution process of the BIPV sector, it is important to recall the context of rapid development experienced by the traditional PV sector, which managed to decrease its cost very rapidly during the last decade, with an estimated ~80% cost reduction in the 2008-2012 period only (3). This dramatic cost reduction coming from the PV sector allowed the slow but steady development of the BIPV sector, although, despite the great growth projections drawn by experts, it is a fact that they have been proven to be subsequently overestimated when sticking to the real market deployment of the sector. The cause for this deviation from a real mass market implementation is a consequence of the influence of several factors, amongst which a series of demands from the stakeholders which have not been properly addressed by the BIPV value chain. These key requirements are mainly related to the flexibility in design and aesthetics considerations, lack of tools integrating PV and building performance, demonstration of long-term reliability of the technology, smart interaction with the grid, lack of a clear standardization framework for BIPV and cost effectiveness.

In that scenario of growth, conventional PV solutions (i.e. ground-mounted, rooftop installations) have represented the greatest share of the market, while BIPV represented only a very niche part, mentioned in around 2% over the global European PV market in 2017 (4). Similarly, the standardization framework of PV and BIPV sectors have followed dissimilar trends, and, while the traditional PV sector has a clear playground with a complete and thorough set of standards aimed at ensuring reliability and safety issues, significant progress is still required for the correct qualification of BIPV systems, needing for specific BIPV testing procedures that account for both PV and construction related issues that collide in real operation conditions. In addition, the adoption of those new testing methodologies need to be seamlessly integrated under the scope of the CPR 305/2011 for construction products, which represents a great challenge itself.

As of today, the current regulatory framework of BIPV is mainly grounded on the standard EN 50583, which gathers a set of norms coming separately from standard PV (e.g. IEC 61215, IEC 61730, etc.) and traditional "non-active" construction products (e.g. EN 14449, EN 12600, etc.). However, an assessment of the features, operation conditions and requirements to be fulfilled by BIPV systems clearly evidences that such approach is not valid and efforts for defining new testing procedures are required. A clear and specifically adapted standardization framework is therefore needed in order to prospect a realistic market implementation, supporting the qualification of BIPV systems at different levels, encompassing quality, reliability, performance and safety considerations.

Within this section, a comprehensive analysis of the standardization framework of BIPV is provided, together with a broader vision of some of the key aspects related to BIPV qualification.

2.2 From PV plants to an active building skin: a change of approach towards the market implementation with "quality"

How can we integrate PV on vertical façades? This is a recurrent question that still creates difficulties for many stakeholders coming from the PV sector and not familiar with a building skin system. A full integration of PV is possible both in ventilated and in standard façades as demonstrated by the Partners of the Project Consortium. Whichever the case, solution providers should be contacted in the early phases of the project and involved since the Early Design Phase (EDP).

There are still barriers and constraints hindering the full implementation of BIPV into the building envelope, ranging from economic or financial barriers to legislative and institutional obstacles, or purely technical issues at both urban and building levels. Today's BIPV market can provide a clear catalogue of BIPV technical solutions, namely a structured scheme of elements to make the building skin active (5). However, a detailed study of the building skin construction technology is essential:

- to analyse the relationship of the PV components (PV cells, ribbon, junction-box, cables, etc.) with the layering, the different sub-systems and envelope materials;
- to define the construction interferences to be solved by the technical solution in order to properly satisfy the building's technical requirements (e.g. water tightness, mechanical stability, etc.) and PV functionality.

The **building skin engineering** should be a crucial step to be considered both in R&D and in real Architecture, Engineering and Construction (AEC) process, in order to evaluate all the construction aspects interacting between PV and the building envelope (such as physical integration, functionality, building/electro-technical requirements, cabling integration, etc.). Functionality, performance, aesthetics and energy use have to be assessed and addressed by a unitary solution case-by-case.

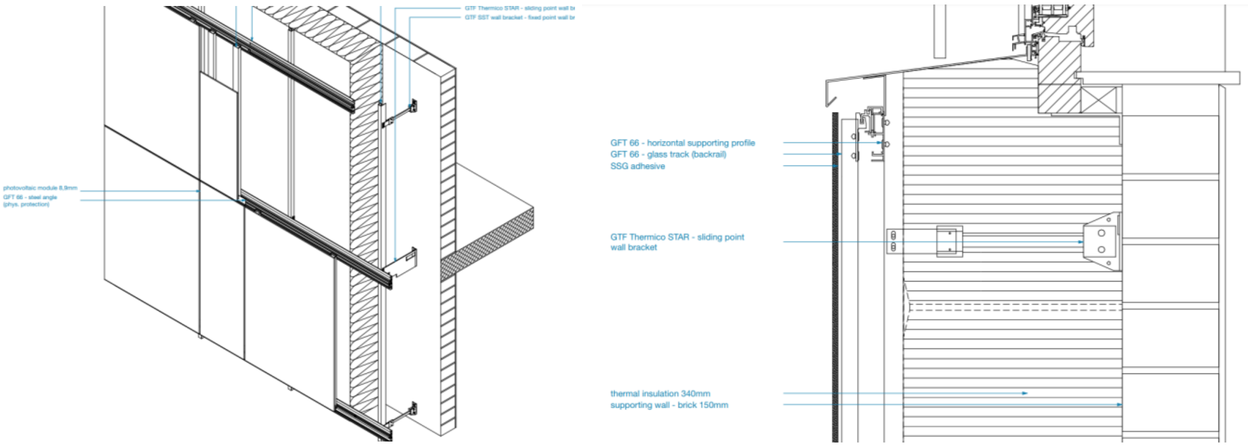

Figure 2.1. Construction detail of a BIPV façade system. Residential Building Renovation Hofwiesenstrasse, Zurich. Source of detail: Viridén + Partner AG. Redrawn by: BUK-ETHZ (source: www.solarchitecture.ch)

The topic of BIPV façades today demonstrates tangible feasibility and design flexibility. However, specific technical requirements related to construction (Figure 2.1) and the related issues are often perceived as obstacles for the full implementation of BIPV in the built environment, namely in two specific contexts: the urban and building levels (6). The former includes issues related to characteristics of the urban area where the building is located, which can affect the BIPV concept and installation. The latter is related to the issues that arise when considering the specific building typology and building envelope for the BIPV installation (Figure 2.2). From previous project investigations (6), it emerges that several strategies to reduce or eliminate technical constraints and limitations are possible, by implementing both a design and a technical approach.

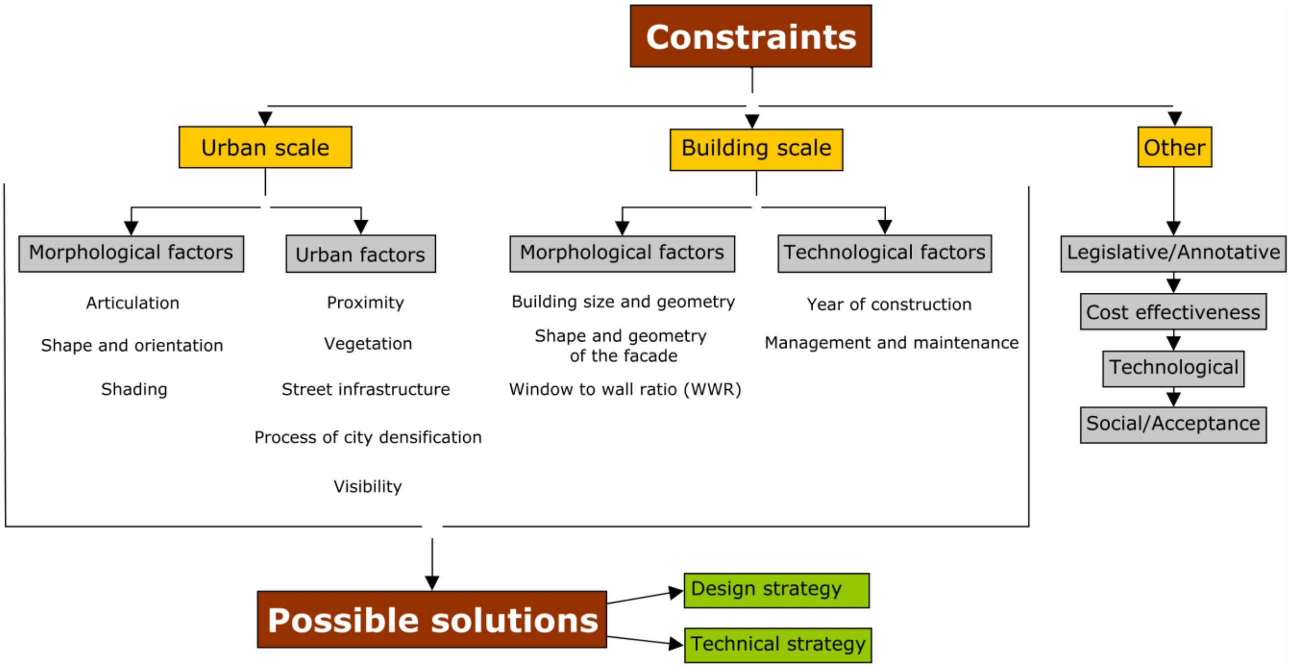

Figure 2.2. Flowchart of main barriers for BIPV implementation (source: SUPSI).

Typical installation conditions in urban settlement often cause shading problems and non-optimal scenarios. Local, partial and unexpected shadings which generate operating non-conventional conditions for PV (with possible hot-spots) are possible in areas with variable conditions depending on urban density, vegetation, people and user conditions. On the one hand, technical solutions such as accurate electrical wiring, the use of appropriate PV technology or technical devices (power optimizers, micro inverters, by-pass diodes, dummies) can moderate or eliminate some problems that building and urban situations create on a PV plant (shading, non-optimal exposure, etc.).

On the other hand, implementing an accurate BIPV design approach during architectural concept and building skin engineering can help to avoid some of the critical aspects affecting PV energy behaviour. E.g. taking into account some basic design rules and optimizing design factors such as PV plant configuration, geometry, exposure, string layout, etc. according to the urban or building context.

Due to the many technical, construction, energy, economic and legislative reasons an integrated evaluation of BIPV in a broader building perspective is today crucial. This integrated approach must be the driving factor for supporting the growth of BIPV in the built environment.

Thus, apart from technical barriers, today many actors **consider the legislative aspects a main obstacle** for BIPV market implementation. This also clearly emerged in **Deliverable 1.3 "Collection of building typologies and identification of possibilities with optimal market share"** (see on www.bipvboost.eu) where, among the key-topics for boosting BIPV, "Technology and technical standards" was one of the most relevant. An assessment methodology used in the business field, the value proposition canvas, has been applied to the main stakeholders in order to determine the main factor of attractiveness for the BIPV market implementation and its evolving opportunities in the horizon 2020 to 2030. To define the correct reference framework from existing norms and codes ensuring a proper performance assessment and quality of the installation was claimed as a key-indicator.

2.3 Insight on the BIPV normative framework and qualification

Some preliminary aspects have to be clarified before entering the key-topic of qualification and standardization. Firstly, what is and what is not meant as a "conventional PV" module and which are the related standards; secondly, what is a "BIPV module or system" and the related standards. Finally, the use of PV in BIPV projects can be used as an example.

2.3.1 Conventional PV modules and systems

According to the International Electro technical Commission Glossary (http://std.iec.ch/terms/terms.nsf/) a photovoltaic module is a "*complete and environmentally protected assembly of interconnected PV cells"* (IEC 60269-6, ed. 1.0-2010). A PV panel is defined as a *"PV module mechanically integrated, pre-assembled and electrically interconnected"* (IEC 60269-6, ed. 1.0 (2010-09)). A PV system *"is a system comprises all inverters (one or multiple) and associated BOS (Balance-Of-System components) and arrays with one point of common coupling, described in IEC 61836 as PV power plant"* (IEC 61727, ed. 2.0 (2004-12)). What is worth to note is that the keyword "building" doesn't produce any relevant result concerning BIPV for "standardized IEC terminology" in the IEC glossary (latest access: 2019.08.26).

Therefore, based on such a definition, a "conventional/standard" PV module can be defined as a PV module that has not been developed for any specific building skin system or application, but that is mainly developed and conceived as an electrical device and it has not been manufactured and qualified to satisfy a specific building role or requirements.

In particular, conventional PV modules are subjected to the electro technical certifications in accordance with the IEC standards as shown in Table 1. What is relevant to note is that, the design qualification of conventional PV modules is envisioned without taking into account any specific building applications (only the new IEC 61215-2:2016 declares that "additional requirements may apply for certain installations and climates" for static loads but there is no specific reference to building applications). Similarly, with regard to the module safety qualification, IEC 61730-1:2016 sets that "this international standard defines the ***basic requirements for various applications of PV modules, but it cannot be considered to encompass all national or regional codes***. "***Specific requirements, e.g. for building, marine and vehicle applications, are not covered***".

As a result, a conventional PV module is introduced on the market with a datasheet reporting the main electro technical characteristics and performances without any information about building applications.

Table 2.1. The IEC legislative framework for terrestrial PV module design and safety qualification

BEFORE 2016	AFTER 2016
• IEC 61215:2005 – Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval • IEC 61646:2008 – Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval	• IEC 61215-1:2016 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements • IEC 61215-1-1:2016 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules • IEC 61215-1-2:2016 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-2: Special requirements for testing of thin-film Cadmium Telluride (CdTe) based photovoltaic (PV) modules • IEC 61215-1-3:2016 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-3: Special requirements for testing of thin-film amorphous silicon based photovoltaic (PV) modules • IEC 61215-1-4:2016 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-4: Special requirements for testing of thin-film $Cu(In,GA)(S,Se)_2$ based photovoltaic (PV) modules • IEC 61215-2:2016 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test procedures
• IEC 61730-1:2004 +AMD1:2011 + AMD2:2013 CSV – Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction • IEC 61730-2:2004 +AMD1:2011 CSV – Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing	• IEC 61730-1:2016 – Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction • IEC 61730-2:2016 – Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing

It is important to highlight that IEC 61215-1:2016 sets that *"**Changes in material selection, components and manufacturing process can impact the qualification of the modified product**. Material in direct contact with each other shall be tested in all applicable combinations unless equality can be proven"*. Thus any modification in the design, materials, components or processing of the module may require a repetition of some or all the qualification tests to maintain type approval. In detail, the latter introduces the technical specification IEC TS 62915 for the details of retesting.

As a conclusion, it can be concluded that the existing normative framework for "standard" PV components cannot encompass all national or regional building codes and specific requirements, such as building requirements which are not covered.

2.3.2 BIPV modules and systems

Several definitions of BIPV have appeared in literature, at both national and international level in last years. The acronym **BIPV** refers to modules and systems in which the photovoltaic element takes, in addition to the function of producing electricity, the role of a building element or construction product. However, apart from possible contradictions trying to find the "perfect" definition of BIPV, what makes BIPV really tangible and concrete for the market and its stakeholders today, is its use as a building skin element, such as a glass, a cladding element, a window, etc. In a legislative perspective, in the EU context, a **construction product** is thus defined as *"any product or kit which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works". Specifically, its* ***performance*** *can be defined as "the performance related to the relevant essential characteristics, expressed by level or class, or in a description"* (art. 2 CPR 305/2011). The **basic requirements for construction works** are set out in Annex I and they are the following ones:

1. Mechanical resistance and stability
2. Safety in case of fire
3. Hygiene, health and the environment
4. Safety and accessibility in use
5. Protection against noise
6. Energy economy and heat retention
7. Sustainable use of natural resources

However, in recent years, the integration of modules in architecture is strongly evolving. New BIPV products, with their custom sizes and characteristics, are able to fully replace some building components. By BIPV element we mean a building component used as part of the building envelope (covering element of the roof, façade cladding, glass surfaces, etc.), sun protection devices (shading), architectural elements or "accessories" (such as canopies, balcony parapets, etc...) and any other architectural element that is necessary for the proper functioning of the building. This excludes therefore, for the concepts reported in the following of this document, building "independent" or "overlapped" installations such as PV modules simply placed or mounted on pre-existing roofs or other PV systems merely attached to parts of the building that do not assume other function than the solar power generation.

A BIPV component must fulfill a requirement of the building skin besides energy production. Namely, in this report we understand as BIPV cladding, a PV layer/component that cannot be removed from the building skin without compromising any technological/constructive primary requirement of the component/layering underneath or the whole building (that is, for definition, incomplete without the PV component) (www.bipv.ch). A **functional integration** refers to the role of PV modules in the building. For this reason, we can speak about multi functionality or double function criteria.

Photovoltaic elements are considered to be building integrated, if they consist of a building component providing a function as defined for example in the **European Construction Product Regulation CPR 305/2011**.

The building's functionalities in the context of BIPV may be one or more of the following aspects:

- weather protection: rain, snow, wind, hail, UV radiation;
- mechanical rigidity and structural integrity;
- thermal and solar protection such as shading/daylighting;

Thus, the BIPV module is a prerequisite for the integrity of the building's functionality. With the aim of clarify this concept, in 2016 the CENELEC Technical Committee 82 published a not-mandatory **BIPV standard**, the **EN 50583:2016** Photovoltaics in Buildings (part 1: BIPV modules and part 2: BIPV system).

Specifically, *this standard states that "photovoltaic modules are considered to be **building-integrated**, if the PV modules form a construction product providing a function as defined in the European Construction Product Regulation CPR 305/2011. Thus, the BIPV module is a prerequisite for the integrity of the building's functionality. If the integrated PV module is dismounted (in the case of structurally bonded modules, dismounting includes the adjacent construction product), the PV module would have to be replaced by an appropriate construction product".*

Depending on both the main mounting categories based on a technological-building approach (roof, façade and external devices) and the main composing material (e.g. glass, membrane, metal, plastic, etc.), the essential BIPV performances are defined, as well as the main reference building standards.

In summary, what is important to note, as a pre-requisite for BIPV qualification from the state-of-art as also explained in the next chapters, is that:

- The CE mark for BIPV, as a building product and according to the EN 50583, has to be released in accordance with building product harmonized standards to demonstrate compliance with the CPR
- The CE mark that is already applied to PV modules is in accordance with the EN 61730 but, in this case, the performances that are declared are not related to any building application.
- The EN 50583:2016 is not a mandatory standard and not a harmonized standard (even if it represents the unique normative concerning BIPV at EU level nowadays)
- Typically, the standard in force for the building skin components are extended and applied to BIPV to ensure an adequate performance as a construction element (e.g. this is already adopted in many BIPV glasses) but…
- there are missing gaps also in the building normative, that calls for further developments

2.3.3 Essential requirements for BIPV as a construction product

The s goal of the **CPR 305/2011** is to ensure that reliable information on construction products in relation to their performances is provided. This is achieved by providing a "common technical language", offering uniform assessment methods of the performance of construction products. This common technical language is to be applied by:

- the manufacturers when declaring the performance of their products, but also by
- the authorities of Member States when specifying requirements for them, and by
- their users (architects, engineers, constructors…) when choosing the products most suitable for their intended use in construction works.

The Regulation No 305/2011 (Construction Products Regulation, or CPR), entered into force on 1st of July 2013 in all European Members States, replaced the Construction Products Directive (Council Directive 89/106/EEC) (CPD). Among the provisions of CPR, it seeks to clarify the affixing of CE marking to construction products. The **Declaration of Performance (DoP)** is the key concept in the CPR and it serves to deliver the information about the essential characteristics of the product that a manufacturer wants to make available on the market. The manufacturer shall draw up a DoP when a product covered by a **harmonized standard (hEN)** or a **European Technical Assessment (ETA)** is placed on the market. The manufacturer, by drawing up a DoP, assumes the responsibility for the conformity of the construction product with the declared performance. Derogations and simplified procedures are reported in art. 5 and art.36 of CPR.

Harmonized European Standards provide a solid technical basis for manufacturers for testing the performance of their products. Using these standards, the manufacturer will be in position to make the declaration of performance (DoP) of his product as defined in the Construction Products Regulation (CPR) and to affix the CE marking. The harmonized European standards create a common European technical language to be used by all actors in the construction sector to:

- express requirements (regulatory authorities in Member States),
- declare the product performance (manufacturers),
- verify compliance with such requirements (design engineers, contractors).

Harmonized European standards on construction products are elaborated by technical experts working in the framework of the European Standardization Organizations (CEN/CENELEC/ETSI).

The **European Technical Assessment (ETA)** is a document providing information about the performance of a construction product, to be declared in relation to its essential characteristics. The ETA provides a way for the manufacturer to CE-mark a product. The ETA can be issued in the following cases:

- The product is not or not fully covered by any harmonized technical specification such as European Assessment Documents (EADs) or European Standards (hENs)
- The product is covered by a European Assessment Document (EAD)

A European Technical Assessment (ETA) is issued on the basis of a European Assessment Document (EAD), or ETAG used as EAD, which describes the type of product(s) it applies to, the list of essential characteristics in relation to the intended use foreseen by the manufacturer, the methods and criteria for assessing the performance in relation to the essential characteristics, and the principles for the applicable factory production control. A request for a ETA by a manufacturer for any construction product not covered or not fully covered by a harmonized standard and for which the performance in relation to its essential characteristics cannot be entirely assessed according to an existing harmonized standard can be addressed to a Technical Assessment Body (TAB) designated in the product area in question. The European Technical Assessment (ETA) shall be issued by a TAB based on an EAD adopted by the European Organization for Technical Assessment (EOTA).

The **European Assessment Document (EAD)** is a harmonized technical specification in the sense of Regulation (EU) No 305 /2011 (CPR). It contains, at least:

- a general description of the construction product and its intended use (Chapter 1 - Scope),
- the list of essential characteristics relevant for the intended use (Chapter 2) and
- methods and criteria for assessing the performance of the product (Chapter 2),
- principles for the applicable factory production control (Chapter 3 - AVCP).

Formerly, European Technical Approval Guidelines (ETA Guidelines or ETAGs) were elaborated upon the mandate of the European Commission in order to establish how Approval Bodies should evaluate the specific characteristics/requirements of a construction product or a family of construction products. ETAGs were used as basis for European Technical Approvals (ETAs) until 30th June 2013. As of 1st of July 2013 no new ETAGs will be developed. Published ETAGs may be used by TABs as EADs and their technical assessment methods can serve to issue ETAssessments. Additionally, EOTA is committed to develop ETAGs used as EADs until 2020 into EADs.

The development of an EAD follows the definition of a work program in cases a manufacturer made a request for a European Technical Assessment (ETA) of a construction product and no appropriate basis for the technical assessment of such a product yet exists. A list of references of the final EADs is published in the Official Journal of the European Union (OJEU). EOTA ensures that EADs are kept publicly available.

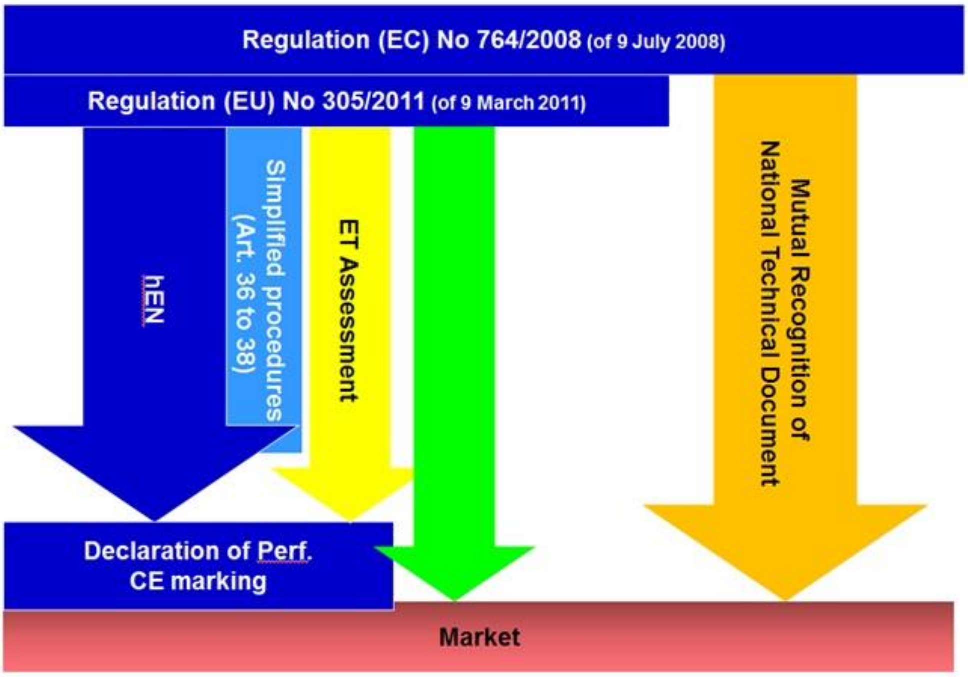

Figure 2.3. Procedure for CE marking of a construction product (© EOTA 2013)

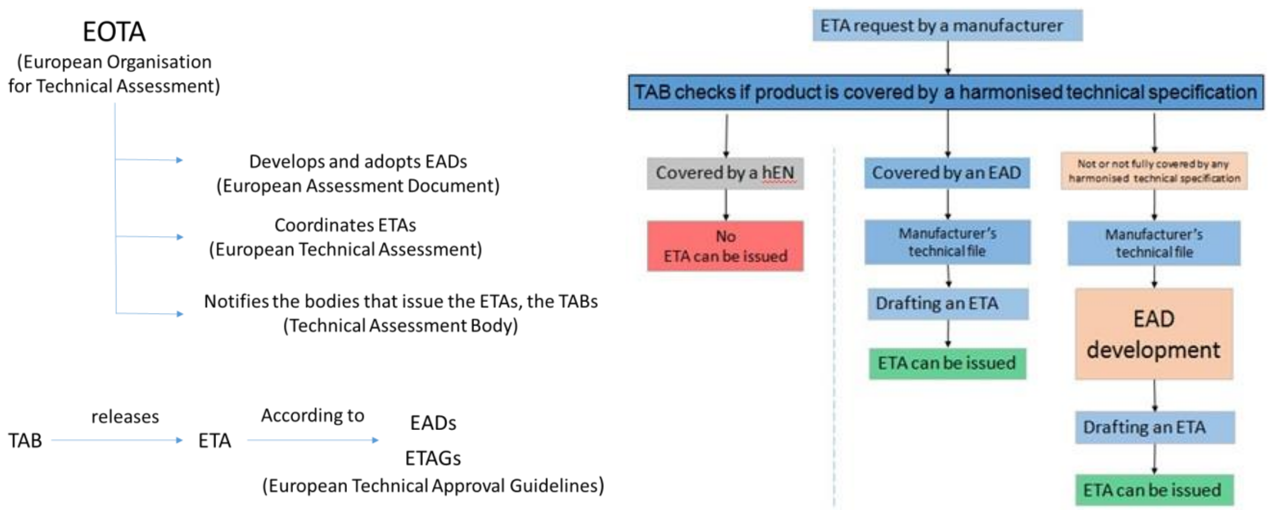

Figure 2.4. EOTA issuing scheme (left) and (right) the development of an EAD. The latter follows the definition of a work program in cases a manufacturer made a request for a European Technical Assessment (ETA) of a construction product and no appropriate basis for the technical assessment of such a product yet exists. The Technical Assessment Body (TAB) which has received the request for an ETA will define the work program taking into account the essential

characteristics, relevant for the intended use and based on the agreement between the manufacturer and the TAB (Source: EOTA) .

The CPR states that *" 'construction product' means any product or kit which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works".* Thus a BIPV system, conceived as an integral part of the building skin, can be included in the field of application of CPR.

The main goal of the CPR is the removal of technical barriers to trade in the construction products sector for the placing on the market of construction products by establishing harmonized rules in relation to their essential characteristics.

A product is suitable for intended use if it complies with:

- A harmonized European Standard, or
- A European Technical Approval (ETA), or
- A non-harmonized technical specification recognized at Community level.

The **basic requirements for construction works** set out in Annex I constitute the basis for the preparation of standardization mandates and harmonized technical specifications. The **essential characteristics** of construction products shall be laid down in harmonized technical specifications in relation to the basic requirements for construction works. The seven basic requirements, which construction products should satisfy, as defined in the CPR, are presented in the following:

Mechanical resistance and stability

The construction works must be designed and built in such a way that the loadings that are liable to act on them during their constructions and use will not lead to any of the following:

A. collapse of the whole or part of the work;
B. major deformations to an inadmissible degree;
C. damage to other parts of the construction works or to fittings or installed equipment as a result of major deformation of the load-bearing construction;
D. damage by an event to an extent disproportionate to the original cause.

Safety in case of fire

The construction works 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 construction works are limited;
C. the spread of fire to neighbouring construction works is limited;
D. occupants can leave the construction works or be rescued by other means;
E. the safety of rescue teams is taken into consideration.

Hygiene, health and the environment

The construction works must be designed and built in such a way that they will, throughout their life cycle, not be a threat to the hygiene or health and safety of workers, occupants or neighbors, nor have an exceedingly high impact, over their entire life cycle, on the environmental quality or on the climate during their construction, use and demolition, in particular as a result of any of the following:

A. the giving-off of toxic gas;
B. the emissions of dangerous substances, volatile organic compounds (VOC), greenhouse gases or dangerous particles into indoor or outdoor air;

C. the emission of dangerous radiation;
D. the release of dangerous substances into ground water, marine waters, surface waters or soil;
E. the release of dangerous substances into drinking water or substances which have an otherwise negative impact on drinking water;
F. faulty discharge of waste water, emission of flue gases or faulty disposal of solid or liquid waste;
G. dampness in parts of the construction works or on surfaces within the construction works.

Safety and accessibility in use

The construction works must be designed and built in such a way that they do not present unacceptable risks of accidents or damage in service or in operation such as slipping, falling, collision, burns, electrocution, injury from explosion and burglaries. In particular, construction works must be designed and built taking into consideration accessibility and use for disabled persons.

Protection against noise

The construction works must be designed and built in such a way that noise perceived by the occupants or people nearby is kept to a level that will not threaten their health and will allow them to sleep, rest and work in satisfactory conditions.

Energy economy and heat retention

The construction works and their heating, cooling, lighting and ventilation installations must be designed and built in such a way that the amount of energy they require in use shall be low, when account is taken of the occupants and of the climatic conditions of the location. Construction works must also be energy-efficient, using as little energy as possible during their construction and dismantling.

Sustainable use of natural resources

The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following:

A. reuse or recyclability of the construction works, their materials and parts after demolition;
B. durability of the construction works;
C. use of environmentally compatible raw and secondary materials in the construction works.

One of the innovations in the new CPR is that sustainability is now included as one of the essential requirements. It also introduces simplified procedures in order to reduce the costs incurred by enterprises, in particular small and medium enterprises (SMEs). A CE mark attests, in simple words, the ability of a construction product, in terms of performance, to comply with the aforementioned essential requirements defined by hEN or ETA. A list of harmonized standards relevant to CPR, is published in the Official Journal of European Union. These standards are usually categorized according to the materials used, the application etc., and cover the basic performance characteristics required by a product or family of products. More technical details, e.g. on calculation methods or on test methods, are referenced and covered by more specific supporting standards.

2.3.4 Can we use standard PV in building skin?

So far, the majority of **BIPV applications and projects** have been developed using the following product's categories:

- *Conventional PV modules* used in building application (almost exclusively for roofs) thanks to an adaption of some module's features (e.g. special frames for roof integration and water tightness). The certifications scheme in these product cases usually include IEC standards and, case-by-case, the compliance with some building requirements (e.g. water tightness, fire safety, etc.). Generally speaking, such products usually have a low extra-cost in comparison to conventional PV. They are generally PV modules/kits adapted for roofs, which represent the major part of the market. The application in building skin is under responsibility of installers very often.
- *PV modules declared as BIPV systems* (mainly with glass-glass based BIPV modules) usually produced by building industries capable to adapt an existing building product to make it active with PV (e.g. curtain walls or cold façade systems). In this case, the certifications scheme, adapted from the conventional building products, usually go beyond the IEC standards, including building performances assessment and qualification (e.g. norms on safety of glazing which are typically respected by glass manufacturers producing glass-based PV modules). Such products usually have an extra-cost in comparison to the not-active building system from which they derive, and they cannot be compared directly to a conventional PV module for their multi functionality.

However, the main question very often is still: *"is it possible to use a "conventional" PV module for BIPV project?"*. In the current framework, this is still a recurrent question since it opens the way of a simplified approach, in using conventional modules, in reaching cost effectiveness, in focusing on only electrical aspects without opening building sector, etc. But, for what it was premised in the previous sections, the enquiry can be considered as a "misleading" question since, the real logic process to evaluate the applicability of a component in the building skin is, first of all, to define its application role in the building envelope, then to define the technological requirements to satisfy and the relative legislative/technical framework in force to qualify/test/certify them; and, finally, to check if the component under investigation is compliant with the applicable standards arising from the building sector (European, national, local, etc.) in order to be installed and introduced on the market.

In general, the ***phases of the process*** are the design phase (e.g. building architectural design, envelope engineering, etc.), the product's manufacturing (R&D, production, CE-marking, etc.), the installation as well as the operating-life. Each of these phases involve different stakeholders, reference normative/requirements, goals and responsibilities. Moreover, the same evaluation could be specifically focused on a ***single technical requirement***, e.g. for mechanical safety, fire safety or acoustics. Thus, the goal would be to assess if a conventional module satisfies a technological requirement for a building application.

It is relevant to note that some building requirements cannot be generalized but they are usually ***local-based*** since they are defined by the local normative framework (national, regional, etc.) depending on several factors:

- Building location (e.g. mechanical safety for snow, wind, earthquake or special requirements for durability, exposure, etc.)
- Building typology/function (e.g. acoustical, thermal or daylighting requirements)
- Urban area (e.g. specific requirements for visual assessment in some protected areas, or local conditions of shading, irradiation, etc.)

- Building skin technical element (e.g. roofs and façade have completely different technological solutions)
- Local urban/building planning and regulations

Moreover, very often the **application** context generates further requirements that have to be respected (e.g. cost-effectiveness, aesthetics, minimum energy performance, etc.) at product and system level driving the development.

Therefore, within this methodological framework we can affirm that, in order to check the ***applicability of whatever active PV component in the building skin***, the main steps are:

- To define in detail the ***technical element of the building envelope*** where PV will have to be integrated (e.g. mullion/transom curtain wall, cold façade, opaque discontinuous roof, parapet, etc.), its construction and functional requirements, the building typology and the intended use;
- To define the ***performance levels and the reference normative*** that such an application requires as a building component (applicable standards, European and local regulations) ***to be correctly designed***, ***manufactured and installed*** as part of the building skin. It is remarkable to observe as these steps can be defined for one or more phases of the process (design to installation, maintenance, etc.).
- To check if the component satisfies the performance request of the building skin (does it respond to the requirements set by normative?), defining its definitive applicability as a building element or if it needs to be adapted.

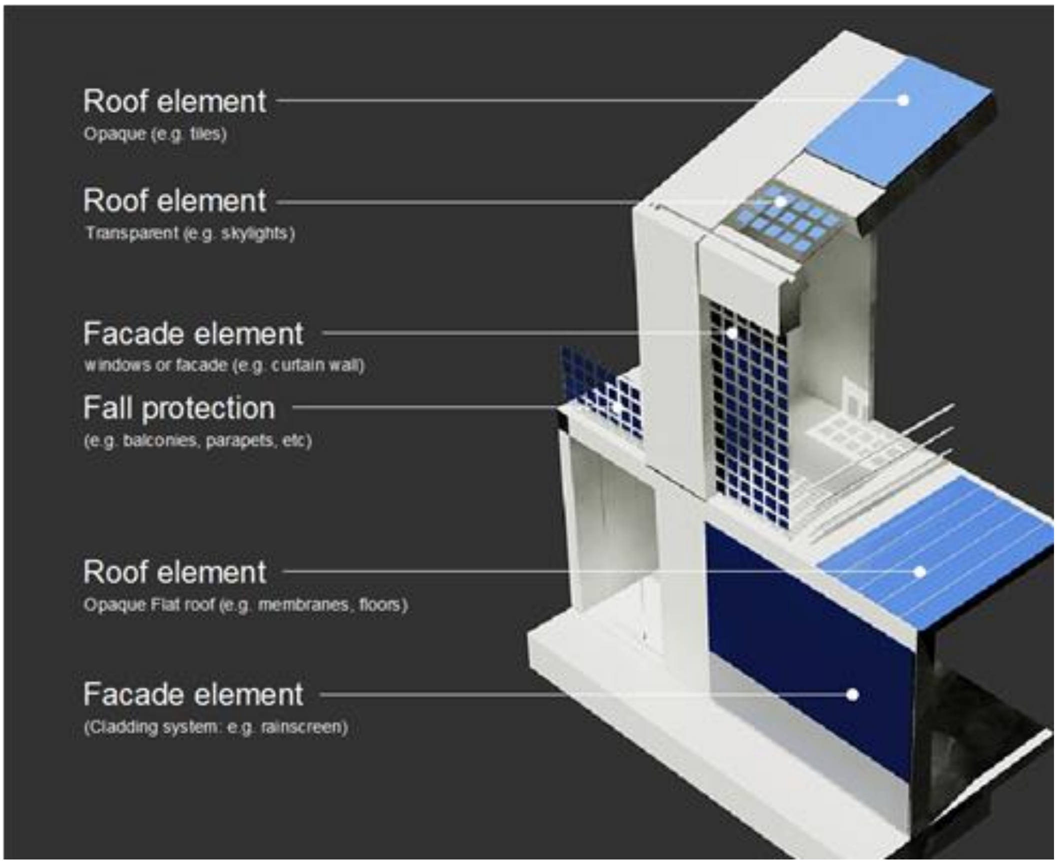

Figure 2.5. Examples for integration of PV elements as part of the building skin. (Source: SUPSI)

2.4 BIPV customization and product qualification

The discussion between **standardization and customization** of PV elements for building use, namely between the possibility of using "conventional/standard" PV or BIPV "tailored products" as building elements is a key-topic today. A conventional PV module could be generally installed as a BAPV system when it is certified in accordance with the IEC standards. However, in most cases a conventional PV module is not suitable to be used in the building skin and it needs to be partially modified/customized, in order to be compliant with all the building requirements in different scenarios. Manufacturers, architects, researchers and building contractors are trying to find the best way to optimally balance the need of **customization** of a PV component (to obtain a product suitable for architecture and building integration) and the need to optimize, on the other hand, the **cost-effectiveness** in terms of production, performance, qualification/certification, etc. It is not a simple challenge since very often architectural design requires specific and tailored solutions for each single project, also considering the fact that conventional **building products are going more and more towards a mass-customization** as a common option available for architects and customers. Moreover, on the other hand, also PV products are more and more developed with advanced electrical and energy requirements (to ensure efficiency, reliability, safety, etc.), hence making difficult to ensure the electro technical product's qualification.

The use of a conventional PV element in BIPV projects must be subjected to a specific evaluation of the final intended use in building and to the assessment of the relative building requirements. As a result, depending on the BIPV project – namely, the building envelope application- the legislative framework has to be defined in order to verify the suitability of the element for such an application. In many cases the "building assessment" leads to corrective actions in the module's design in order to make the component compliant with the building skin use. However, if the corrective action implies changes in the PV module design, this not only will involve the assessment according to the applicable building standards but it also will imply the retesting in accordance with the **IEC Rates Standards** as a mandatory procedure. In detail, the procedures for the initial qualification and additional retesting of a standard PV module are defined in the Technical *Specification IEC TS 62915 Photovoltaic (PV) modules – Type approval, design and safety qualification –* ***Retesting*** *(formerly referred as "Retesting Guideline "Product or Process Modifications Requiring Limited CBTL Retesting to Maintain Safety Certification for IEC 61730-1:2004 Ed. 1.0 and IEC 61730-2:2004 Ed. 1.0").* As stated in this guideline, "Changes in material selection, components and manufacturing process can impact the safety of the modified product" so, some additional tests are required to maintain the safety requirements of an already certified product, depending on the following modifications:

a) Change in cell technology,

b) Modification to encapsulation system,

c) Modification to superstrate,

d) Modification to back-sheet/substrate,

e) Modification to frame and/or mounting structure,

f) Modification to junction box/electrical termination,

g) Change in cell interconnect materials or technique,

h) Change in electrical circuit of an identical package,

i) Higher power output (by 10% or more) in the identical package including size and using the identical cell process,

j) Qualification of a frameless module after the design has received certification as a framed module.

While, the following modifications don't require re-testing:

- fewer cells in module,
- smaller cells in module, as long as each cell has the same number of interconnects and equivalent numbers of solder bonds per unit area,
- up to 20% larger module area with the same number of cells.

For example, if a PV module is used as opaque cladding of a ventilated façade, among several requirements, it shall guarantee an adequate mechanical resistance to withstand the wind load without damages or permanent deformations. If the PV module is not able to fulfil these requirements, its structure shall be modified. As an example, among possible solutions, the front glass thickness shall be increased (or the glass type changed) or the rear mounting structure should be modified. In both cases, thus, there is the need to retest the conventional PV module (Figure 2.6).

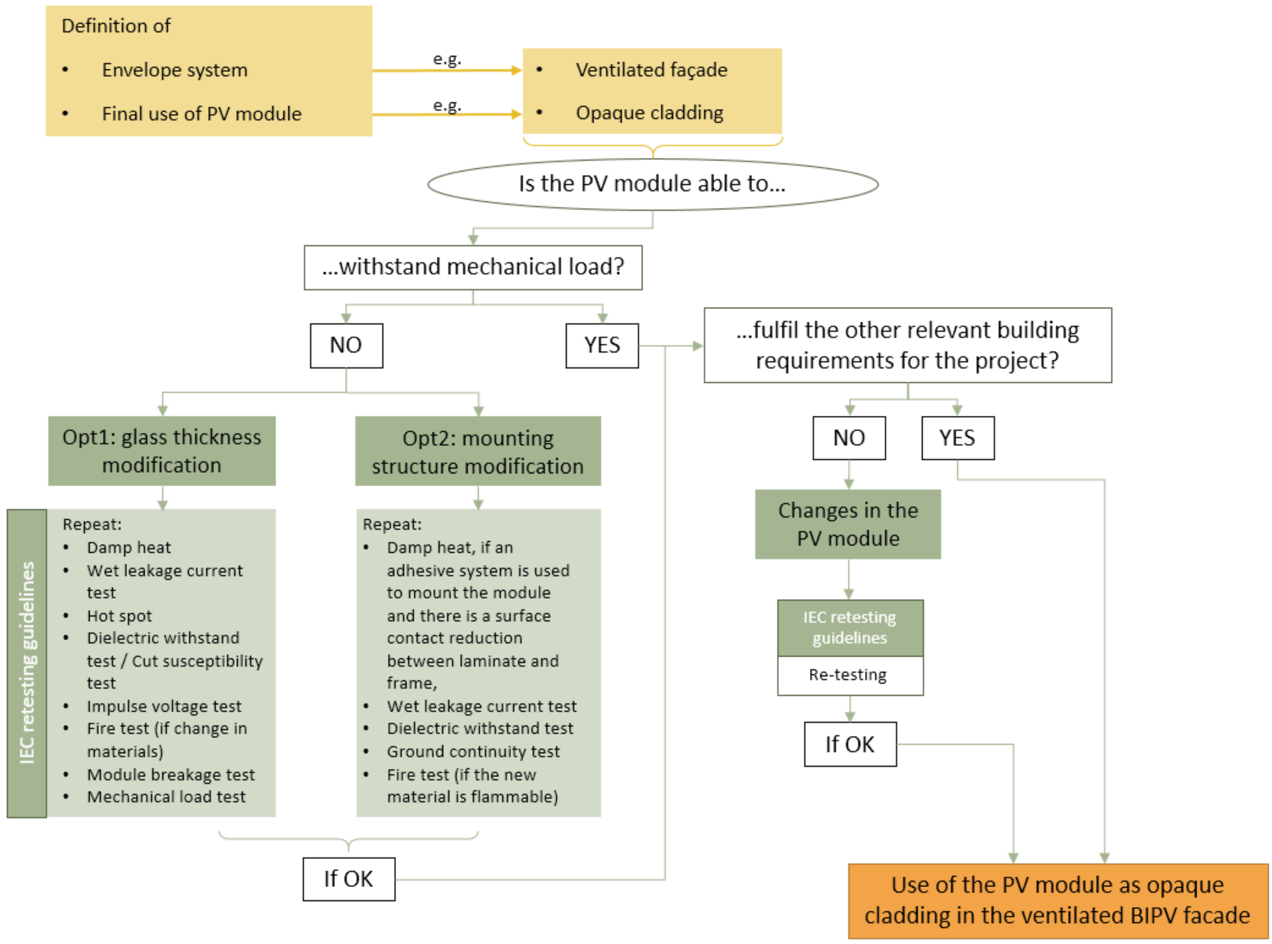

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Figure 2.6. Example of a procedure to verify the suitability of a BIPV module to be used in building skin, with a specific focus on the IEC retesting for two modifications in the PV module design

Often changes in the aesthetics, especially on the front glass of a conventional PV module, are requested in order to obtain a more appealing pattern or design. In this case, the "architectural" customization involves similarly the retesting of the PV module. This means that, nowadays, the use of a PV element in building skin has to be evaluated case by case in the single project. If structural modifications are applied to the component this often brings the need to double-check the qualification issues for electro technical and building normative.

2.4.1 Example of extended models in the current IEC framework: modifications to the power output

Once the parent model gained the IEC type-approval certification, a number of variants derived from the type-tested model can be selected by the manufacturer and submitted to a reduced re-testing sequences, in order to maintain the initial qualification and extend the validity to a wide range of products, derived from the approved parent product. This approach guarantees the quality of the whole family of products and allows to save time and cost of certification.

In particular, all the variants with higher or lower output power (by 10 % or more, due to the variation of the transmittance of the coloring layer), with identical design and size and using the identical cell process, have to be submitted to re-testing, according to IEC TS 62915, cl. 4.2.1 (e.g. different material, i.e. any change in specification of the material or any of its layers, different surface treatment, e.g. any coating on frontsheet -inside or outside)

For IEC 61215, only the following tests have been repeated on samples showing higher or lower output power (due to a different coloring):

- *Hot-spot endurance test*
- *Thermal cycling test, 200 cycles*
- *Bypass diode thermal test*

For IEC 61730, the following safety test has been repeated:

- *Reverse current overload test*

2.4.2 Example of extended models in the current IEC framework: size variations

In order to further extend the validity of the certification of the BIPV family of products, other aspects, from a constructive point of view, have been considered: in particular, the dimensional customization of the BIPV products that are related mainly with the structural and mechanical characterization. According to IEC TS 62915, the following re-testing procedure has to be followed to cover the size variations:

cl. 4.2.11 Change in PV module size

For increase by more than 20 % of length, width or area

Repeat for IEC 61215:

- *Thermal cycling test, 200 cycles*
- *Damp heat test*
- *Static mechanical load test*
- *Hail test (if non-tempered glass or if non-glass)*

Repeat for IEC 61730:

- *Module breakage test (MST 32)*

The role of BIPV components within the building skin technical elements and their function determine the characteristics, the performance request and the regulatory framework to adopt. E.g., the characteristics and requirements of protection against the fall from a balustrade, the thermal insulation of a component for façades or windows, the acoustic protection rather than the ability to allow a light diffusion inside the building, are just some possible examples demonstrating the wide range and the radical difference of a BIPV component from a conventional module in terms of quality.
For this reason, it is not possible to use the test and validation procedures for standard PV, but some new methods will have to be provided. In turn, it is not possible to refer exclusively to building codes in some cases, as following described, since they don't contain any provision for active elements like PV is. A BIPV module that works as a roofing tile, may find itself responding to non-uniform snow loads or to a certain wind direction while the mechanical test procedure for standard PV describe with a uniform load test the mechanical capabilities. A BIPV product that acts as a floor glass pane will certainly undergo, to dynamic, repetitive and non-homogeneous mechanical loads and partial shading and so many other cases can be described. It will therefore be necessary to describe, for each application field and product type, new procedures to correctly qualify the relevant performance levels.

2.5 Assessing the performance levels of BIPV to evaluate the building applicability: analysis of some real design scenarios

As already introduced, in order to understand if a component can be used or not in BIPV projects, it is necessary to evaluate if it complies with the normative framework in force. This is valid in the specific project context and for what concerns the building skin system, the material and technical application. Indeed, since BIPV modules by definition should be tested and qualified in accordance with both electro-technical and building standards for their intended use, conventional PV modules to be used as construction elements should satisfy the building requirements needed for the functionality of the building skin and the normative applicable.

2.5.1 Performance levels of a glazed BIPV component for a specific application in the building skin

PV modules are considered to be building integrated, if they constitute a building component providing a function as defined for example in the European Construction Product Regulation CPR 305/2011. Specifically, the EN 50583:2016 provides a collection of both electro technical and building standards that are relevant for BIPV product depending on their mounting category and their main encapsulation material.

To clarify this concept, in this sub-paragraph a **BIPV glass module** is taken as an example but the same approach can be extended to other BIPV products with other mounting categories and other main materials.

In this case, Table 2.2 shows the reference building standards of a **BIPV glass module when it is used as a skylight** accessible from inside, in addition to the IEC standards. This means that a glass-based BIPV module to be installed as glazing of a skylight accessible from inside shall:

- be tested in accordance with the IEC 61215 and IEC 61730,
- be able to stand the static load defined in accordance with the EN 14449 and the Eurocodes,
- be tested in order to obtain the fire rating classification,

- be tested in accordance with the EN 12600 for building safety,
- be tested in accordance with EN 410 and EN 673 for the determination of optical and thermal properties respectively,
- be tested for protection against noise and for the sustainable use of natural resources.

In particular, Figure 2.7 shows two certificates for a BIPV glass. On one hand, the BIPV glass module is certified as a PV module according to the IEC 61215 and IEC 61730, on the other hand, the BIPV glass module is considered as a building product and hence it is subjected to the pendulum body impact test (in accordance with the EN 12600) as required by the harmonized standard EN 14449 "Glass in building - Laminated glass and laminated safety glass — Evaluation of conformity/ Product standard" to distinguish laminated glass from laminated safety glass. In this case, the EN50583 is respected and the BIPV component is compliant with all the existing standards, apart from eventual local normative setting stricter rules.

In conclusion, it arises that the approach set in the BIPV standard **EN 50583-1:2016** for glass modules so far requires a **twofold certification**: one for the PV electro-technical requirements and another one for the building product "laminated glass" for building uses.

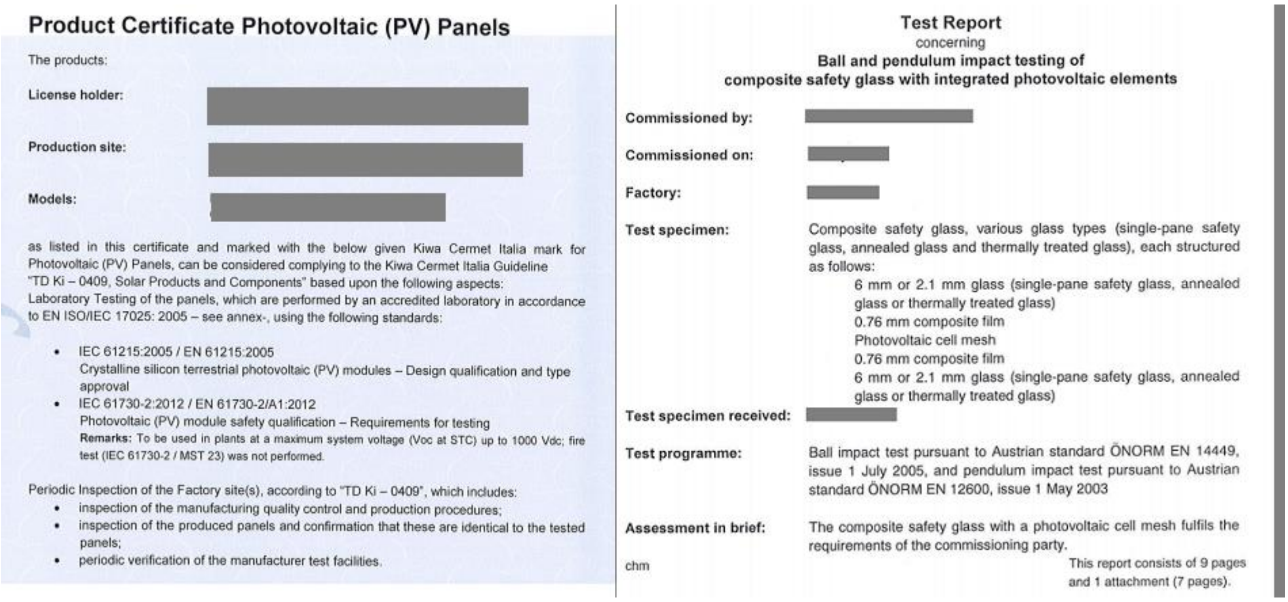
However, currently this doesn't cover a general extension of the qualified product for its applicability for the building skin since the topic (in design stage) is the **need to evaluate the suitability of the BIPV glass module for the specific project** (e.g. for defining the ability to withstand mechanical loads such as snow/winds defined in accordance with Euro codes and/or local codes in the specific context). It is evident that the safety for wind load depends on the actions in force that vary according to location.

Table 2.2. Example of reference standards for glass-based BIPV modules for skylights accessible from inside

REQUIREMENTS	STANDARDS, GUIDELINES, TEST METHODS	COMMENT
1.Mechanical resistance and stability	EN 1990 EN 1991 EN 1993 EN 1999 Local codes hEN 14449	General: As building construction products, BIPV modules have to be designed to comply with the wind, snow and mechanical loads as well as other requirements set out in the Eurocodes EN 1990, EN 1991, EN 1993 and EN 1999. Glass modules: glass-based BIPV modules shall comply with the respective product standards for glass in buildings. For laminated glass apply hEN 14449.
2.Safety in case of fire		General: Manufacturer to declare the fire rating in accordance with the standard EN 13501-1 for classification. Further requirements depend on application and country.
3.Hygiene, health and the environment		

REQUIREMENTS	STANDARDS, GUIDELINES, TEST METHODS	COMMENT
4.Safety and accessibility in use	EN 12600	General: the classification of pendulum body impact resistance in accordance with EN 12600 is required for CE marking
5.Protection against noise	EN 12758	
6.Energy economy and heat retention	EN 673 EN 410	General: the calculation of the PV glass solar factor under EN 410 might remove the part of the incident irradiance transformed into electricity and the optical inhomogeneity in the glass due to the disposition of the solar cells
7.Sustainable use of natural resources	EN 15804 CEN/TR 15941 EN 15942 EN 15978	

As already discussed, when PV modules are compliant with electro technical standards, they can be surely used for conventional PV plants (such as open fields or Building Added Photovoltaics, where PV is simply added and overlapped to the building envelope without providing additional building functionalities) but they are not generally suitable for Building Integrated Photovoltaic (BIPV) installations due to the fact that ***IEC standards do not set building requirements***. Indeed, as stated in the EN 50583-1:2016, ***if a PV module is used for building integrated PV installations, it has to perform as a building element***, for the role that it is going to assume.


Product Certificate Photovoltaic (PV) Panels

The products:

License holder: [redacted]

Production site: [redacted]

Models: [redacted]

as listed in this certificate and marked with the below given Kiwa Cermet Italia mark for Photovoltaic (PV) Panels, can be considered complying to the Kiwa Cermet Italia Guideline "TD Ki – 0409, Solar Products and Components" based upon the following aspects:
Laboratory Testing of the panels, which are performed by an accredited laboratory in accordance to EN ISO/IEC 17025: 2005 – see annex-, using the following standards:

- IEC 61215:2005 / EN 61215:2005
  Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval
- IEC 61730-2:2012 / EN 61730-2/A1:2012
  Photovoltaic (PV) module safety qualification – Requirements for testing
  Remarks: To be used in plants at a maximum system voltage (Voc at STC) up to 1000 Vdc; fire test (IEC 61730-2 / MST 23) was not performed.

Periodic Inspection of the Factory site(s), according to "TD Ki – 0409", which includes:

- inspection of the manufacturing quality control and production procedures;
- inspection of the produced panels and confirmation that these are identical to the tested panels;
- periodic verification of the manufacturer test facilities.

Test Report
concerning
Ball and pendulum impact testing of composite safety glass with integrated photovoltaic elements

Commissioned by: [redacted]

Commissioned on: [redacted]

Factory: [redacted]

Test specimen: Composite safety glass, various glass types (single-pane safety glass, annealed glass and thermally treated glass), each structured as follows:
6 mm or 2.1 mm glass (single-pane safety glass, annealed glass or thermally treated glass)
0.76 mm composite film
Photovoltaic cell mesh
0.76 mm composite film
6 mm or 2.1 mm glass (single-pane safety glass, annealed glass or thermally treated glass)

Test specimen received: [redacted]

Test programme: Ball impact test pursuant to Austrian standard ÖNORM EN 14449, issue 1 July 2005, and pendulum impact test pursuant to Austrian standard ÖNORM EN 12600, issue 1 May 2003

Assessment in brief: The composite safety glass with a photovoltaic cell mesh fulfils the requirements of the commissioning party.

chm

This report consists of 9 pages and 1 attachment (7 pages).

Figure 2.7. Certificates for a BIPV glass module. Left: certificate in accordance with the IEC 61215:500 and IEC 61730-2:2012. Right: test report for assessing the pendulum body impact resistance (in accordance with the EN 12600), necessary to distinguish laminated glass from laminated safety glass.

It is necessary to identify the ***intended final application in the building envelope*** and the ***main module's material*** in order to assess and verify the compliancy with the building requirements. In particular, such requirements arise from the legislative framework about buildings and building's products and only if the performances of the conventional PV modules fulfil these requirements, the conventional PV product/system can be applied in the BIPV skin.

In order to clarify this methodology, the following sub-paragraphs provides some examples and hints for mechanical and fire requirements.

2.5.2 Mechanical requirements of BIPV glass in façade

When glass-based PV modules are used in the building envelope as a façade cladding, the requirements on the construction safety and the mechanical behavior are particularly significant in comparison to conventional PV plants since in their final use they constitute building elements.

In particular, the mechanical requirements can be identified for two different levels: the module/product level and the envelope system level. Indeed, when glass-based PV modules (which are generally laminated glass) are installed as glazing elements of façades, they shall be compliant with the harmonized technical specifications EN 14449 "Glass in building - Laminated glass and laminated safety glass — Evaluation of conformity/ Product standard". Moreover, depending on the mounting structure and fixing configurations, the whole envelope system should ensure mechanical safety and adequate operational conditions (e.g. adequate resistance preventing excessive deflections) along with the safety of users indoor or outside the building. Specifically, for this example, conventional glass-glass PV modules are supposed to be installed as a **glazing elements of a double skin façade** and, in the following sections, a first analysis of the mechanical requirements at the module/product level is described, as well as a second analysis related to the mechanical requirements at the envelope system level.

Module/product level

When glazed PV modules are installed as glazing elements of a double skin façade, they shall have both the IEC certification for PV products and the certification in accordance with the EN 14449.

In particular, the IEC 61215-2 sets that the mechanical ability of the PV module to withstand a minimum static load (e.g. wind or snow), that is in the amount 1600 Pa, with 1,5 safety factor (compliant with the previous value of 2'400 Pa, equals to 240 kg/m^2), without electrical damages, shall be verified. On the "building product" side, the EN 14449 requires the evaluation of the mechanical resistance against wind, snow, permanent and imposed load in accordance with the design standards for glass (e.g. prEN 13474 or prEN 16612) which set that the design load shall be defined in accordance with the Euro codes.

Envelope system level

In addition to the mechanical requirements that have to be fulfilled at the module/product level, also the mechanical requirements of the double skin façade with PV modules shall be fulfilled. In detail, a double skin façade is considered as a curtain wall, in accordance with the definitions of the EN 13830:2003.

Specifically, this standard states that the curtain wall kit shall be able to withstand the wind load ***without damages or permanent deformations***. In particular, the wind load shall be determined in accordance with the Euro code "Actions on structures - General actions - Part 1-4: Wind actions" with the specific coefficients for the determination of the wind pressure load, that are developed at the national level. In Switzerland, for instance, it is possible to determine the wind load thanks to the standard SIA 261:2014 "Actions on Structures" but the load will depend on:

- Geographical location,
- Terrain category,
- Building height and form.

Therefore, the load (and the consequent suitability of the pre-defined component for the application considered) can vary from building to building and depending on the location. For this reason, it is fundamental to verify whether the wind load can be "tolerated" by the double skin façade under consideration both in terms of resistance, limit states, etc. i.e. to verify that also the ***maximum deflections*** of both structures (e.g. mounting structures) and glazing elements ***are lower than the ones set in the reference standards***. It is evident that such requirements are not defined and assessed for a conventional PV panel.

In conclusion, the use of glass PV products for BIPV shall be subjected to a set of specific evaluations, just for the mechanical requirements, that are established for the envelope's system from the regulatory framework in force for the building sector. It is not possible to define a priori whether an element is applicable since the IEC mechanical static load test is not meant to determine the suitability of conventional glass PV modules for building projects. Generally, this requirement is evaluated by façade engineers during the design phase through a specific FEM analysis of the façade system that consequently set out the main features of the component/system (e.g. glass thickness, glass typology, encapsulant, etc..) or verify the suitability of a pre-defined component through a reverse engineering process.

For other details, see also "*Saretta, E., Bonomo, P., Frontini, F. (2016). Laminated BIPV glass: approaches for the integration in the building skin. In Jens Schneider and Bernhard Weller (Eds.), Engineered Transparency 2016: Glass in Architecture and Structural Engineering (363-372). Ernst&Sohn.*".

2.5.3 Fire safety requirements of BIPV glass in façade

The use of glass PV modules in the building's envelope requires that the PV module is considered also as a building element. Similar to the mechanical requirements, also fire safety requirements can be identified for two different levels: the module/product level and the envelope system level.

When fire safety has to be assessed, two main concepts shall be considered at least:

- Fire resistance
- Reaction to fire

In this section, a specific example is provided in order to clarify the approach for the definition of fire safety requirements. Specifically, a conventional glass-glass PV module is considered to be installed as glazing element of a double skin façade in a building located in Lugano, Switzerland.

Module/product level

As already introduced, when conventional glass PV modules are installed as glazing elements of a double skin façade, they shall have both the IEC certification for PV products and the certification in accordance with the EN 14449.

With regard to the fire resistance requirements, the article about the fire resistance of the IEC 61730-2:2016 states that "***PV modules as building product*** – i.e. serving as roof covering materials, ***elements for building integration or that are mounted on buildings – are subjected to specific safety requirements originating from national building codes***". In particular, for glass PV modules (e.g. laminated glass) the fire resistance performance shall be tested in accordance with the EN 13501-2. In addition to the fire resistance test, the IEC 61730-2:2016 includes the **ignitability test** in order to evaluate if ignition occurs and the spread of flames due to an external fire source. Specifically, the test is based on the ISO 11925-2:2010 that – in the original version – is also **useful to assign the reaction to fire classification for building products** in accordance with the EN 13501-1:2009 (and amendments), which is also defined in the standard EN 14449 for the definition of the reaction to fire class for laminated glass and laminated safety glass.

As a consequence, performing the original version of the ISO 11925-2:2010 on a conventional glass PV module can allow obtaining the CE mark for PV modules as a construction product and also to identify the reaction to fire class of the product as a laminated glass in accordance with the EN 14449. This evaluation can allow establishing if the module under investigation (e.g. a conventional product serially produced and not intended for building use) is adequate to be used in buildings, i.e. if the reaction to fire prescriptions stated in the national/local building codes are fulfilled.

Envelope system level

Once the reaction to fire class is defined as introduced in the previous paragraph, it is necessary to evaluate the requirements set in the national/local building standards about:

- Fire resistance
- Reaction to fire

Depending on the final intended use of the PV module (glazing element) and the building envelope system (double skin façade, curtain wall, roofing shingle, etc.).

As also discussed in the report "Fire safety of BIPV façades", there are some specific fire resistance test methods for double skin façade, whose resulting performances shall be compared with the building requirements set at the local level, which include also the reaction to fire requirements.

In the Swiss case, the relevant fire protection standards for buildings to consider are the following ones:

- VKF – Fire Protection Norm (1-15)
- VKF – Fire Protection Directives:
  - *Building materials and construction parts (13-15)*
  - *Use of building material (14-15)*
- VKF – Explanatory Notes:
  - *Building with double skin façades (102-15)*
- VKF – Memorandum:
  - *Solar systems (2001-15)*

With regard to the reaction to fire requirement, the outer façade of the double skin system shall be realized with RF1 materials. However, three classes of fire safety requirements can be identified when specific double skin façade systems are conceived, as shown in **Table 2.3**.

Table 2.3. Three classes of fire safety requirements for double skin façades, in accordance with VKF regulations.

FIRE COMPARTMENTS OF THE BUILDING ARE EXTENDED ALSO IN THE DOUBLE SKIN FAÇADE	No fire compartments	Inner façade with fire resistance
No need for fire protection active system. If a fire protection active system is installed also in the cavity, material RF3 (cr) can be used for the outer skin.	Need for fire protection active system. If a fire protection active system is installed also in the cavity, material RF3 (cr) can be used for the outer skin.	No need for fire protection active system. If a fire protection active system is installed also in the cavity, material RF3 (cr) can be used for the outer skin.

In conclusion, the use of conventional glass PV modules for BIPV projects shall be subjected to specific evaluations of the fire safety requirements that are typical of the building's type and the building envelope's system. It is not possible to define a priori whether an element is applicable or not for some reference scenarios as i.e. descried in the previous case-studies.

For other details, see "*Bonomo, P., Frontini, F., Saretta, E., Caccivio, M. Bellenda, G., Manzini, G. Cappellano, P.G. (2017) Fire Safety of PV Modules and Buildings: Overviews, Bottlenecks and Hints, EU PVSEC 2017*"

2.6 Progresses made at EU and international level: complexity and unification lack

Building integration of photovoltaics typically deals with two different regulation schemes: one derived from the building side, often regulated in local building codes, harmonized EN and international ISO standards; the other from the electro-technical side, with international IEC standards and local regulations. An important factor is the complexity of the regulatory framework, and very often, there are a lot of local, regional and national rules to be considered during the process of realizing a BIPV project. In the absence of a unified normative framework, as it happens for conventional PV or for building products, each country temporarily adopted different measures trying to regulate the adoption of PV in Buildings. Especially for some sensitive requirements, such as fire safety, locally adopted regulations, technical recommendations and guidelines by local authorities or at national level provide the current reference criteria. The overlapping between the PV and building sector is the barrier for a clear understanding in many cases (7). Thus, for the use of the same BIPV products it is often necessary to comply with different regulations that cause indecisions and difficulties in the products' diffusion. Nowadays each country adopts its own prescription and the BIPV manufacturers are constrained to refer to the laws in force in the specific states without being able to take advantage of a generally accepted rule. The first steps in the creation of a specific BIPV regulation framework were made with the introduction of the standards EN 50583-1: 2016, Photovoltaics in buildings – Modules (8) and the EN 50583-2: 2016, Photovoltaics in buildings – Systems. The first BIPV European standard analyzes the different assembly categories and groups them in five installation typologies. This standard collects the inputs provided by the photovoltaic and building requirements but it does not enter into the details of new testing procedures or qualification. According to EN 50583 Photovoltaic modules are considered to be building-integrated, if the PV modules form a construction product providing a function as defined in the European Construction Product Regulation CPR 305/2011. Thus the BIPV module is a prerequisite for the integrity of the building's functionality. If the integrated PV module is dismounted (in the case of structurally bonded modules, dismounting includes the adjacent construction product), the PV module would have to be replaced by an appropriate construction product. Inherent electro-technical properties of PV such as antenna function, power generation and electromagnetic shielding etc. alone do not qualify PV modules as to be building-integrated. The data sheet information for BIPV modules shall conform to EN 50380. In addition the data sheet information for BIPV modules shall include the information as required for CE marking according to product standards that comply with the CPR (e.g. EN 14449 or prEN 1279-5). Instructions for storage, handling, erection, fixation, operation, maintenance, dismounting and recycling of the BIPV modules are to be stated. Further requirements on PV modules that contain glass are contained in Annex A.

EN 50583 series "Photovoltaic in Buildings" (9), previously mentioned, was issued in 2016 at the European level as the first reference standard for BIPV. Moreover, as reported in the results of Subtask C on Task 15 IEA-PVPS, different new work topic proposals were launched internationally, the ISO/TS 18178 (Laminated Solar PV glass) by ISO TC160 (Glass in building), and several within the IEC technical committee TC82 (Photovoltaics). 82/1055/NP (PV roof applications, 2015), resulting in pr IEC 63092, and 82/888/NP (PV curtain wall applications, 2014), resulting in pr. IEC 62980, were not successful, or made very slow progress over several years. Therefore, in 2017, a new attempt was made within IEC TC82 (82/1339/DC) to establish a project team, the PT 63092 "Building Integrated Photovoltaics (BIPV)", which included experts from ISO, IEC, and the IEA PVPS Task 15. This project team comprises 40 members from 15 different countries.
The report "Analysis of requirements, specifications and regulation of BIPV" issued by IEA PVPS Task 15 Subtask C – International framework for BIPV specifications (10) provided a review of current regional and international standards and drafts that are either dedicated to BIPV or are frequently referenced in BIPV standards/drafts. The "basic requirements" defined by EN50583 were broken down into lists of concrete technical requirements for BIPV that can be addressed by standards and technical specifications. This information is already being used as input by the IEC Project Team PT 63092, that is currently preparing an international BIPV standard. Categories concerning the necessity and suitability of international standardization for BIPV were defined. The authors recommended that three categories, "internationally mandatory", "useful to design BIPV" and "useful to characterize BIPV, but no need for pass/fail criteria" be addressed at the international standardization level. Based on these categories, the identified technical BIPV requirements were categorized, providing a clear recommendation of topics that should be addressed by international standards on BIPV. For more details the report will be available at http://www.iea-pvps.org.

In the recent Commission Recommendation (EU) 2019/1019 of 7 June 2019 on building modernization, the requirements on 'proper installation' for on-site electricity generation is defined as a generic reference to the need to ensure that the system is installed in a way that will ensure safe and optimal operation. Usually this is linked to requirements on the qualification of the installer (e.g. certified installer) and to specific technical guidelines. For PV systems, standards applying to building-integrated photovoltaics (BIPV) can be relevant in this context and EN50583-2 is mentioned (11).

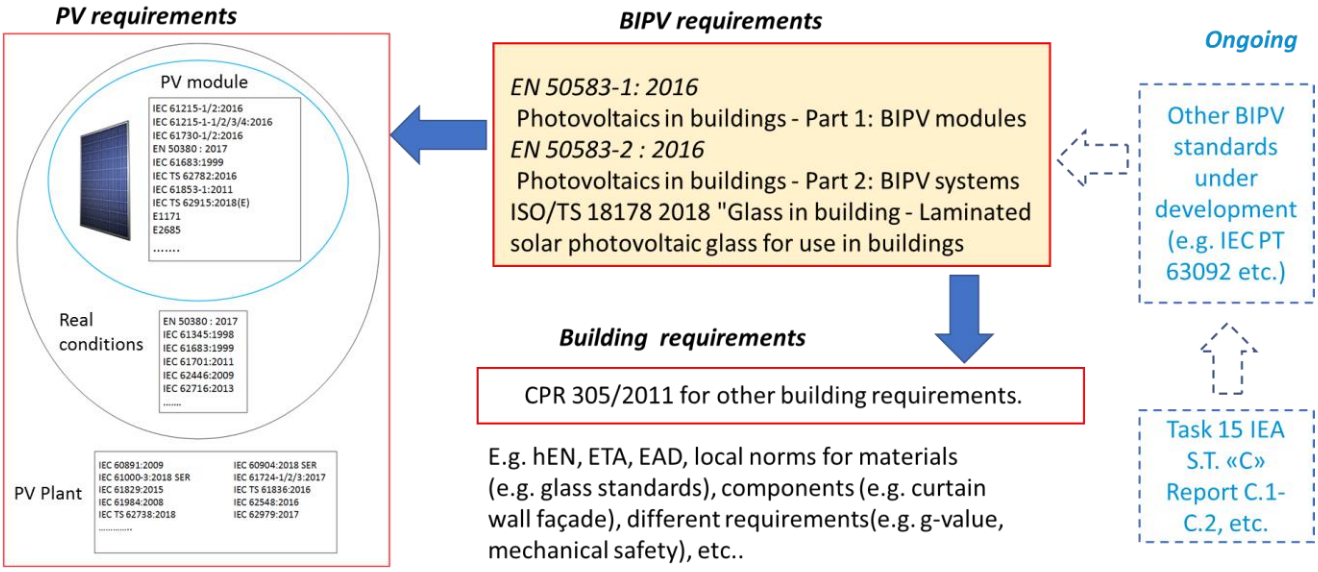


Figure 2.8. BIPV current normative status. Building integration of photovoltaics typically deals with two different regulation schemes: one derived from the building side, often regulated in local building codes, harmonized EN and international ISO standards; the other from the electro-technical side, with international IEC standards and local regulations.

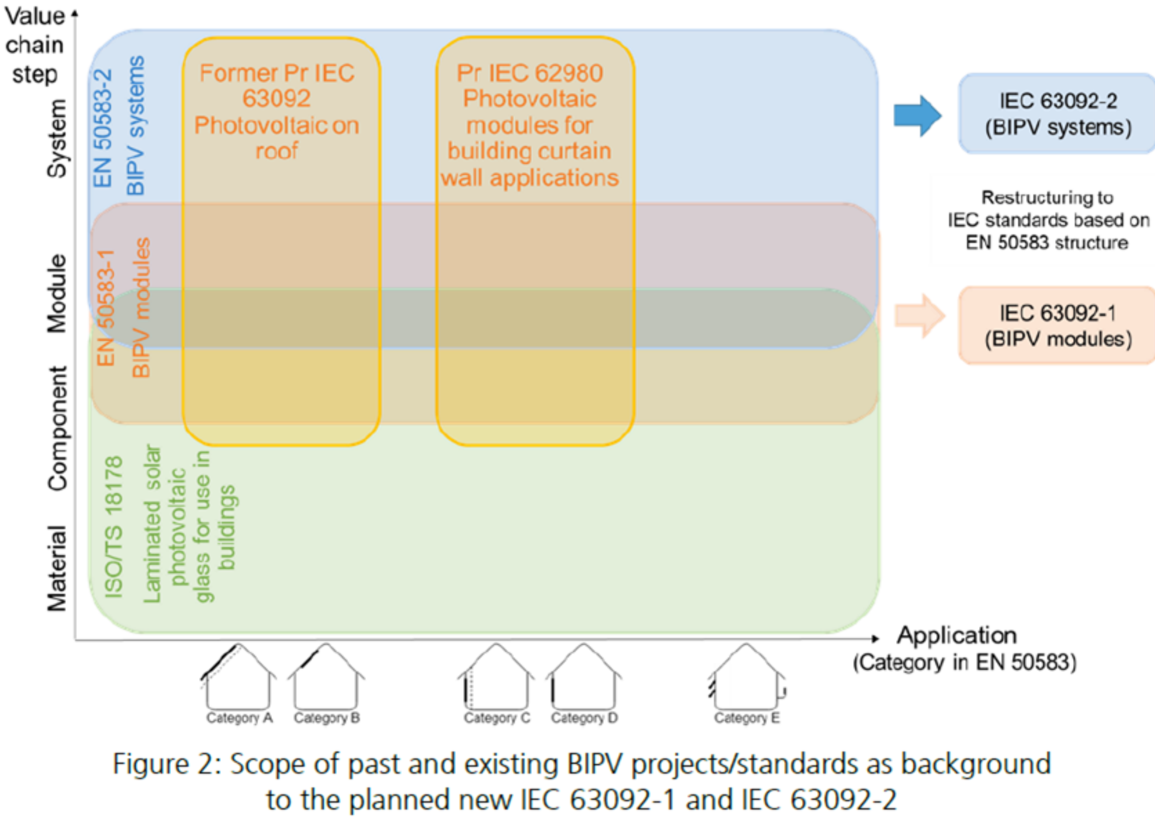


Figure 2.9. Ongoing developments for BIPV (Source: Task15 IEA-PVPS)

2.7 What about the real market in the current situation?

A real example, as reported below, provides evidence of the current **difficulties in qualifying BIPV products** and the correlated risks in terms of responsibility in which players today incur. Some performance don't have a clear reference in the actual normative so that, in cases when this **lack** doesn't become a **"no go"** for the building process, the problem is solved thanks to the expertise of operators and stakeholders (engineers, manufacturers, installers) who try to combine in the best way the existing indications.
Fire risk is one of these fields that can be used as example. Fire risk for PV and BIPV installations is not negligible and must be addressed to avoid economic losses and protect people who can be involved in case of fire. In accordance with building and electro-technical standard IEC 61730-2:2016, today the fire safety requirements for PV modules mounted on (BAPV) or in (BIPV) building envelopes must comply with national building and construction regulations and the related requirements. If, on the one hand, electro-technical and building standards set requirements to prevent fire hazard of (conventional or added) PV and (non-active) building envelope systems respectively, on the other hand, fire safety requirements are not harmonized at International and European level for BIPV, being typically defined in the national and/or local regulations.

As example, we can consider the Swiss legislative framework actually in force for BIPV façades, described below:

- Memorandum about solar systems 2001-15 (VKF)
- Fire Protection Directive 14-15 "Use of Building Materials" (VKF)
- Fire Protection Directive 13-15 "Building Materials and Constructive Parts" (VKF)
- Document on the state of the technique of fire safety compliant with the VKF memorandum mentioned above (Swissolar, 2015)

In conclusion, the following aspects can be highlighted as the **borders of implementation of BIPV in the current normative framework (referred, as example, for fire safety)**:

1. *State-of-art*. The requirements, prescription and test methods actually in force for BIPV façades, are related to the **building normative framework** applicable for traditional façade technologies. This means that these standards do not consider the peculiarities due to the presence of PV elements which could represent further risks for fire. As a consequence, the regulation should be further **developed and improved** in order to consider the real conditions of BIPV systems and define requirements and dedicated testing procedures;

2. *Need of filling the missing gap.* Fire propagation should be carefully taken into account for BIPV façades, by considering specific aspects/requirements/needs related to this **new construction typology** which is an active façade, e.g. to evaluate the behavior of the electrical devices (more and more used as power optimizer, micro-inverters, sensors, cabling, etc.) in the spread of flame, because of the presence of particular electrical elements (e.g. cablings, optimizers…) that are not part of a conventional building façade.

Therefore, even though the Swiss Regulation about fire safety of façades is today very detailed providing a clear reference framework, the peculiarities and the performance of a BIPV façade could call for further investigation in developing new reference requirements, testing procedures and performance verification for BIPV building skin scenarios (7).

- *How do BIPV players get oriented in the current framework?*

Designers, manufacturers and installers currently mainly **overlap procedures** developed for **standard PV** with other standards already present in the **building sector** (for non-active elements) such as norms related to glass, to fire safety, etc. In other cases, not addressed by this overlapping, the definition of the performance levels is based on their experience (e.g. glass producers have a great experience in glass performance/qualification which they extend to active products) or derived from other similar projects.

- *Which are the consequences on the market?*

The conditions under which BIPV have been introduced into the market so far are basically the following:

1) **Abandoning the BIPV option** by opting for the standard applied PV. It is more convenient and apparently easier to realize. This is not a possible option under the perspective of nZEBs on PEB for the coming years, since more and more additional surfaces will be necessary and PV will have to be part of the building skin in order to comply with energy efficiency targets.
2) Products introduced into the market with the label of "BIPV" but in **derogation of any building regulations** (conventional PV modules, forced to be applied without any qualification for building requirements) with consequent potential high risk that critical events may occur for safety, reliability, etc. during operation and across the lifetime.
3) Products introduced on the market that **fully comply existing PV and building codes** for the specific case. This process so far is demonstrated typically affordable for only the big players (or relevant/pilot projects), since the great cost of the building can absorb the qualification costs.

Indeed, another crucial point is the **time and cost** of the certification and the retesting process, as today structured and conceived, which has a great impact on the market. In fact, for the manufacturers the high costs of the certification process, which very often cover only a limited group of product families (as mentioned in 2.4), are often the reason for not dealing with BIPV in cases when the client requests don't meet their "pre-defined" and "pre-qualified" product families.

2.8 Related risks for BIPV quality in real installations

In addition to the qualification of a new product for installing it as a new component, it is important to ensure that the PV plants **behave properly in real operating conditions both as an electrical device and as a building component**. In 2.2 we described how the boundary conditions, the environment, the urban and building aspects create a special scenario for BIPV applications, strictly diverse from ideal ones for PV. E.g. just focusing on **energy aspects**, in some cases the expected productions of BIPV plants resulted different with respect to those expected, thus affecting the investments and the planned benefits. This contributed to reduce confidence and trust in the technology. But, what are the real reasons? Is it really BIPV itself?

These situations occur due to different causes among which:

- *Incorrect energy yield calculations in design phase.* The lack of specific design tools for modelling and simulation of BIPV in a building/urban condition (shading, surroundings, detailed electrical design/layout and simulation according to complex environmental scenarios, etc.) is one of the practical limitations to an accurate design of BIPV plants. A conventional design, based on a yield estimation conducted similarly to a standard PV plan, typically fails, not representing the operating real conditions (e.g. temperatures in building skin applications which are significantly different from open rack systems, dirtiness related to urban area or building morphology, impact of partial shading due to the building use, aesthetics, etc.) and it's the main reason of the performance gap between design and real operation;

- *Non-optimal electrical layout in design phase*. One of the main causes of losses in energy generation within BIPV systems is the partial shading, especially in façades. This effect can lead to a significant increase of the cell temperature in case of presence of hotspots. The exact point at which the PV cell becomes a power consumer instead of producer changes between different types of cells and diodes which try to prevent this phenomenon allowing the current flows through an alternative path, when cells are shaded or damaged. The configuration of the diodes in the module is very important and can lead to different module behavior. Nowadays, trends toward urban installations are increasing the occurrence of such partial array shading, where careful considerations need to be taken about the configuration, size, number of strings, and their connections to the inverters, while taking into account the costs and complexity of the system. The need to optimize string configurations for PV systems located in dense urban environment where different strings are exposed to partial shadings throughout the year, due to the neighboring constructions and other obstructions, is another cause of incorrect design (12).

Other examples concerning non-proper O&M strategies, installation mistakes, etc. and the same reflections could be made not only about the energy yield but also focusing on other requirements such as mechanical, fire, etc. The emerging aspect is that today BIPV cannot rely on a clear normative framework so that the cause of performance problems or risks related to BIPV can be also related to the current missing gaps within the process. This was evident in cases of malfunctioning and more serious critical events that have led to fire triggering, ignited by the PV system, remained limited and affected only the plant itself, in other cases, with the spread of the flames, the fire spread in the building and serious consequences occurred (13) (14). In this framework, it is necessary the realization of clear procedures that allow reducing as much as possible the probability of occurrence of dangerous scenarios and that allow reducing the effects once unleashed. There are many causes that bring failures on PV plants. Among these, focusing on the fire risk, some of the most important are reported in the table below:

Table 2.4. Main causes of PV plants failures. Source: Roma, corpo Nazionale dei Vigili del Fuoco - Nucleo investigativo antincendi Capanelle. *Relazione tecnica sugli incendi coinvolgenti impianti fotovoltaici* (15)

CAUSE	RISK	WHERE
Electrical wiring	Photovoltaic electric arc	Connectors
		Cables
		Junction boxes
Insulation / integrity loss	Internal oxidation	Solar cells
	Short circuit	Internal connections
	Photovoltaic electric arc	Cables
Shading	Hot spot	Module – solar cells
Dirt		
Overheating	Flame ignition	String boxes
		Inverters

The above causes can bring serious damage to the plants and lead to fire, so it is needed defining complete procedures to allow an effective control under construction and in O&M.

2.9 Conclusions on the current standardisation framework

As of today, the current regulatory framework of BIPV is mainly grounded on the standard EN 50583, which gathers a set of norms coming separately from standard PV and traditional "non-active" construction products. However, an assessment of the features, operation conditions and requirements to be fulfilled by BIPV systems clearly evidences that such approach is not valid and efforts for defining new testing procedures are required. The CE mark for BIPV, as a building product and according to the EN 50583, has to be released in accordance with building product harmonized standards to demonstrate compliance with the CPR. However, the CE mark that is already applied to PV modules is in accordance with the EN 61730 but, in this case, the performances that are declared are not related to building application. Designers, manufacturers and installers currently mainly overlap procedures developed for standard PV with other standards already present in the building sector (for non-active elements) such as norms related to glass, to fire safety, etc. In other cases, not addressed by this overlapping, the definition of the performance levels is based on their experience (e.g. glass producers have a great experience in glass performance/qualification which they extend to active products) or derived from other similar projects.

Therefore, in order to check the applicability of whatever active PV component in the building skin, as a first step it is needed to define in detail the technical element of the building envelope where PV will have to be integrated, its construction and functional requirements, the building typology and the intended use. Accordingly, it is possible to define the performance levels and the reference normative that such an application requires as a building component (applicable standards, European and local regulations) to be correctly designed, manufactured and installed as part of the building skin. Typically, the standard in force for the building skin components are extended and applied to BIPV to ensure an adequate performance as a construction element (e.g. this is already adopted in many BIPV glasses) but there are missing gaps also in the building normative, that calls for further developments. Consequently, a possible path is considered achievable by developing a new approach for the qualification of BIPV products, coherent with the principles of CPR 305/2001 considering BIPV as a construction product, grounded on the analysis of the missing gaps and criticalities emerged at the state-of-art. To use the performance-based approach, it is necessary to define, for each of the different requirements to be achieved, limit states (LS). The specific development of new procedures for the qualification of a BIPV product family requires including both the PV active part and the building skin functional construction, providing energy production and construction functionalities, respectively. In order to draft a roadmap for a new approach, the definition of the missing gaps in the regulatory framework is reported in the following chapter.

3 MISSING GAPS IN THE STANDARDIZATION FRAMEWORK

In the current regulatory framework, there are real **missing gaps** for the correct description of the BIPV, due the lack of harmonized standards and technical procedures specifically developed for BIPV as discussed in previous chapters. This topic has been discussed and addressed in previous researches by authors who contributed in the report "Proposed Topics for Future International BIPV Standardisation Activities" from **Task 15 IEA-PVPS** which identified areas where there is still a need for international standardisation on multifunctional characterisation of BIPV modules and systems and to recommend approaches which could be taken to meet this need. Features of BIPV, which require modifications to existing testing procedures, entitled types of testing and proposed test modifications to account for BIPV features.

As it can be observed in Figure 3.1, the **missing gaps can be identified at several levels**, starting from the PV element level, to the system level until reaching the application level on the building. As seen in the previous chapters, these deficiencies do not allow a correct and complete characterization of the BIPV elements, which therefore potentially can bring risk of failures in installation by adopting current procedures.

3.1 Levels of normative Missing Gaps (MG)

A question typically arises in the real market among operators: "what legislation should be used for a photovoltaic system that will be placed on a building as building skin active element?". As mentioned in Section 2, the current building regulations are well detailed and they deal with the various subjects of the building skin qualification. The Construction Sector is the biggest single area of work in CEN with around 3000 work items, both product standards and test methods. Among these about 600 product standards will be harmonized under the Construction Products Regulation (EU 305/2011) and another 1500 supporting standards are required to allow for the CE marking of the relevant construction products (16).

However, in the construction regulations, active parts concerning PV are not taken into consideration. Conversely, the PV standards do not deal with building related aspects, which evidences the existing lack of coordination between the two sectors. From this point, missing gaps can be defined at different levels:

- FIRST LEVEL. Basic BIPV construction element (component)
- SECOND LEVEL. Technological BIPV system
- THIRD LEVEL. Building application

Considering the requirements of the Construction Products Regulation (CPR), a number of harmonized product standards may need amendments to allow for the establishment of DoP (Declaration of Performance) for BIPV products.

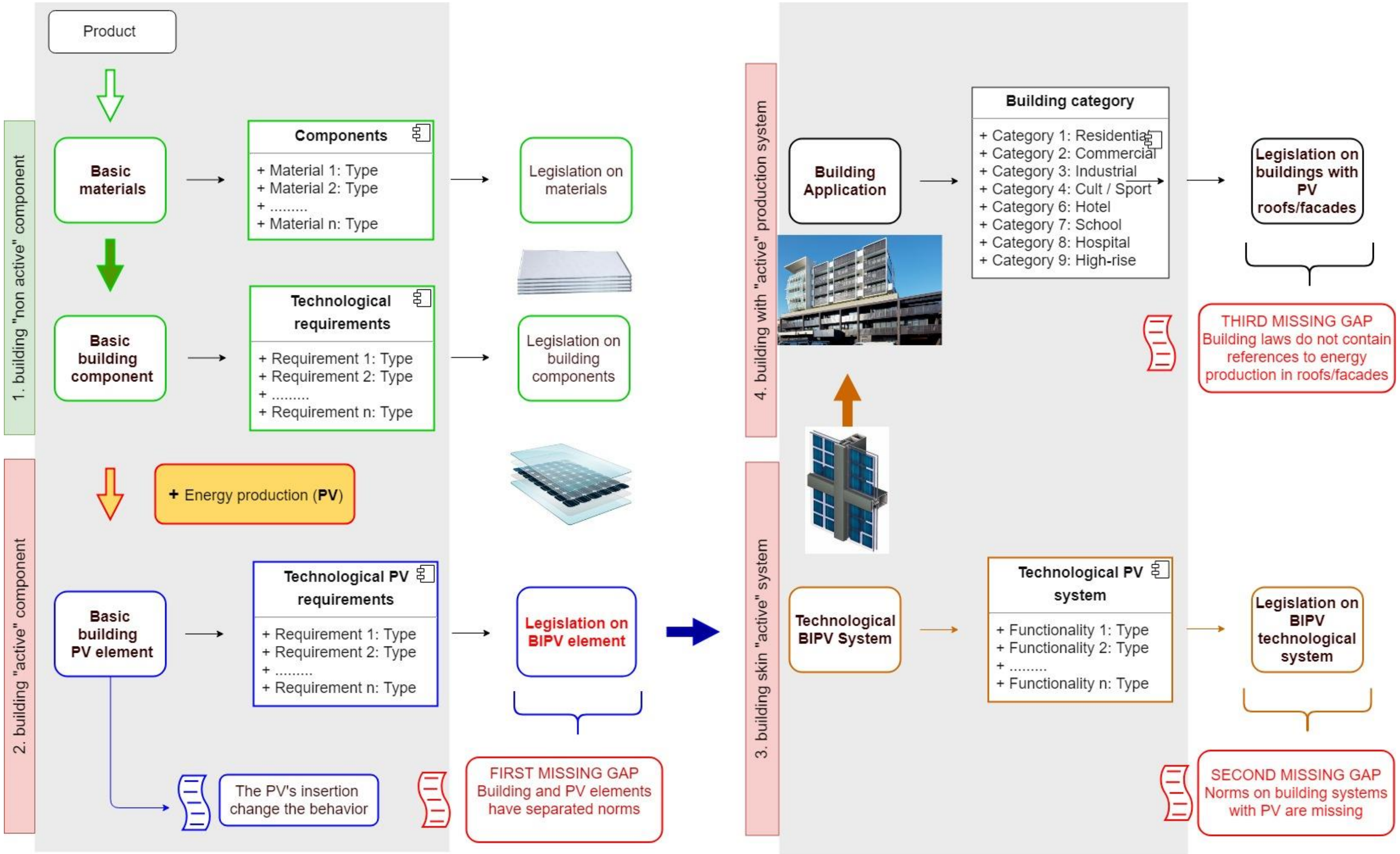


Figure 3.1. Missing gaps related to BIPV (source: Bonomo P. et.al., performance assessment of BIPV systems: from current normative framework to next developments, EUPVSEC 2019 (17))

3.2 Multi functionality MG: Building + PV is not BIPV

BIPV is a multifunctional construction product. However, a BIPV product cannot in any way be considered only as a building component since it has an active part for electricity production and will therefore have to satisfy the Low Voltage Directive, 2014/35/EU of electrical products and all the rules derived from it. For both sectors it will be necessary to find a methodology bringing union and standardization to well-defined rules that are not just the sum of them. In the unification process some requirements can be integrated with each other, others will remain unchanged for the respective sector while others will not be used because not necessary or redundant. Here it is important to note that there is currently a grey area in the legislation in which no clear rules are in force. Some concrete examples are described in Section 2.5 to provide idea on technical requirements needing harmonization.

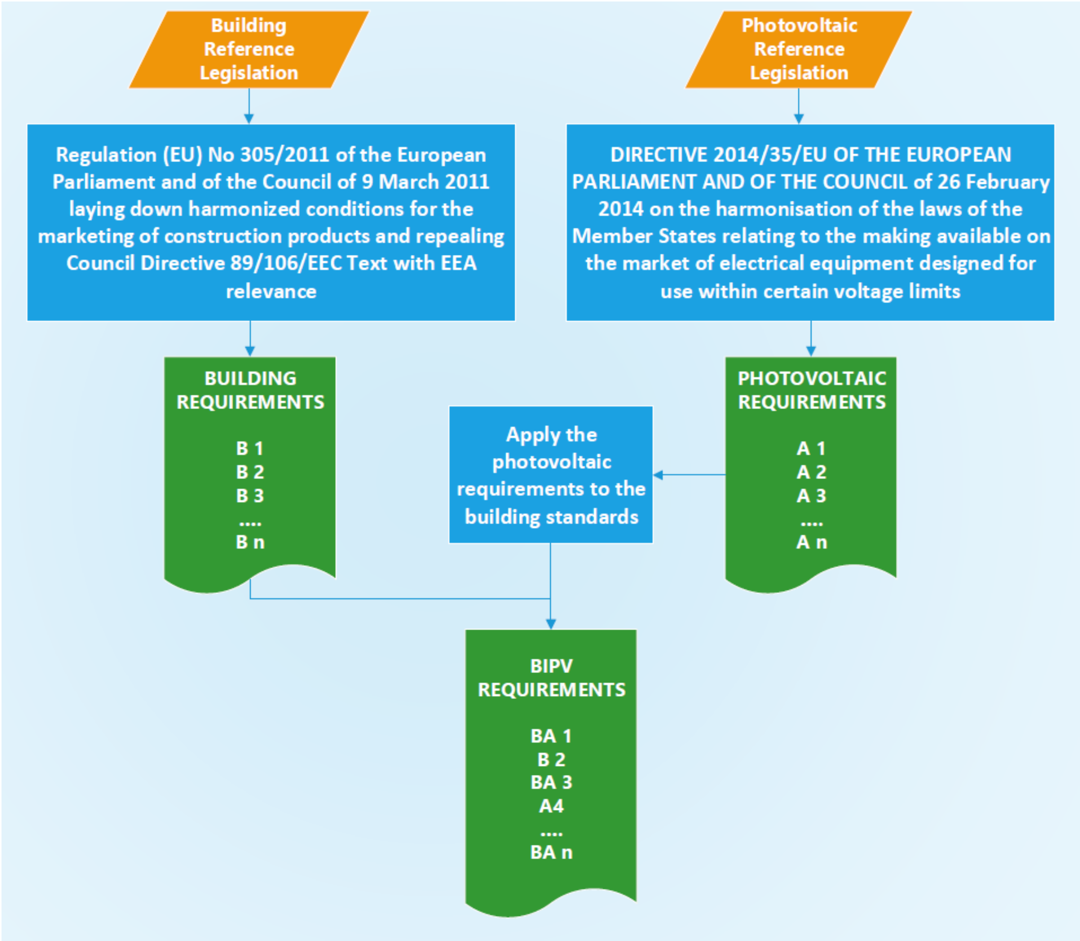


Figure 3.2. Different regulatory frameworks that will have to flow into a single BIPV regulatory framework

3.3 Typological MG: innovative products have not a reference

Very often, novel BIPV products designed to be integrated as construction elements cannot be directly tested based on the applicable PV standards. Testing procedures have been essentially developed for the standard PV modules and the same tests, in the absence of other specifications, are currently extended for the "active part" of BIPV components. This approach finds several limitations since BIPV is entering more and more complex construction products which cannot be longer assimilated to bare PV modules. For example, in **colored PV glasses**, where for aesthetic reasons the glasses are subjected to coloring, texturing, etc., with a consequent non-uniformity of radiation, it will be necessary to develop specific procedures to evaluate how non-uniformity affects the non-conventional electrical behavior (e.g. hot-spot test). Another example could be the use of glass modules with **bifacial cells** in which the standard test procedures should be adapted for a correct qualification. Again, many products, derived directly from building systems (e.g. **prefabricated and composite insulated panels**), already possess specific rules and tests according to building requirements (they can be already certified according to harmonized standards under the CPR 305) but since they integrate PV, they cannot be longer described by the IEC standards for some requirements. Many procedures conceived for a regular PV module in fact cannot be considered still technically valid for composite building components (e.g. procedures for ageing tests in case of multi-layered components with different construction parts interacting with the main active cladding are not specified in the current IEC 61215). Therefore, in order to overcome today's constraints for the market adoption, it is needed to draw and carry out new testing procedures for these **product families**.

3.4 Harmonization MG: a BIPV unified normative is lacking

A "local-based and performance-based approach" is the typical method required for evaluating the compliancy of the construction elements with the relevant building requirements. This approach consists in the identification of the final use and functions of the building envelope. In such a way, it's possible to identify the envelope technological system and solution and to establish the relative reference requirements, namely through the standards and regulations in force, in accordance with the national/local legislative framework.

For instance, BIPV modules can be used as the glazing elements of vertical curtain walls. Curtain walls are regulated in accordance with the EN 13830 "Curtain walling – Product standard" and the glazing elements are regulated depending on their characteristics (e.g. IGU or laminated glass) in accordance with the standards for glass to be used in buildings. In this case, the curtain wall system made of laminated glass-based BIPV modules, according also to the building type and use, shall be able to fulfil the essential building requirements such as the "mechanical resistance and stability" as well as the "safety in case of fire" among others.

With regard to the "mechanical resistance and stability" of BIPV glazing elements of vertical curtain walls, "the electro-technical standard IEC 61215-2:2016 prescribes a mechanical load test based on a prescriptive approach that does not take into account some important aspects for safety and serviceability in buildings such as the deflections of laminated BIPV glass as an evaluating criterion. On the other hand, the relevant standards for laminated glass to be used in buildings (Euro codes, standards for curtain walls, standards for laminated glass) define the principles and the evaluation methods for the design of a laminated glass according to a performance-based design approach".

Accordingly, in some areas, there is not a well-defined practice or **procedure for ensuring the compliance** of BIPV components with the existing normative and in most of the cases this topic is still **fragmented in PV and building sectors** separately, under the responsibility of the different actors involved in the process.

A step has been made in the field of the "safety in case of fire" for BIPV modules with the new version of the IEC 61730. Indeed, the 2016-version of this standard sets that PV modules integrated in buildings have to be tested in accordance with relevant national fire regulations. However, nowadays the local fire regulations do not take into account the use of PV modules, especially in non-conventional applications like façades. Hence, attention should be payed to the peculiarities of the BIPV systems behavior in case of fire to develop new harmonized standards.

Therefore, starting from the "integrated" approach introduced by EN 50583:2016, an **effort of harmonization and definition of new performance reference and procedures for BIPV products** is today necessary and it should be referred to both the design and product qualification process, including installation and O&M. This doesn't only call into question the reference to building codes but also, in some cases, the definition of new procedures specifically developed for BIPV product families and categories (18).

3.5 Flexibility MG: new standardization approach for customized BIPV

The **actual retesting approach** for variations of the BIPV product, as discussed in 2.4, is an example in **lack of flexibility** of current standards applied to BIPV. Standard modules are made on a large scale and therefore produced in countless specimens and placed on the market with those specific technical, physical and dimensional characteristics. The BIPV manufacturers are characterized for offering a vast range of sizes or applications and very often, customized for each project. For this reason, it becomes extremely **expensive** for the manufacturer to retest for each required design change (e.g. differs from the others in size, number of cells and other aspects). A clear market barrier for small producers who are unable to afford product certification and retest is linked to the lack of flexibility in the normative framework.

Standard module (FIPV for Field Integrated PV)

Photovoltaic product

- Made in series (vast number)
- Commodity
- Defined product
- Certified as it is
- Compliance with product normative framework

BIPV module

Building product + add energy

- Made for specific use
- Customization product
- Designed product
- Certified for specific use
- Compliance with different normative framework
  . Building
  . Thermal
  . Electric
  . Etc.…

Figure 3.3 Main differences between standard photovoltaics and a BIPV product

Also in MCS 017 (19)) the approach is prescriptive since for any declared (certified) BIPV product family, two categories of parameters are listed, which must stay the same across the product family or that can vary (under controlled circumstances) across the product family. Concerning glazing and building requirements, the norm states that manufacturers shall ensure that all products within a product family comply with the following glazing standards (as applicable) and "all products are designed and constructed to meet the requirements within the relevant national Building Regulations applicable for the application that the product is intended". Building and PV integration is the still the open point.

It should be considered that for a BIPV-plant of 20 kWp in which the product is customized, so that a re-testing is necessary, the cost of a product certification can reach an incidence of 50% approximately. If we assume 4000 €/kWp, with a final construction cost of 80,000 €, in fact a cost for a complete PV module certification is about 40'000 €: the affordability to certify case-by-case for small plants is very hard, if not impossible. This still remains a **major barrier in the current normative procedure**. How to face this barrier? In the following box we report an extract from CPR 305/2011 where a procedure for construction products is already well affirmed and some principles aimed at addressing customization, cost saving and support small enterprises are enclosed.

How to overcome the current standardization approach with a new qualification scheme supporting both BIPV quality and cost-effectiveness?

If we affirm that BIPV is a construction product, a possible approach is considered in CPR 305/2011. As already mentioned, according to CPR, when a construction product is covered by a harmonized standard or conforms to an ETA which has been issued for it, the manufacturer shall draw up a **declaration of performance (DoP)** when such a product is placed on the market. By drawing up the declaration of performance, the manufacturer shall assume responsibility for the conformity of the construction product with such declared performance. Moreover, the CPR provides further indications concerning the qualification approach for customized products. A manufacturer may refrain from drawing up a declaration of performance when placing a construction product covered by a harmonised standard on the market where the construction product is **individually manufactured or custom-made** in a non-series process in response to a specific order, and installed in a single identified construction work, by a manufacturer who is responsible for the safe incorporation of the product into the construction works, in compliance with the applicable national rules and under the responsibility of those responsible for the safe execution of the construction works designated under the applicable national rules (Art.6 CPR 305/11). Manufacturers shall ensure that procedures are in place to ensure that series production maintains the declared performance (Art.11 CPR 305/11). A further principle is introduced in CPR concerning the possibilities to use **simplified procedures** (Art.36 CPR 305/11) in determining the product-type. A manufacturer may replace type-testing or type-calculation by Appropriate Technical Documentation demonstrating that:

- for one or several essential characteristics of the construction product, which the manufacturer places on the market, that product is deemed to achieve a certain level or class of performance **without further testing or calculation**, in accordance with the conditions set out in the relevant harmonised technical specification
- the construction product, covered by a harmonized standard, which the manufacturer places on the market corresponds to the product-type of another construction product, manufactured by another manufacturer and already tested in accordance with the relevant harmonized standard. When these conditions are fulfilled, **the manufacturer may use the test results obtained by another manufacturer** only after having obtained an authorisation of that manufacturer, who remains responsible for the accuracy, reliability and stability of those test results.

Micro-enterprises (Art.37 CPR 305/2011) manufacturing construction products covered by a harmonised standard may replace the determination of the product-type on the basis of type-testing by using methods differing from those contained in the applicable harmonized standard. When a manufacturer uses these simplified procedures, the manufacturer shall demonstrate compliance of the construction product with the applicable requirements by means of a Specific Technical Documentation and shall demonstrate the equivalence of the procedures used to the procedures laid down in the harmonised standards.

A change of approach in this direction, in a future normative development for BIPV to ensure product durability, reliability and safety without creating unaffordable costs would result in a radical change in the whole sector and in a market competitiveness for the coming years.

4 ROADMAP FOR A PERFORMANCE-BASED APPROACH IN BIPV QUALIFICATION

All questions discussed so far, including the potential to introduce a new qualification approach inspired by the principles of the CPR 305/2011 for BIPV, encounter a major basic aspect which is a pre-requirement: **the lack of harmonized standards or technical normative (hEH, ETA, EAD, etc.) supporting the BIPV sector**. From the analysis of the current regulatory framework, it emerged that the current BIPV standardization framework is not sufficiently developed, so that it arose the need to identify new performance levels and test methodologies suited to ensure the quality of PV modules in the building skin. Therefore, a possible path is considered achievable by developing a **new approach for the qualification of BIPV products**, **coherent with the principles of CPR 305/2001** considering BIPV as a construction product, grounding on the analysis of the missing gaps and criticalities emerged in the previous chapters. This part applies to active construction products containing PV parts as specified in the EN 50583-1: 2016 Photovoltaics In Buildings - PART 1: BIPV modules and EN 50583-2: 2016 Photovoltaics In Buildings - PART 2: BIPV systems. It focuses on the properties relevant to essential building requirements as specified in the CPR 305/2011, and concurrently, the applicable electro-technical requirements stated in the Low Voltage Directive 2006/95/EC/ or CENELEC standards. This chapter will provide a **roadmap describing the principles and basic approaches to define new reference performance-based procedures for BIPV products qualification**, as a general guideline for operators as well as the basic ground for next developments of the BIPVBOOST project in the coming years.

4.1 Performance-based approach for BIPV: reference criteria

The **prescriptive codes** have a long history and, while they have their limitations, they also have advantages, such as being more straightforward to apply. This approach requires that each element of a building has a minimum acceptable standard. For example, prescriptive tables provide a specific value for different types of construction across different scenarios. When using the prescriptive path to code compliance, this method doesn’t require conducting calculations and merely involves following a chart. The prescriptive approach has been around for a long time in PV codes (e.g. IEC normative) since a PV module is a standard element applicable in standard scenarios and also because, in some areas, it may be hard to define the exact performance levels. However, this approach demonstrated all the limits applied to BIPV, since the several and complex scenarios in the built environment cannot be standardized in pre-defined scenarios and the prescriptive perspective would introduce too restrictive compliance criteria for building components and their application fields, which would result ineffective for the real market needs.

Contrariwise, some of the advantages of a **performance-based** regulation include the support of a safety culture, fostering of an open, fair, and predictable framework through the rationalization of the regulatory process and favoring contacts between regulators and industry. As a matter of principle, performance-based procedures do not prescribe the value of the characteristics, nor the criteria for deciding on the suitability of a particular product, but provide the means to assess them. Prescription and criteria are matters for regulations, usually set by national authorities, or the user e.g. architect, building owner. A performance-based procedure must be based on the reliability-based principles that have to be defined as a number of limit states to be explicitly checked. The performance-based approach to design usually relies on the use of engineering principles, calculations and/or appropriate software modelling tools to substantiate the proposed solution and to satisfy the limit-state. When using the performance-based pathways to code compliance, values are entered into a model, allowing the building designer to optimize the various components, equipment and assemblies, saving money, time and operating expenses.

However, since the prescriptive approach is simple to implement in achieving the desired level of safety, it can be a first choice when specifying a safety strategy only if its use can be justified because it offers flexibility in design, reduced construction cost and improved safety. The method based on prescriptive procedures is not free of design limitations and does not provide detailed information about the performance under complex scenarios, which is often crucial if a failure in real operating conditions must be avoided. The approach of performance-based design becomes therefore more and more suited for BIPV sector and recent market dynamics also considering that it is already implemented in building industry (e.g. structural, fire, energy engineering, etc.).

Due to counterpoising effects of those aspects, it is not possible to a-priori evaluate which approach leads to the safest or the most economical design in general terms. A detailed study of the different aspects is therefore of interest in the next part of the project (T5.2. Development of specific performance-based laboratory testing procedures for BIPV modules). Anyway, the testing procedures will have to be developed in the perspective of supporting a higher design flexibility based on performance objectives, to constitute a beneficial and competitive concept for BIPV engineering, ensuring a higher reliability level of a design choice, a simplification of the testing procedures and a reduction of the needed time and costs.

As already adopted in Eurocodes, the BIPV system and its construction parts should be designed, executed and maintained in such a way that the structure during its intended life, with appropriate degrees of **reliability** and in an **economic way**, will remain fit for the use for which it is required, will sustain all actions and influences likely to occur during execution and use, will not be damaged or will have a controlled damage by pre-defined events, impact or consequences. The choice of the levels of reliability should take account of the relevant factors, including the possible cause and/or mode of attaining a **limit state**; the possible consequences of **failure** in terms of risk to life, injury and potential economic losses; public aversion to failure, and social and environmental conditions in a particular location; the expense and procedures necessary to reduce the risk of failure (https://eurocodes.jrc.ec.europa.eu/). The levels of reliability that apply to a particular BIPV family may be specified by classifying the structure as a whole or by classifying its components. The system "**working life**" is another important aspect since it represents the assumed period for which it has to be used for its intended purpose with anticipated maintenance but without major repair being necessary. The notion of design working life is useful for the selection of design **actions** (e.g. mechanical load, temperature, etc.), the consideration of material **property** deterioration (e.g. fatigue, ageing), evaluation of the life cycle **cost** and developing maintenance strategies. The procedure for BIPV qualification should assume that appropriate measures are taken in order to provide a component/system, which corresponds to the requirements and to the assumptions made in the design. These measures comprise testing procedures with definition of the reliability requirements, and they should be integrated with organizational measures and controls for the stages of design, execution, O&M.

4.1.1 Limit states for BIPV

To use the performance-based approach, it is necessary to define, for each of the different requirements to be achieved, **limit states (LS)**. A limit state is a condition of a system (a structure in case of structural engineering where the method was introduced) beyond which it no longer fulfills the relevant pre-defined (e.g. Design) criteria. The condition may refer to a degree of actions on the system (e.g. a load on a structure), while the criteria refers to system integrity, fitness for use, durability or other requirements. A system designed by LS is proportioned to sustain all actions likely to occur during its design life, and to remain fit for use, with an appropriate level of reliability for each limit state. Procedures and codes based on LS implicitly define the appropriate levels of reliability by their prescriptions.

For BIPV products, we define three possible limit states, as following described.

Table 4.1. Limit states for a performance-based assessment of BIPV

BIPV-Serviceability Limit State (SLS) *"BIPV product under* a frequent use condition *can change the behavior/condition but it must remain reliable and functional for its intended use without damages".*
The SLS represents a condition in which the BIPV building skin module/system is useable as originally intended and designed in a frequent use condition. The system, under SLS actions, must remain reliable and functional for its intended use (e.g. energy production, building functions ensured, etc.) after being subjected to routine/typical loading/agent and it is not compromised in any of its building and electrical performances. Example: A normal wind load is applied to the system in operation. It behaves in an elastic mechanical state, the energy production is not affected and the action doesn't compromise in any way the materials and building/electrical functions, safety, efficiency and reliability. After the action the construction come back to the initial state.
BIPV- Safeguard limit state (SfLS) *"BIPV under a rare event may suffer permanent damages but it must ensure a safe user evacuation for people and things. It does not maintain the initial functionality".*
After a rare event that induces a certain input action (e.g. mechanical action, electrical load, etc.) the system may suffer permanent damages and performance reduction, being also economically unrecoverable, but it should ensure a safe user evacuation and a certain residual protection against after possible shocks (e.g. avoiding collapses). The SfLS represents a condition in which the safety of a BIPV building skin system and its users is ensured. Safety, in terms of construction and electrical aspects, is safeguarded and it can be assumed as long as this state is fulfilled. Example: a rare and unexpected mechanical load, exceeding the design load, is applied to the system in operation. It suffers a construction damage with breakage of parts, being unable to still function as a skin cladding (e.g. water-tightness, weather protection, mechanical stability are lost), and with interruption of its energy production. However, the systems don't suffer a complete collapse (parts are still attached to frames and don't fell down, electrical shocks are avoided thanks to protection systems, etc.) so that people safety is still safeguarded after the event as long as the system is replaced.
BIPV-Ultimate limite state (ULS) *"BIPV collapses in a performance mechanism. Safety conditions are no longer guaranteed".*
In principle, collapse occurs when the first element in a system reaches collapse in a performance mechanism according to a limit value. The different definitions of collapse available in codes and the published literature can be used to define collapse predictions.

Example: The same used for SfLS but with the difference that the systems suffer a complete collapse (parts are not attached anymore to frames and fell down, electrical shocks and other phenomena can seriously be a danger for people) so that people safety is at risk after the event.

In defining **LS within new testing procedures**, starting from the general definition above, specific definitions will have to be found in relation to the technical requirement investigated, to both the electrical and building aspects involved (e.g. the same LS can involve the definition of different electrical and construction safety/reliability levels) and also in relation to the product family concerned.

4.1.2 BIPV product families and references to existing normative

The specific development of new procedures for the qualification of a BIPV product family requires including both the PV active part and the building skin functional construction, providing energy production and construction functionalities, respectively: **composite units** for building skin claddings, with an active PV layer, are concerned. The construction part belongs, in accordance with CPR No 305/2011 (e.g. harmonized standard or EAD), to a certain construction component family. The PV part, in accordance with electro-technical normative (e.g. IEC 61215) belongs to a certain PV module family. Moreover, since the active part can be made of another element assembled to the construction kit (e.g. a glass-glass opaque PV laminate with c-Si cells bonded to another construction element) it also belongs, in accordance with CPR No 305/2011, to a construction material family (e.g. the Glass in building — Laminated glass and laminated safety glass as define, according to EN14449).
The **product family** can be categorized and sub-divided according to the main components, materials and intended use in the building skin and construction:

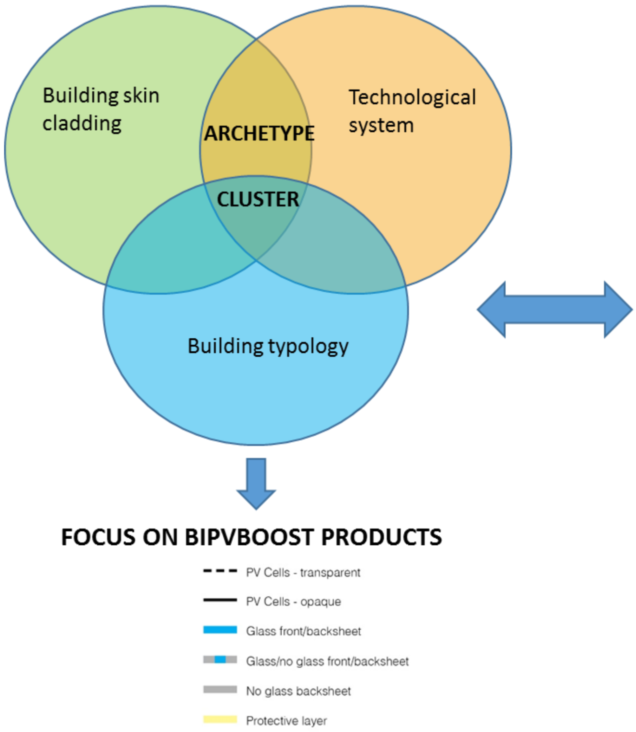
- **BIPV Family:** Construction+PV composite product (e.g. Composite cladding system);
- **Construction product/Building skin sub-level**: Construction sub-element/system (e.g. As defined in hEN, ETA, EAD according to CPR 305/11)
- **Construction main material sub-level**: e.G. Laminated glass and laminated safety glass (E.g. according to EN1444);
- **PV module sub-level**: E.g. Crystalline silicon terrestrial photovoltaic (PV) modules (E.g. EN 61215);
- **Building use sub-level**: E.g. building type definition, if needed (residential, high-rise, etc.)

Based on this scheme, the **classification** could be in principle based on the intended use or on architectural category rather than based on the material making up the product (see EN 50583:2016). However, defining in advance a predefined set of families of products it is not of interest in the proposed approach since it could only generate constraints and difficulty. First of all, a family of BIPV products could have the same **behavior for a particular requirement** (e.g. mechanical load) but different behavior for other requirements (e.g. fire behavior). Thus, a definition of categories to which apply procedures would fail. Secondly, we're going to define, for each requirement under investigation, the possibility to refer the **procedure to specific product classes** already set in existing norms (e.g. standards already existing according to CPR305/11 in order to normatively reference the procedure to existing norms) and eventually extend the validity of the testing procedure to a range of parameters that are allowed to vary across the product family. A section in the procedures to be developed in the next T5.2 of the project will set out the extent of variations and customization levels permitted for component parts in the BIPV product family.

The procedure will have to specify how it is exactly **correlated to existing norms**. If it is linked to a specific chapter of a norm as an annex/replacement/specifications. e.g. “the procedure described in 6.1 is intended as an alternative testing method in place of chapter 5.4.1.2 of EN12600”. The references to international standards, technical reports and guidelines or to national standards in some cases (or regulations) will ensure that the content, in whole or in part, are normatively referenced for its application.

By considering the product family and the correlated Limit States, the main **product classes** applicable to the tested requirements will be listed, by specifying the main parameters defining it, in relation to reproduction of the environmental and operative conditions, installation scenarios, etc. (General, Construction aspects, Electrical aspects, Aspects related to application conditions or intended use in building, etc.)

As a general reference of building skin systems anyway, we propose to use the classification representing the main archetypal systems existing on the market (see Report D1.3 BIPVBOOST, available at www.bipvboost.eu).



CLASSIFICATION B: WP1- Archetypes		
	1	Semi-Transparent insulated glazing
	Technological system	Curtain wall, Skylight
	Cladding	Glazed, Transparent, Insulated
	2	Semi-Transparent laminated glazing
	Technological system	Double skin, Canopy, Railing, Louvre
	Cladding	Glazed, Transparent, Laminated
	3	Opaque glazed element
	Technological system	Rainscreen façade, Spandrel , Cold roof, Railing , Louvre
	Cladding	Glazed, Opaque, Laminated
	4	Opaque no-glazed element
	Technological system	Rainscreen façade,Cold roof, Railing, Louvre
	Cladding	No glazed, Opaque
	5	Opaque prefab element
	Technological system	Prefab roofs or facades
	Cladding	Multifunctional, Opaque

Figure 4.1 BIPV products segmentation according to archetypal application as described in D1.3

In this case there are 3 fundamental parameters for classification:

- building skin cladding
- the technological system
- the building typology

From these 3 parameters some families can be obtained that will have to be subjected to stress to validate the result. In the next step of Task 5.2 in which all the characteristics and expected behaviors will be analyzed in detail along with specific requirements to obtain new test procedures to qualify BIPV solutions, the product families will be further defined, where possible, or referenced to already existing normative classes. The family will be intended as the reference BIPV composite product group on which the specifications and test procedure of the document are applied.

4.1.3 Combined testing approach: beyond standard conditions

BIPV research teams around the globe have taken on the challenge of generating knowledge and providing solutions related to the integration of photovoltaic technologies in buildings. These research teams are in contact with each other on a regular basis e.g. though conferences, international consortia and in the IEA PVPS Task 15 community. The report "BIPV research teams & BIPV R&D facilities. An international mapping" by IEA PVPS Task 15, Subtask E (20) gives a general overview of the international BIPV-related research teams and facilities, information regarding BIPV outdoor testing facilities dedicated to BIPV. However, at the state-of-the-art, most of the facilities are based on procedures and standards set for energy rating of conventional PV (e.g. IEC 61853-3&4), applied on products or mock-ups representing BIPV installation scenarios, showing often the **limits** of such an approach if compared with **real installation conditions in building skin**.

Given the complexity of BIPV products, it is not possible to create a specification valid for each BIPV family. The crucial point is to understand that it is not possible to **describe the BIPV's behavior** with only PV rules; it is also true the opposite so that only building rules are not valid for taking into account the interaction of the PV active part. The standard PV conditions applied so far surely did not describe properly how the BIPV module behaves in operating conditions and in building skin scenarios. The PV active part e.g. influences and changes some construction characteristic and behavior (e.g. thermal conditions of the cladding, electrical safety, etc), so that new testing procedures should introduce the **combined effect of PV and building performance**. For example, A typical BIPV specific characteristic is a higher operating temperature, compared to the standard PV module (and some conventional building products). BIPV module's temperature can be very different with respect to the same "non-active" building component, moreover there could be hotspots and at the same time a mechanical stress as hail impact. Consequently, BIPV modules are subjected in the real conditions to different stress like mechanical and thermal loads. About the thermal impact on the electrical power output and building functions of BIPV products, the current standards consider these characteristics separately from the standard PV module and conventional building products. E.g. up to now, there has not been much information available about the thermal impact on the electrical power output together with thermal and mechanical relevant building functions. Hence, the accuracy of the system and building design could not be achieved. In some previous researches the investigation of thermal impact on electrical, thermal and mechanical characteristics has been investigated on different load scenarios, operating temperature, load duration and different mounting systems, by displaying the results of the combined effect (21).

Starting from these considerations, a new approach should consider the contemporaneity of effects/actions in order to accurately describe the BIPV behavior in a performance-based approach aimed at reproducing the limit states, the quality and reliability issues related to operating conditions. It is important to analyze the behavior of a BIPV product not only in its starting life but also considering the occurrence of limit states and performance needs according to a **lifetime and working time** in order to relate limit states and critical conditions to the lifetime. Moreover, also the analysis of failure modes events and **post-failure behavior** should be properly addressed according to the LS defined (what if a BIPV parapet reach the ULS in terms of electrical and building safety?). The next Task 5.2 will try to implement such an approach in developing new testing procedures.

4.2 Workflow for developing new testing procedures: structure, key-steps and link to normative

This chapter shows a conceptual workflow that will be applied as basis for the new procedures in the next Task 5.2. This procedure will lead to the required result starting from the missing gaps previously analyzed, considering the boundary conditions (regulatory framework, typology and functionality, external environment etc.), by defining key process indicators to arrive at the performance assessment.

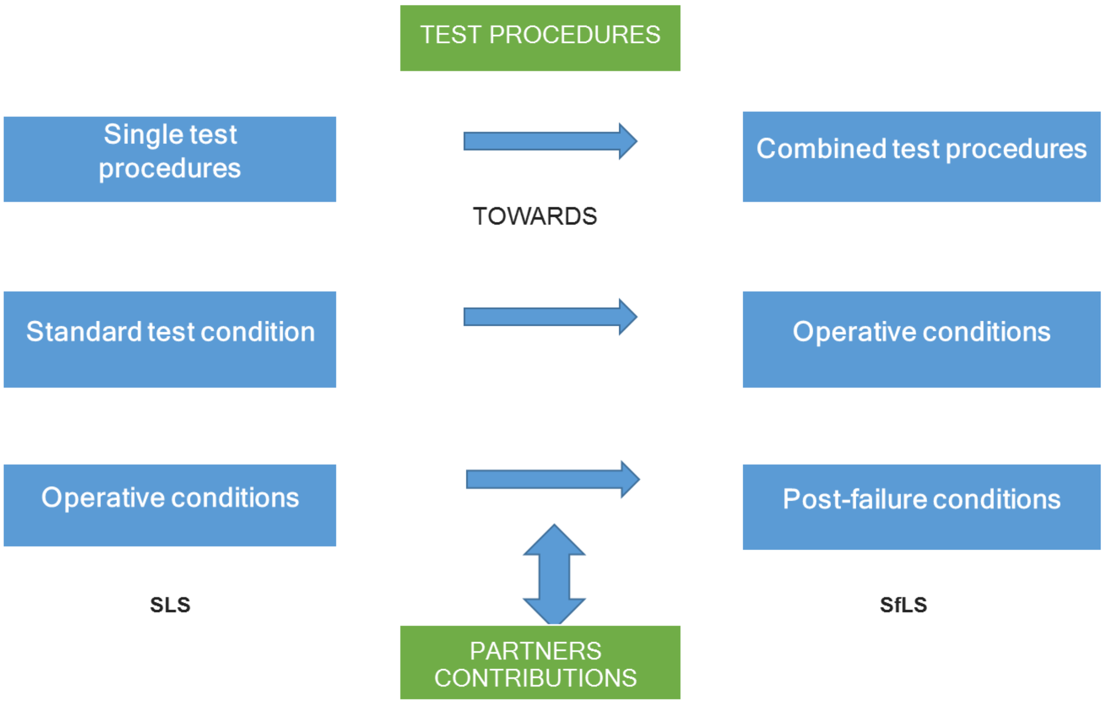


Figure 4.2 Key-points for developing new testing procedures in next stages of the project

The workflow is divided in key-steps:

0. **Missing gaps previously identified**: the need, goals and motivation for the procedure are clear
1. **Definition of results/expectation**: the scope of the testing procedure and the specific technical requirement to be addressed/assessed are defined
2. **Key-Process Analysis**: all boundary conditions for the new procedure have to be identified in order to clarify the links of the procedure in terms of normative references, process, product family extension, etc.

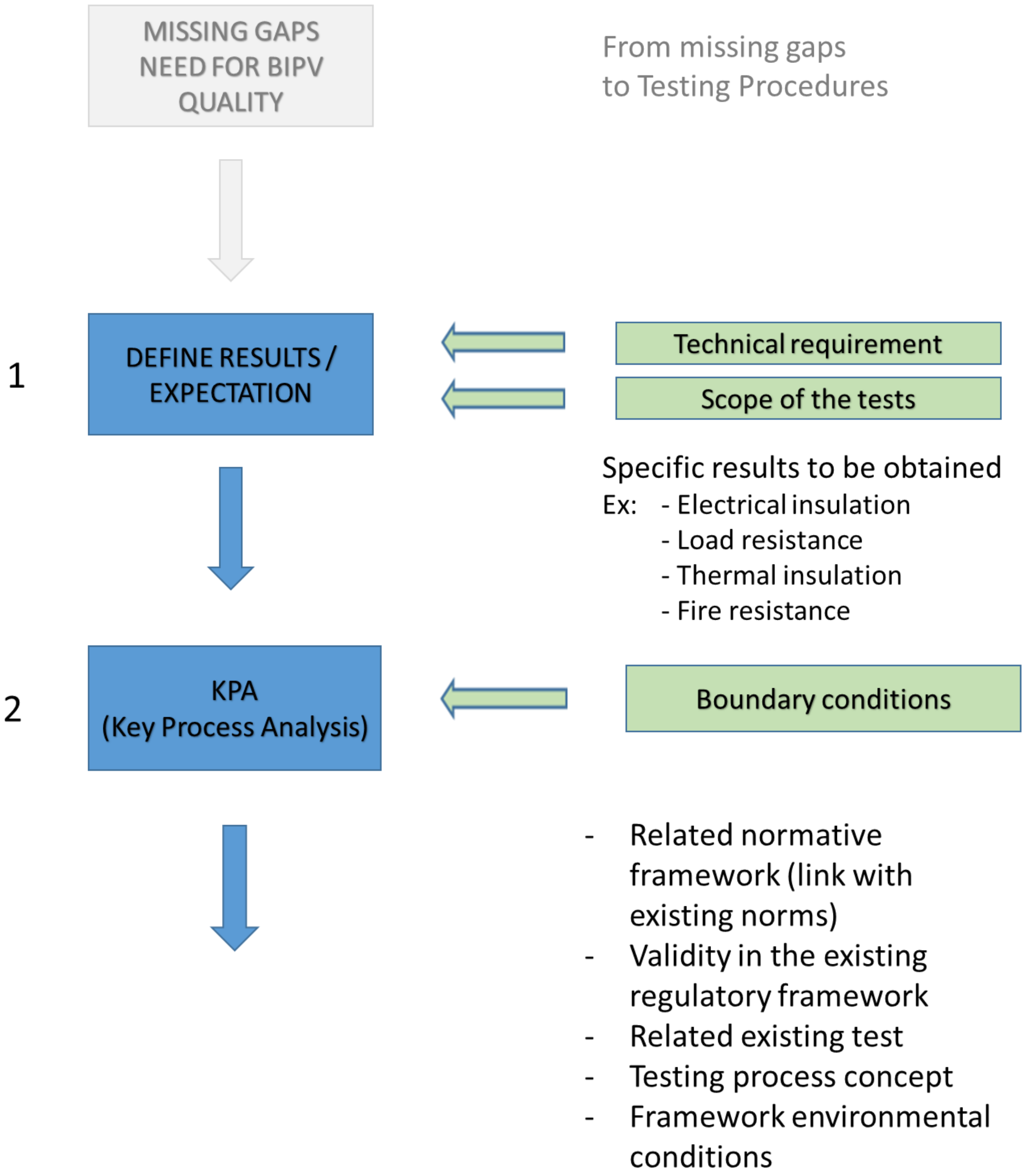


Figure 4.3 Workflow for developing new testing procedures: part 1 and 2.

3. **Definition of test methodologies and equipment**, in order to set and define which are the product families, the limit states, the combined performance, the eventual post-failure aspects involved in the testing procedure, including the description of testing equipment and test validity and repeatability.
4. **Definition of the output targets for the test procedure**, namely the KPIs resulting as "value" of the test describing the BIPV performance

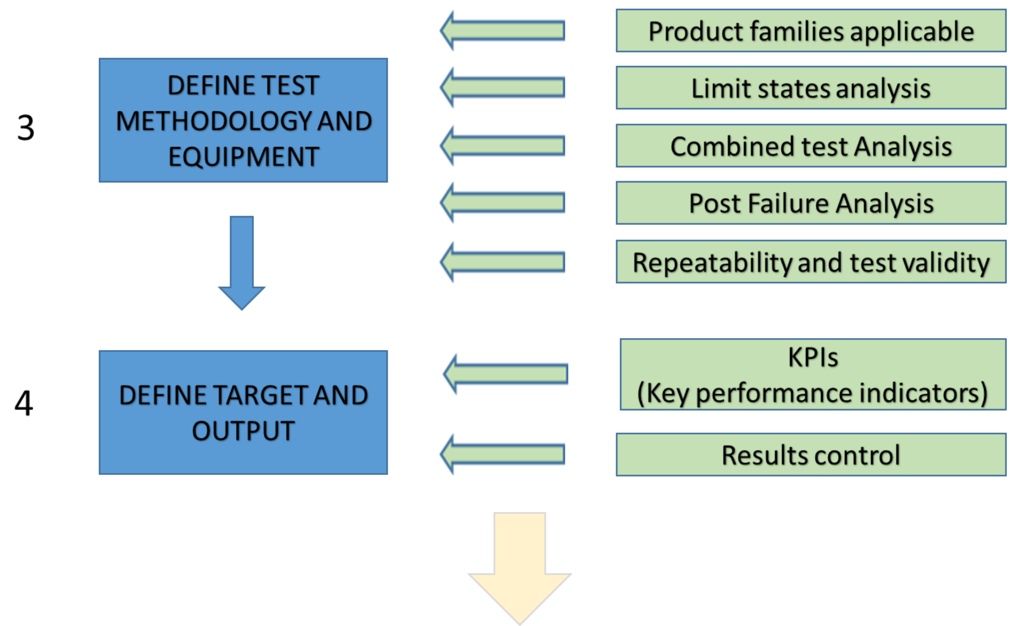


Figure 4.4 Workflow for developing new testing procedures: part 3 and 4.

Last but not least, it must be considered that a test methodology has an impact in a whole perspective so that the design of the workflow cannot focus only on technical aspects, but consequences concerning cost, process, real market, etc. have to be considered in order to really address and support the BIPV sector.

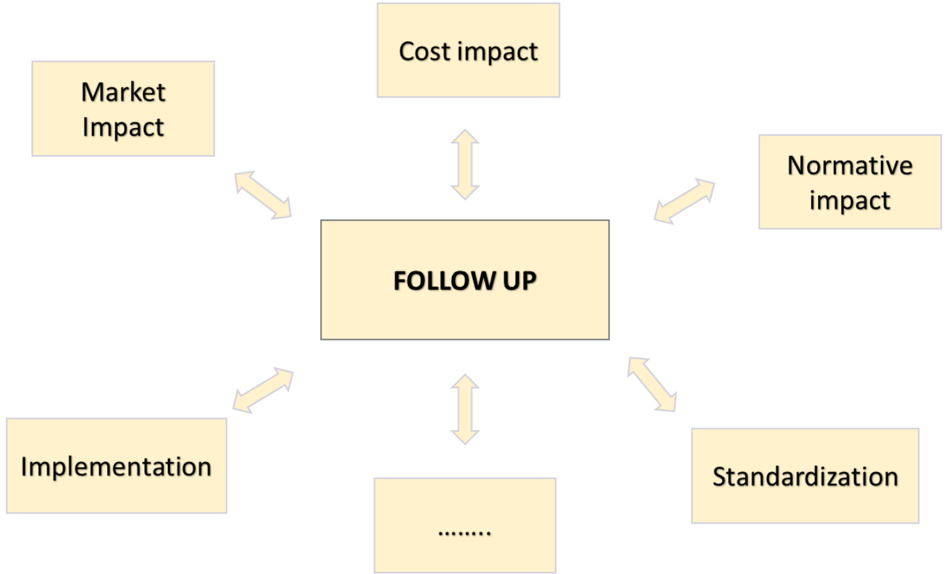


Figure 4.5 . Development of new testing procedures. Additional actions to be considered.

5 CONCLUSIONS

The development of BIPV products playing a multifunctional role, involves the use of several materials that must coexist in the same unitized construction component. These elements, electrically active and non-active, assembled together, mutually induce and influence changes both in the energy performance and in the construction requirements, such as the energy yield, dissipation of heat, the mechanical and fire behavior, etc. This performance relations have been only partially investigated at the state-of-the-art of BIPV quality assessment. However, due to the weight, size and the interaction between PV and building parts, the quality assessment requires to go further than the application of the test methodologies provided separately by the PV or by the building regulations.

As of today, the current regulatory framework of BIPV is mainly grounded on the standard EN 50583, which gathers a set of norms coming separately from standard PV and traditional "non-active" construction products. However, an assessment of the features, operation conditions and requirements to be fulfilled by BIPV systems clearly evidences that such approach is not valid and efforts for defining new testing procedures are required. Designers, manufacturers and installers currently overlap procedures developed for standard PV with other standards already present in the building sector (for non-active elements) such as norms related to glass, to fire safety, etc. In other cases, the definition of the performance levels is based on their experience (e.g. glass producers have a great experience in glass performance/qualification which they extend to active products) or derived from other similar projects. Therefore, a possible path is considered achievable by developing a new approach for the qualification of BIPV products, coherent with the principles of CPR 305/2001 considering BIPV as a construction product, grounded on the analysis of the identified missing gaps and criticalities. In 2017, a new attempt was made within IEC TC82 (82/1339/DC) to establish a project team, the PT 63092 "Building Integrated Photovoltaics (BIPV)", which included experts from ISO, IEC, and the IEA PVPS Task 15. However, to make tangible innovation, this research path will have to be implemented within a unified and effective approach aimed at developing and make available a clear normative framework ensuring reliable, safe and efficient products for the market in a cost-effective way. The specific development of new procedures for the qualification of a BIPV product family requires including both the PV active part and the building skin functional construction, providing energy production and construction functionalities, respectively. Through the implementation of a Limit State (LS) approach within new testing procedures, specific definitions will have to be found in relation to the technical requirements investigated, to both the electrical and building aspects involved (e.g. the same LS can involve the definition of different electrical and construction safety/reliability levels) and also in relation to the product family concerned.

Under this perspective, cost and time saving will have to be taken into account in order to answer the main market demands, by reducing the number of steps needed for the qualification, eliminating duplicities, requiring only certain limited tests for upgraded or modified products, achieving direct acceptance by regulators, retailers, buyers and vendors in many countries. On this ground, next activities will be aimed at progressing on the research and development of new qualification procedures, as a support to other actions devoted to progress on standardization.

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