PERFORMANCE ASSESSMENT OF BIPV SYSTEMS: FROM CURRENT NORMATIVE FRAMEWORK TO NEXT DEVELOPMENTS

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ABSTRACT: 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 more evolved than the only energy production, is imposing a profound change in the sector of Building Integrated Photovoltaics (BIPV), with major challenges to be addressed in the coming years. Supported by an increasing technological development, by digitization and process innovation, such systems will progressively be implemented in the construction market allowing the achievement of the nZEB policies. BIPV products are evolving from the basic architectural integration towards multifunctional products, aggregating essential PV requirements with additional requirements from the building skin such as thermal insulation, solar control, fire safety, water tightness, etc.

However, to effectively enter the building market, the BIPV products will necessarily have to respect the goal of cost-effectiveness as well as the compliance with adequate quality, safety and reliability levels. In this context, the H2020 project "BIPVBOOST" is focused on obtaining a reduction in costs along the entire value chain by pursuing product and process innovation, thus supporting the BIPV implementation in a wider mass market of the built environment. In addition to a technological development, it is essential to solve the interconnection between PV product standards, construction industry standards and specific rules for the installation and use in buildings. The EN 50583-1:2016 and EN 50583-2:2016 [1] made a first step in this direction by defining the properties and the applicable regulatory framework for PV systems 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 elements, so that a significant progress regarding BIPV qualification is still needed, and it represents a current barrier for the market access. It arises the need to identify new “multi-disciplinary” reference requirements, to improve the definition of the performance levels and to develop new test methodologies better suited to the use of PV in the building skin. Therefore, these issues will be addressed within the project by identifying the gaps in the current standards and by implementing a performance-based approach for the qualification of BIPV products. The paper, summarizing the first investigations of the project, will provide an overview on the current normative framework, reporting the main missing gaps and a roadmap to define new reference procedures for BIPV products qualification, setting the basic ground for next developments in the coming years.

Keywords: BIPV performance assessment, standards, performance-based approach, quality, BIPV testing

1 INTRODUCTION

Directive 2010/31/EU of the European Parliament and of the Council (‘EPBD’) is the main legislation, together with Directive 2009/125/EC of the European Parliament and of the Council and Regulation (EU) 2017/1369 of the European Parliament and of the Council, addressing energy efficiency in buildings in the context of the 2030 energy efficiency targets. The EPBD has two complementary objectives, namely, to accelerate the renovation of existing buildings by 2050 and to support the modernisation of all buildings with smart technologies. It is important to ensure that the improvement of energy performance of buildings follows an integrated approach, taking into account measures both on building envelope and on technical building systems.

BIPV systems are increasingly playing a fundamental role in the construction sector [2]. Supported by a growing technological development and market demand, BIPV not only performs an aesthetical function but becomes an intrinsic part of the building envelope, providing additional functionalities, where energy production becomes an additional one. Examples of this are the thermal insulation properties, the noise reduction capacity, the ability to adapt the solar factor, or the compliance with safety regulations [3], [4], [5]. In this context, the use of BIPV systems in architecture requires progressing from the current regulatory framework, still lacking of a combined PV-construction vision, to a new standardisation framework that thoroughly addresses a specific BIPV product qualification and certification procedure, allowing a wider market implementation [6]. A first step was given by the BIPV standard EN 50583 (parts 1 and 2), which proposes a standardization of BIPV elements as conventional building and photovoltaic products, separately. However, the coupled PV-construction related performance of an electrically active building skin system can significantly differ from a traditional construction system or a non-integrated PV module. Following that conviction, the general approach of the paper considers the BIPV product as a complete building product (thus already established in the construction sector and with clear functionalities, requirements and regulatory framework) with an added function of energy production, by integrating PV elements (cells, modules, etc.), power electronics, etc. In this context, the purpose of the work is to provide a comprehensive overview on the current regulatory framework applicable to construction and PV products, while identifying the main missing gaps and proposing routes for new qualification methodologies specifically adapted to BIPV products. This will require to understand, from a global perspective, how can PV related features, components (solar cells, junction-box, etc.) and performance levels (energy, mechanical, fire, safety…) be precisely taken into consideration within a standard or normative approach developed for a building product. By focusing on pre-defined requirements and specific product technologies developed within the consortium, new approaches will be set to determine, test and validate the behaviour of BIPV products, considering the fundamental aspects of multifunctionality and cost reduction.

2 METHODOLOGY

The purpose of this paper is to identify the **main routes** to contribute to a BIPV **cost reduction** through an advanced scheme supporting the qualification for a massive and reliable implementation in the building sector. In the realization of a **new approach for products qualification**, it is fundamental to control the level of performance for different **BIPV product families**, which cannot be easily standardized in conventional categories, and to focus on specific **technical requirements**, identifying missing gaps in the current framework and proposing new procedures that tackle them accordingly.

As an essential preliminary investigation, the paper starts identifying the **state of art** of the regulatory framework, detecting the current **missing gaps** related to the most relevant BIPV features, components and performances and defining the **main routes** for new qualification procedures applicable in the BIPV sector. The process will be supported by the direct feedback of the industrial partners of the consortium (Onyx Solar, Flisom, Ernst Schweizer, Tulipps and PIZ). The activity is also the joined result of the participation from SUPSI, TECNALIA and CSTB in other projects and actions related to the standardization topic such as the most recent Task 15 IEA-PVPS Subtask C: International framework of BIPV specifications [6], Construct-PV [7] and PVSITES (Grant Agreement nº 691768) [8].

3 STATE OF ART IN BIPV NORMATIVE FRAMEWORK AND QUALITY ASSESSMENT

Solar PV technology today has the potential to exploit existing buildings' surfaces. 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 an adequate quality, safety and reliability. 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 nZEB policies.

Nevertheless, the current regulatory framework mainly collects norms created for standard PV or, on the other hand, for "non-active" traditional building products, thus lacking of the required combined framework required for a BIPV element, which combines functionalities coming from both fields. As a result, significant progress for the adequate qualification of BIPV systems is still needed, which represents a current barrier for its market deployment. From the current regulatory framework, it arises the need to identify new "multi-disciplinary" approaches, to define adequate performance levels and develop new testing methodologies better suited to the qualification of PV in the building skin.

3.1 Conventional PV modules and systems

According to the International Electro technical Commission Glossary a PV 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 that 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)). In particular, conventional PV modules are subjected to the electro technical certifications in accordance with the IEC standards. What is relevant to note is that, the 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). 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".*

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 application.

3.2 BIPV modules and systems

In the EU context, a construction product is 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).

With the aim of clarifying 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 systems). Specifically, this standard sets 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"*.

In the Commission Recommendation (EU) 2019/1019 of 7 June 2019 on building modernisation, 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 [9].

In summary, the current situation for making available a product on the market is that:

- The CE mark 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 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 EN 50583:2016 is not a mandatory standard, even though the unique normative concerning BIPV at EU level.
- Typically, the standard in force for the building skin components are extended and applied to BIPV to ensure an adequate construction performance (e.g. this is already adopted in many BIPV glasses).
- The building normative, which were not originally is conceived for "active" elements, especially with regard to some technical requirements for BIPV (fire, mechanical), that demand further developments and investigations[10] [11].

3.4 Can we use standard PV modules in the building skin?

So far, the majority of BIPV applications have been developed according to the following product's categories and approaches:

- *Conventional PV modules* are used in building applications (mostly for roofs) thanks to an adaption of some module's features (e.g. special frames for roof integration and water tightness). The certification scheme in these product cases usually include IEC standards and, case-by-case, the compliance is extended to some relevant building requirements (e.g. water tightness, fire safety, etc.). Such products usually have a low extra-cost for a final user quite comparable to conventional PV, since they are generally quite standardized PV modules/kits adapted for building mounting (e.g. on/in-roof). The application in the building skin is mainly under the responsibility of installers and partially of the manufacturers of the basic components.

- *PV modules declared as BIPV systems* (mainly with glass-based BIPV modules) are usually produced by building industries capable of adapting building glasses and transform them into active elements by means of PV cells (e.g. curtain walls or cold façade systems). In this case the certification schemes, referred to the conventional building products, usually go beyond the IEC standards, including building performances assessment and qualification according to CPR 305/2011 (e.g. norms on safety of glazing which are typically respected by glass manufacturers producing glass-glass PV modules). Such products cannot usually be directly compared to a conventional PV module for their multi functionality and performance.

However, the main question very often is still: *"is it possible to use a "conventional" PV module for a BIPV project?".* This is still a recurrent question since it opens the way to a simplified approach, using conventional modules, cost effectiveness, in focusing on only electrical aspects without opening building quality issues. For what it is reported in the previous sections, the enquiry can be considered as a "misleading" question. The real logic process to evaluate the applicability of a component in the building skin is, first, to define its construction 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 quality standards arising from the building sector (European, national, local, etc.) in order to be safely installed and introduced on the market. 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 in a building perspective today are:

- To define the **technical element of the building envelope** where PV will have to be integrated (e.g. 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 a 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 performance** satisfies the performance targets of the building skin (does it respond to the requirements set by normative?), defining its applicability ranges as a building element or if it needs to be adapted.

3.5 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. It is not a simple challenge since very often architectural design requires specific and tailored solutions for each single project. In many cases the "building assessment" leads to corrective actions in the module's design in order to make the component compliant to 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 require retesting in accordance to the IEC Standards as a mandatory procedure. In detail, the procedures for the initial qualification and additional retesting of a standard PV module are unified 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 demonstrate the safety requirements of an already certified product, depending on the related modifications. This leads to uncertainty and unclear situations in the current market as described in the next paragraph.

3.6 What about the real market in the current situation? How do BIPV players get oriented in the current framework?

Real example and user stories provide evidence of the current difficulties in qualifying BIPV products and the correlated risks in terms of responsibility in which players today incur. In further detail, some technical performance bridging PV and construction aspects do not have a clear reference in the actual normative. In cases when this lack does not become a "**no go**" for the process, the problem is usually solved thanks to the expertise of operators and stakeholders (engineers, manufacturers, installers) which, in response to specific orders, try to combine in the best way the applicable rules, taking the **responsibility** for a safe incorporation of products in construction works. Accordingly, designers, manufacturers and installers currently tend to **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.

The conditions under which BIPV has been introduced to the market so far are basically the following:

1) Abandoning the BIPV option, by opting for the standard applied PV on roof. Likely, this is not supposed to be a possible option in the perspective of nZEBs for the coming years, since more and more surfaces beyond the roof will be necessary to achieve energy efficiency targets.

2) Products introduced on the market with the label of "BIPV" but in derogation of building regulations under the CPR 305/2011 (conventional PV modules applied without any qualification for building requirements) with consequent potential risk that critical events may occur for safety, reliability, etc. during operation and across the lifetime.

3) Products introduced on the market which fully comply existing PV and building codes under CPR 305/2011 (e.g. harmonized standards for glass) for the single identified construction work. The matching of this process with IEC qualification is quite hard, time consuming and costly so that it is put in action typically by the big industrial players (or relevant/pilot projects), since they can afford costs, or the building can absorb the qualification costs.

The high costs of the certification process, which very often covers only a limited group of product families, are often the reason for not dealing with BIPV (or using pre-defined and non-optimal configurations) in cases when the client requests don't meet the "pre-defined" and "pre-qualified" product families which have been already tested by the manufacturer/installer.

4 MISSING GAPS IN THE STANDARDIZATION FRAMEWORK AND QUALIFICATION APPROACH

The identification of the most relevant missing gaps in the standardization and qualification approaches has been addressed in previous researches such as within IEA PVPS task15 [12]. This research identified areas where there is still a need for international standardisation on multifunctional characterisation of BIPV modules/ systems and to recommend approaches which could be taken to progress towards the creation of a specific standardisation framework adapted to BIPV. Features of BIPV, which require modifications to the existing testing procedures, entitled types of testing and proposed test adaptations to account for BIPV features, such as the presence of solar cells, junction-box, electricity generation, etc.

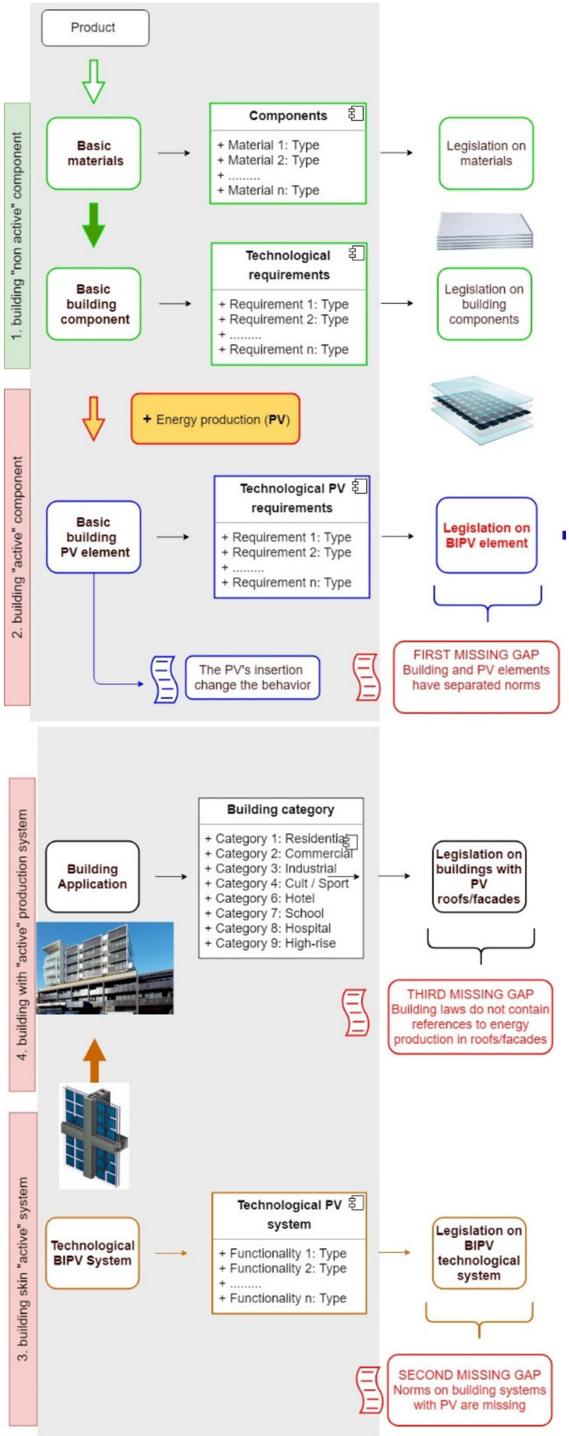

Figure 1: Flowchart for BIPV product qualification and normative assessment with current missing gaps

As it can be observed in Figure 1, grounding on this studies we identified several levels of missing gaps, starting from the PV element, to the system level until reaching the application level on the building. As it has been described in the previous chapters, by adopting actual procedures these deficiencies do not allow a correct and complete characterization of the BIPV elements, which therefore create uncertainty and it can potentially could bring risks of failure during service life, if current testing procedures are applied.

4.1 Different levels of Missing Gaps in the normative

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 previously mentioned, the current building regulations 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 them, 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 [13].

However, in these construction regulations, active parts concerning PV are not taken into consideration. Conversely, the PV standards do not deal with construction aspects and do not take into consideration that photovoltaics can be used on buildings. Based on this context, the missing gaps can be defined at different levels (Figure 1):

- 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 305/2011), a number of harmonized product standards may need amendments to allow for the establishment of Declaration of Performance (DoP) for BIPV products.

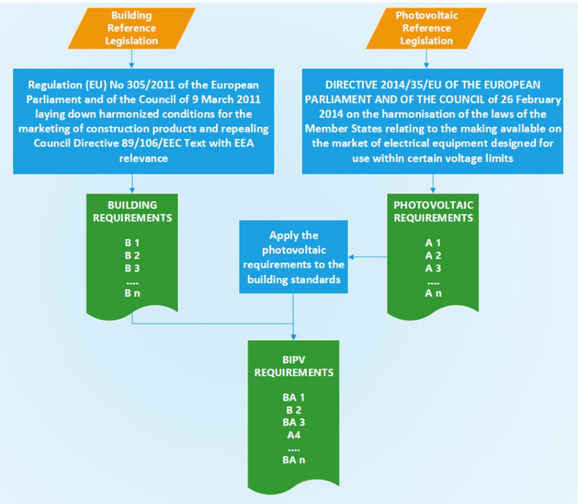

Figure 2: Different regulatory frameworks that will have to flow into a single BIPV regulatory framework

4.2 Multi functionality of BIPV: the basic gap to cover

BIPV is a multifunctional construction product. For both PV and building sectors, it will be necessary to find a methodology that brings union and standardization to well-defined rules which are not just the sum of them. In the unification process some requirements can be integrated with each other, others can remain unchanged for the respective sectors while others again cannot be used because they are not necessary or redundant. It is important to note that there is currently a grey area in the legislation in which clear rules are not in force.

4.3 Gap for quality assessment in innovative products

Very often, when BIPV products designed to perform specific construction functions are used, standard PV test are not directly applicable. Many of the existing PV testing procedures have been 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 for the energy rating and type approval. But this approach today presents several limitations since BIPV is entering more and more complex construction products which cannot be longer assimilated to a rigid monolithic module. E.g. in **coloured PV glasses** [14], where for aesthetic reasons the glass layers are subjected to colouring (in form of a mesh of spots), colouring, 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 behaviour (e.g. hot-spot test). Again, many products, derived directly from **building systems** (e.g. prefabricated and composite insulated panels), already possess specific rules and tests according to construction requirements (they can be already certified according to harmonized standards under the CPR 305/2011). However, since they integrate PV, they can no longer be effectively described by the IEC standards for some requirements (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). In order to reduce the risk perception and ease its market adoption, it is necessary to develop new testing procedures tailored to the BIPV product families that are already commercially available and those that are about to come. Therefore, starting from the “integrated” approach proposed 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 concepts for BIPV product families and categories.

5 ROADMAP FOR A PERFORMANCE-BASED APPROACH IN BIPV QUALIFICATION

From the analysis of the current regulatory framework, a possible path is considered achievable by developing a new approach for the qualification of BIPV products, coherent with the principles of CPR 305/2011 considering BIPV as a construction product, grounded on the analysis of the missing gaps shown in the previous chapters. This chapter will provide a **roadmap** describing the principles and basic approaches for the definition of 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.

5.1 Performance based approach for BIPV: criteria

The **prescriptive codes** have a long history and, while they have their limitations, main advantages are in being more straightforward to apply. This approach requires that each element of a building has a minimum acceptable standard. 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. 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 thoroughly checked. The design of a performance-based approach 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**. 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 step of the research. Anyway, the testing procedures will have to be developed aiming to 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 time and costs.

5.2 Limit states for BIPV product families

Under a 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, but the scope can be also extended beyond safety considerations) beyond which it no longer fulfils the relevant pre-defined criteria. For BIPV products, we can define three possible limit states, as following described.

Table 1: BIPV Limit states for a performance-based qualification approach

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 regular routine loading and without any of its building and electrical performances being affected after the test.
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, which 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 guaranteed and it can be assumed as long as this state is fulfilled.
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.

5.3 Towards new testing procedures

The specific development of new procedures for the qualification of a BIPV product family requires including both the BIPV module and the mounting solution, providing energy production and construction functionalities, respectively. The product families 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.)

At the state-of-the-art, BIPV systems are based on testing procedures and standards addressed to the energy rating of conventional PV (e.g. IEC 61853-3&4), applied on products or mock-ups representing facades or roofs. New testing procedures should introduce the combined effect of PV and building performance (e.g. to evaluate the thermal impact on the electrical power output and building functions), taking into account BIPV real installation conditions. Starting from these considerations, a new approach should consider the contemporaneity of effects/actions in order to accurately describe the BIPV behaviour aimed at reproducing the limit states, the quality and reliability issues related to operating conditions. It is also relevant to analyse a BIPV product considering the probability of occurrence of limit states and performance needs during the expected service life in order to relate critical conditions to real scenarios.

6 CONCLUSIONS AND FUTURE CHALLENGES

The construction of multifunctional BIPV products that can perform different functions, involves more and more the use of several materials that must coexist in the same 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 behaviour, etc. These performance relations have been only partially investigated at the state of art of BIPV quality assessment. However, due to their 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 the building regulations. 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 making available clear normative procedures applicable and ensuring reliable, safe and efficient products for the market in a cost-effective way. 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 standardisation.

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