Seamless-PV

D6.5 Progress on standardisation activities of IPV solutions

Initial version

T6.10 Progress on standardisation activities of IPV solutions

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Summary of SEAMLESS-PV PROJECT

A novel manufacturing process for integrated photovoltaics

Integrated photovoltaics (IPVs) have demonstrated their success and impact in their use as building-integrated photovoltaics. They are also considered promising in several other sectors. Their adaptation to other industries or devices could offer surprising benefits. Unfortunately, the very need for adaptable IPV solutions hinders their expansion as their current manufacturing processes cannot create IPV solutions customised to each sector. The EU-funded SEAMLESS-PV project aims to tackle this by developing revolutionary tools for photovoltaic manufacturing as well as new IPV products that offer improved efficiency, adaptability, and integrability while at the same time showcasing their cost-effectiveness in comparison to competitors.

The title of the SEAMLESS-PV project is "Development of advanced manufacturing equipment and processes aimed at the seamless integration of multifunctional PV solutions, enabling the deployment of IPV sectors". SEAMLESS-PV is a Horizon Europe Innovation Action started in January 2023 that will continue through December 2026.

More information can be found at:

https://www.seamlesspv.eu/

https://cordis.europa.eu/project/id/101096126

EXECUTIVE SUMMARY

This document proposes an innovative testing methodology for integrated photovoltaic (IPV) solutions, comparing newly developed accelerated testing sequences with conventional IEC standard test sequences, within the context of the dual-function complexity of IPV solutions. Furthermore, it provides a methodology for incorporating the unique and specific characteristics of BIPV products into reaction to fire testing.

For now, IPV products must comply with both PV-specific standards and the specific regulations of each application. The D6.5 document introduces a pre-compliance test sequence combining damp heat, humidity freeze, and thermal cycling tests, with integrated dark IV continuous monitoring and insulation test checks. The results of the combined accelerated test sequences are compared to separate, stand-alone IEC tests, using prototype samples from e-PIZ, to validate the accuracy and relevance of the proposed test sequence.

Given that fire safety is a critical factor for IPV solutions, the work includes a dedicated testing activity focused on reaction to fire testing. The work evaluates the project's solutions under the fire hazard scenarios and proposes testing guidelines for alternative fire testing methodology.

During ongoing task work, an important finding emerged: there is a significant testing gap related to pre-laminate certification. Currently, there are no clear guidelines for certifying intermediate photovoltaic laminates that are not yet finalized end-products but are intended for further modification and integration (such as in building-integrated photovoltaics or vehicle-integrated applications). This finding is particularly relevant given the evolving nature of integrated photovoltaic solutions. Further investigation into this topic is ongoing and may contribute valuable input to standardization efforts within IPV-related working groups.

The current report is the first version of this work. A second and final version of this work will be reported in D6.6 by the end of Seamless-PV project.

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Index

Tables

Figures

1 INTRODUCTION

1.1 Description of the deliverable content and purpose

This deliverable D.6.5 "*Progress on Standardisation Activities of IPV*" provides an initial version of the work done in Task 6.10 of WP6 within the SEAMLESS-PV project, detailing the progress achieved, so far. A second and final version of this work will be reported in D6.6 by the end of Seamless-PV project.

The focus of this task is to establish quality criteria for Integrated Photovoltaic (IPV) multifunctional products through pre-normative research. This document outlines the status of testing methodologies and preliminary standardization approaches, forming the basis for future validation and final reporting.

The main objective of this deliverable is to define testing and qualification methodologies for key IPV application segments: Building-Integrated Photovoltaics (BIPV), Infrastructure-Integrated Photovoltaics (IIPV), Vehicle-Integrated Photovoltaics (VIPV), and Agrivoltaics (AGRI). These methodologies are aligned with existing international PV standards such as IEC 61215 and IEC 61730, with adaptations to meet the specific requirements of IPV.

The deliverable draws from task 2.2 (D2.2) findings and includes an analysis of sector-specific standardization needs, identifying areas where existing standards require adaptation or extension. The document describes the development of testing methodologies that focus on critical performance aspects for each IPV segment. Test methodologies tailored to the IPV sector will be developed, incorporating automobile-specific criteria based on IEC 61215 [1], [2] and UN/ECE R43 Regulation [3]. These methodologies will be used to determine and validate the feasibility of pre-laminated technology and for future technology validation testing. For the BIPV segment, significant attention is given to ongoing standardization efforts, as this sector represents a major area of application and regulatory focus. Testing methodologies for BIPV address key criteria such as structural integrity, electrical performance, and fire safety. These methodologies build on previous work, including advancements from the BIPVBOOST project [4] and Task 15 of the International Energy Agency (IEA) [5]. For IIPV, VIPV, and AGRI, the deliverable proposes preliminary recommendations for testing procedures. These recommendations are based on an analysis of the unique operating environments and mechanical constraints associated with each application.

Prototypes developed within the project, particularly BIPV solutions, have been selected and will be subjected to initial testing to assess their robustness. These tests help validate the proposed methodologies and inform adjustments needed for broader application. The deliverable also highlights the importance of bridging the gap between construction-related standards and photovoltaic-specific requirements, ensuring comprehensive qualification frameworks. In addition to electrical performance and environmental durability, particular attention is devoted to fire safety testing, especially for BIPV products. The deliverable sets the basis for a dedicated fire reaction testing methodology under development, aligned with European construction regulations. The second phase of this work will focus on validating the proposed methodologies through practical application to selected BIPV products. The lessons learned from these validation efforts will be incorporated into the final deliverable (D6.6) and publish by the end of the project, contributing to the development of robust standards for IPV products.

The outcomes of the SEAMLESS-PV project are intended to support ongoing standardization activities and provide clear guidance for industry stakeholders, ensuring that IPV products meet the necessary performance, safety, and regulatory requirements for market deployment.

1.2 Reference material

The Deliverable has used data from the following documents:

- BIPVBOOST project: Deliverable D5.2. Report on the project developments of specific performance-based laboratory testing procedures for BIPV products [6].
- SEAMLESS PV project: Deliverable D2.2. Analysis of regulatory frameworks applicable to IPV systems.
- SEAMLESS PV project: Deliverable: D6.4. Performance risks and identification of related gaps in current standardisation frameworks of IPV products.

1.3 Relation with other activities in the project

Table 1 depicts the main links of this deliverable to other activities (work packages, tasks, deliverables, etc.) within the SEAMLESS project. The table should be considered along with the current document for further understanding of the deliverable contents and purpose.

Table 1: Relation between current deliverables and other activities in the project

Project activity	Relation with current deliverable
Task 2.2	This task analyses the current regulatory framework applicable in BIPV, IIPV, VIPV, and AGRI segments. D2.2. Analysis of regulatory frameworks applicable to IPV systems.
WP6	WP6 will develop products in different IPV segments. These will be used for the validation of new testing procedures in Task 6.10 and indoor testing activities of Task 6.11.

1.4 List of abbreviations

Table 2: List of abbreviations

Acronyms	Meaning
AgriPV	Agrivoltaics
BIPV	Building integrated photovoltaics
BIPVBOOST	Building-Integrated Photovoltaics Boost H2020 – EU R&D project

CINEA	European Climate, Infrastructure and Environment Executive Agency
CPR	Construction Products Regulation
CST	Compressive shear test
DH	Damp Heat
DSC	Differential scanning calorimetry
DuT	Device under Test
EAD	European Assessment Document
EA-PVPS	International Energy Agency - Photovoltaic Power Systems Programme
EC	European Commission
EL	Electroluminescence
EU	European Union
FTIR	Fourier Transform Infrared spectroscopy
HF	Humidity Freeze
IEC	International Electrotechnical Commission
IGU	Insulated Glass Unit
IIPV	Infrastructure-Integrated Photovoltaics
IPV	Integrated Photovoltaics
ISO	International Organization for Standardization
IV	Current-Voltage (electrical performance curve)
LVD	Low Voltage Directive
MPP	Maximum Power Point
MQT	Module Quality Test
MST	Module Safety Test
NB	Noise Barrier
NTP	New Testing Procedure
PAR	Photosynthetically Active Radiation
PID	Potential-Induced Degradation
PV	Photovoltaic
PV-IGU	Photovoltaic Insulated Glass Unit
PVNBs	PV Noise Barriers
RH	Relative Humidity

SBI	Single Burning Item (reaction to fire test)
SEAMLESS-PV	Development of advanced manufacturing equipment and processes for seamless IPV integration
SLS	Serviceability Limit State (thermal classification)
STC	Standard Test Conditions
TC	Thermal Cycling
TS	Technical Specification
VIPV	Vehicle-Integrated Photovoltaics
WG	Working Group
WP	Work Package

2 ANALYSIS IPV REGULATORY GAPS AND DEFINITION OF IPV QUALITY CRITERIA

2.1 General introduction

The development of innovative integrated photovoltaic solutions across diverse sectors presents unique challenges in standardization and regulatory compliance. Unlike conventional photovoltaic systems, which adhere to established IEC standards, IPV products merge multiple industries such as construction, transportation, and agriculture with photovoltaics.

Current IEC standards, such as IEC 61215 [1], [2] for design qualification and type approval and IEC 61730 [7], [8] for safety of PV modules, are primarily tailored for PV modules designed for rooftop or solar power plant applications. These standards do not fully address the multifunctional nature of IPV systems or their sector-specific requirements. For instance, BIPV products must meet structural and fire safety standards applicable to construction materials, as well as electrical safety standards for PV devices. This dual compliance often requires drawing upon testing methodologies from both industries to satisfy the diverse requirements of specific applications.

IPV products must also comply with national regulations, which can vary significantly between countries. This variability further complicates the standardization landscape, as products must be tailored to meet specific national requirements in addition to international guidelines.

Recognizing these challenges, the IEC has established several technical committees and working groups to develop new standards and guidelines for the IPV sectors:

- Building Integrated Photovoltaics (BIPV). The IEC Technical Committee 82 (IEC TC 82) focuses on solar photovoltaic energy systems. Within this committee, Working Group 2 (WG2) addresses modules, non-concentrating systems, and components, which include BIPV applications. Notably, IEC 63092-1:2020 [9] specifies requirements for BIPV modules, and IEC 63092-2:2020 [10] outlines requirements for BIPV systems.
- Infrastructure Integrated Photovoltaics (IIPV): While there is no dedicated IEC working group exclusively for IIPV, aspects of infrastructure integration are considered within IEC TC 82's scope, particularly in relation to PV systems integrated into structures.
- Vehicle Integrated Photovoltaics (VIPV): The IEC has initiated efforts to address VIPV through the establishment of Project Team 82-10 (PT 82-10) under IEC TC 82. This team is tasked with developing standards for PV modules integrated into vehicles, focusing on unique requirements such as vibration resistance, safety, and performance under dynamic conditions.
- Agrivoltaics (AgriPV): Currently, there is no specific IEC working group dedicated solely to AgriPV. However, the integration of PV systems into agricultural settings is an emerging area of interest within IEC TC 82, and future standardization efforts may evolve to address the unique challenges of AgriPV applications.

In task T6.10, named “Progress on standardisation activities of IPV solutions” in Seamless-PV project, we aim to propose and validate complementary testing methodologies that bridge sector-specific requirements. This work builds upon inputs gathered during the previous BIPVBoost project [4]. The practical aspect focuses on validating the proposed methodology across a wide range of IPV products.

2.2 Overview of key IPV regulatory gaps

Based on the analysis conducted in deliverable document D6.4: "Performance risks and identification of related gaps in current standardisation frameworks of IPV products", this section highlights the most pressing regulatory challenges across the Integrated Photovoltaics (IPV) sectors. These challenges represent areas where prioritization in standardization efforts is critical to advancing the adoption and safety of IPV technologies. **¡Error! No se encuentra el origen de la referencia.**

Table 3: Overview of key IPV regulatory gaps

IPV Sector	Key Regulatory Gaps
Building Integrated Photovoltaics (BIPV)	• **Dual Compliance**: BIPV products must comply with both electrical safety PV standards (e.g., IEC 63092, IEC 61730), as well as construction product regulations (CPR 305/2011). These overlapping requirements create complexity and are not always aligned. • **Fire Safety**: Existing fire safety standards were designed for non-energy-generating materials. They often fail to properly account for the specific fire risks associated with photovoltaic systems integrated into buildings. • **High Operating Temperatures**: Integration with building materials increases operating temperatures, affecting durability and safety. IEC TS 63126:2020 offers guidance for high operating temperatures in hot climates, but broader application in IPV context is still limited. • **Mechanical Integrity**: Testing methods must address the combined effects of mechanical stress and thermal loads occurring in BIPV. Current testing methods do not fully reflect how these combined stressors affect long-term reliability.

IPV Sector	Key Regulatory Gaps
Infrastructure Integrated Photovoltaics (IIPV)	*SEAMLESS-PV project focuses on PV noise barriers (PVNBs) as representative IPV application. The identified key regulatory gaps were analysed with IPV noise barriers in mind. Note that other IPV applications may face different regulatory challenges.* • **Electrical Risks**: PV Noise Barriers (PVNBs) can pose risks of electrical discharges during vehicle impacts or collisions, requiring enhanced safety protocols. • **Mechanical Challenges**: Existing standards for noise barriers (e.g., EN 14388 [12]) do not consider the added mechanical stresses introduced by the integration of PV modules. This includes potential issues related to panel weight, wind load, and structural anchoring. • **Fire Safety**: Fire safety protocols must be tailored to account for the specific characteristics of PV products, including the unique fire risks introduced by the presence of photovoltaic systems.
Vehicle Integrated Photovoltaics (VIPV)	• **Dynamic Stress**: Standards such as IEC 61215 [1], [2] do not account for vibrations, shocks, and temperature fluctuations in vehicle operation. • **Electrical Safety**: Unique risks like electrical isolation and discharge risks in the event of vehicle collisions. need specific testing protocols. • **Thermal Management**: Managing heat dissipation in VIPV systems presents a challenge not addressed by current standards.
Agrivoltaics (AgriPV)	• **Framework Inconsistencies**: Absence of a universal definition for AgriPV creates discrepancies in standard application across regions. • **Operational Risks**: Safety concerns from agricultural machinery and environmental conditions need to be addressed. • **Balancing Functions**: Existing standards rarely ensure that energy production is compatible with agricultural productivity, such as maintaining sufficient light transmission, crop health, or farm accessibility. Standards must ensure that energy generation does not interfere with agricultural productivity.

The regulatory gaps identified across IPV sectors highlight the need for a more harmonized and sector-specific approach to standardization. For BIPV, addressing dual compliance and fire safety is paramount, while IIPV and VIPV require enhanced protocols for mechanical and electrical safety. In the case of Agrivoltaics, standardization must resolve inconsistencies and ensure compatibility with agricultural functions. A concerted effort to close these gaps will enable safer and more widespread adoption of IPV technologies. This work focuses on the critical areas of mechanical integrity, electrical safety, and fire safety: three pillars identified through gap analysis as essential for IPV products. These areas provide valuable insights and form the foundation for advancing toward harmonized standardization.

2.3 Overview of quality criteria for each IPV sector

This chapter proposes a tailored set of quality criteria for each major IPV sector, based on state-of-the-art research and standards development initiatives. These criteria should encompass both traditional PV performance indicators and application-specific functional requirements, addressing mechanical robustness, environmental resilience, electrical safety, durability, and dual-use efficiency. The aim is to support pre-normative research and harmonization of future certification schemes.

Table 4 Main technical quality criteria

IPV Sector	Main Technical Quality Criteria
Building Integrated Photovoltaics (BIPV)	• Electrical compliance and grounding. • Structural load bearing. • Fire resistance and reaction to fire: critical especially in high-rise façades building. • Visual uniformity: Visual architectural integration affects real estate value and regulatory approval. • Water tightness and air permeability: Must ensure that building remains watertight. • Environmental impact: As BIPV becomes widespread, LCA and recyclability play a role.
Infrastructure Integrated Photovoltaics (IIPV)	*SEAMLESS-PV project focuses on PV noise barriers (PVNBs) as representative IPV application. Following technical quality criteria are dedicated to IPV noise barriers.* • Noise attenuation compatibility: PV integration must not compromise sound absorption or reflection properties. • Electrical disconnection safety: After impact or storm damage, the system must be able to isolate itself electrically. • Fire resistance: Must resist flame spread and smoke production, especially near busy roads.
Vehicle Integrated Photovoltaics (VIPV)	• Shock resistance and vibration: A module embedded in a car roof must not crack or delaminate after 100,000 km on rough terrain. Testing per ISO 16750-3 ensures this. • Dynamic hot spot resistance. • Electrical Isolation: In potential crash scenarios, modules must not pose an electrocution hazard – safe disconnection is critical.

IPV Sector	Main Technical Quality Criteria
Agrivoltaics (AgriPV)	• Light transmission and PAR compatibility: The PV layout must allow enough photosynthetically active radiation (PAR) for crops. • Crop yield impact: Quality of the system is measured by energy-to-crop yield ratio. • Agricultural access and maintenance: AgriPV structure must consider farm machinery and harvesting operations. • Soil impact: AgriPV must not degrade soil or water retention.

Each IPV sector has unique quality requirements shaped by its operational environment, functional role, and regulatory context. Understanding these criteria in practice is essential for designing and certifying safe, durable, and market-ready products.

3 QUALIFICATION APPROACH

3.1 General introduction

In the context of IPV products, pre-compliance testing is a systematic approach designed to address the multifunctionality of IPV products operating as both energy generators and structural components. The testing methodology aims to tackle technical challenges early in the development process, reducing risks during formal certification and ensuring the long-term reliability of the final products.

Pre-compliance testing is based on a performance-based testing approach, where *performance* refers to the ability of IPV products to reliably and safely fulfil their intended roles throughout their lifecycle. Unlike conventional photovoltaic modules, IPV products are subjected to additional environmental stresses arising from their integration into buildings, vehicles, or infrastructure. For example, BIPV products must meet structural load requirements while also complying with electrical safety standards. Similarly, VIPV systems face dynamic stresses from vehicle motion, while IIPV systems must endure vibrations and environmental exposure unique to roadways and bridges.

In this approach, *performance* is defined through limit states, specific thresholds or conditions beyond which the product no longer meets predefined criteria. Limit states account for electrical, thermal, and mechanical aspects, addressing gaps in existing standards that often consider these parameters independently. This methodology also redefined the thermal boundary conditions to account for the impact of elevated temperatures.

Development of performance-based testing procedures also provides flexibility in design while ensuring compliance with essential regulatory requirements. By defining representative product types and testing them against a set of performance levels or classes, manufacturers can streamline testing processes, reduce time and costs, and create a more competitive framework for innovation. Pre-compliance testing also ensures regulatory readiness, providing valuable insights for product design optimization and outlining future pathways for IPV standardization.

3.2 Evolving testing approaches for multifunctional IPV

To develop qualification approach for IPV solutions, a literature review was conducted to assess recent developments in testing methodologies, and their relevance for testing IPV products. The IPV products dual natural, as both structural or infrastructural components and energy-generating systems pose unique challenges for performance and long-term reliability assessment. As emphasized by Weiß et al. (A*ccelerated aging tests vs field performance of PV modules*, 2022 [13]), singular, standardized tests serve as a baseline for evaluating PV module quality and are widely used for type approval and safety qualification. However, these standardized tests, often fail to address the complex, real-world environmental conditions encountered during the operation, especially in non-conventional applications like IPV. Standard tests typically apply single stressors under idealized, constant conditions, which differ from the multi-factorial nature of actual outdoor environments. For instance, BIPV products are integrated directly into the building envelope and exposed to specific installation and location stressors that differ significantly from those experienced by open-rack PV systems. However, standard IEC normative still apply the same sequential, single tests methodology for both systems, without accounting for these contextual differences. BIPV modules might experience elevated temperatures due to reduced ventilation, uneven irradiance due to shading and orientation, and greater exposure to moisture, condensation, and pollutants, in urban settings. Weiß et al. [13] argue that combined stress testing offers a more realistic simulation of complex operational environments. The combined accelerated testing methodology applies multiple environmental stressors simultaneously or in carefully designed sequences. This more accurately represents operational loads, enabling the detection of failure modes that standard sequential testing may miss. Weiß et al. [13] point out that degradation patterns resulting from such combined tests often closely resemble degradation patterns observed in field-aged modules.

The need for application-specific testing protocols was emphasized during discussions within task 6.10 of the project. The heterogeneity of the solutions developed in the project highlights that the IPV testing procedure requires more than a conventional single stressor testing method. This led to the understanding that new testing procedures must incorporate a combination of several environmental stressors. The aim of this approach is twofold: first, to accelerate degradation mechanisms that are likely to occur in real IPV scenarios due to the specific integration environments; and second, to achieve a more representative testing methodology that accounts for the influence of the installation context.

4 TESTING METHODOLOGIES FOR IPV SOLUTIONS

This chapter presents the testing methodologies developed for IPV solutions, addressing both environmental durability and fire safety performance. It includes the implementation of a new proposed combined environmental aging procedure, alongside planned approaches for fire resistance evaluation.

4.1 Environmental aging sequence

This section presents a new testing procedure aimed at evaluating IPV solutions under selected environmental conditions in a controlled laboratory setting. The first part describes the individual tests commonly used and individually conducted in accordance with relevant IEC 61215 [1], [2] and IEC 61730 [7], [8] standards. The second part introduces a novel approach that combines these individual tests into a single, modern accelerated aging sequence.

4.1.1 General Overview

The new testing procedure developed in the project proposes an accelerated environmental aging sequence designed to validate the reliability of IPV solutions. This methodology integrates individual tests from IEC international standards (IEC 61215 [1], [2] and IEC 61730 [7], [8]) into a combined procedure, adapting product testing temperature thresholds based on the thermal classes. The thermal classes, named as Serviceability Limit State (SLS) conditions are established in accordance with IEC 63126 [28]. Their relevance for BIPV products was assessed in the previous project - BIPVBoost, through empirical analysis of BIPV module operating temperatures under non-conventional scenarios. This work serves as a reference baseline for the current approach. Further details can be found in the public deliverable D5.2: 'Report on the project developments of specific performance-based laboratory testing procedures for BIPV products' [6].

4.1.2 Overview of selected environmental aging tests

The foundation of the proposed new testing procedure is grounded in understanding of individual environmental stress tests, as defined in the IEC 61215-2:2021 [1,2] standard. The following subsections describe three key tests—thermal cycling, damp heat, and humidity freeze—which together simulate the dominant environmental stressors encountered by PV modules during operation. The environmental stress tests described, represent established industry practices, and serve as the foundation for certification procedures and reliability assessment of photovoltaic modules. These standardized tests are designed to replicate key degradation mechanisms and validate the long-term module reliability. They are a baseline for qualifying modules to international standards and provide the basis for commercial guarantees—now commonly offering 25 years of warranted performance for standard crystalline silicon modules.

Thermal Cycling Test

The thermal cycling test simulates daily and seasonal temperature fluctuations, which cause material expansion and contraction, leading to mechanical fatigue and contact degradation. As specified in IEC 61215-2:2021 (MST 11) [1,2], the device under test (DUT) is cycled between −40 °C and +85 °C, with heating and cooling rates not exceeding 100 °C per hour. At both temperature extremes, the DUT is held for a minimum of 10 minutes to ensure full thermal stabilization.

Each complete cycle must be completed within 6 hours, and the test is repeated for 200 cycles. During the high-temperature dwell phase, the module operates under maximum power point (I_{mpp}) conditions, while at other stages, it is kept under near open-circuit conditions (current <1% of I_{mpp}) This approach simulates the interaction of thermal and electrical stresses affecting cell interconnections, solder joints, and encapsulant behaviour.

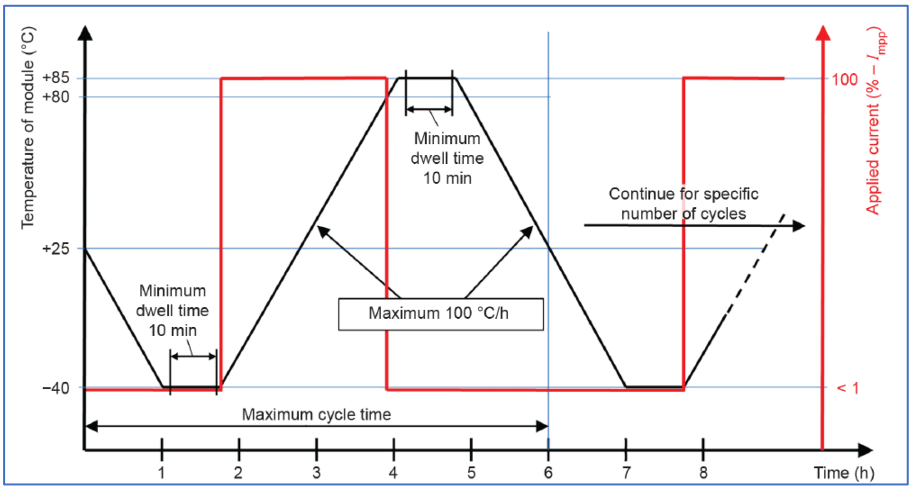

Figure 1 Thermal Cycling Test Procedure (MST 11 Profile)

Damp Heat Test

The damp heat test evaluates the durability of PV modules exposed to long-term heat and humidity, simulating conditions such as those in tropical or coastal climates. As defined in IEC 61215-2:2021 (MQT 13) [1], the DUT is exposed to a constant climate of 85 ± 2 °C temperature and 85 ± 5% relative humidity for a duration of 1,000 hours (approximately 42 days). The module remains unpowered throughout the entire exposure period. Before the damp heat test starts, the device under test undergoes a series of pre-characterisation tests, including visual inspection, insulation resistance measurement, and performance testing under standard test conditions (STC).

This test is particularly effective in detecting corrosion, moisture ingress, delamination, and encapsulant discoloration. Following the exposure, modules are re-tested for electrical performance and must show less than 5% power loss (relative to initial STC measurements), and no critical visual or safety-related degradation.

Humidity Freeze Test

The humidity freeze test is designed to replicate stresses induced by moisture absorption followed by sudden freezing, particularly relevant in climates with both high humidity and sub-zero temperatures. According to IEC 61215-2:2021 (MST 12) [1,2], the DUT is first held in an environment of +85 °C and 85 ± 5% RH for a minimum of 20 hours, ensuring full moisture saturation. It is then cooled in two steps: first to 0 °C at a rate not exceeding 100 °C/h, then to −40 °C at a rate not exceeding 200 °C/h. The module is held at −40 °C for at least 30 minutes, allowing any absorbed moisture to freeze completely. The DUT is subsequently returned to ambient and then reheated to +85 °C. This full cycle is repeated typically for 10 cycles. During the ramps and low-temperature hold, relative humidity is not controlled, in accordance with the standard. After the test, the module is inspected for cracks, corrosion, delamination, or other visible damage, and re-tested for performance. As with the other tests, a degradation in power output of more than 5%, or any critical failure, results in disqualification.

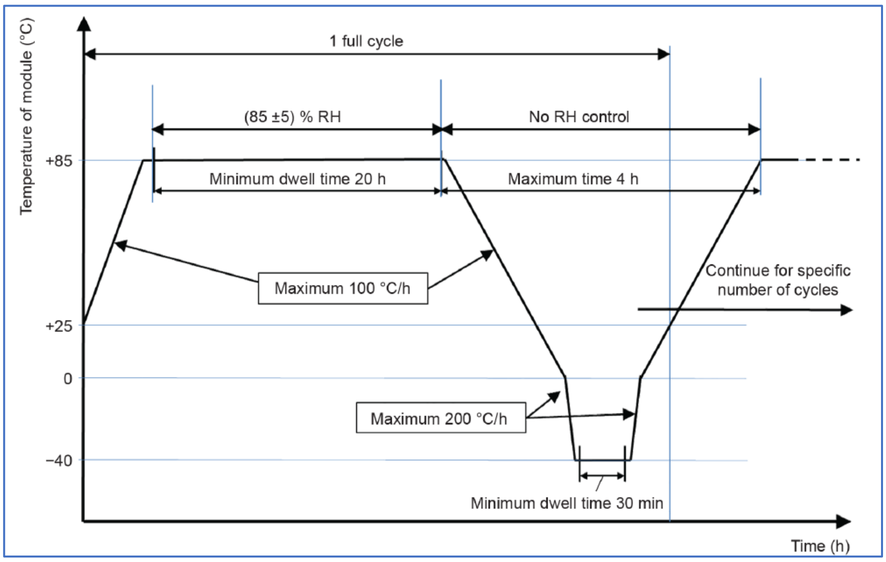

Figure 2 Humidity Freeze Test Procedure (MST 12 Profile)

Performing TC, DH and HF tests independently presents significant infrastructure and logistical demands. In a conventional setup, a laboratory must operate at least three separate environmental chambers, each configured for one of the standard tests: thermal cycling, damp heat, and humidity freeze. The IEC 61215-2:2021 [1] standard typically requires a minimum of 10 modules per test, to allow for consistent statistical evaluation, destructive testing, and redundancy in case of measurement anomalies. This results in high spatial and energy demands, especially for long-duration tests (e.g. 200 thermal cycles or 1,000 hours of damp heat), and limits testing throughput.

To address these constraints, advanced in-situ monitoring strategies are being developed as an alternative to periodic chamber opening. These include:

- Dark I-V monitoring, which allows real-time tracking of module degradation using built-in or external sensing systems without needing light sources.
- Continuous insulation resistance logging, helping detect moisture ingress or insulation failure without interrupting test conditions.
- Embedded temperature and current sensors, to ensure test consistency and support degradation modelling.

In summary, each of the IEC environmental tests described above targets distinct degradation pathways. Thermal cycling primarily addresses thermo-mechanical stress, such as solder joint fatigue and interconnection failure, caused by repeated temperature fluctuations under electrical load. Damp heat focuses on long-term chemical and moisture-related degradation, including corrosion, encapsulant browning, and potential-induced degradation (PID), by exposing the module to prolonged high humidity and temperature without electrical bias. Humidity freeze simulates cyclic moisture absorption and freezing, testing the module's resistance to mechanical cracking and delamination due to expansion of trapped water at sub-zero temperatures. While each test isolates a particular stress factor, real-world conditions often involve overlapping stressors acting simultaneously. Therefore, combining these tests into a single, integrated aging sequence can better simulate the complex environmental challenges faced by PV modules in the field. This approach may also reduce test duration, minimize sample and space requirements, and enable more realistic evaluation of reliability. The following section introduces such a combined methodology tailored for IPV, integrating thermal, humidity, and electrical stress in a controlled and accelerated manner.

4.1.3 New Testing Procedure – Environmental aging

The development of the proposed New Testing Procedure (NTP) responds to the need for a more representative, integrated, and efficient method for evaluating the reliability of IPV modules. While the conventional IEC 61215 qualification relies on individual environmental stress tests applied sequentially, each designed to isolate a particular failure mode. The real-world operating conditions of IPV systems typically involve the simultaneous and overlapping action of multiple environmental stressors, including thermal cycling, humidity, mechanical strain, and irradiance. The NTP has therefore been designed as an accelerated, combined environmental aging procedure that reproduces these concurrent stress factors in a single, continuous sequence. The proposed test sequence integrates the fundamental stress elements of three IEC qualification tests: thermal cycling, damp heat, and humidity freeze. In the NTP, the environmental chamber is programmed to alternate between extreme low temperatures (−40 ± 2 °C) and high temperatures corresponding to the Serviceability Limit State (SLS) thermal class defined for the module under test (+85 ± 2 °C, thermal class 0). The cycle includes controlled temperature ramps with a maximum slope of 200 °C/h and stabilization periods of at least 10 minutes at both extremes. Additionally, a high-humidity dwell (85 °C, 85% RH) is maintained for five hours at the high-temperature phase to simulate the cumulative moisture-induced degradation mechanisms typically addressed in damp heat testing. Each complete cycle has a total duration of approximately eight hours and is repeated 200 times, thereby enabling the simultaneous representation of 200 thermal cycles, 1000 hours of damp heat, and 10 humidity freeze cycles in a condensed time frame.

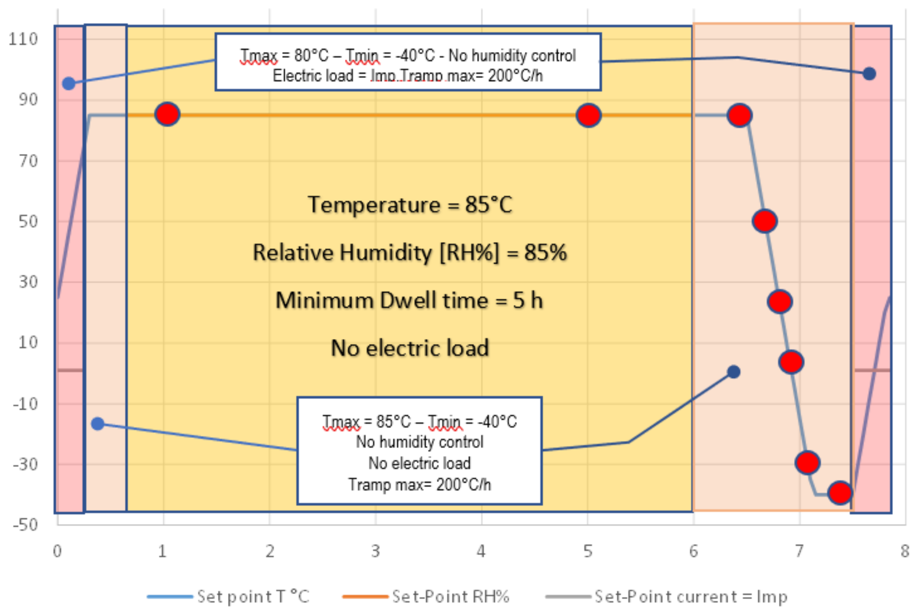

Figure 3 New testing procedure profile for SLS thermal class 0

The NTP allows all stress factors to be applied within a single chamber using a single sample set, significantly reducing logistical complexity and the number of required modules. Furthermore, while traditional IEC protocols generally call for only a limited number of interim characterizations (typically at ¼ or ½ of the total test duration), the NTP incorporates in-situ monitoring to allow for continuous tracking of the degradation process.

This real-time characterization is enabled by designed Smart Rack #01 setup. It is a multifunctional testing platform developed within the BIPVBoost project.

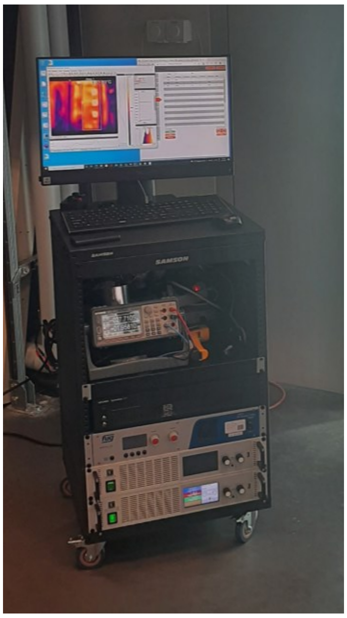

Figure 4 Smart Rack #01 setup for in-suite monitoring

The device is capable of monitoring multiple physical and electrical parameters under varying environmental conditions. It supports the measurement and logging of local module temperatures at several backsheet locations and uses infrared thermography for surface temperature profiling. Importantly, it permits the application and control of electrical operating points—including maximum power point (MPP), short-circuit current, open-circuit voltage, and reverse-bias conditions—while performing full IV curve acquisitions. The system is also equipped for high-voltage insulation resistance measurements across the thermal classification range. This enhanced monitoring capacity facilitates early identification of failure indicators, such as increases in series resistance, shunt leakage, or insulation breakdown, without interrupting the test sequence. Of particular interest is the use of dark IV measurements, which can reveal subtle changes in diode behaviour and contact integrity long before power loss becomes detectable under STC. By leveraging such techniques, the NTP not only reduces the number of test interruptions but also yields a more granular degradation dataset, supporting more accurate modeling of aging kinetics and reliability forecasting.

Compared to conventional IEC testing, the NTP offers a set of distinct advantages:

- Reduced test duration and resource consumption,
- Improved representation of real-world degradation conditions,
- Minimized chamber access interruptions, and improved fault detection sensitivity through continuous monitoring.

4.2 IPV Fire Safety Testing Procedures

4.2.1 General Overview

The SEAMLESS-PV project focuses on integrated photovoltaic (IPV) products, targeting four primary market segments: Building-Integrated Photovoltaics (BIPV), Infrastructure-Integrated Photovoltaics (IIPV), Agrivoltaics (Agri-PV), and Vehicle-Integrated Photovoltaics (VIPV). In Deliverable D2.2, the regulatory framework for IPV products was analysed, examining European and national standards with a focus on key markets. Among the highlighted segments, BIPV is given particular attention here, as it relates to the building sector, which accounts for 40% of the total energy consumption in the European Union [15]. Architecturally integrated photovoltaic modules hold significant potential by serving as both functional building envelope components and sources of renewable electricity. However, despite their advantages, BIPV modules pose fire safety challenges. The increasing use of photovoltaic systems has been accompanied by sporadic accidental combustion incidents, raising safety concerns. While PV-related fires remain rare, their impact on structural integrity and occupant safety can be significant. They can be classified as a low-probability and high-impact event. Fire safety, is therefore, a critical consideration for all IPV products. These systems must exhibit robust fire reaction properties, prevent fire propagation, and avoid hazardous ignition scenarios in case of malfunction. In specific cases, such as VIPV and IIPV systems, fire behaviour may be influenced by their operational environments, requiring tailored testing protocols that account for these unique characteristics.

For BIPV products, fire safety is paramount as they are integrated into buildings and function as construction components. Due to the use of polymeric materials with varying combustibility, along with electrical and electronic components, these products require thorough testing to assess their fire behaviour. Additionally, the rapid growth of the BIPV market has outpaced fire safety standards, creating critical gaps. Fire safety requirements differ globally, complicating compliance and testing for manufacturers. Current building codes fail to address the unique fire risks of electrically active BIPV systems, such as internal ignition, material combinations, and active panels during fires. In some cases, existing test methods do not reflect realistic conditions, such as high heat fluxes, active elements, and toxicity risks. Updated and unified standards are needed to provide clear and well-defined testing procedures for BIPV systems.

As part of Seamless-PV Task 6.10, efforts are underway to develop a new test procedure for evaluating the reaction to fire of BIPV products comprehensively and clearly, aiming to enhance the safety of BIPV systems across diverse building applications.

4.2.2. Fire safety standards and regulations

For photovoltaic (PV) modules, many countries directly or indirectly reference international standards that include fire safety considerations, such as IEC 61730 [8] and UL 1703 [16]. However, these standards are primarily made for PV modules as electrical and electronic components and do not address the specific requirements for BIPV products.

In Europe, the IEC 61730 series, "Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction" and "Part 2: Requirements for testing," serves as the reference for PV module safety [7], [8]. These standards are harmonized with European Union legislation through their publication in the Official Journal of the European Union and are required under the Low

Voltage Directive (2014/35/EU) [17]. Harmonized standards provide a presumption of conformity to legislative safety, health, and environmental requirements but remain optional. Manufacturers may choose alternative technical solutions to demonstrate compliance with the directive. The Low Voltage Directive specifically covers electrical equipment with voltages between 50 and 1000 V AC and between 75 and 1500 V DC. Regarding electrical safety in PV applications, IEC 61730, is the main reference. For fire safety, the primary reference is ISO 11925-1:2020, "Reaction to fire tests — Ignitability of products subjected to direct impingement of flame." [18] The ISO 11925-1:2020 standard ("Reaction to fire tests — Ignitability of products subjected to direct impingement of flame") defines the so-called Ignitability Test, also known as MST24. This test is referenced in IEC 61730-2 [8] as one of the main methods used to assess fire hazard in photovoltaic modules. While IEC 61730 addresses electrical safety for PV modules as electrical equipment, it lacks explicit references for integrated PV solutions such as infrastructure-integrated (IIPV), vehicle-integrated (VIPV), and building-integrated (BIPV) photovoltaics. The standard states that "PV modules mounted in or on buildings, in general, shall fulfil national building and construction regulations and requirements." In the absence of such national requirements, international and national standards can be referenced to determine suitable testing protocols. Notably, IEC 61730-2 [8] emphasizes that "Fire tests are nationally regulated and typically only required for building-integrated or building-added products. Hence, the applicability of a fire test does not depend on the class but on the mounting location and typology. This highlights the need to consider the final mounting solution when evaluating the fire behaviour of BIPV products.

For construction products, including BIPV, the European Construction Products Regulation (CPR 305/2011) [11] specifies the performance requirements and cites harmonized standards necessary for compliance. Reaction to fire classification for construction materials is defined in EN 13501-1 [19], which relies on harmonized testing methods developed by the CEN/TC127 committee. These methods enable consistent fire performance classification across EU member states and non-MS countries, such as Switzerland, have initiated mutual recognition agreements on conformity assessment countries.

To ensure the quality and reliability of building integrated photovoltaic (BIPV) products, specific standards have been established. Two notable examples are EN50583 and IEC 63092, which outline the essential qualities that BIPV products must meet and reference the corresponding testing standards that apply. Despite the existence of these standards, practical guidance on testing BIPV products in accordance with recognised international norms remains limited.

4.2.3 Methodology

The SEAMLESS_PV project aims to address the gaps in fire safety testing methodologies for BIPV products. Current efforts focus on developing a specific methodology tailored to the unique characteristics of BIPV products while adhering to standard EN 13501-1 [19]. Reaction to fire is a key fire protection measure, especially during the early stages of fire propagation (pre-flashover). It measures the extent to which a material contributes to a fire under defined conditions.

EN 13501-1 classifies reaction to fire performance based on two primary tests:

- Single Burning Item (SBI) Test (EN 13823) [20]: Evaluates the reaction to fire of construction products, excluding flooring, under the thermal attack of a single burning item.

- Small Flame Test (EN ISO 11925-2 [21]): Determines the ignitability of products subjected to direct flame impingement under zero imposed irradiance, using vertically oriented samples.

The methodology under development aims to adapt these tests to account for the unique attributes of BIPV products, such as the presence of photovoltaic cells, junction boxes, connectors, and cables. These components are often already tested according to other standards. However, once integrated into the BIPV product, they must be tested under actual use conditions as a final product.

Specific adjustments to the SBI and Small Flame Tests will be proposed, considering the differences between BIPV and traditional construction products. For instance, existing European Assessment Documents (EADs) for ventilated facades often impose dimensional requirements for SBI tests that may not align with BIPV product configurations. Additionally, these EADs frequently overlook unique BIPV variables, such as cell density and the positioning of electrical and electronic components.

In the absence of harmonized product standards for innovative BIPV solutions, the SEAMLESS_PV project will propose updates to EN 50583 standard, "Photovoltaics in buildings," Parts 1 and 2 [22], [23]. Recommendations will include reaction to fire classification procedures specific to BIPV products, starting from the harmonized tests, and addressing gaps in current methodologies in the product standard. A key deliverable will be a standardized testing methodology for BIPV products, improving test reproducibility across laboratories. The proposed annex to EN 50583 will streamline the testing process for manufacturers, facilitating market entry for BIPV products. Recommendations for fire safety tests will also be provided for the IIPV and AGRI-PV sectors. For photovoltaic systems integrated into road demonstrators as noise barrier solutions in the IIPV sector, the harmonized standard SIST EN 1794-3:2016, "Road traffic noise reducing devices - non-acoustic performance - Part 3: Reaction to fire - Burning behaviour of noise reducing devices and classification. [24]" is a key reference for fire safety requirements. This standard provides authorities, designers, and specifiers with critical guidance regarding the reaction to fire, smoke density, and toxic fumes of materials used in noise-reducing devices. Specifically, the standard outlines a methodology for managing the substantial components of non-homogeneous products (as defined in EN 13501-1 [19] and ISO 5659-2:2017-05 [25]). It addresses how to handle non-homogeneous products and clarifies under what conditions the influence of non-substantial components on the overall classification result can be disregarded. This standard remains for products used as noise barriers a key reference for safety compliance and informed design decisions when implementing IIPV solutions.

In summary, the methodology developed within SEAMLESS-PV will identify and prioritize key variables influencing reaction to fire performance through a comprehensive literature review. The goal is to close existing gaps and create a robust, unified testing framework tailored to BIPV products, ensuring safety and compliance with European standards.

4.2.4 Testing procedure

This section describes the process that will be followed to define the proposed protocol for testing the PV products and defining the positions of the electrical elements. The results of this work will be shared in the final deliverable D6.6.

The definition of this test procedure is based on the test used to assess the fire safety performance of BIPV products in the framework of EN 13501-1 [19] and specifically on the SBI test (EN 13823 [20]). This procedure will introduce specific improvements that address the unique characteristics of BIPV systems, such as the presence of junction boxes and electrical components. A detailed approach is provided for their position during the test, treating these elements not as isolated components but as integral parts of the PV module or system.

It is important to mention and take into account during this protocol definition that there are harmonised standards such as EN 14351-1 [26] (Windows and doors - Product standard, performance characteristics - Part 1: Windows and external pedestrian door assemblies) and EN 14449 [27] (Glass in buildings - Laminated glass and laminated safety glass - Conformity assessment/Product standard) that set mandatory requirements under the Construction Products Regulation (CPR) that include products with photovoltaic parts inside.

The research methodology is structured in a step-by-step process aimed at developing and validating a suitable SBI test protocol for BIPV systems. The main phases are as follows:

1. Analysis of the specific testing requirements according to the SBI (EN 13823 [20]). The new protocol has to be designed in compliance with this regulation to be applicable
2. Identification of challenges in applying the SBI test to BIPV products. (Including issues related to electrical connection, device dimension, junction boxes, cables, and connectors.)
3. Definition of the research methodology and the testing sequences with Seamless products for adapting the SBI test methodology to BIPV products.

The research will focus on theoretical and experimental approaches to the following parameters:

- Placement of junction boxes and cables.

Key research questions include:

- Where should the junction box be positioned (e.g., near to the burner, at a specific distance, or within a critical area)?
- In the case of ventilated façades, how many junction boxes should be incorporated?

Regarding the positioning of junction boxes, both junction boxes are located on the rear side.

The research methodology will be conducted in the following steps:

1. Test characterization: The first step involves mapping the test, including the temperatures reached and their distribution, without the influence of any combustible materials.
2. Analysis of the influence of electrical elements on the SBI test: To determine whether these elements are truly significant or negligible, several tests will be conducted to analyse how they interfere with test results.
3. Evaluation of different configurations: An analysis will be carried out to determine how different positioning configurations of these elements can impact on the results of a single product.
4. Proposal for a configuration: A configuration proposal will be designed, considering potential risks, to ensure that the worst-case scenario is assessed, and that the configuration suits each product tested.

5. Evaluation and validation of configuration proposal: Various configuration proposals will be tested with Building-Integrated Photovoltaic (BIPV) products to compare and validate them.

5 EXPERIMENTAL IMPLEMENTATION

This section outlines the experimental implementation of the combined environmental aging procedure (NTP) and describes the planned methodology for evaluating fire safety.

5.1 New testing procedures validation

The NTP validation will be conducted using multiple sample types, including two modules of the e-PIZ BIPV solution (as the primary test subject), standard crystalline silicon (c-Si) reference modules, and a VIPV laminate (as an additional comparison case). The combined testing sequence will be benchmarked directly against the standard IEC 61215:2021 [1,2] protocol, in which each environmental stress test—thermal cycling, damp heat and humidity freeze is performed independently and sequentially. The comparative validation methodology comprises the following steps:

1. Pre-characterization: All samples will undergo complete baseline characterization prior to environmental testing This includes:
    - Visual inspection (front/rear),
    - Electrical performance testing (I-V curve under STC),
    - Electroluminescence (EL) imaging,
    - Insulation resistance measurements.
2. New Testing Procedure - Environmental Aging:
    - Sample 1 (e-PIZ) will be tested using the new combined environmental test procedure, integrating thermal, humidity, and freezing stressors into one cyclic sequence.
    - Sample 2 (e-PIZ reference) will undergo conventional IEC testing, where thermal cycling, damp heat, and humidity freeze are executed separately in accordance with IEC 61215-2:2021 [1,2].
    - Additional c-Si reference modules will be tested following the IEC standard sequences to provide baseline comparability across technologies.
    - The VIPV laminate will be tested using the combined sequence to evaluate the method's applicability to lightweight and unconventional designs.
3. In suite test monitoring:

    During the combined test (Sample 1) in-situ monitoring will be conducted using Smart Rack #01, enabling continuous tracking of key electrical parameters, surface and backsheet temperatures, insulation resistance, and leakage currents. For Sample 2 and c-Si reference modules, measurements will be taken after each IEC test segment, including IV performance, EL imaging, and insulation resistance.
4. Post-characterization:

    After completing all test cycles, all samples will be re-evaluated using the same procedures as in pre-characterization: I-V curve measurements, EL imaging, insulation testing, and visual inspection. Any irreversible degradation will be documented and compared.

5. Comparative Analysis:

   The results will be compared across all samples in terms of:

   - Relative power loss under STC,
   - Evolution of electrical and thermal defects (from EL and thermal imaging),
   - Changes in insulation resistance,
   - Presence of visual or structural defects.

The focus will be given to identifying early-stage failure mechanisms and evaluating whether the combined sequence reliably captures new, critical degradation pathways.

5.2 Fire safety validation

The testing procedure currently under development within the SEAMLESS-PV project does not introduce a new testing method but builds upon the existing standard methodology. However, unlike the traditional approach, the procedure developed in SEAMLESS-PV specifically defines and integrates the unique features of BIPV products into the test execution, such as the presence and positioning of junction boxes. The validation of the methodological choices, including the placement and number of junction boxes considered during testing, will be carried out through preliminary tests, providing a clear rationale for each decision.

6 PRE-LAMINATE CERTIFICATION

6.1 Pre-laminate pre-certification approach

In the development and industrialization of IPV, a significant portion of the manufacturing chain relies on semi-finished products, such as pre-laminated composites or BIPV laminates, that are intended for subsequent integration into building elements, vehicle surfaces, or customized mounting systems. These products, while technically sophisticated, remain non-final assemblies, lacking key structural or electrical components required by full certification protocols. As a result, their evaluation poses unique challenges that are not addressed by existing photovoltaic qualification standards. IEC 61215 and IEC 61730 address performance and safety aspects of standard PV modules, including requirements for environmental durability, mechanical strength, and electrical safety, but are not fully suited to semi-finished or integrated IPV products. Pre-laminates often lack finalized mechanical support structures, encapsulation layers (e.g., rear glass or backsheet), or completed interconnections. As such, many standard tests (e.g., mechanical load, insulation resistance, PID, or fire safety) are inapplicable or yield inconclusive results when applied directly to such intermediate products.

Three key limitations arise in this context:

1. Absence of a standardized framework for testing or qualifying semi-finished laminates. There is currently no harmonized methodology within IEC or similar bodies that allows for partial validation or conditional approval prior to full module integration.
2. Barrier to market adoption and scalability, particularly for IPV producers who aim to commercialize subassemblies or outsource final integration to third parties. Without partial conformity assessment, entry into the value chain is hindered.
3. Mismatch between test assumptions and physical reality, where standard mechanical or environmental stress tests assume the presence of features (e.g., full encapsulation, rigid framing, electrical load conditions) that are not yet present in pre-laminated samples.

This gap is particularly critical in sectors such as VIPV or customized BIPV, where pre-laminated elements must be embedded into functional enclosures or carriers before the product can be tested in its final state. Without meaningful intermediate validation, risks of undetected process flaws or material incompatibilities may propagate downstream. In response to these limitations, a dedicated characterization and screening protocol for pre-laminates has been developed and is detailed in Deliverable D5.2 (Seamless PV project). This protocol is not intended to replace formal certification but rather to support quality assurance, verify material compatibility, and offer pre-normative input for potential future standardization. It includes a set of physical, mechanical, and chemical analyses applied both before and after lamination:

Table 5 Characterization protocol - laminate testing

#	Characterization tool	Module structure	Pre-lam or final laminate	Comment
1	**Visual inspection**	GL/GL & GL/BS	Both	Visual control of defects (presence of bubbles, haziness, dust, etc.)

2	**Peel test 90°**	GL/GL & GL/BS	Pre-lam	Adhesion test (to glass, backsheet or solar cell)
3	**Differential scanning calorimetry (DSC)**	GL/GL & GL/BS	Pre-lam & final laminate	Degree of crosslinking for thermoset polymers and melting temperature T_m.
4	**Compressive shear test (CST)**	GL/GL	Final laminate	Shear stress of glass laminate
5	**Rheology of polymers**	Both, polymer	Both	To assess the viscoelastic properties of the polymer after pre-lam and final lamination processes
6	**Gas chromatography**	Both	Pre-lam	Used to assess the concentration of additives (adhesion promoters & cross-linking promoters) after pre-lamination as a function of storage time. The information that can be obtained is rather qualitative.
7	**Fourier Transform Infrared spectroscopy (FTIR)**	Both	Pre-lam	FTIR in transmission mode as an alternative to Gas-chromatography.

These tools collectively enable early detection of material incompatibilities, quality drift in the lamination process, and shelf-life limitations of stored pre-laminated components. Although they do not directly provide compliance with IEC module-level requirements, they support internal qualification, process optimization, and pre-screening before resource-intensive final module assembly and testing.

From a research and regulatory perspective, this pre-laminate testing protocol also represents a potential foundation for future pre-normative frameworks. As market adoption of BIPV/IPV grows—and with it, the demand for modular and flexible supply chains—the need for structured intermediate validation is expected to increase. Task 6.10 will further investigate viable pathways for validating and certifying semi-finished IPV products. This includes defining critical performance indicators, developing intermediate testing sequences, and exploring how such evaluations can complement final certification without introducing regulatory conflicts.

The task will focus on:

- Investigating the specific characteristics and critical performance requirements of semi-finished laminates.
- Exploring possible methodologies to evaluate their reliability, electrical safety, and environmental durability before final integration.
- Analysing how intermediate testing approaches could be structured without contradicting final certification needs for the complete system.

7 CONCLUSION

This initial report summarizes the progress achieved in Task 6.10 of the SEAMLESS-PV project regarding the adaptation of environmental testing procedures for Integrated Photovoltaic (IPV) products. The work is focused on identifying sector-specific regulatory gaps, quality criteria, and on the development of combined environmental testing methodologies to better reflect the real-world conditions experienced by IPV systems. The approach builds on existing IEC testing protocols, adapting and combining thermal cycling, damp heat, and humidity freeze procedures into integrated sequences.

Continuous electrical monitoring (dark IV and insulation resistance) during environmental stress conditions has been introduced to detect early failures and better assess the long-term reliability of IPV products. A major part of the work includes the fire safety aspects of IPV solution, where a specific methodology under the existing SBI framework is under development. The outcomes of this work will contribute to a more representative and efficient testing framework for IPV products, supporting pre-compliance evaluations and informing future validation activities. The next phase will focus on the practical validation of these combined testing methodologies using Seamless-PV prototypes, aiming to confirm their applicability across a wide range of integrated photovoltaic solutions.

The fire reaction tests performed on BIPV products will generate results that support the normalization of the testing procedure. This will ensure that all laboratories and manufacturers have access to a harmonized, transparent, and product-specific testing framework, promoting consistency and comparability across different assessments.

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