



D6.7 Report on testing sequences and prototype manufacturing needs for each IPV product

T6.11 Indoor performance validation and testing to support market deployment



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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 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/>

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EXECUTIVE SUMMARY

Integrated Photovoltaic (IPV) modules are not only considered as electricity generating units, but also as construction, infrastructure, agricultural or vehicle components, depending on their intended application. Therefore, in addition to being subject to specific technical requirements due to their use as electricity generators, they are also subject to regulatory requirements depending on the final application. Furthermore, these requirements depend on the location of the installations, as they may be subject to national regulations. This creates a complex regulatory framework.

The IPV products developed during the Seamless-PV project will be evaluated for compliance with all specifications and performance under real operating conditions. This will demonstrate technology readiness level (TRL) 6 /7 of the technology in question, which will be achieved by manufacturing and installing demonstrators. In order to facilitate this demonstration, it is necessary to verify that the aforementioned products comply with the relevant regulatory and standardisation frameworks.

This document outlines the validation and requirements for each of the products developed in the project, taking into account the specific development undertaken, the intended final application and the location of the demonstration. These tests are defined as indoor tests. Furthermore, the integration, installation methodology and maintenance procedures will be evaluated in order to anticipate potential issues and develop potential solutions prior to the installation of the final demonstrators. The aforementioned tests will henceforth be referred to as outdoor tests and are also described in this document.

The objective of this deliverable is to compile the necessary information and define the requisite tests for each product, as well as the specimens that will need to be manufactured. For each case, due to the technological changes made, the final application of the products or the location, the testing requirements may vary. The final ambition is to have safety and efficient product for the demo in the future.

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Project partners

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Index

Document control sheet	ii
Acknowledgements	vi
Disclaimer	vi
Project partners	vi
1 INTRODUCTION	1
1.1 Description of the deliverable content and purpose	1
1.2 Reference material	2
1.3 Relation with other activities in the project	2
1.4 List of acronyms	2
2 GUIDELINES FOR UNDERSTANDING INDOOR AND OUTDOOR TESTS TABLES	4
2.1 Indoor tests for compliance	4
2.1.1 Requirements	4
2.1.2 Standards	5
2.2 Outdoor tests for monitoring	9
3 COLOURED FILMS AND MODULES	11
3.1 Technology description	11
3.2 Testing sequence	12
3.2.1 Qualification requirements and indoor compliance testing activities	12
3.2.2 Outdoor performance testing activities	15
4 BIPV MODULES WITH INCREASED ADAPTABLE & CUSTOMIZABLE SIZES	17
4.1 Technology description	17
4.2 Testing sequence	18
4.2.1 Qualification requirements and indoor compliance testing activities	18
4.2.2 Outdoor performance testing activities	21
5 ROOFING SHINGLE	23
5.1 Technology description	23
5.2 Testing sequence	24
5.2.1 Qualification requirements and indoor compliance testing activities	24
5.2.2 Outdoor performance testing activities	26
6 BIPV FAÇADE CLADDING SYSTEM	27
6.1 Technology description	27
6.2 Testing sequence	29
6.2.1 Qualification requirements and indoor compliance testing activities	29
6.2.2 Outdoor performance testing activities	32

7	FULL BLACK MODULES FOR UNIFORM ROOF OR FAÇADE.....	34
7.1	Technology description.....	34
7.2	Testing sequence.....	35
7.2.1	Qualification requirements and indoor compliance testing activities.....	35
7.2.2	Outdoor performance testing activities.....	36
8	NOVEL PVNBs.....	37
8.1	Technology description.....	37
8.2	Testing sequence.....	38
8.2.1	Qualification requirements and indoor compliance testing activities.....	38
8.2.2	Outdoor performance testing activities.....	40
9	ADVANCED LIGHTWEIGHT AND FULLY INTEGRATED SOLUTIONS FOR A PASSENGER CAR	41
9.1	Technology description.....	41
9.2	Testing sequence.....	44
9.2.1	Qualification requirements and indoor compliance testing activities.....	44
10	ADVANCED LIGHTWEIGHT AND FULLY INTEGRATED SOLUTIONS FOR A CARGO BOX AND SMALL TRUCK	46
10.1	Technology description.....	46
10.2	Testing sequence.....	48
10.2.1	Qualification requirements and indoor compliance testing activities.....	48
11	ADAPTED MODULE FOR AGRI-PV	49
11.1	Technology description.....	49
11.2	Testing sequence.....	51
11.2.1	Qualification requirements and indoor compliance testing activities.....	51
11.2.2	Outdoor performance testing activities.....	52
12	LIGHTWEIGHT COMPOSITE SOLUTIONS FOR GREENHOUSES	53
12.1	Technology description.....	53
12.2	Testing sequence.....	54
12.2.1	Qualification requirements and indoor compliance testing activities.....	54
12.2.2	Outdoor performance testing activities.....	56
13	CONCLUSIONS	57
14	REFERENCES.....	58

Tables

Table 1.1: Relation between current deliverable and other activities in the project	2
Table 1.2: List of acronyms	2
Table 2.1: Classification of risk of falling debris according EN 1794-2 Annex A	7
Table 2.2: Classification of light reflection according EN 1794-2 Annex D	7
Table 2.3: Classification of reaction to fire according EN 1794-3 Annex D	7
Table 3-1 PV related test sequence for Coloured films and modules	13
Table 3-2 Sector related test sequence for Coloured films and modules	14
Table 3-3 Outdoor performance testing for Coloured films and modules	16
Table 4-1 PV related testing for BIPV modules with increased adaptable & customizable sizes	19
Table 4-2 Sector related testing for BIPV modules with increased adaptable & customizable sizes	20
Table 4-3 Outdoor testing related testing for BIPV modules with increased adaptable & customizable sizes	22
Table 5-1 PV related testing for roofing shingle	24
Table 5-2 Sector related testing for roofing shingle	25
Table 5-3 Outdoor testing related testing for roofing shingle	26
Table 6-1 PV related testing for BIPV façade cladding system with glass	29
Table 6-2 PV related testing for BIPV façade cladding system with lightweight film	30
Table 6-3 Sector related testing for BIPV façade cladding system with glass	31
Table 6-4 Outdoor testing for BIPV façade cladding system with lightweight film	32
Table 7-1 PV related testing for full black modules for uniform roof or façade	35
Table 7-2 Outdoor testing for full black modules for uniform roof or façade	36
Table 8-1 PV related testing for novel PVNBs	38
Table 8-2 Sector related testing for novel PVNBs	39
Table 8-3 Outdoor testing for novel PVNBs	40
Table 9-1: PV related testing for advanced lightweight and fully integrated solutions for a PASSENGER CAR	44
Table 9-2: Sector related testing for advanced lightweight and fully integrated solutions for a PASSENGER CAR	45
Table 10-1 PV related testing for advanced lightweight and fully integrated solutions for a CARGO BOX and SMALL TRUCK	48
Table 11-1: Module characteristics	49
Table 11-2: PV related testing for adapted module for Agri-PV	51
Table 11-3: Outdoor testing for adapted module for Agri-PV	52
Table 12-1: PV related testing for lightweight composite solutions for greenhouses	54
Table 12-2: Sector related testing for lightweight composite solutions for greenhouses	55
Table 12-3: Outdoor testing for lightweight composite solutions for greenhouses	56

Figures

Figure 2.1: Classification according EN 13501-1 6

Figure 3-1 IEC 63092-1 Application categories12

Figure 6-1: e-PIZ 54 prototypes.27

Figure 6-2: e-PIZ 54 mock-up sensors distribution.....33

Figure 6-3: Rendering of the expected e-PIZ 54 mock-up in SUPSI.....33

Figure 9-1: A rough schematic of LYL's VIPV module stack and how it is fabricated.43

Figure 9-2: The top view shape of the LY0 hood panel along with its 2D-dimensions (note: the values are in mm).43

Figure 11-1: Example of semi-transparent modules (source: Onyx)49

Figure 11-2: Photovoltaic module - general view.....50

Figure 11-3: Detail 1 of the module.....50

1 INTRODUCTION

The SEAMLESS-PV project will assess the developed IPV products to determine compliance with specifications and performance under real operating conditions. Prior to the evaluation, a series of internal tests will be conducted to validate the products' compliance with regulatory and standardization frameworks, referred to as indoor tests. Additionally, factors like installation methods and maintenance procedures will be assessed to identify potential issues and develop effective solutions before implementing the final demonstrators. These tests, referred to as outdoor tests, aim to ensure optimal efficiency in the final IPV products.

This document defines both the indoor and outdoor tests for each of the products developed in the SEAMLESS-PV project within WP6. It also specifies the specimens to be manufactured in order to be able to carry out the corresponding tests.

The scope of this report is limited to provide a description of testing plan and the specimen definition that are necessary for the aforementioned testing. In the following phase of the project, two further deliverables will be prepared in accordance with Tasks 6.11 and 6.12. The first of these is D6.8, which will constitute a report on the indoor validation tests. The second is D6.10, which will present the results of the outdoor testing activities and an analysis of whether the developed product meets the requisite reliability, stability, and safety standards for each use case.

1.1 Description of the deliverable content and purpose

This document is structured according to the products developed within the SEAMLESS-PV project. For each product, the document outlines the **compliance tests**, which are defined as indoor testing, and the **monitoring tests**, also defined as outdoor testing.

The indoor tests are validation tests designed to ensure that products comply with the necessary requirements. These include tests for photovoltaic performance, safety, and ageing. Besides, other tests are designed to verify compliance with the requirements of the addressed sector: a) for obtaining building permits/construction approvals and ensure the safety characteristics of the Building Integrated Photovoltaic (BIPV); b) for obtaining building permits for the Photovoltaic noise barrier (PVNB) elements; c) the passengers safety for the VIPV solutions; d) Safety and accessibility for the Agro-PV solutions.

On the other hand, outdoor tests are planned before the installation of the final demonstrators. This intermediate phase will evaluate the integration, installation methodology and maintenance procedure in order to anticipate potential problems and provide solutions before the final demonstrators are installed. These final tests will facilitate high quality monitoring of all pilot lines, thereby supporting an accurate assessment.

In order to conduct the proposed tests, the purpose of this deliverable is to compile the necessary information and define the requisite tests for each product, as well as the specimens that will need to be manufactured.

1.2 Reference material

This Deliverable has taken some data from:

- SEAMLESS-PV project. Deliverable D2.2 – Analysis of regulatory frameworks applicable to IPV systems
- SEAMLESS-PV project. Deliverable D6.1: Report on the preliminary design of IPV solutions

1.3 Relation with other activities in the project

Table 1.1 depicts the main links of this deliverable to other activities (work packages, tasks, deliverables, etc.) within SEAMLESS-PV project. The table should be considered along with the current document for further understanding of the deliverable contents and purpose.

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

Project activity	Relation with current deliverable
WP 8	This package outlines the demo definition, specifying the intended applications for the final use, as well as the specific requirements for each product at designated demo locations. The tests defined in the current deliverable align with these requirements

1.4 List of acronyms

Table 1.2: List of acronyms

Acronyms	Meaning
BIPV	Building Integrated Photovoltaic
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
EAD	European Assessment Document
EN	European Norm
hEN	Harmonized European Norm
IPV	Integrated Photovoltaic
JB	Junction box
PV	Photovoltaic
PVNB	Photovoltaic noise barrier
RTM	Resin transfer moulding
SBI	<i>Single burning item</i>

STC	Standard Test Conditions
TRL	Technology readiness level
UV	Ultraviolet
	Low Voltage Directive (LVD)
	Construction Products Regulation (CPR)

2 GUIDELINES FOR UNDERSTANDING INDOOR AND OUTDOOR TESTS TABLES

2.1 Indoor tests for compliance

The indoor tests are validation tests designed to ensure that products comply with the necessary requirements. These include tests for photovoltaic performance, safety, and ageing. Besides, other tests are designed to verify compliance with the requirements of the addressed sector: a) for obtaining building permits/construction approvals and ensure the safety characteristics of the Building Integrated Photovoltaic (BIPV); b) for obtaining building permits for the Photovoltaic noise barrier (PVNB) elements; c) the passengers safety for the VIPV solutions; d) Safety and accessibility for the Agro-PV solutions.

2.1.1 Requirements

To understand the requirements for installation and compliance, it is crucial to grasp key regulatory frameworks established by the European Commission:

1. **Electrical and System Requirements.** All Integrated photovoltaic solutions, as electrical components or systems, must adhere to **Low Voltage Directive (LVD) 2014/35/EU** [15] [16](or CENELEC standards) for components, ensuring:
 - i. **Protection against electrical hazards.**
 - ii. **Safeguards against risks from external influences.**
2. **Construction Product Requirements.** BIPV and road-sector PVNB products, classified as construction materials, must satisfy the **Construction Products Regulation (CPR) 305/2011** [16], which mandates:
 - i. **Mechanical resistance and stability.**
 - ii. **Fire safety.**
 - iii. **Hygiene, health, and environmental impact.**
 - iv. **Safety and accessibility during use.**
 - v. **Noise protection.**
 - vi. **Energy efficiency and thermal performance.**
 - vii. **Sustainable use of natural resources.**
3. **Vehicle safety glazing Requirements.** Safety glazing materials intended for installation in vehicles must comply with the Uniform Provisions concerning the Approval of Safety Glazing (UNECE R43) [23] which mandate:
 - i. All glazing materials, including glazing material for the manufacture of windscreens, shall be such that, in the event of shattering, the danger of bodily injury is reduced as far as possible. The glazing material shall be sufficiently resistant to the incidents likely to occur in normal traffic, and to atmospheric and temperature conditions, chemical action, combustion and abrasion
 - ii. Safety glazing materials shall in addition be sufficiently transparent, shall not cause any noticeable distortions of objects as seen through the windscreen, and shall not

give rise to any confusion between the colours used in road traffic signs and signals. In the event of the windscreen's shattering, the driver shall still be able to see the road clearly enough to be able to brake and stop his vehicle safely.

Although there are no regulations which specifically pertain to VIPVs as of writing, the glass-free hood being developed by LYL is technically part of the vehicle as a glazing and can thus be reasonably argued to fall under the scope of vehicle safety glazing requirements such as UNECE R43.

These directives ensure that integrated photovoltaic (IPV) systems meet both electrical and application-specific safety standards—such as those for construction and vehicle integration—thereby enabling market access and operational compliance across sectors. For AgriPV, unlike other integrated photovoltaic applications, regulatory requirements are largely comparable to those for conventional PV modules.

2.1.2 Standards

The document outlines detailed tables specifying the technical requirements for each product developed within the Seamless-PV project, as well as the samples to be manufactured for testing. These tables are designed to ensure compatibility with the demonstration sites and guarantee successful integration and installation. To accurately interpret these tables, it is crucial to understand the role of each column and the associated technical standards, which underpin compliance, performance, and safety across all applications.

EU Standard Framework

The EU standardization landscape includes European Norms (ENs), Harmonized European Norms (hENs), and European Assessment Documents (EADs), each serving distinct roles in ensuring product compliance and market access:

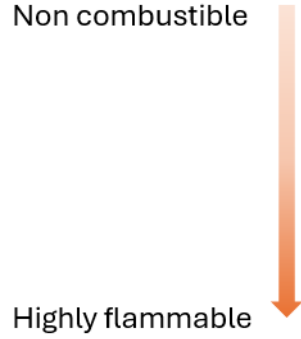
- **European Norms (ENs):** Developed by CEN (European Committee for Standardization) and CENELEC (European Committee for Electrotechnical Standardization), ENs harmonize technical requirements across the EU. While voluntary by default, they become mandatory when referenced in EU legislation, such as the Construction Products Regulation (CPR) or Low Voltage Directive (LVD). ENs are foundational for CE marking, product testing, and cross-border trade.
 - **EN 50583-1/-2:** Photovoltaics in buildings – Part 1: BIPV modules and – Part 2: BIPV systems [2][3].
 - **IEC 63092-1/2** is mentioned several times in the document. Consider that this standard is closely related to EN 50583-1/-2 but while EN 50583-1/-2 is a European Standard, IEC 63092-1/2 is an international standard that references international standards (IEC/ISO) where possible [19][20].
- **Harmonized European Norms (hENs):** These are ENs explicitly referenced in EU legislation to demonstrate compliance with harmonized basic requirements (e.g., safety, durability, fire resistance). Compliance with hENs is a recognized method to meet EU regulatory obligations.
 - **hEN 14388**[4]: Road traffic noise reducing devices – Specifications [7].

- **European Assessment Documents (EADs):** Used under the CPR for products lacking harmonized standards, EADs provide technical assessments to evaluate compliance with essential requirements (e.g., safety, environmental impact). They are issued by notified bodies and serve as a bridge for innovative or niche products.
 - **EAD 090062-01-0404:** Kits for external wall claddings mechanically fixed [13].
 - **EAD 040914-00-0404:** Vecture kits – prefabricated units for external wall insulation and their fixing devices[12].

Qualification / Classification standard:

A standard that categorizes products into predefined classes or levels based on their performance (e.g., fire reaction, sound insulation, impact resistance). Ensures products meet specific safety or performance thresholds for market access.

- **EN IEC 61730-1:** Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction [1].
- **EN 13501-1:** Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests. Classifies fire into A1 (non-combustible) to F (highly flammable) and defined the test to carry in other to obtain each classification for each product [5].



Fire performance	Smoke	Droplets
A1		
A2	s1	d0
B	s2	d1
C	s3	d2
D		
E		d2
F		

Figure 2.1: Classification according EN 13501-1

- **EN 1794-2** Road traffic noise reducing devices – non-acoustic performance – Part 2: General safety and environmental requirements. This document specifies the methods and criteria for assessing the overall safety and environmental performance of road traffic noise reduction devices under typical roadside conditions. Suitable test methods are provided where necessary. Each topic is dealt with separately in Annexes A to E [10].

- Annex A – risk of falling debris

Table 2.1: Classification of risk of falling debris according EN 1794-2 Annex A

Class	Test (kJ)	Results
0	Not tested	
1	0,5	B: Detached pieces that comply with the criteria
2	0,5	C: No pieces detached
3	6,0	B: Detached pieces that comply with the criteria
4	6,0	C: No pieces detached

- Annex D – light reflection

Table 2.2: Classification of light reflection according EN 1794-2 Annex D

Class	Reflection value
0	Not tested
1	Reflection greater than 80
2	Reflection between 40 and 80
3	Reflection below 40

- **EN 1794-3** Road traffic noise reducing devices – Non-acoustic performance – Part 3: Reaction to fire – Burning behaviour of noise reducing devices and classification [11].

Table 2.3: Classification of reaction to fire according EN 1794-3 Annex D

Class	Description
1	if the panel has been damaged to an extent greater than that defined for classes 2 and 3
2	if the damaged area above the source is less than 0.06 m ² and does not extend more than 200 mm above the base of the panel, and the panel has not burned through to the opposite side
3	if there is no damage other than decolouration

- **EN IEC 61215-1**: Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements [17].

- **IEC/TS 62915:** Photovoltaic (PV) modules – Type approval, design and safety qualification – Retesting [21].

Test standard:

A standard that specifies the methodology for testing a product's properties (e.g., mechanical, thermal, fire behaviour). Provides step-by-step procedures to measure performance under controlled conditions. Many of these standards not only outline testing procedures but also establish classification criteria.

- **CEN/TS 1187** – Test methods for external fire exposure to roofs. Specifies four methods for determining the performance of roofs to external fire exposure [4].
- **EN 13823:** Specifies a test method for determining the reaction to fire behaviour of construction products, excluding floor coverings, when exposed to the thermal attack of a single burning item (SBI) [6]
- **EN 1793-5:** Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 5: Intrinsic characteristics – In situ values of sound reflection under direct sound field conditions [8].
- **EN 1794-1** Road traffic noise reducing devices – non-acoustic performance – Part 1: Mechanical performance and stability requirements[9]. This European standard specifies the criteria for rating traffic noise reduction devices according to their basic mechanical performance under standardized exposure conditions, regardless of the materials used.
 - Annex A: Resistance to wind load and load due to vehicle traffic
 - Annex E: Substitute load for dynamic actions caused by snow removal
- **EN 1794-2** Road traffic noise reducing devices – non-acoustic performance – Part 2: General safety and environmental requirements [10]. This document specifies the methods and criteria for assessing the overall safety and environmental performance of road traffic noise reduction devices under typical roadside conditions. Suitable test methods are provided where necessary. Each topic is dealt with separately in Annexes A to E.
 - Annex A – Risk of falling debris
 - Annex D – Light reflection
- **EN 1794-3:** Road traffic noise reducing devices – Non-acoustic performance – Part 3: Reaction to fire – Burning behaviour of noise reducing devices and classification [11].
- **EN IEC 61215-2:** Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures [18].
- **IEC 63092-2:** Specifies BIPV system requirements and testing methodologies. Both building requirements and the applicable electrotechnical requirements as well as defining testing methodologies [20].
 - Annex A: Resistance to wind-driven rain of BIPV roof coverings with discontinuously laid elements – Test methods
- **ISO 11925-2:** Reaction to fire tests – Ignitability of products subjected to direct impingement of flame. This document specifies a method of test for determining the

ignitability of products by direct small flame impingement under zero impressed irradiance using vertically oriented test specimens [22]

Type of test:

- Destructive test: The sample is damaged or altered during testing and cannot be reused.
- Non-Destructive: The sample remains intact and reusable after testing. Allows reusing the same sample for multiple tests.

Expression of product performance:

- Pass/Fail: Binary result indicating compliance with a requirement.
- Class: Assigned category based on performance
- Level: Numerical rating
- Description: Qualitative or quantitative statement of performance

Minimum target:

The minimum performance value, class, level or description a product must achieve to comply with a requirement. The minimum performance value, class, level, or description a product must meet to comply with a requirement. *NA* is used when no minimum target is defined for the demonstration installation.

Specimen dimensions:

The physical size and shape of the test sample

Quantity:

The number of samples required for testing, based on:

- Test standard requirements.
- Whether tests are destructive or non-destructive.

Testing location:

The facility where tests are conducted

2.2 Outdoor tests for monitoring

On the other hand, outdoor tests are planned before the installation of the final demonstrators. This intermediate phase will evaluate the integration, installation methodology and maintenance procedure in order to anticipate potential problems and provide solutions before the final demonstrators are installed. These final tests will facilitate high quality monitoring of all pilot lines, thereby supporting an accurate assessment.

In order to conduct the proposed tests, the purpose of this deliverable is to compile the necessary information and define the requisite tests for each product, as well as the specimens that will need to be manufactured.

For this purpose, informative tables have been created that include the following information:

- **Description of the Test:** A brief explanation of the purpose and procedure of the test.
- **Physical Set-up:** Details of the equipment and configuration used during the test
- **Specimen Dimensions:** The physical size and shape of the test sample.
- **Quantity:** The number of samples required for testing.
- **Testing Location:** The facility where tests are conducted

3 COLOURED FILMS AND MODULES

3.1 Technology description

General description

The technology development is related to the use of coloured interlayer films. ONYX and CSEM are focused on improving these materials and production processes for successful implementation in BIPV, preventing wrinkle formation and ensure a uniform appearance, thereby achieving a photovoltaic technology with broad aesthetic value.

Application description

The technology developed will be integrated in a ventilated Façade in Florence, Italy (Demo #1).

According to IEC 63092-1 (**Photovoltaics in buildings - Part 1: Requirements for building-integrated photovoltaic modules**, see Figure 3-1) this technology belonged to category C (i.e. Application categories).

System description

Coloured (dark grey) BIPV photovoltaic ventilated façade with high architectural value. The system contemplates a horizontal metal structure in "omega" type galvanized steel profiles anchored to the load-bearing structure of the facade by means of "IsoBar" type structural fixings produced by **EJOT**; a vertical metal structure composed of extruded aluminium profiles with tracks for anchoring photovoltaic panels, produced by **ONYX SOLAR ENERGY**.

Module description

The PV panels defined for the installation are modules with square shape, about 1.2 sqm and with a total thickness of the glass of 11.8 mm. The weight and dimensions are limited due to the building height as it will be installed on the top of the building and on the south façade. The first approach is to include two different colours in the panels and intercalate them along the façade, adding aesthetic and energy value to the building.

ONYX will manufacture the PV modules integrating the novel colour interlayer developed at CSEM.

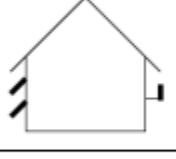
Category A	Sloping, roof-integrated, not accessible from within the building The BIPV modules are installed at a tilt angle between 0° and 75° from the horizontal plane [0°,75°], (see Figure 1), with another building product installed underneath (see Note).	
Category B	Sloping, roof-integrated, accessible from within the building The BIPV modules are installed at a tilt angle between 0° and 75° from the horizontal plane [0°,75°], (see Figure 1).	
Category C	Non-sloping (vertically) envelope-integrated, not accessible from within the building The BIPV modules are installed at a tilt angle between 75° and 90° from the horizontal plane [75°,90°], (see Figure 1) with another building product installed behind (see Note).	
Category D	Non-sloping (vertically), envelope-integrated, accessible from within the building The BIPV modules are installed at a tilt angle between 75° and 90° from the horizontal plane [75°,90°], (see Figure 1).	
Category E	Externally-integrated, accessible or not accessible from within the building The BIPV modules are installed to form an additional functional layer (as defined in 3.1) exterior to its envelope (e.g. balcony balustrades, shutters, awnings, louvers, brise soleil, etc.).	
NOTE A BIPV module is considered to be "not accessible" when another building product (represented by a dashed line in the pictograms) is present, which among other functions prevents: a) the interior surface of the module from being touched, and b) large pieces (in case of breakage) falling onto adjacent accessible areas within the building.		

Figure 3-1 IEC 63092-1 Application categories

3.2 Testing sequence

3.2.1 Qualification requirements and indoor compliance testing activities

CSEM has been performing and will continue to perform lifetime testing activities (according to the relevant industry standards, i.e. IEC 61215/61730) as a support to the developments of the colour foils developed by CSEM and used by ONXX and as a support to ONXY for the introduction of the foils in their manufacturing lines and in the modules used in DEMO-1, which requires a careful fine-tuning of the process parameters. Lifetime testing includes climatic (UV, thermal cycles, damp-heat, etc.), electrical (wet and dry insulation, etc.) and mechanical (hail test and wind loads, etc.) stresses and is regularly used as a feedback loop in material and product optimization and development. The test listed below will be performed on the final product developed for DEMO-1, to gain customer confidence.

Photovoltaic related:

Table 3-1 PV related test sequence for Coloured films and modules

Essential Safety Requirements defined in Low Voltage Directive	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Protection against hazards arising from electrical equipment	Electrical safety	EN 50583	EN IEC 61730-1 +	EN IEC 61215-2 Sequence C -only (IEC 61215-1)	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	One module	4	CSEM, Neuchatel
Protection against hazards which may arise from external influences on the electrical equipment	Electrical safety after accelerated ageing		EN IEC 61215-1 + IEC TS 62915							

Sector-related:

Table 3-2 Sector related test sequence for Coloured films and modules

Basic requirements defined in CPR 305/2011	Performance	EU Standard	Classification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Safety in case of fire	Reaction to fire	EN 50583 and EAD 090062-01-0404	EN 13501-1	EN 13823	Destructive	Class	No needed, but desirable, reference: B, s2-d0	(1000 + d) x 1450 mm	3	Tecnalia (Azpeitia)
								500 x 1450 mm	6	
								(200+d) mm x 1000 mm	3	
								(800) x 1000 mm	3	
								(200 + d) x 450 mm	3	
								(800) x 450 mm	3	
Safety and accessibility in use	Wind load resistance	EN 50583 and EAD 090062-01-0404	EAD 090062-01-0404 (Annex E)	EAD 090062-01-0404 (Annex E)	Destructive	Level	1500 Pa	1200x1000 mm	4 (2x2)	Tecnalia (Azpeitia)
										Tecnalia (Azpeitia)
	Impact resistance	EN 50583 and EAD 090062-01-0404	EAD 090062-01-0404 (Annex G)	EAD 090062-01-0404 (Annex G)	Destructive	Description	NA	1200x1000 mm	4 (2x2)	Tecnalia (Azpeitia)
										Tecnalia (Azpeitia)

3.2.2 Outdoor performance testing activities

CSEM will perform the outdoor monitoring of at least two modules placed side-by-side. The modules will be mounted on the monitoring station of CSEM in Neuchatel and module-level monitoring will be performed. A conventional (non-coloured) module (used as benchmark) will be measured against one (or two) coloured module as the ones planned to be adopted in DEMO-1. The comparison of the two different products is aimed at investigating which effects (angle-of-incidence, low-irradiance performance, etc.) might impact the energy yield of a BIPV module when introducing a coloured foil. In conditions different from Standard Test Conditions (STC) laboratory conditions. See D6.9 for a description of the monitoring set-up

Table 3-3 Outdoor performance testing for Coloured films and modules

Description of the test	Physical set-up	Specimen dimensions	Quantity	Testing location
Monitoring of at least two modules placed side-by-side. I.e. a conventional (non-coloured) module (benchmark) and one coloured module to be used in DEMO-1	Module-level outdoor monitoring system with simultaneous Acquisition of meteorological data (Irradiance, ambient temperature, module temperature, humidity, etc.	Module	2	CSEM, Neuchatel CH

4 BIPV MODULES WITH INCREASED ADAPTABLE & CUSTOMIZABLE SIZES

4.1 Technology description

General Description

3S has changed the cell size for its standard product from M2 to G12 cells to achieve greater efficiency, to keep up with the market and to save costs. Within the project frame, different colours (encapsulants, decorative foils, coating) and anti-glare technologies were produced and tested. Based on these test results, it was decided that the DEMO system should be made with Kromatix colour technology. This technology combines colour and anti-glare effect, which is an advantage for many facades.

Application description

The developed modules will be integrated in a ventilated Façade in Switzerland (Demo #2). Based on the IEC 63092-1 application classifications, this technology is classified under Category C (see Figure 3-1).

System description

The modules are installed as a ventilated façade with the 3S mounting system (shingled, with overlapping area). It is planned to use a sub construction from a new partner for cost saving reasons and to have a System which is tested and approved for the EU market.

The façade is built as far as possible with the four standard module sizes. Some modules are manufactured to customer-specific sizes, for example for the side finishes, for the window surrounds or at the architect's request due to the aesthetics.

Module description

3S will produce the PV Modules with a coloured and satinated front glass. The module thickness is 9mm (Front-glass: 4mm + Back-glass: 4mm). The modules for the façade are rectangular and for the customized sizes, the minimum and maximum dimensions are as follows:

- minimum size: 452mm x 614mm
- max. size: 1650mm x 1190mm

The modules must contain at least 2 strings of 5 cells each and a maximum of 6 strings of 8 cells each.

With the coloured and satinated glass, the modules are designed to meet high aesthetic standards.

4.2 Testing sequence

4.2.1 Qualification requirements and indoor compliance testing activities

CSEM has been performing and will continue to perform lifetime testing activities (according to the relevant industry standards, i.e. IEC 61215/61730) as a support to the developments of 3S BIPV modules, with particular focus on increased customization possibilities. Some of these modifications to the conventional BIPV modules of 3S will be adopted and demonstrated in DEMO-2. Life-time testing includes climatic (UV, thermal cycles, damp-heat, etc.), electrical (wet and dry insulation, etc.) and mechanical (hail test and wind loads, etc.) stresses and is regularly used as a feedback loop in material and product optimization and development.

Based on the retesting guideline IEC/TS 62915 the most relevant and critical tests for a modification of the **front glass** are Damp Heat test (MST 53) and Material creep test (MST 37). Therefore, CSEM and 3S have decided to perform these tests.

The test listed below will be performed on the final product developed for DEMO2, to gain customer confidence.

Photovoltaic related:

Table 4-1 PV related testing for BIPV modules with increased adaptable & customizable sizes

Essential Safety Requirements defined in Low Voltage Directive	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Protection against hazards arising from electrical equipment	Electrical safety	EN 50583	EN IEC 61730-1 + EN IEC 61215-1 + IEC TS 62915	EN IEC 61215-2 Damp heat test (MST 53) Materials creep test (MST 37)	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	One module	4	CSEM (Neuchatel)
Protection against hazards which may arise from external influences on the electrical equipment	Electrical safety after accelerated ageing									

Sector related:

Table 4-2 Sector related testing for BIPV modules with increased adaptable & customizable sizes

Basic requirements defined in CPR 305/2011	Performance	EU Standard	Classification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Safety in case of fire	Reaction to fire	EN 50583 and EAD 090062-01-0404	EN 13501-1	EN 13823	Destructive	Class	B-s1, d0	785 x 975 mm	4	Tecnalia (Azpeitia)
								190 x 975 mm	4	
								785 x 475 mm	4	
								190 x 475 mm	4	
								500 x 1450 mm	4	
Safety and accessibility in use	Wind load resistance	EN 50583 and EAD 090062-01-0404	Annex E	Annex E	Destructive	Level	2400 Pa	1650 x 1190 mm	4	Tecnalia (Azpeitia)
	Impact resistance		Annex G	Annex G	Destructive	Description	NA			

4.2.2 Outdoor performance testing activities

CSEM will perform the outdoor monitoring of at least two modules placed side-by-side. The modules will be mounted on the monitoring station of CSEM in Neuchatel and module-level monitoring will be performed. A conventional module (used as benchmark) will be measured against one (or two) innovative module developed by 3S as the ones planned to be adopted in DEMO-3. The comparison of the two different products is aimed at investigating which effects (angle-of-incidence, low-irradiance performance, etc.) might impact the energy yield of a BIPV module when introducing specific product modifications (e.g. introduction of colour). In conditions different from STC laboratory conditions.

Table 4-3 Outdoor testing related testing for BIPV modules with increased adaptable & customizable sizes

Description of the test	Physical set-up	Specimen dimensions	Quantity	Testing location
Monitoring of at least two modules placed side-by-side. I.e. a conventional module (benchmark) and one innovative module developed by 3S to be used in DEMO-3	Module-level outdoor monitoring system with simultaneous Acquisition of meteorological data (Irradiance, ambient temperature, module temperature, humidity, etc.	Module	2	CSEM, Neuchatel CH

5 ROOFING SHINGLE

5.1 Technology description

General description

The technology development is based on the manufacturing of a lightweight composite roofing shingle using a one-shot Resin transfer moulding (RTM) process, which enables a design with curved transitions that can be seamlessly integrated into the roof. The final modules will be black, and back-contact solar cells will be used, for achieving a fully integrated appearance of the solar cells.

Application description

The developed modules will be integrated in a residential building in Belgium. Based on the IEC 63092-1 application classifications, this technology is classified under Category A (see Figure 3-1).

System description

The modules will be mounted on top of the roof's battens, with an overlapping area. Each shingle has a vertical part on either side, that inserts into a gutter, to collect the water and provide adequate watertightness.

The shingles will be secured using tile fixing hooks. Additionally, rubber joints will be added in the overlapping area and in contact with the gutter, to ensure the watertightness of the roof.

The roof will be covered with as many normal modules as possible, and the remaining gaps will be filled by cutting the needed number of modules to the desired size. This cut up modules will not include solar cells.

Module description

The modules are made of a monolithic composite material inside with the solar cells are embedded. The size of a tile will be 600x700mm, with 2mm thickness.

The shingles consist of a main flat part, containing the solar cells, with a vertical part on either side of the module, that fits into the gutters. The transition between the flat part and the vertical part is curved, for better aesthetics and an easier manufacturing process. Both the flat part and the vertical parts have a trapezoidal shape to them, being shorter and narrower at the top, so that the tiles can correctly overlap and fit with each other.

5.2 Testing sequence

5.2.1 Qualification requirements and indoor compliance testing activities

Photovoltaic related:

Table 5-1 PV related testing for roofing shingle

Essential Safety Requirements defined in Low Voltage Directive	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location		
Protection against hazards arising from electrical equipment	Electrical safety	EN 50583	EN IEC 61730-1 + EN IEC 61215-1 + IEC TS 62915	EN IEC 61215-2 Sequence C - only (IEC 61215-1)	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	Module	4	Tecnalia		
Protection against hazards which may arise from external influences on the electrical equipment	Electrical safety after accelerated ageing			IEC 61215-2 MQT 17								
	Hail test						PASS	Module	2	SUPSI		

Sector related:

Table 5-2 Sector related testing for roofing shingle

Basic requirements defined in CPR 305/2011	Performance	EU Standard	Classification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Safety in case of fire	Reaction to fire	EN 50583	EN 13501-1	CEN/TS 1187:2012	Destructive	Class	No needed, but desirable, reference: Broof (t1)	a tile: 700 x 600 mm	8	Tecnalía (Azpeitia)
Hygiene, health and the environment	Watertightness		IEC 63092 Annex A (modified according Tecnalía procedure)		No destructive	Description	No water penetration	a tile: 700 x 600 mm	9	Tecnalía (Azpeitia)
Safety and accessibility in use	Wind load resistance		According to Tecnalía procedure		No destructive	Level	800 Pa			
	Snow load resistance		According to Tecnalía procedure		No destructive	Level	895 (N/m ²)			
	Impact resistance		According to Tecnalía procedure		Destructive	Description	NA			

5.2.2 Outdoor performance testing activities

Table 5-3 Outdoor testing related testing for roofing shingle

Description of the test	Physical set-up	Specimen dimensions	Quantity	Testing location
Monitoring of four modules replicating the roofing installation of the product (wooden battens, gutters, fixing hooks).	General sensors for meteorological characterization: • Irradiance: DNI, DHI, GHI, albedo Kipp Zonnen RAZON+ for DNI and DHI, HukseFlux SR 30 M 2 D 1 Eko MS 80 s (class A pyranometers). • Global tilted Irradiance HukseFlux SR 30 MS 80 s (class A pyranometers), Atersa MET calibrated cell. • Wind Speed, Relative humidity, Air Temperature, Rain. Other specific equipment for the characterization of the PV behaviour like voltage/current sensors, automatic IV tracers, daylight electroluminescence, data loggers etc. The mounting structure (wooden battens, gutters, etc.) with the PV tiles on top will be installed on the following structure: 	1 tile: 700 x 600 mm	4	Tecnalia (Derio)

6 BIPV FAÇADE CLADDING SYSTEM

6.1 Technology description

General description

The e-PIZ 54 prototypes, illustrated in Figure 6-1, represent an integration of the PIZ Rock Metabio H54 panel with the 3S glass-glass PV module.



Figure 6-1: e-PIZ 54 prototypes.

Application description

The e-PIZ 54 modules are developed as a multifunctional building-integrated photovoltaic façade cladding system: Category D according to the IEC 63092-1 (see Figure 3-1).

These modules produce energy while delivering high thermal and effective acoustic insulation. The system boasts a thermal resistance value of $1.18 \text{ m}^2\text{K/W}$ and a weighted sound reduction index of 13 dB.

System description

Each module can have customized measures, as 900 mm x 500 mm as shown in the previous image till 1200 mm x 600 mm, with a weight of 35 kg/m^2 and a nominal peak power till approximately $170\text{--}180 \text{ W/m}^2$.

The e-PIZ 54 modules are equipped with an integrated fixing and mounting system, and feature a pre-defined path for electrical wiring, simplifying installation and reducing the overall installation time. It also is underlined that the reduced weight of the product permits installers to move panels manually avoid using machinery for the installation and make it easier.

The customization can be done also varying the finishing: an option is to use transparent glass, which reveals the solar cells and the distinctive PIZ pattern, or coloured glass that covers the entire surface.

Module description

The PIZ Rock Metabio H54 panel consists of a 45-mm-thick insulation layer coupled with an 8-mm-thick mortar layer. The 3S glass-glass PV module comprises two layers of glass: a 3,2 mm fully tempered (Thermally toughened glass) front layer, and a 2.1 mm semi-tempered (Heat strengthened glass) rear layer. These are integrated with silicon half-cut solar cells and a 3 layer of POE encapsulant sheets, one on front glass (transparent) and two behind the cells (one black

and one transparent). A junction box (JB) containing all the essential electrical components is attached to the module's rear.

Transparent silicon is used to bond the mortar layer to the rear glass surface of the glass-glass PV module. The adhesive is applied exclusively behind the solar cells and along the edges of the module avoiding being visible.

6.2 Testing sequence

6.2.1 Qualification requirements and indoor compliance testing activities

Photovoltaic related tests:

Veture kit with lightweight glass

Table 6-1 PV related testing for BIPV façade cladding system with glass

Essential Safety Requirements defined in Low Voltage Directive	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Protection against hazards arising from electrical equipment	Electrical safety	EN 50583	EN IEC 61730-1 +	EN IEC 61215-2 Sequence C -only (IEC 61215-1)	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	One module	4	SUPSI
Protection against hazards which may arise from external influences on the electrical equipment	Electrical safety after accelerated ageing		EN IEC 61215-1 + IEC TS 62915							

Veture kit with lightweight film

Table 6-2 PV related testing for BIPV façade cladding system with lightweight film

Essential Safety Requirements defined in Low Voltage Directive	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Protection against hazards arising from electrical equipment	Hail test	EN 50583	EN IEC 61730-1 + EN IEC 61215-1 + IEC TS 62915	IEC 61215-2 MQT 17	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	One module	4	SUPSI

Sector related:**Veture kit with glass**

Table 6-3 Sector related testing for BIPV façade cladding system with glass

Basic requirements defined in CPR 305/2011	Performance	EU Standard	Classification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Safety in case of fire	Reaction to fire	EN 50583 and EAD 040914-00-0404	EN 13501-1	EN 13823 SBI	Destructive	Class	B, s1-d0	805 x 498 mm	9	Tecnalia (Azpeitia)
								263 x 498 mm	9	
								494 x 498 mm	9	
				ISO 11925-2 flammability		250 x 90 mm	10	Tecnalia (Azpeitia)		
Safety and accessibility in use	Wind load resistance		Annex E	Annex E	Non-Destructive	Level	400 Pa	1199 X 600	9	Tecnalia (Azpeitia)
	Impact resistance		Annex L	Annex L	Destructive	Description	NA			

Veture kit with lightweight film

Not needed

6.2.2 Outdoor performance testing activities

Table 6–4 Outdoor testing for BIPV façade cladding system with lightweight film

Description of the test	Physical set-up	Specimen dimensions	Quantity	Testing location
The e-PIZ 54 mock-up is designed to validate the project technology at Technology Readiness Levels (TRL) 6. Compliance with TRL 6 for the coloured and transparent BIPV modules will be verified through the following analyses: • Electrical Performance: Compare energy yield and Performance Ratio (PR) of insulated and open-rack systems. • Temperature: Measure and compare the back-of-module, junction box, and air gap temperatures, and determine the 98th percentile operating temperature according to IEC TS 63126. • Shading: Evaluate the impact of shading on operating conditions and temperature, focusing on worst-case hotspot scenarios.	The e-PIZ 54 mock-up at SUPSI's outdoor facility simulates a multifunctional BIPV façade, oriented south (180° azimuth) with a vertical tilt (90°). It comprises 15 modules, including a 3x3 grid with 5 dummy and 4 functional photovoltaic modules, 2 open rack installations, and 4 e-PIZ modules from the BIPVboost project for comparison. Monitoring is conducted using Gantner's Outdoor Solar Field Test (OTF) system, enabling passive MPPT, IV curve analysis, and the recording of parameters such as I_{sc}, R_{sc}, I_{mp}, V_{mp}, R_{oc}, and V_{oc}. Additionally, a comprehensive array of sensors is integrated, including: • 11 Point-Sensitive Resistance Temperature Detectors (RTDs), with 6 measuring the glass/mortar interface temperature and 5 for junction box temperature. • 3 HIH-5030/5031 humidity sensors. For accurate irradiance data collection, a Zipp & Zonen CM11 Pyranometer is mounted co-planar with the modules on the left side of the structure, complemented by a Si-mV-85-Pt100-4L Silicon Irradiance Sensor. This setup ensures detailed and precise environmental monitoring for performance evaluation.	e-PIZ 54 916 x 471 mm e-PIZ (BIPVBOOST) 1110 x 451 mm	e-PIZ 54 11 e-PIZ BIPVBOOST 4	SUPSI's outdoor facility in Mendrisio, Switzerland (45° 52.2' N, 8° 58.6' E, 354 m elevation).

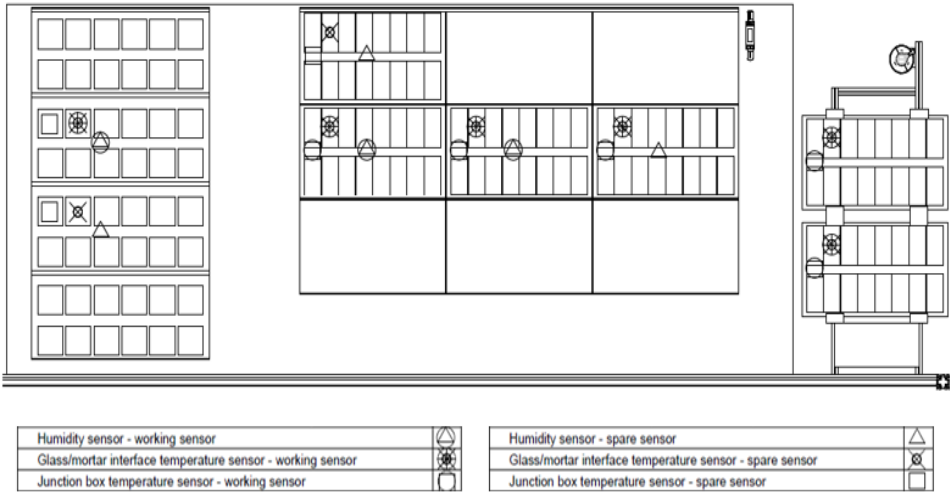


Figure 6-2: e-PIZ 54 mock-up sensors distribution



Figure 6-3: Rendering of the expected e-PIZ 54 mock-up in SUPSI

7 FULL BLACK MODULES FOR UNIFORM ROOF OR FAÇADE

7.1 Technology description

General Description

The PV elements to demonstrate consist in black BIPV modules of different sizes and PV modules from 3S company. They will be integrated into a curtain wall facade configuration aiming a full wall coverage including all its outlines.

An instrumentation will be performed to evaluate the thermal behaviour and electrical production of PV modules and to measure the weather data. The electrical connection will be done with inverters considering the temperature distribution along the facade.

Application description

The demonstration will be performed on the southern facade of FACT experimental building of 6.6 m (3.33*2) height and 6.99 (2.33*3) m width nearly. Thus, BIPV modules will be installed on 6 test cells (3 per floor). The PV modules will be integrated in a curtain wall facade configuration with fully open-air gap.

Based on the IEC 63092-1 application classifications, this technology is under Category C (see Figure 3-1).

System description (ventilated façade)

All facades of the cells considered will be isolated. PV modules will be integrated into a curtain wall ventilated façade configuration with at least 10 to 20 cm of air gap thickness depending on the fixings used.

The PV modules will be mounted in PV strings connected to inverters or DC electronic charges with MPP tracking system according to their size (1 string if all PV modules are identical) and nominal electrical characteristics. For this, a layout will be proposed by adapting the size of the PV modules to the facade outlines (walls and columns, among other).

Module description

PV modules will be full black with black interconnection. Their sizes (4 in total) would vary from 750x390mm² to 1110x590mm².

PV modules already on the market from 3S will also be integrated on the facade.

7.2 Testing sequence

7.2.1 Qualification requirements and indoor compliance testing activities

Photovoltaic related

Table 7-1 PV related testing for full black modules for uniform roof or façade

Essential Safety Requirements defined in Low Voltage Directive	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Protection against hazards arising from electrical equipment	Electrical safety	EN 50583	EN IEC 61730-1 +	EN IEC 61215-2 Sequence C -only (IEC 61215-1)	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	One module	4	CEA
Protection against hazards which may arise from external influences on the electrical equipment	Electrical safety after accelerated ageing		EN IEC 61215-1 + IEC TS 62915							

Sector related

Not required for the corresponding application.

7.2.2 Outdoor performance testing activities

Table 7-2 Outdoor testing for full black modules for uniform roof or façade

Description of the test	Physical set-up	Specimen dimensions	Quantity	Testing location
Weather measurements	Ambient temperature (PT100 in radiation shield).	1 BIPV facade (6,66 m x 6,99 m) nearly	1	FACT
	Solar global radiation in the plane of PV module (pyranometer)		1	
	Wind velocity and direction (anemometer and weathervane).		1	
Thermal measurements	One temperature at the backside of PV module (T-type thermocouples) and on the wall.		6 (behind PV modules) 6 (on the wall)	FACT
Aerodynamic measurements	Air temperature in the air gap (T-types thermocouples).		6	FACT
	Air flow rate or air velocity in the air gap.		2	
Electrical measurements	Power (Pmpp), voltage (Vmpp), current (Impp) (continuous measurement) before and after inverter.		1	FACT

8 NOVEL PVNBs

8.1 Technology description

General Description

The technology developed in this demo is a novel photovoltaic noise barrier (PVNB) for multifunctional acoustic abatement. This product will be installed in a highway to reduce noise to nearby buildings.

This product is a combination of two main parts: On the top, the PV glass panel to generate electricity which can be used to illuminate nearby streetlamps or illuminate signs on the road itself (Innovative part). And, on the bottom, an absorptive commercial noise barrier. A surface of 150 sqm of PBNBs in a highway on the north of Spain will be installed.

Application description

PVNBs represent a PV solution that enhances sound attenuation and provides free energy thanks to PV-glass. These PVNBs will be implemented at A8/AP8 highway at Bizkaia Connected Corridor living lab.

System description:

The final product is a system that integrates acoustic and photovoltaic solutions into a modular system to make it multifunctional: protect users nearby from noise pollution and produce clean and free energy.

The maximum dimensions of the screens have been established based on the modularity of the panels provided by ONYX, adapting to the common dimensions of road noise barriers that could replace existing structures.

The design of the panels seeks an optimal balance between acoustic, mechanical and power generation properties. As for the support structure, a frame with a U-shaped profile is designed, sized to withstand external forces such as wind and snow. This frame incorporates the wiring system and junction boxes. The preliminary design includes a lateral fixing system by means of screws to the pillar, maximizing functional and aesthetic integration.

Module description:

ONYX will manufacture the PV part of the PVNBs. This PV part will use new cell formats, trying to achieve a good balance between semi-transparency level and power generation.

The PVNBs have the followings characteristics:

- Bifacial silicon solar cells, to increase the power generation.
- A total thickness of 15.8 mm. The use of different thicknesses for the front and rear glass since an asymmetrical thickness improves the acoustic abatement.
- Large and rectangular formats, around 5 sqm, in order to avoid joints as many as possible since they could be a critical point for the acoustic abatement.
- Finally, at the bottom, the acoustic material will be integrated which allow to improve the acoustic insulation.

8.2 Testing sequence

8.2.1 Qualification requirements and indoor compliance testing activities

Photovoltaic related:

Table 8-1 PV related testing for novel PVNBs

Essential Safety Requirements defined in Low Voltage Directive	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Protection against hazards arising from electrical equipment	Electrical safety	EN 50583	EN IEC 61730-1 +	IEC TS 62915- 2- Sequence C (MQT 10), (MQT 11), (MQT 12) and Sequence E (MQT 13) -only	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	1800 mm x 900 mm	4	Tecnalia
Protection against hazards which may arise from external influences on the electrical equipment	Electrical safety after accelerated ageing		EN IEC 61215-1 +					210 mm x 297 mm	4	

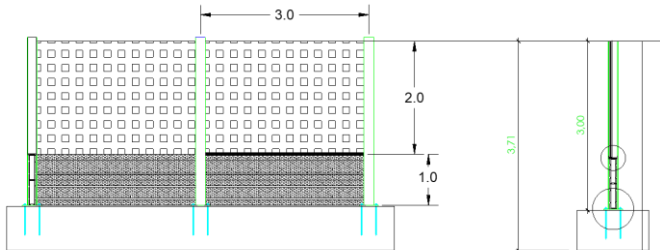
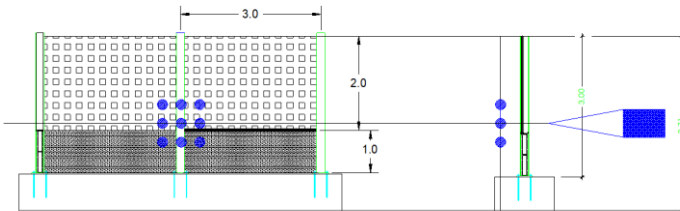
Sector related

Table 8-2 Sector related testing for novel PVNBs

Basic requirements defined in hEN 14388	Performance	EU Standard	Classification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Noise reduction	Diffuse sound field	hEN 14388	NA	1793-1	Non destructive	DLR (dB)	25 dB	Complete noise barrier 2,76 m x 3,54 m	2	Tecnalia (Vitoria)
	Direct sound field		NA	1793-5	Non destructive	DLSI (dB)	25 dB	4 x 6 m	1	Becsa
Stability requirements	Wind load		NA	5.2 EN 1794-1 Annex A	Calculation	kN/m	NA	NA	NA	Becsa
	Snow load		NA	5.6 EN 1794-1 Annex E	Calculation	kN	NA	NA	NA	Becsa
Safety in use	Risk of falling debris		EN 1794-2 Annex A	EN 1794-2: Annex A	Destructive	Weight / Size	NA	2x3 m (The PV panel, with their respective fixing system)	1	Tecnalia (Azpeitia)
	Light reflection		EN 1794-2 Annex D	5.4 EN 1794-2 Annex D	Non destructive	Class	NA	Minimum 100 mm x 100 mm	1	
Fire behaviour	Reaction to fire		EN 1794-3	EN 1794-3	Non destructive	Class	Class 2	Complete noise barrier	1	

8.2.2 Outdoor performance testing activities

Table 8-3 Outdoor testing for novel PVNBs

Description of the test	Physical set-up	Specimen dimensions	Quantity	Testing location
Initial structural tests of the photovoltaic acoustic barrier system, installation of panels, joints, ducts, wiring, profiles, and screws.	Two sections of photovoltaic acoustic screen, with an intermediate profile that serve for subsequent acoustic insulation and safety tests.  Visual & technical test on the assembly and disassembly of the systems and test about the equipment necessary for the installation of the system	6 m x 3 m	1	Becsa
Acoustic performance tests for the acoustic efficiency of joints, profiles, panels, and systems	Measurement chain with 9-microphone array and equipment for data acquisition of the acoustic behaviour of the system 	6 m x 3 m	1	Becsa

9 ADVANCED LIGHTWEIGHT AND FULLY INTEGRATED SOLUTIONS FOR A PASSENGER CAR

9.1 Technology description

General description

The technology in the VIPV demonstrator which is relevant in this section are double-curved solar panels that fit flush on the roofs, hoods, and/or trunks of electric passenger vehicles. The core of these lightweight solar panels are prelaminates which are composed of highly performant solar cells placed meticulously atop a patterned conductive back sheet (CBS) and sandwiched between front and back encapsulants. These prelaminates are then laminated with front & back sheets which lend the finished panels their mechanical rigidity and robustness (see Figure 9-1).

Application description

In general, surfaces which possess high surface areas like a car's roof, hood, or trunk are ideal spaces for vehicle-integrated photovoltaics (VIPVs). For the purposes of the SEAMLESS-PV demonstrator, a panel will be designed and manufactured to fit seamlessly on the hood of an electric passenger car. Unless otherwise communicated by the company, Lightyear 0 (LY0), LYL's very own electric vehicle, will be the car that the company will develop a hood panel for in the context of the consortium's overarching objectives.

Due to the lack of time to develop panels for all the surfaces of LY0, LYL chose to focus on one surface: the hood. The hood surface is arguably one of the hardest to develop panels for because compared to the other surfaces, it needs to pass stringent pedestrian safety tests on top of photovoltaic functionality and robustness tests. More specifically, the hood panel under development will have to conform to automotive safety standards like the UNECE R43.

Photovoltaic-wise, LY0's full-scale panels will be subjected to a handful of tests described in IEC 61215-2 and IEC 61730. In essence, they will undergo Sequence C as described in IEC 61215-2; the battery of tests in this sequence will gauge the reliability and functionality of the hood panel being developed. In addition, a hotspot endurance test will be conducted on the panel in order to ascertain that it would not break, delaminate, or evolve defects when hotspots appear on it due to partial cell shading.

System description

After its installation on a passenger car, the double-curved solar panel will be outfitted with a power electronics system (i.e. multiport converter) which will enable an efficient transfer of power from the panel to the car's battery. In the case of the demonstrator for SEAMLESS-PV, the panel will be connected to a test battery setup to enable the precise measurement of both the modules and the multiport converter's performances in real-time.

Module description

The specific stack composition of the modules that will be used for indoor testing of VIPV modules (i.e. BOM 3) is described elsewhere (i.e. Deliverable 5.1) and will not be discussed in this section. Instead, this section will provide the dimensions of the samples that will be used for testing purposes. In total, there are 2 types of samples which will be utilized in testing, and they are described below:

Mini-modules as samples for the ball-drop test (UNECE R43)

To gauge pedestrian safety, a ball-drop test as specified in the UNECE R43 standard will be done on small, flat samples called “mini-modules”. Essentially, these mini modules are square in shape and will have dimensions of 300 mm x 300 mm.

Full-scale panels as samples for Sequence C as described in IEC 61215-2

To gain as much insight as possible about the company’s technology from a product perspective, LYL will be fabricating full-scale panels for the tests in Sequence C as described in IEC 61215-2. By doing so, the company will be able to gauge the performance and robustness of its chosen bill of materials (i.e. BOM 3 as discussed in Deliverable 5.1) when applied to large, VIPV-bound panels.

Having said that, the top view shape of the LY0 hood panel that will be integrated on the demonstrator and its respective 2D-dimensions are noted in Figure 9-2.

It is worth reiterating that LYL’s full-scale panel technologies are all double-curved and the LY0 hood panel illustrated in Figure 9-2 is not an exception. The main reason why the curvatures of the LY0 hood panel were not shown in Figure 9-2 is that the panel possesses various curvatures along its length and width, making it difficult and complex to illustrate. As such, it was decided not to show the curvature of the panel at all and instead show what the panel looks like from a top view perspective and its dimensions along its length and width.

For the photovoltaic tests that will be performed on the full-scale panel samples that will be subjected to testing, the IV measurement procedure will have to be modified somewhat because of the curved nature of the samples. Likewise, the hot spot endurance test that is planned would necessitate a light source/a series of light sources which will illuminate the curved surface of the hood panel homogeneously. LYL will closely collaborate with SUPSI, the accredited testing partner involved in the SEAMLESS-PV project, regarding the extent that can be done to accommodate the changes needed to test the full-scale panel samples as close as possible to the requirements set in IEC 61215-2 and IEC 61730.

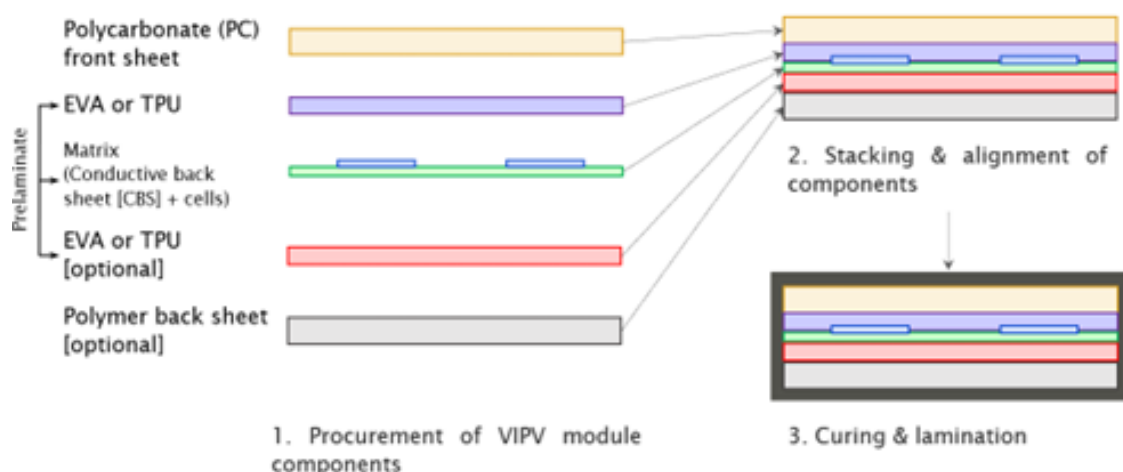


Figure 9-1: A rough schematic of LYL's VIPV module stack and how it is fabricated.

The process begins with gathering the required materials (Step 1); followed by their stacking and alignment (Step 2); and, finally, the curing and lamination of the stack (Step 3). Note the definition of a prelaminate here. It is composed of the matrix (i.e. CBS + cells), front encapsulant, and optionally, a back encapsulant. For more information about this, please refer to Deliverable 5.1.

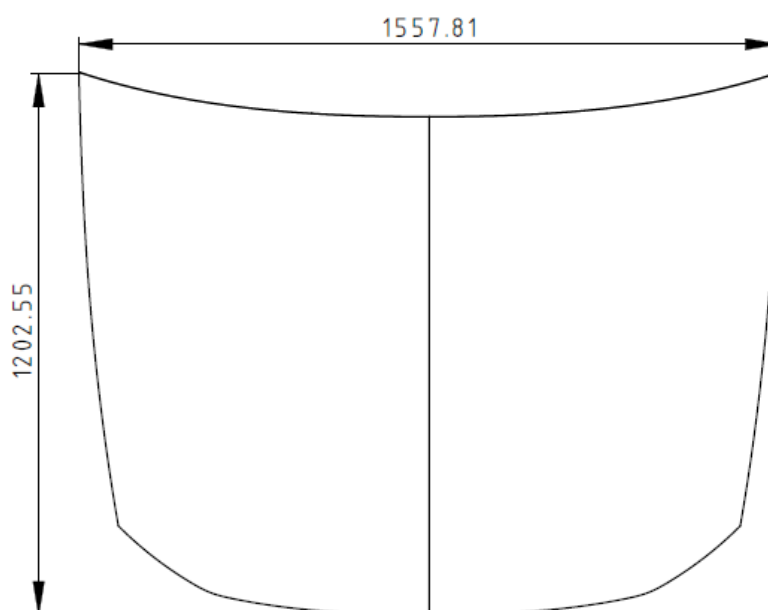


Figure 9-2: The top view shape of the LY0 hood panel along with its 2D-dimensions (note: the values are in mm).

Like all the other VIPV technologies developed by Lightyear Layer (LYL), the LY0 hood panel is double-curved. However, this aspect of the module is not depicted in the figure because illustrating them proved difficult and complex. As such, the panel's various curvatures are not shown in the figure above.

9.2 Testing sequence

9.2.1 Qualification requirements and indoor compliance testing activities

Photovoltaic related

Table 9-1: PV related testing for advanced lightweight and fully integrated solutions for a PASSENGER CAR

Essential Safety Requirements defined in Low Voltage Directive	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Protection against hazards arising from electrical equipment	Electrical safety	EN 50583	EN IEC 61730-1 + EN IEC 61215-1 + IEC TS 62915	EN IEC 61215-2 Sequence C - only (IEC 61215-1)	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	Full-scale panel	2	SUPSI
Protection against hazards which may arise from external influences on the electrical equipment	Electrical safety after accelerated ageing			IEC 61215-2 - Hot spot	Destructive	Description	No evidence of major visual defects. Functional Same insulation resistance	Full-scale panel	1	SUPSI

Sector related

Table 9-2: Sector related testing for advanced lightweight and fully integrated solutions for a PASSENGER CAR

Basic requirements UNECE R43	Performance	EU Standard	Classification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Mitigation of bodily injury	Mechanical strength	-	UNECE R43	UNECE R43 -8.1.2. Ball-impact test (227 g ball)	Destructive	PASS/FAIL 1. The ball does not penetrate the test piece 2. The test piece does not break into separate pieces	PASS 8/10 mini modules should pass	30 cm x 30 cm	10	LYL

10 ADVANCED LIGHTWEIGHT AND FULLY INTEGRATED SOLUTIONS FOR A CARGO BOX AND SMALL TRUCK

10.1 Technology description

General description

BRANKA is developing a set of photovoltaic solutions specifically designed for integration into cargo boxes and small trucks, within the scope of Task 6.7. These solutions build upon the *Solarface®* technology platform developed in WP4 and further enhanced in WP5, based on prepreg composite encapsulation processes. The goal is to provide fully integrated, lightweight, and aesthetically seamless VIPV modules tailored for logistics and light commercial vehicle applications.

These PV systems will replace conventional outer layers of vehicle structures, enabling solar energy generation for auxiliary systems (e.g., refrigeration, telematics) while preserving mechanical and aesthetic functionality. The approach allows for cost-efficient integration in vehicle assembly lines, a critical factor for market adoption.

Application description

The main application involves the integration of glass-free PV panels into the roof and side panels of cargo boxes and small trucks, enabling energy-autonomous operation in logistics fleets. The technology is co-developed with LIDERKIT, a European leader in modular cargo box manufacturing, and supported by TECNALIA for validation.

These modules are designed for integration during manufacturing, and they are compatible with:

- Curved and flat composite panel geometries
- Adhesive based assembly
- Internally integrated cable routing

The use of back-contact or visually optimized c-Si cell layouts will ensure minimal visual disruption on the vehicle surface, addressing aesthetic demands in the transport and retail sectors.

System description

The system developed by BRANKA consists of a prelaminated monolithic PV skin formed by a sandwich structure using advanced prepreg materials. Key characteristics include:

- Encapsulation matrix: Thermoset resin systems
- Fire reinforcement: Woven glass fibre for weight optimisation
- Front surface: Transparent composite layer with **anti-scratch coating** under evaluation for automotive durability
- Back side: Composite or compatible surface with integration-ready features (routing channels, fixation zones)

- Electric interface: Junction box and cable routing fully embedded into the carbo box sandwich cored structures

The structure is processed enabling short cycles, high repeatability, and compatibility with curved surfaces. The module is designed to support common environmental loads (vibration, thermal cycling, UV exposure) found in commercial transport operations.

Module description

The reference module fabricated for demonstration and testing purposes features the following characteristics:

- Cell configuration: Zebra cells
- Weight: <6.5 kg/m²
- Encapsulant: Thermoset resin and fibre composite with UV stability
- Front protection: Transparent thermoset layer with optional scratch-resistant surface
- Back sheet: White coated composite layer compatible with vehicle body materials
- Visual finish: Seamless, uniform black and white surface for aesthetic integration

10.2 Testing sequence

10.2.1 Qualification requirements and indoor compliance testing activities

Photovoltaic related

Table 10-1 PV related testing for advanced lightweight and fully integrated solutions for a CARGO BOX and SMALL TRUCK

Essential Safety Requirements defined in Low Voltage Directive,	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Protection against hazards arising from electrical equipment	Electrical safety	EN 50583	EN IEC 61730-1 + EN IEC 61215-1 + IEC TS 62915	EN IEC 61215-2 Sequence C -only (IEC 61215-1)	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	Full-scale panel	3	TECNALIA
Protection against hazards which may arise from external influences on the electrical equipment										

Sector related

Not required for the corresponding application

11 ADAPTED MODULE FOR AGRI-PV

11.1 Technology description

General description

AKUO and ONYX have been cooperating to develop semi-transparent modules for Agri-PV applications. The semi-transparency level has been defined by finding a trade-off between agricultural needs and PV production, maximizing the synergies between the two applications.

The semi-transparency is reached by using glass-glass modules with cut cells and specific intercell distance.



Figure 11-1: Example of semi-transparent modules (source: Onyx)

Module description

The dimensions and characteristics of this modules are the following:

Table 11-1: Module characteristics

Module glass-glass dimensions (mm)	2382 x 1134 x 9,8
Glass dimension (mm)	2382 x 1134 x 4
Cell technology	Mono-crystalline silicon Bifacial half cells 10 bus bar
Cell dimension (mm)	182 x 91
Number of cells	76 (4 strings / 19 cells per string)
Encapsulant	EVA
Power	240 W 89 W/m ²
Weight	54 kg 20 kg / m ²
Transparency level	54 %

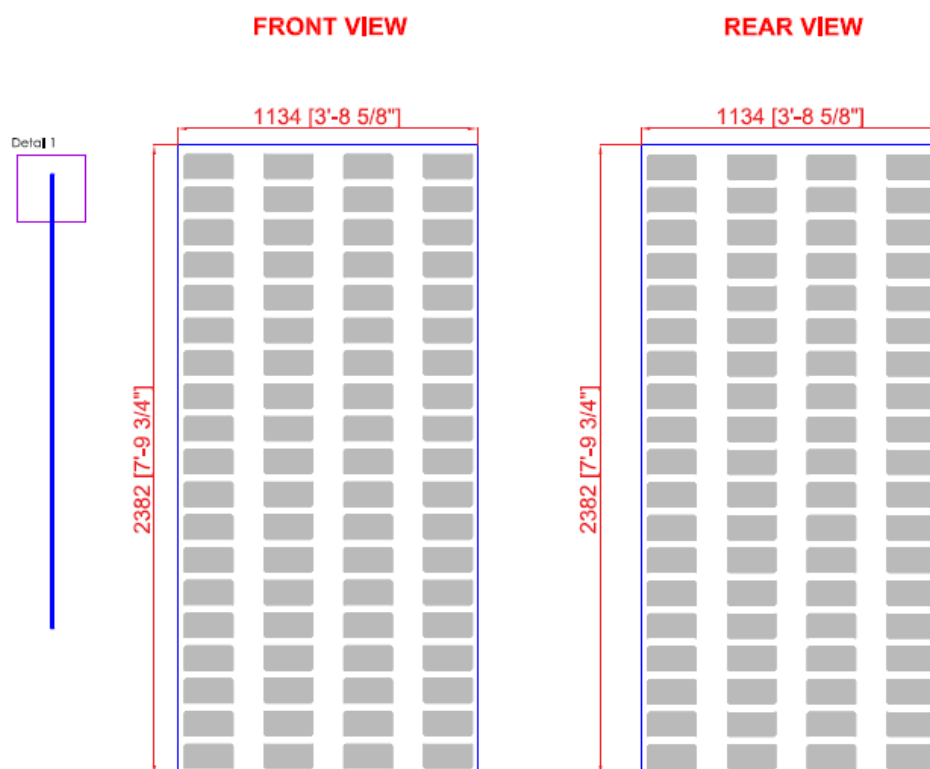


Figure 11-2: Photovoltaic module - general view.

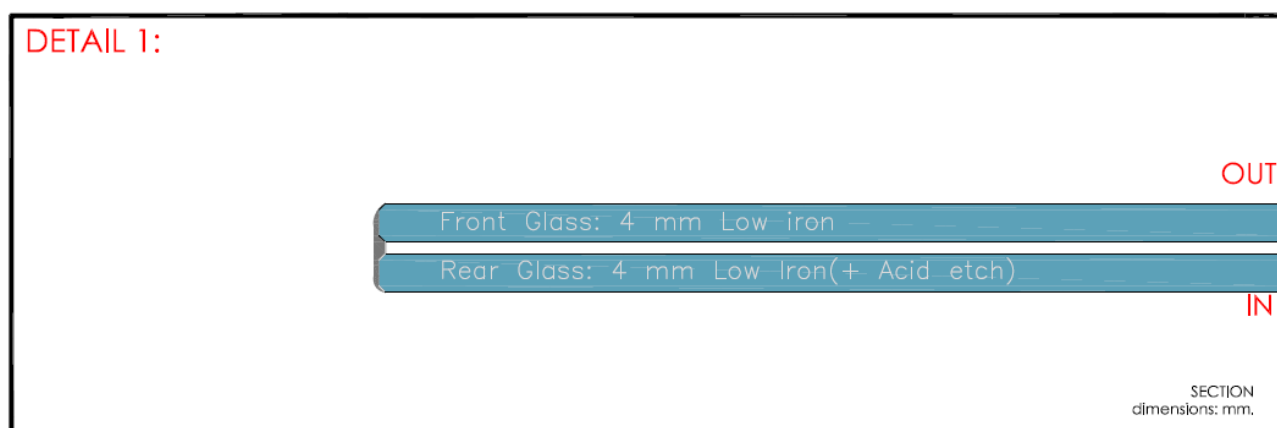


Figure 11-3: Detail 1 of the module.

11.2 Testing sequence

11.2.1 Qualification requirements and indoor compliance testing activities

Photovoltaic related

Table 11-2: PV related testing for adapted module for Agri-PV

Essential Safety Requirements defined in Low Voltage Directive,	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Protection against hazards arising from electrical equipment	Electrical safety	EN 50583	EN IEC 61730-1 + EN IEC 61215-1 + IEC TS 62915	EN IEC 61730-2 + EN IEC 61215-2 Sequence C - only	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	One module	4	CEA
Protection against hazards which may arise from external influences on the electrical equipment	Electrical safety after accelerated ageing									

Sector related

No needed

11.2.2 Outdoor performance testing activities

Table 11-3: Outdoor testing for adapted module for Agri-PV

Description of the test	Physical set-up	Specimen dimensions	Quantity	Testing location
Monitoring of the performance	Electrical measurements in DC: Power (Pmpp), voltage (Vmpp), current (Impp) (continuous measurement) with DC electronic loads	PV module	4	CEA
Temperature	Thermocouples (behind each PV module)	PV module	4	CEA
Luminosity under panels	Weather station: light meter	PV module	4	CEA
Analysis of light spectrum	Weather station: Solar global radiation in the plane of PV module and on the horizontal plane (pyranometers), pyrgeometer (IR solar radiation measurement), pyrheliometer (direct solar radiation), diffuse solar radiation, radiometers UV-A and UV-B in the horizontal plane sensor.	PV module	4	CEA

12 LIGHTWEIGHT COMPOSITE SOLUTIONS FOR GREENHOUSES

12.1 Technology description

General Description

The technology development is based on the manufacturing of a lightweight composite PV module by means of prepregs manufacturing technology using a hot press. This process allows the industrial manufacturing of composite parts (PV modules in this case) in a reliable and repetitive way. The manufactured modules will be natural colour (not painted) and bifacial half-cut M10 solar cells has been selected as the PV technology.

Application description

The PV modules designed and manufactured for this task will be installed in a greenhouse located in Derio (Spain), property of NEIKER. The greenhouse consists of an enclosure of rigid polycarbonate panels fixed to a galvanized steel structure.

The greenhouse enclosure is regulated by standard UNE-EN 13031-1:2020.

System description (greenhouse)

The modules will be mounted on the greenhouse envelope panels and the underlying structure by means of auto drill screws and neoprene washers in order to assure water tightness.

The distribution of the modules on the greenhouse envelope will be such that the luminosity of the greenhouse is adequate for the crop in question and as uniformly distributed as possible.

Furthermore, the installation of the modules will be resolved by trying to ensure that their replacement, if necessary, is as simple as possible and without compromising the envelope of the greenhouse.

Module description (manufacturer, the innovation within the project, dimensions...)

The modules are made of composite, with an epoxy resin as the matrix and glass fibre as reinforcement. As a result of the manufacturing process, bifacial half cut M10 solar cells are integrated within the composite material.

The size of the modules will be, approximately, 400 mm x 1000 mm x 1 mm (thickness) and will be flat but adaptable to the curved shape of the greenhouse envelope.

Two strings of 10 cells each are foreseen for each module, with an approximated output power of 67 Wp.

BRANKA SOLUTIONS will be responsible for the manufacturing of the modules.

This technology and solution allow a simple integration into the application, with the advantage of low added weight to the structure, adaptability to the curved shapes of the envelope and simple replacement of the modules, if necessary.

12.2 Testing sequence

12.2.1 Qualification requirements and indoor compliance testing activities

Photovoltaic related

Table 12-1: PV related testing for lightweight composite solutions for greenhouses

Essential Safety Requirements defined in Low Voltage Directive,	Performance	EU Standard	Qualification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Protection against hazards arising from electrical equipment	Electrical safety	EN 50583	EN IEC 61730-1 + EN IEC 61215-1 + IEC TS 62915	EN IEC 61730-2 + EN IEC 61215-2	Destructive	PASS /FAIL (performance loss <5%; Insulation Resistance >40 Mohm/m2)	PASS	Module	4	Tecnalia
Protection against hazards which may arise from external influences on the electrical equipment	Electrical safety after accelerated ageing			Sequence C - only						
	Hail test			IEC 61215-2 MQT 17					2	SUPSI

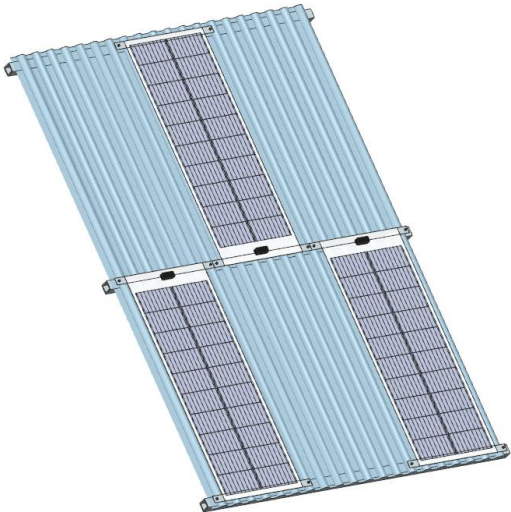
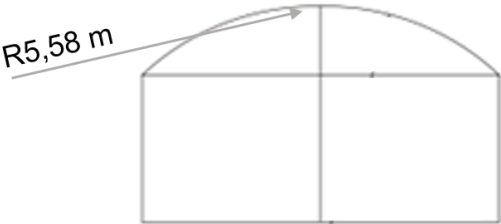
Sector related

Table 12-2: Sector related testing for lightweight composite solutions for greenhouses

Basic requirements defined in CPR	Performance	EU Standard	Classification standard	Test Standard	Type of test	Expression of product performance	Minimum target	Specimen dimensions	Quantity	Testing location
Safety and accessibility in use	Wind load resistance	NA	NA	NA	Destructive	Level	NA	1030x400mm	2	Tecnalia (Azpeitia)

12.2.2Outdoor performance testing activities

Table 12-3: Outdoor testing for lightweight composite solutions for greenhouses

Description of the test	Physical set-up	Specimen dimensions	Quantity	Testing location
Monitoring of 5 modules replicating the greenhouse installation (modules attached to corrugated polycarbonate sheets). A 3D drawing of the set-up of 3 of the modules is shown below: 	General sensors for meteorological characterization: • Irradiance: DNI, DHI, GHI, albedo Kipp Zonnen RAZON+ for DNI and DHI, HukseFlux SR 30 M 2 D 1 Eko MS 80 s (class A pyranometers). • Global tilted Irradiance HukseFlux SR 30 MS 80 s (class A pyranometers), Atersa MET calibrated cell. • Wind Speed, Relative humidity, Air Temperature, Rain. Other specific equipment for the characterization of the PV behaviour like voltage/current sensors, automatic IV tracers, daylight electroluminescence, data loggers etc. The mounting structure (polycarbonate sheets.) with the PV modules on top will approximate the greenhouse cover curvature: 	1 module: 1020 x 400 mm	5	Tecnalia (Derio)

13 CONCLUSIONS

The information necessary to define the validation tests has been collected. This information defines the requirements for each product developed in the SEAMLESS-PV project. These requirements have been defined in order to comply with the corresponding permits, to ensure safety and to evaluate the performance and ageing of the products and enable their installation on the demonstrations. The definition of the specimens needed to carry out the specified tests has also been included. In addition, the process for evaluating the installation methodology and anticipating potential problems has been defined.

Based on the information presented in this document, it is expected that all products will meet the requirements and that there will be no problems in installing them in the respective demonstration sites. Finally, once the tests have been defined, it has been found that all of the above tests can be covered by different project partners, thus facilitating the validation process. The information provided in this document will allow the project to proceed with the manufacture of the samples and the planning and execution of the tests.

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