Solar Window Block Catalogue

Window block samples for laboratory testing

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Adaptable and adaptive RES envelope solutions to maximise energy harvesting and optimize EU building and district load matching

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List of abbreviations and acronyms

a-Si	Amorphous silicon
BIPV	Building-integrated photovoltaic
c-Si	Crystalline silicon
DC	Direct current
IGU	Insulating glazing unit
MPPT	Maximum power point tracking
PV	Photovoltaic
VM	Ventilation machine
XPS	Extruded polystyrene insulation

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Executive summary

Prefabricated window block systems provide valuable opportunities for enhancing energy performance of existing buildings, minimizing the impact on building occupants. In addition, these systems allow for effective integration of active components to maximize renewable energy sources exploitation, as is the case of the solar window block.

The research presented in this document focuses on the manufacturing of the different solar window block samples for laboratory testing. The three mock-ups have been developed considering different solar window package options, to promote their applications in demo-case buildings during the Energy Matching project activities and foster replication after project end.

The technology development work has been carried forward in close cooperation with technology providers involved in the project consortium, with the aim of pre-assessing industrial feasibility of the product and highlighting technical issues that may arise when mounting the system, prior to the construction work phase. Afterwards, the manufacturing process has been accomplished by different partners of the project, being Eurofinestra the window block manufacturer and integrator of the technologies implemented in the system. Rest of technologies integrated in the window block has been provided by different partners, such as, the photovoltaic glass-glass modules by Onyx, the PV click&go structure by Tulipps and the automatic shading system by Pellini.

Besides the overview of the solar window block designs and technical features, this document gathers also the manufacturing process of the different samples and the main modifications and issues highlighted during the production phase.

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1. Introduction

The work presented in this report as part of the H2020 Energy Matching project is the continuation of the solar window block development process, and consequently a continuation of the previous reports “D3.1 Conceptual designs of a range of window block systems” and “D3.2 Technical specifications of window block components”.

“D3.1 Conceptual designs of a range of window block systems” report aimed at describing the development and the conclusions related to the solar window block system for the residential building energy retrofit. As a consequence, a catalogue of possible technical solutions were developed with the aim of enhancing the retrofitted window thermal performance, minimizing the risk of errors during window’s replacement, thus increasing energy efficiency compared to traditional window solutions. As a result, the most promising options were shortlisted to be further developed.

“D3.2 Technical specifications of window block components” aimed at detailing the technological design of the three shortlisted solar window block configurations, to bring forward the manufacturing of real scale visual and performance mock-ups. Technical specifications, manufacturing processes and expected performances at component and system level of the proposed solutions were presented.

Shortlisted window block solutions have been further developed and manufactured, as reported in this document. These manufactured solutions have been installed in Eurac outdoor lab for testing activities, as it is further explained in next sections

2. Design of window block mock-ups

2.1. General overview

The starting point of the work performed is the shortlisted window block configurations resulted from the initial multi-disciplinary analysis and detailed design. The three design configurations are described below.

- Window block 1, with BIPV on the window sill: This solution integrates a PV module in the usual window sill location, a decentralized ventilation unit powered through a battery and the PV system and dynamic reflective integrated shading system.

- Window block 2, with BIPV as an overhang: This solution integrates a PV module in the window overhang position, a decentralized ventilation unit powered through a battery and the PV system and dynamic reflective integrated shading system.

- Window block 3, with vertical fixed BIPV next to the window: This solution integrates a vertical PV module fixed on the wall next to the window, a decentralized ventilation unit powered through a battery and the PV system and dynamic reflective integrated shading system.*

  (* Originally the design of the BIPV installation of this solution was different, the PV system consisted of two PV modules located in both sides of the window, to be used as sliding window shutters. However, due to the non-readiness to market of this solution, it was replaced by the fixed vertical PV solution. Besides, this option was particularly interesting because it will be implemented in the Italian demo case building)

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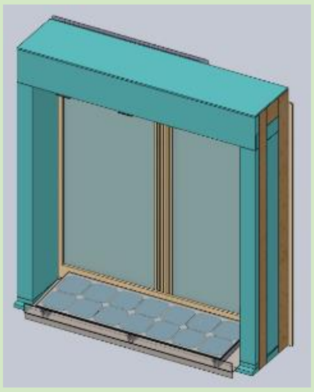
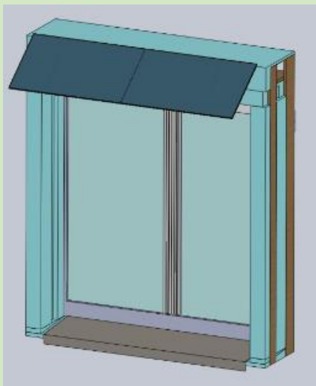
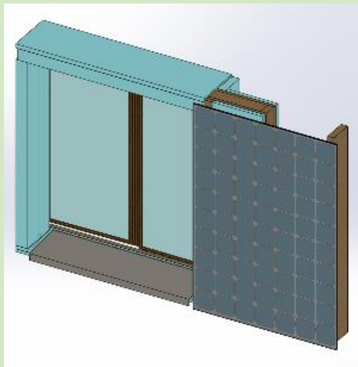
Table 1 shows a general overview of the three window block solutions developed and manufactured, remarking the common components used and the main differences between them. As can be seen, all the solutions integrate motorised reflective venetian blinds incorporated within the Insulating Glazing Unit (IGU) and a decentralised ventilation unit with heat recovery. In fact, the main differences between the different solutions come from the photovoltaic and electrical installation, with different PV module technology, dimensions and integration as well as different batteries and required electrical components.

The different components integrated in the window block solutions and their main features are thoroughly explained in the previous report D3.2. Nevertheless, it should be pointed out that due to a problem arisen during the manufacturing process of the mock-ups, the batteries initially selected and reported in D3.2 had to be replaced by new ones in two of the solutions. As shown in Table 1, the batteries of mock-up 1 and 3 are two 12V (lithium iron phosphate) batteries in series and not one single 24V battery of lithium-ion as used in mock-up 2 and initially foreseen for all the configurations. This new battery configuration fits better with the current produced by the photovoltaic modules of these two solutions, and presents as well improved features (energy capacity of 512Wh and longer life cycles, while initial option has 240Wh).

As a consequence of the different integrations of PV and electrical components, the design of the window block itself is also slightly different between the three configurations. Main differences are the window location within wall thickness, the thermal behaviour indicators of the block and the dimensions of the block.

Table 1. Overview of common components and differences between different window block solutions (Source: Eurac)

MOCK-UPS / COMPONENTS		MOCK-UP 1 – BIPV SILL	MOCK-UP 2 – BIPV OVERHANG	MOCK-UP 3 – VERTICAL BIPV
				
GLAZING		Triple glazing of 52,8mm total thickness		
SHADING		ScreenLine SL22W - V95 coated (reflective)		
WINDOW BLOCK	WINDOW	Versatile continental window		
	PV INTEGRATION	On the sill (below window)	Overhang (above window)	Vertical (aside or underneath window)
	VM INTEGRATION	Above window		Next to window
VENTILATION MACHINE		Thesan Aircare ES		
CONTROL SYSTEM		Shared control for VM and shading		
PV MODULE		c-Si (1140x354mm) 62 Wp	a-Si (1405x400mm) 32 Wp	c-Si (1631x1137mm) 309 Wp

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PV CLICK&GO	Tulipps Cosmos plug&play solution		
BATTERY	2 x 12V series (Li-Fe-Po4)	1 x 24V (Lithium-ion)	2 x 12V series (Li-Fe-Po4)
MPPT	x	Morningstar's SunSaver MPPT	
MPPT & BOOSTER	Genasun GVB-8-Li-28.4V	x	

2.2. Mock-up 1 – BIPV sill

As aforementioned, this window block configuration integrates the PV module on the sill. Consequently, the window block design is adapted in order to place the window decentralised inwards and let space for the PV on the sill surface, as can be seen in the drawings of Figure 1. Besides, small dimension of this photovoltaic module requires the addition of a booster to the system, in order to increase output voltage and allow the charging of the batteries, as it was further explained in D3.2. Figure 2 shows the mock-up 1 set up in the outdoor lab.

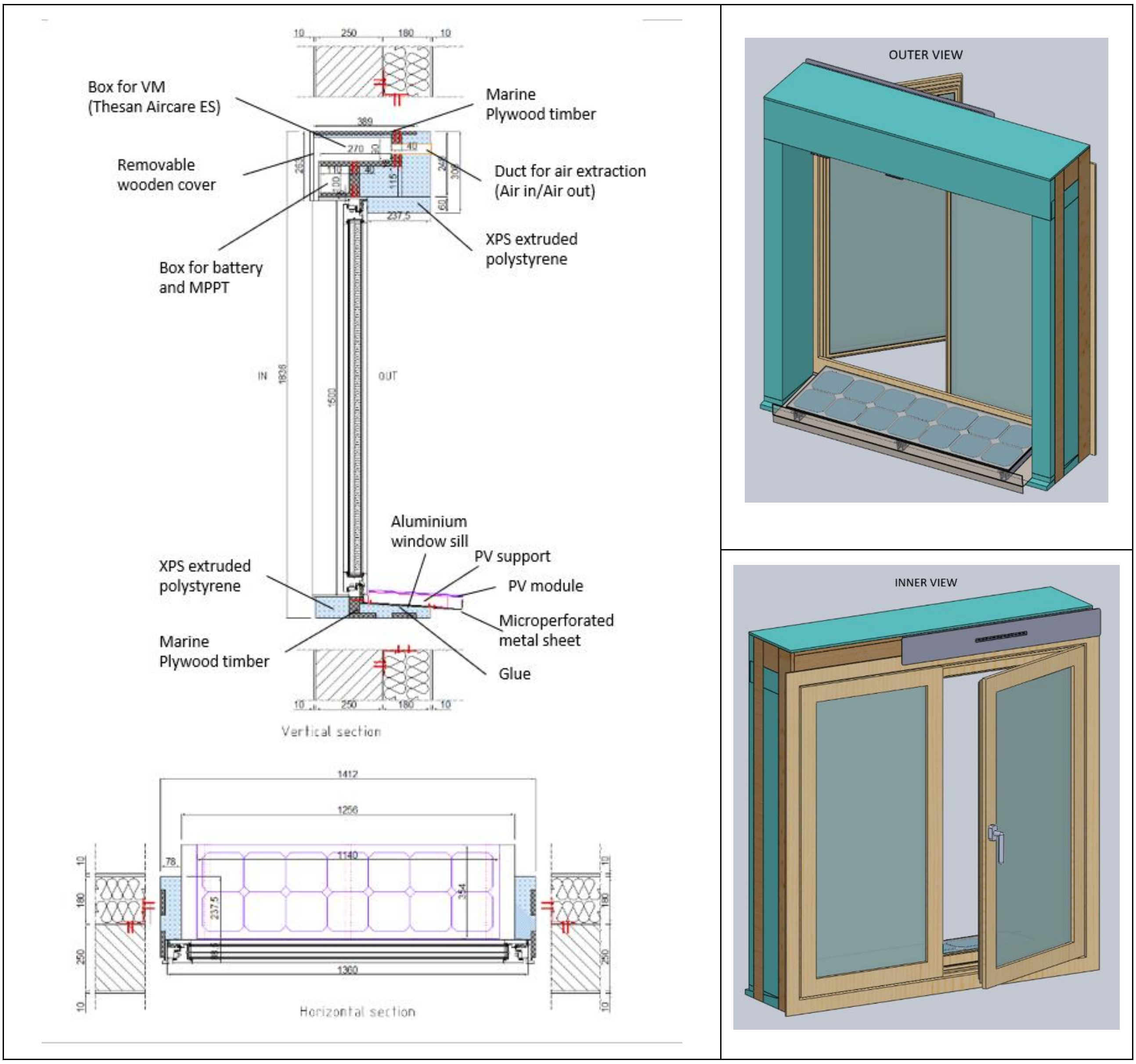

Figure 1. Technical drawings of mock-up 1 - BIPV sill (Source: Eurofinestra and Eurac)

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Figure 2. Window block mock-up 1

2.3. Mock-up 2 – BIPV overhang

This window block configuration integrates the PV module as an overhang, as can be seen in the drawings of Figure 3. Consequently, the window block design is adapted in order to allow proper support for the BIPV overhang and to minimize thermal bridges. Another peculiarity of this solution is the type of photovoltaic technology, which in this case is amorphous Silicon, instead of crystalline Silicon used in the other configurations. Consequently, battery used in this case is different from the other ones, as shown in Table 1. Figure 4 shows the mock-up 2 installed in the outdoor lab.

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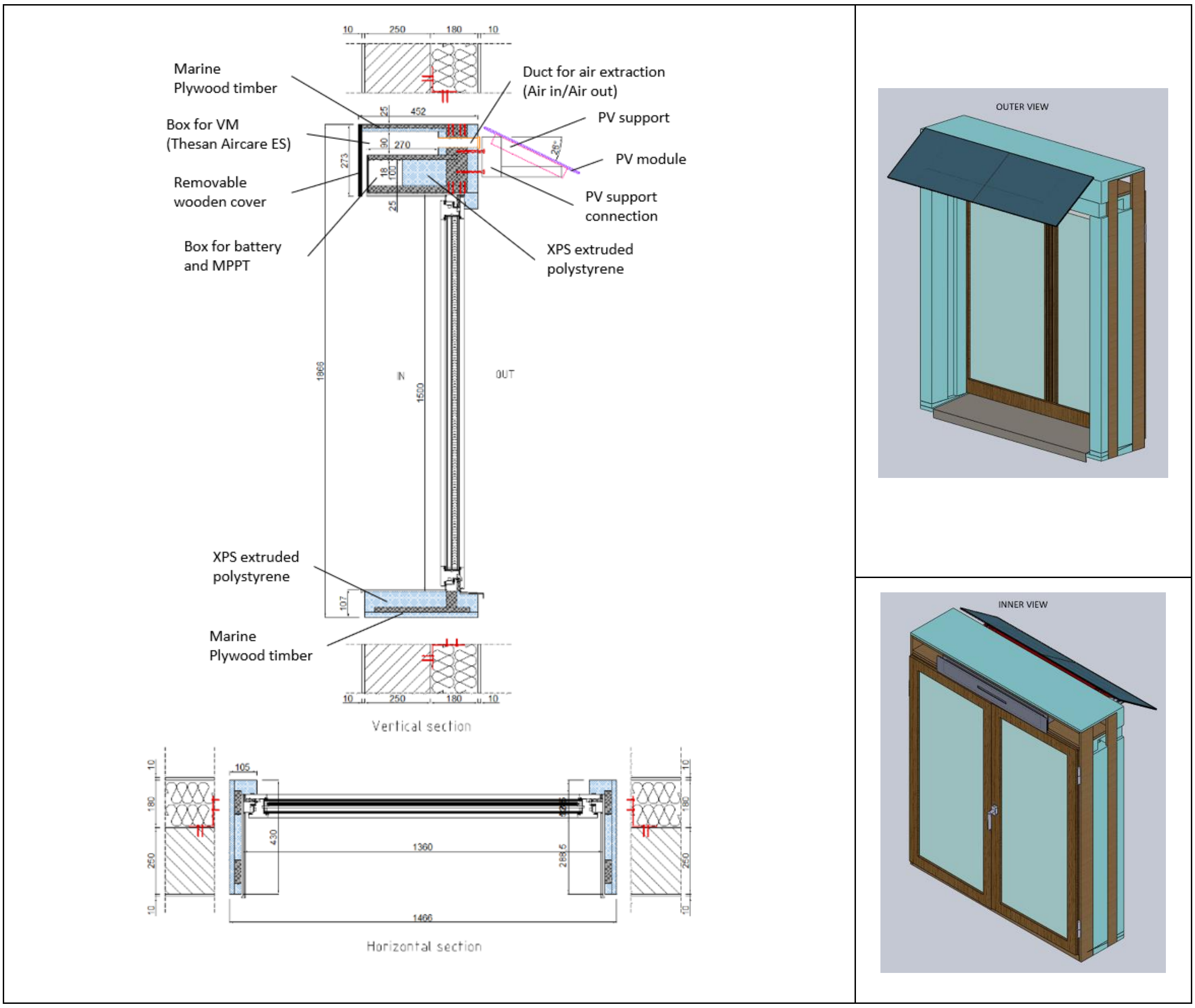

Figure 3. Technical drawings of mock-up 2 - BIPV overhang (Source: Eurofinestra and Eurac)

Figure 4.Window block mock-up 2

2.4. Mock-up 3 – Vertical BIPV

This window block configuration integrates the PV module vertically installed on the façade and the box containing rest of equipment (VM, batteries, MPPT…) behind the PV. This design is conceived with the goal of taking advantage of the whole window hole height for the glazing and using the space behind the PV module to place the container of electrical equipment, as shown in drawings of Figure 5. Moreover, Figure 6 shows the mock-up 3 installed in the outdoor lab.

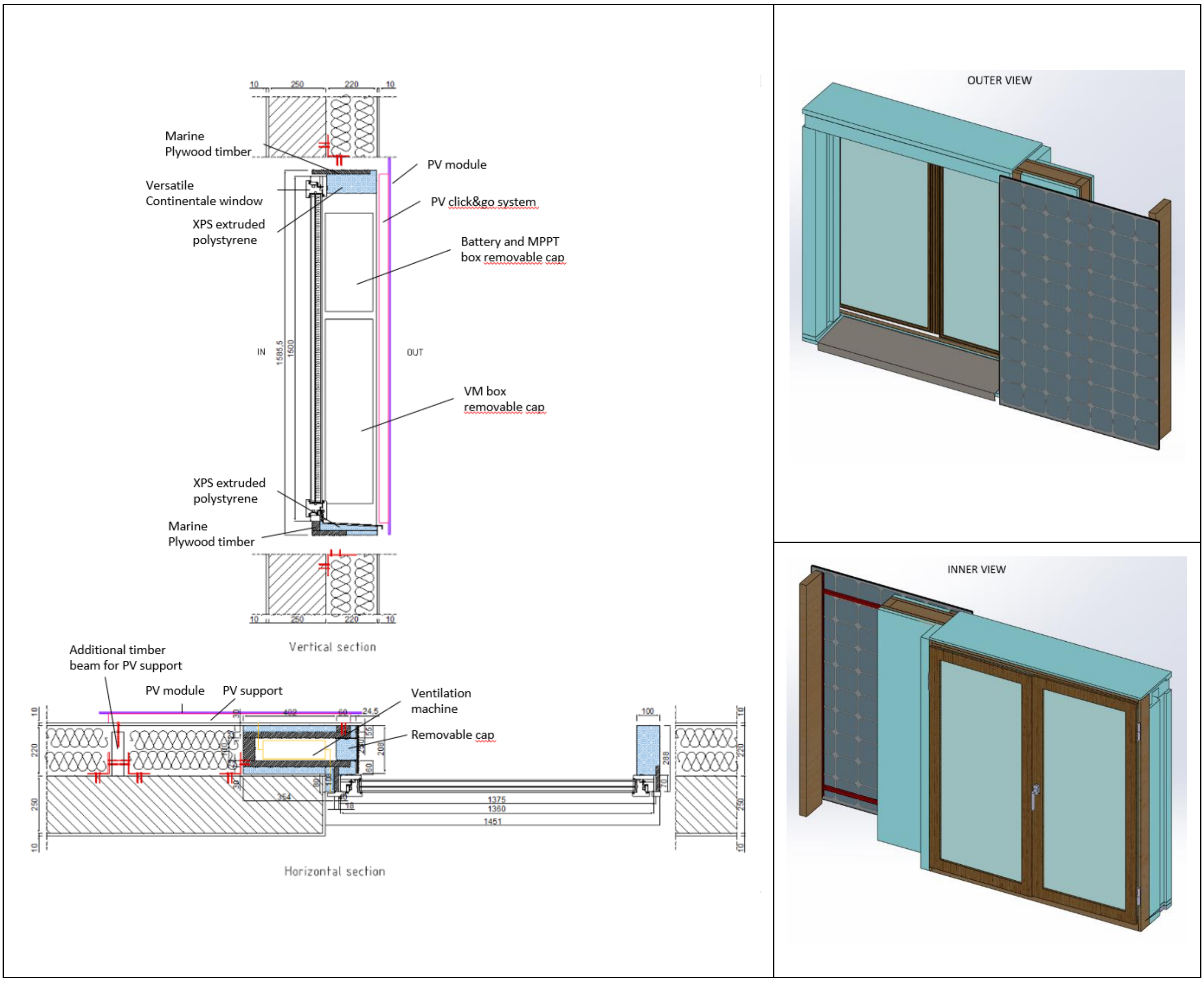

Figure 5. Technical drawings of mock-up 3 – vertical BIPV (Source: Eurofinestra and Eurac)

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Figure 6. Window block mock-up 3

3. Manufacturing of window block mock-ups

The mock-ups realization starts from the windows manufacturing. The frames made by wood and cork layers are made and assembled, then the water-based coating is applied, as shown in Figure 7. When the frames are ready, the shading system electrical device are installed on the frame, as shown in Figure 8.

Figure 7. Window frame manufacturing (Source: Eurofinestra)

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Figure 8. Shading system electrical installation (Source: Eurofinestra)

The glass with integrated shading system is provided by Pellini and then is structural sealed to the frame, as can be seen in Figure 9.

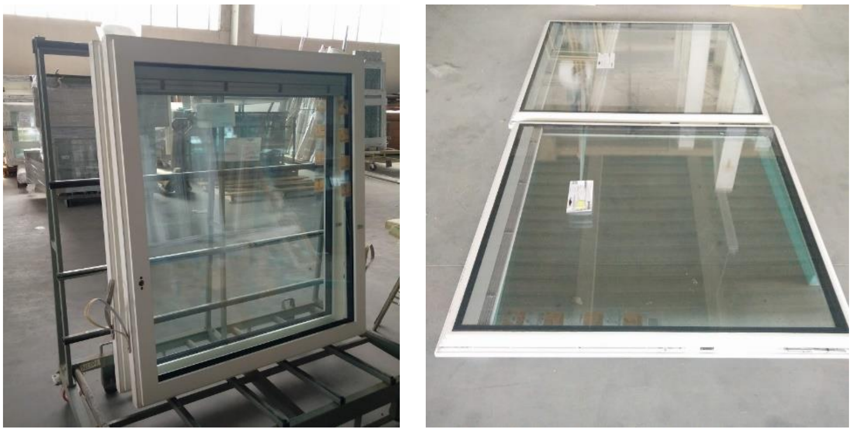

Figure 9. Sealing of the glazing to the window frame (Source: Eurofinestra)

The window block structure, made by XPS and plywood panels are assembled and worked manually in a separated department, as shown in

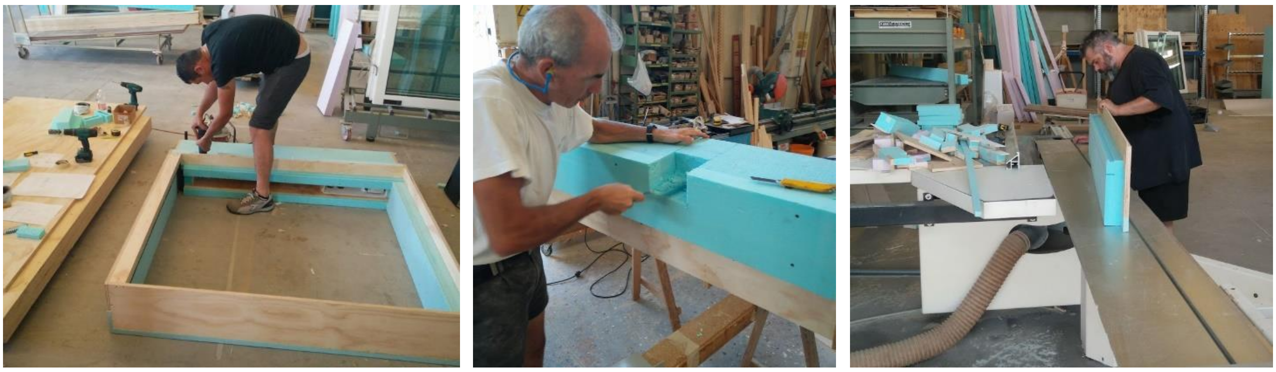

Figure 10. Manufacturing of the window block (Source: Eurofinestra)

A great effort was dedicated to make cable and air duct passages, that are made directly on assembled blocks to avoid interferences between the parts. The mechanical connection of the PV was tested before the final assembly to check interferences and stability. Moreover, a pre-test of electrical components was done during the construction phase, as shown in Figure 11.

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Figure 11. Manufacturing and checks of PV and air ducts (Source: Eurofinestra)

Figure 12. Mock-ups installation in outdoor laboratory (Source: Eurofinestra)

After the installation of the three mock-ups at Eurac outdoor lab as shown in Figure 12, another small but relevant mock-up was produced. This mock-up covers only the upper wooden box, where the components are installed and follows the Italian demo case design, as can be seen in Figure 13. This new mock-up was realized with a first step of engineering and pre-cut for air ducts and cable passages. It is already under tests in Eurac indoor lab in order to test the overheating of the electrical components inside the wooden box of the window block.

Figure 13. Mock-up for electrical components overheating tests (Source: Eurofinestra)

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4. Conclusions

Previously shortlisted and detailed designed solar window block solutions have been manufactured within the frame of the Energy Matching project, as it is described in this report. Three different solar window block mock-ups have been manufactured and installed in the outdoor lab for testing. Besides, these mock-ups fabrication has been useful to detect some difficulties and required modifications, in order to improve the system before its installation in demo-cases.

During mock-ups manufacturing process, some unforeseen needs or modifications have arisen, as listed below:

- As recommended by the ventilation unit provider, a DC/DC converter has been included in the system, in order to limit the voltage input to the VM to 24V. The output from batteries-MPPT system can reach values up to 29V and could damage the VM, so this new component aims to avoid this problem.

- Electrical engineer of the Italian demo-case building also suggested some modifications to improve the system safety, which have been already implemented in the mock-ups:

    - Protect the wooden box where the electrical components are with a fire-resistant material. In this case, magnesium oxide plates have been used to coat the inner part of the wooden box containing electrical equipment.

    - The box containing the electrical equipment should be ventilated to avoid overheating of the electrical components and the surroundings. For that purpose, some grids and holes have been added in order to foster natural ventilation around the electrical components.

Apart from these modifications, some other issues have been detected during the whole block manufacturing chain, that should be also pointed out:

- It has been difficult to couple the different manufacturing timing of the various components in order to optimize whole manufacturing and integration process, with long delivery times specially for PV with click&go system and glazing with the shading integrated.

- The aesthetical integration of the PV on the sill and overhang could be improved.

- The installation of the PV-click&go system for mock-up 3 resulted more difficult than expected, as the positioning of the U rail and their bolt holes should be very accurate.

- Ventilation machine of mock-up 3 takes the outdoor air from a position behind the PV, where the air might be hot during operation. This situation might cause some problems, which will be evaluated during the testing phase.

Apart from identifying possible problems and improvements along the manufacturing chain, the mock-ups have been manufactured in order to test their performance in the outdoor lab. These tests will start in the upcoming months and last until September 2020.

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Technical references

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