RE-SKIN

D5.5 - Techniques/components for windows retrofit and the manufacturing design of the needed components I

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1.0	11/05/2023	Final version addressing all further comments	L. Maestri, A. Miglioli (ZH)

Table of Contents

1. Executive summary 4
2. Technical specifications and guidelines 5
2.1. Overall window substitution 9
2.2. Add a secondary window 11
2.3. Add a film on glazing 13
2.4. Glazing substitution 13
2.5. Improvements on weatherstrips 18
2.6. Roller shutter box insulation 19

List of Figures

Figure 1. Main intervention categories for windows retrofit 7
Figure 2. Reference costs for each type of retrofit intervention 9
Figure 3. Example of the Bio-PUR window frame 10
Figure 4. Example of secondary window system implementation 12
Figure 5. CASE 1 - Glazing substitution on a wooden frame 15
Figure 6. CASE 2 - Glazing substitution on an aluminium frame 16
Figure 7. CASE 3 - Glazing substitution on a PVC frame 17
Figure 8. Solutions for roller shutter box insulation 19

Disclaimer

1. Executive summary

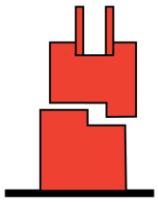
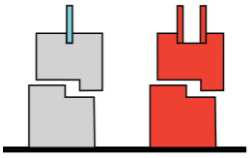
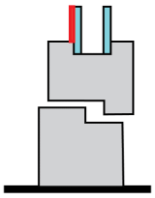
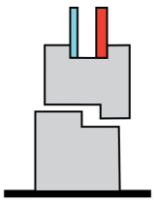
This document is focused on the windows retrofit process. More in detail, it describes the systems and components, designed to enhance windows thermal performance recovering, as much as possible, elements that are currently installed. Also, it explains techniques to be adopted in installing those components and issues to be checked, in order to avoid mismatches between new components and current ones, starting from the lesson learnt from the project HEART. Moreover, for each solution the main issues related to circularity and maintenance are briefly underlined.
Three additional releases of this document are scheduled by month 13, 19 and 27. This first release includes the main data and the characteristics of the components at the current status of development. The subsequent deliverables will include further specifications and/or modifications according to the results of the first testing activity in the case studies and the future development during the project.

2. Technical specifications and guidelines

Generally speaking, in the whole-life environmental perspective, the replacement of the existing windows is more expensive than the retrofit, not only from a sustainable point of view but also from an economic point of view. However, sometimes the window replacement is mandatory if the components are too damaged to be repaired or cannot be disassembled or modified.
Commonly, to define properly the solution to improve the windows performance, it is necessary verifying their current conditions through a detailed inspection, thereby collecting the information on the main window characteristics and state of conservation.
In detail, different intervention levels may be defined according to the state of window systems to be recovered. Currently, they may be grouped as follows:

- overall window system substitution;
- add a secondary window;
- add a film on glazing;
- glazing substitution;
- adding a new glass pane;
- improvement of weatherstrips;
- insulation of the shutter box.

These interventions levels imply different technical solutions, according to the technology of the existing windows installed in the building.
In the next section, all above mentioned intervention solutions are described in detail. The following table shows their pros, cons and feasibility issues for the different window technologies.

Solution	Advantages	Disadvantages	Implementation difficulties		
			Wooden frame	**PVC frame**	**Aluminum/ metal frame**
Overall window substitution 	• high thermal and acoustic insulation; • draught-proofing; • solar gains can be increased or reduced.	• high cost; • high embodied CO_2 emissions; • existing windows must be dismantled; • loss of artistic/cultural value of the existing window (in listed buildings).	Masonry where the existing window is anchored must be recovered.		
Add a secondary window 	• high thermal and acoustic insulation; • draught-proofing; • solar gains can be reduced; • maintenance of artistic/cultural value of the existing window (in listed buildings).	• high cost; • high embodied CO_2 emissions; • possible decrease in visibility; • reduction of window sill space.	Verify available space for the new window installation.		
Add a film on glazing 	• solar gains can be reduced; • glare from sun can be avoided; • low cost.	None	Bad application can leave bubbles on the glass surface.		
Glazing substitution 	• improved thermal and acoustic insulation; • solar gains can be reduced; • windows must not be dismantled; • maintenance of artistic/cultural value of the existing window (in listed buildings).	• implementation process takes longer time than substitute the whole window.	Verify available space to add the new glass. A new stop profile is necessary.	Verify the possibility to disassemble the frame and the available space to add the new glass. A new stop profile is necessary.	Verify the possibility to disassemble the frame and the available space to add the new glass. A new stop profile is necessary.

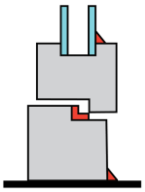
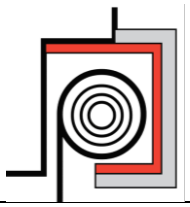
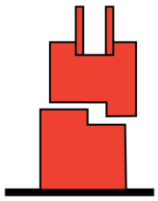
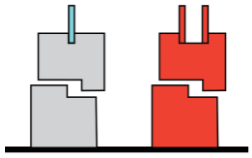
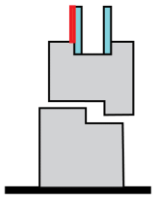
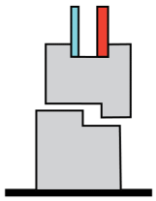
Improvements on weatherstrips 	• reduce thermal losses; • draught-proofing.	None	None
Roller shutter box insulation 	• reduce thermal losses; • avoid mould problems on the wall.	None	Insulation solution must not require disassemble the box and the roller.

Figure 1. Main intervention categories for windows retrofit

The following table shows a rough evaluation of the intervention costs of the different options for the energy requalification of windows. It should be noted that the prices refer to the Italian market and may undergo variations according to market fluctuations and the specific contexts of European countries.

An update of such evaluation will be provided in the next releases of this deliverable.

Solution	**Description and cost range**
Overall window substitution 	*Wooden frame*: 420 - 700 €/m^2 *PVC frame*: 405 - 660 €/m^2 *Aluminum/metal frame*: 630 - 890 €/m^2 *Biobased frame*: 600-800 €/m^2 NOTE: The prices indicated consider a double glazing
Add a secondary window 	*Wooden frame*: 330 - 780 €/m^2 *PVC frame*: 320 - 740 €/m^2 *Aluminum/metal frame*: 500 - 1000 €/m^2 NOTE: The prices indicated consider a double glazing
Add a film on glazing 	Reflective film: 25 - 32 €/m^2 Selective film: 70 - 80 €/m^2 Low emissivity films: 35 - 100 €/m^2 Sun protection films for plastics: 40 - 55 €/m^2 Skilled labor accounts for about 20 - 40 €/m^2, to be assessed case by case, based on the degree of difficulty and the amount of work required.
Glazing substitution 	*Wooden frame*: 300 - 400 €/m^2 *PVC frame*: 150 - 250 €/m^2 *Aluminum/metal frame:* 400 – 550 €/m^2

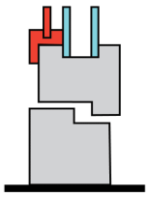
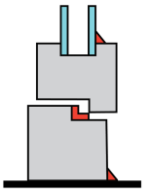
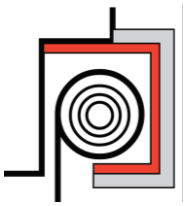
Adding a new glass pane 	100 – 150 €/m^2
Improvements on weatherstrips 	50 – 250 €/each
Roller shutter box insulation 	 Solution with 2 components one of 500 mm of development + rigid base of 240 mm: 50 €/m Solution with 1 component of 790 mm development: 54 €/m

Figure 2. Reference costs for each type of retrofit intervention

2.1. Overall window substitution

In some cases, the window elements cannot be recovered or modified, leading the overall windows substitution the only possible option. In particular, usually it occurs when:

- frame damages are too serious to be repaired;
- the window system cannot be disassembled in base elements (i.e., in case of mono-block plastic frame);
- the system integrity and performance may be compromised while modifying its elements;
- quality and performance of all window elements are too poor.

Obviously, this intervention represents the worst case in terms of resource waste reduction, therefore, two possible solutions may be investigated to reduce the environmental impact, as follows.

1. The first one is useful when the window is directly anchored to the masonry (even if it is quite unusual). In this case, the fixed frame may be kept and reused as a substructure for the new window. This avoids damaging the masonry when removing anchors. Moreover, masonry recovery takes time (that may cause delay in windows installation for few days) and results in a significant cost increase.
2. The second one is to disassemble windows elements in an accurate way to dispatch them in a recycling process.

Circularity issues: in the removal process of the existing window there is a huge opportunity to recover materials that can be sorted and sent to recycle/reuse processes: in this case it is suggested to track the amount (volume/mass) of the specific materials sent to recycle/reuse. The procurement of the new windows should include, in the technical specification, requirements concerning the use of recycled materials or remanufactured elements and the easiness to disassemble in recyclable parts the new windows at the end of their service life.

Maintenance issues: the procurement specifications should include the request for the manufacturer to provide a maintenance and use manual. The installation of the new window should be verified with a design review process to check the accessibility and maintainability features of the windows (for instance to allow for an easy cleaning of the glazed parts or lubrication of the moveable hardware). The easiness to repair/replace the parts with a shorter life span (gaskets, mosquito-net, etc.) should be demonstrated by the manufacturer/supplier.

A further improvement in terms of performance can be obtained by adopting innovative frame materials, such as Biopolyurethane. This material, already tested by INDRESMAT, is able to achieve optimal thermal performance, with a U value (of the frame) equal to 0.8 W/m^2K while ensuring a very low embodied energy compared to traditional solutions.

Figure 3. Example of the Bio-PUR window frame

2.2. Add a secondary window

A secondary window is a fully independent system installed in the window sill. Such solution generally allows to maintain the original window unaltered in the original position, which is of particularly important in listed buildings with cultural or artistic significance. While the new system installed can be openable, fixed, or removable. The main advantages obtained from the addition of a double window system can be summarized as follows:

- reduction of thermal losses through the contribution of the existing window and the new one, which can be a double or triple glazing systems with low U-value and low-emissivity glass (Low-E);
- improvement of acoustic insulation provided by the secondary window system (single or double glazing);
- draughts caused by air infiltration through the existing window can be eliminated by the secondary system, which has more efficient perimeter sealing;
- solar gains can be reduced through the secondary window system which can have a specific treatment;
- the addition of the new window in the external position has a positive effect in terms of protection of the old window from the external agents and subsequent extension of the expected service life of the existing window.

Circularity issues: in this case it should be accounted the amount of materials that is saved by the decision to avoid the removal of the existing window. The procurement of the new windows should include, in the technical specification, requirements concerning the use of recycled materials or remanufactured elements and the easiness to disassemble in recyclable parts the new windows at the end of their service life.
Maintenance issues: the addition of the second window should be carefully verified to avoid any interference with the existing one. The possibility to open and clean the two windows should be assured. The procurement specifications should include the request for the manufacturer to provide a maintenance and use manual. The installation of the new window should be verified with a design review process to check the accessibility and maintainability features of the windows (for instance to allow for an easy cleaning of the glazed parts or lubrication of the moveable hardware). The easiness to repair/replace the parts with a shorter life span (gaskets, mosquito-net, etc.) should be demonstrated by the manufacturer/supplier.

The following picture shows a typical example of a secondary window system.

Figure 4. Example of secondary window system implementation

2.3. Add a film on glazing

A low-cost and efficient solution to improve the window performance is to add a film on the glazing surfaces. However, before to decide to apply a film on the windows pane, the compatibility of the product with the glass should be verified. Moreover, for some particular window configurations, the installation of such films can be more difficult and a bad application on the glass surface can leave bubbles.

The most common applications of (internal) window film are to prevent indoor overheating due to the solar radiation and to provide protection from the sun glare. In the market, several products are available and some of them are listed below:

- glare reduction films, which are, in particular useful, in office spaces. Such film block glare from window preventing eyes discomfort when focus on computer and television screens;
- UV blocking films, which can block the UV radiation that is harmful not only for people skin and eyes, but also for furniture, artworks and objects that can be discolored by the continuous UV exposure;
- spectrally selective films, which are able to reflect a large amount of the solar radiation, but allowing visible light to pass through;
- security window film, which can serve as a safety barrier to prevent the glass to be shattered into many pieces when broken;
- low-e films, designed to retain heat during the winter.

Circularity issues: the advantage of this solution is to avoid the replacement of the existing glazing and this could be accounted highlighting the amount of glass saved. Information on recyclability of the polymeric film shall be requested to the manufacturer/supplier.

Maintenance issues: Information on expected service life of the film shall be requested in the tender process to the bidders. Considering that the life span of the films is normally shorter than the window life span it should be verified the possibility to access easily the windows in order to replace the film. The procurement specifications should include the request for the manufacturer to provide instructions for cleaning and maintenance of the film.

2.4. Glazing substitution

Windows with wooden frames are the most suitable to be repaired and improved, but in many cases modifications on metal and plastic frame are also feasible.

However, if the existing windows will be maintained, it is necessary to reinforce those parts of the window decays characterized by no longer function as per requirements.

Wherever possible, modifications should be carried out in-situ, particularly when the frame cannot be easily removed without damaging either the window or the surrounding walls. In detail, the main repairs that could be necessary for wooden profile are:

- re-secure the open joints by cramping, gluing, re-wedging and pinning, in order to avoid the moisture to enter and cause decay;
- spliced repairs should be made by cutting out rotten wood and splicing or scarfing-in timber inserts which are shaped to obtain the maximum strength and to match the existing profiles;
- cleaning and repairing/replacing missing or broken items;
- when necessary, small areas with material losses can often be filled with wood dust mixed with epoxy resin or polyester resin.

For aluminum or PVC frames, the steps are similar and even simpler, since such materials are not subjected to rot. Thus, the tailored cutting of existing profiles just implies the reconfigurations of the gaskets.

If the quality of the current glazing system is poor, glazing substitution solution may provide a significant thermal performance improvement. It is worth to notice that in timber frame windows, this action must consider some limits due to the frame structure. Specifically, the available glazing thickness must be considered, together with its weight. The glass thickness increase also causes a modification in the glass stop profile. For a limited thickness, the current stop profile may be recovered, by reducing its section; however, reducing its width at less than 20 mm is not recommended, since the anchorage may not be safe.

For wider glazing system, a new glass stop profile should be designed such a way to anchor it to the vertical side of the frame. In this way, this profile may also cover the existing frame and provide a new finishing. This trick may be useful for restoring frames with damaged or lacking finishes. In addition, the profile may be coupled with rigid insulating elements to increase the frame thermal resistance.

Among the large number of glazing options (meeting the previous requirements), designers should also consider the most suitable ones according to the climatic zone of building site.

Circularity issues: in this case it should be accounted the amount of materials that is saved by the decision to avoid the removal of the existing frames.

Maintenance issues: replacement of the glazing system does not significantly impact the maintenance characteristics of the existing windows. A periodical check should be made on the glass

stop systems if they have been reduced in size. Another check should be made on the geometry of the windows considering the increased weight of the glass that the frame must bear.

The most significant solutions among the ones under studying in RE-SKIN, are presented in the following figures, according to the different material profiles.

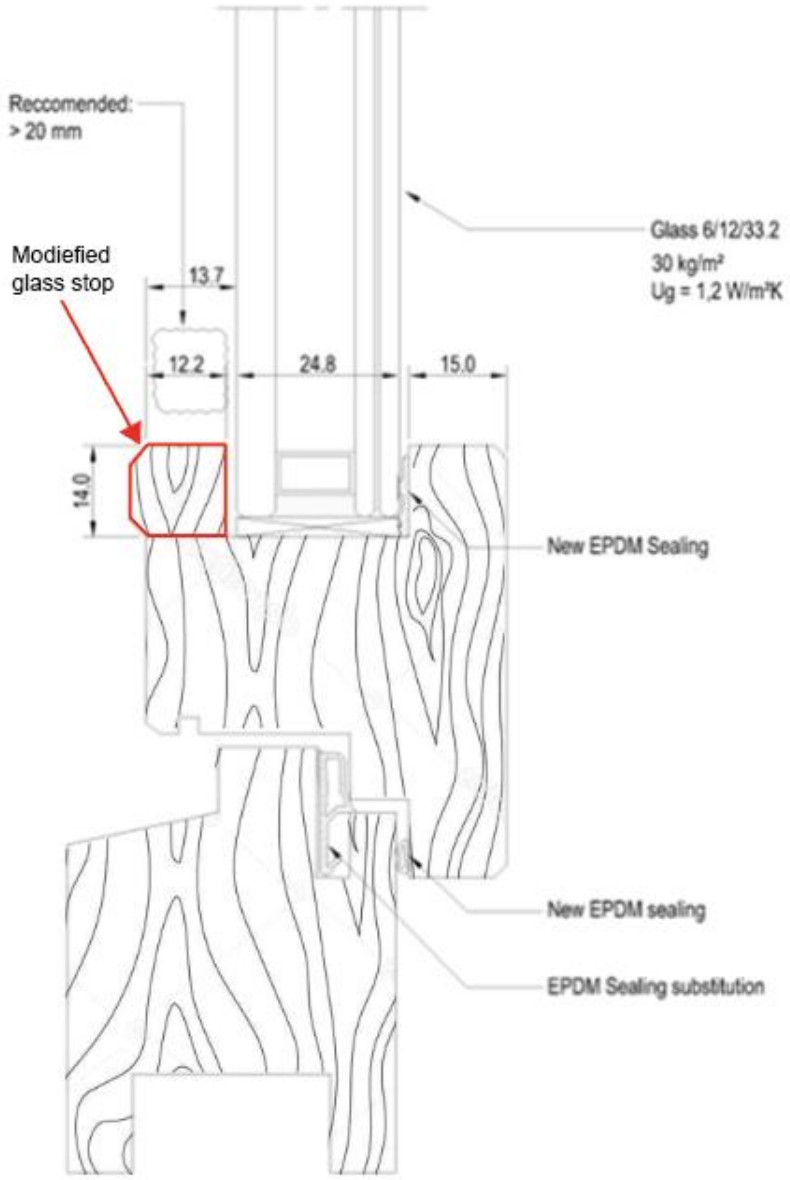


Figure 5. CASE 1 - Glazing substitution on a wooden frame

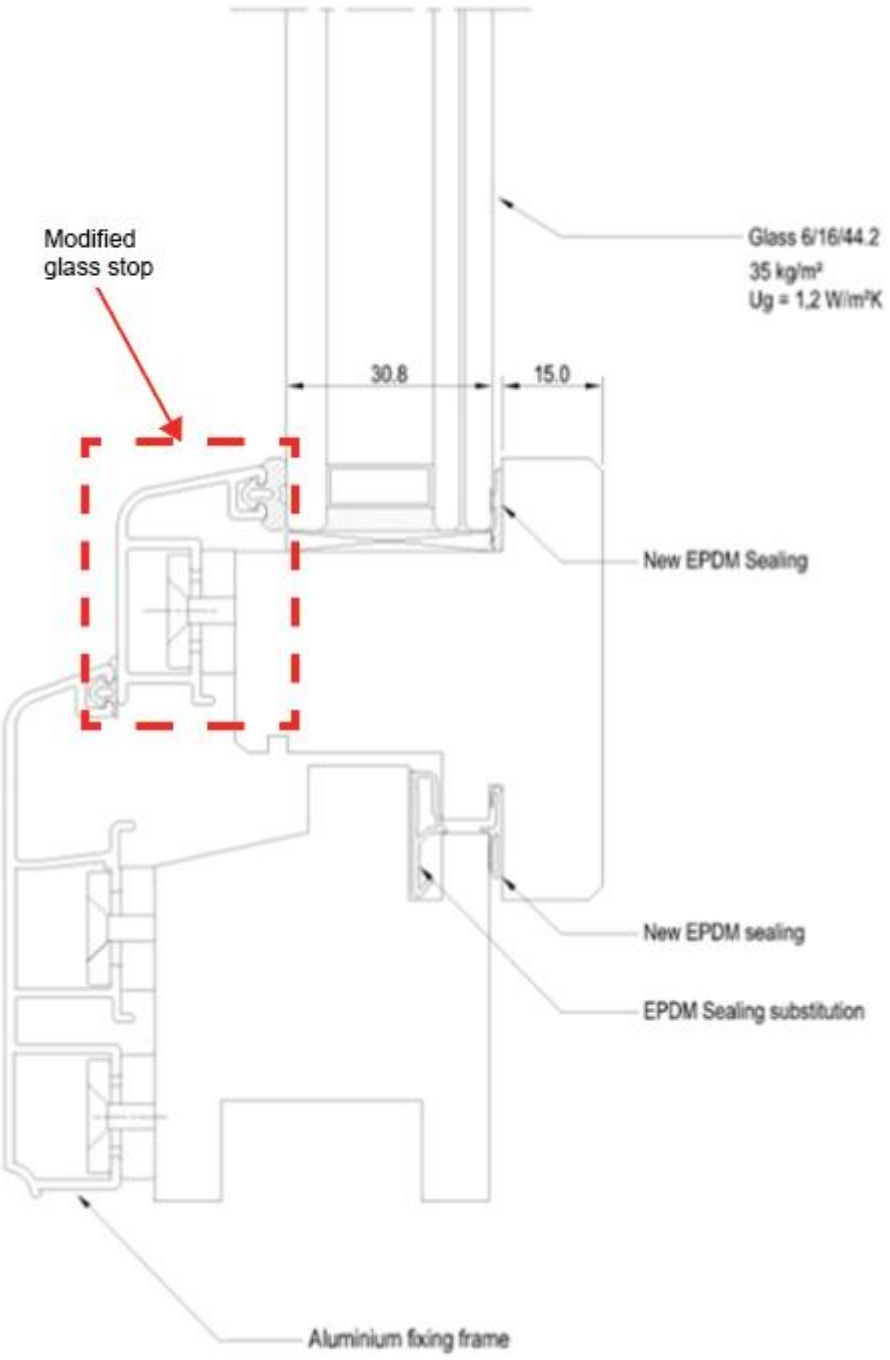


Figure 6. CASE 2 - Glazing substitution on an aluminium frame

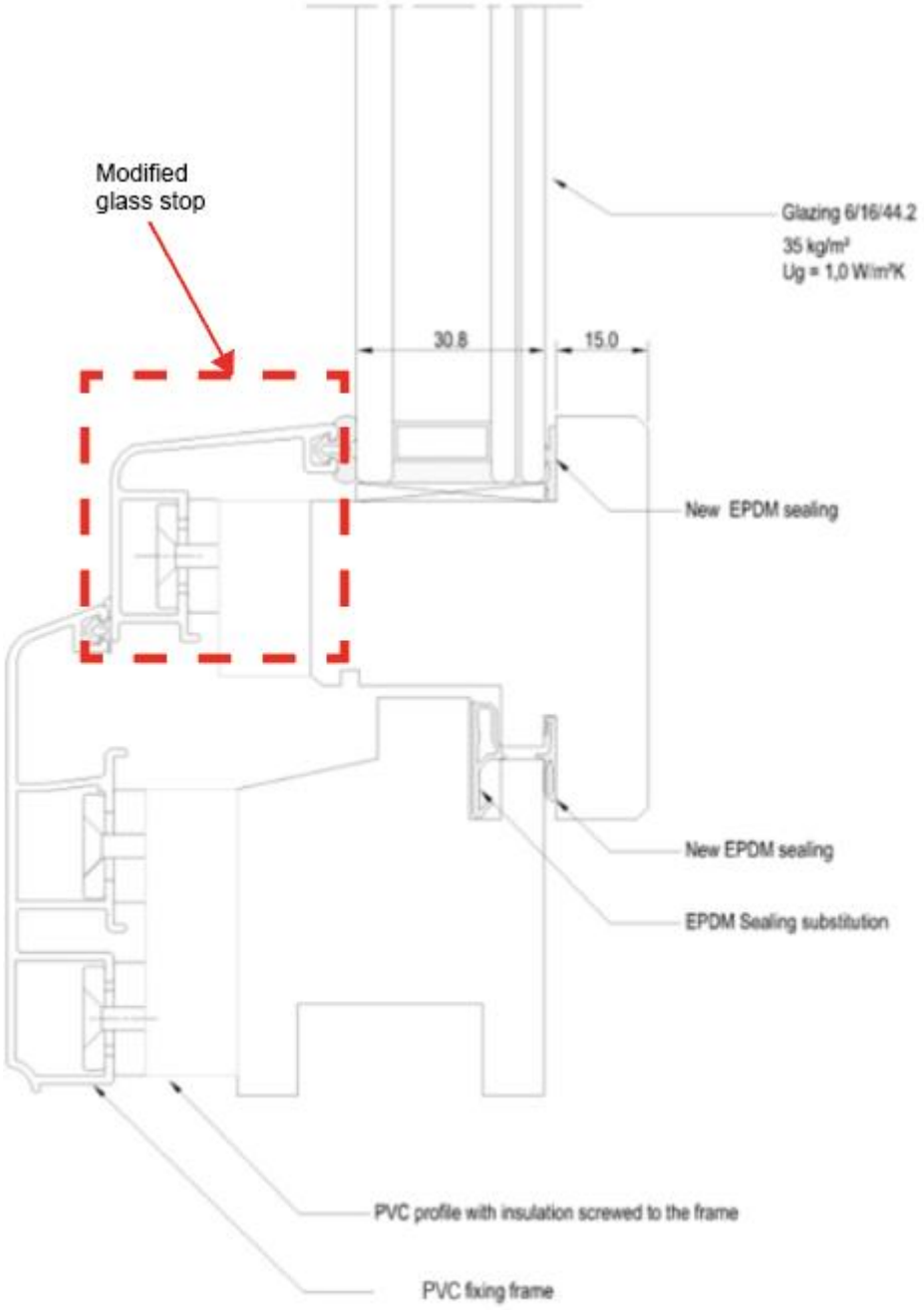


Figure 7. CASE 3 - Glazing substitution on a PVC frame

2.5. Improvements on weatherstrips

Draught-proofing is a low-cost option to improve the thermal performance of existing windows. Since existing windows are often a source of air infiltration, the improvements of weatherstrips is one of the possible solutions to reduce energy consumption and improve thermal comfort without changes in the building appearance and at minimal cost. Among the draught-proofing solutions, using compression strips are usually cheap and easy to install. Compression strips are available in a range of different materials, such as EDPM rubber, silicone, etc.

In order to choose the proper draught-proofing product, the following aspects should be taken into considerations:

- the dimensions of the gaps to be sealed;
- weatherstrips could be seen or not when window is closed and opened;
- the colour of the weatherstrips matching to the window frame;
- consider seasonal expansion and contraction of the window.

This solution doesn't present relevant circularity issues and maintenance issues.

2.6. Roller shutter box insulation

If a roller shutter is present in the window system, its box may represent a node which causes a reduction in thermal performance.

Based on the box and the closing panel geometry and dimensions, different solutions may be adopted to enhance its thermal resistance. The insulation system, in facts, must be suited for mounting without completely disassemble the box and the roller; also, it has to adapt to the box section. The best solutions, identified according to a survey among commercial options, are shown in the following figure.

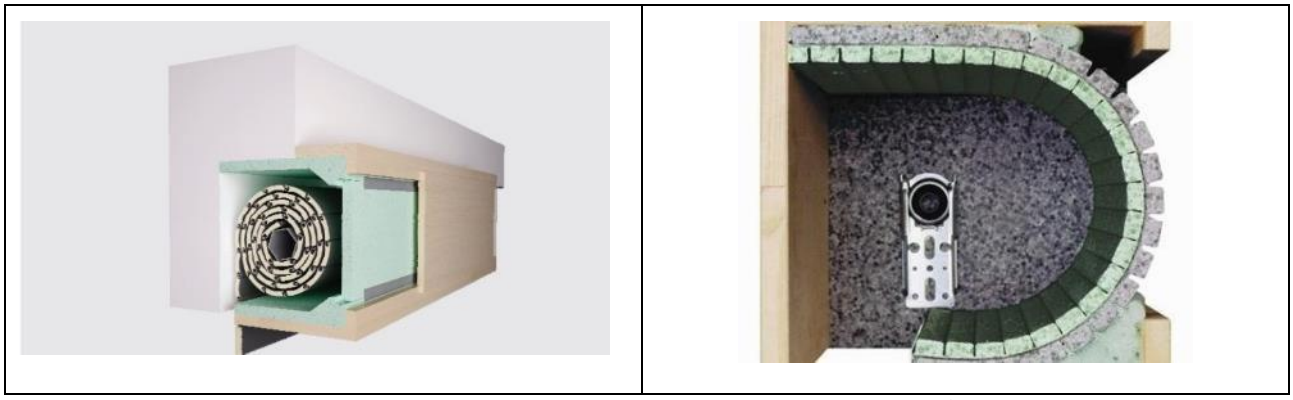


Figure 8. Solutions for roller shutter box insulation[1, 2.]

Typically, the one on the left is suitable when the masonry interface is regular, while the second one can be applied even on curved surfaces. Insulation thickness must be checked according to the available space around the roll.

Circularity issues: The procurement of the new shutter box or the insulating material should include, in the technical specification, requirements concerning the use of recycled materials or remanufactured elements; the easiness to disassemble in recyclable parts the new shutter box at the end of its service life.

This solution doesn't present relevant maintenance issues.

[1] Courtesy of Würth Group
[2] Courtesy of Milesi Plast srl