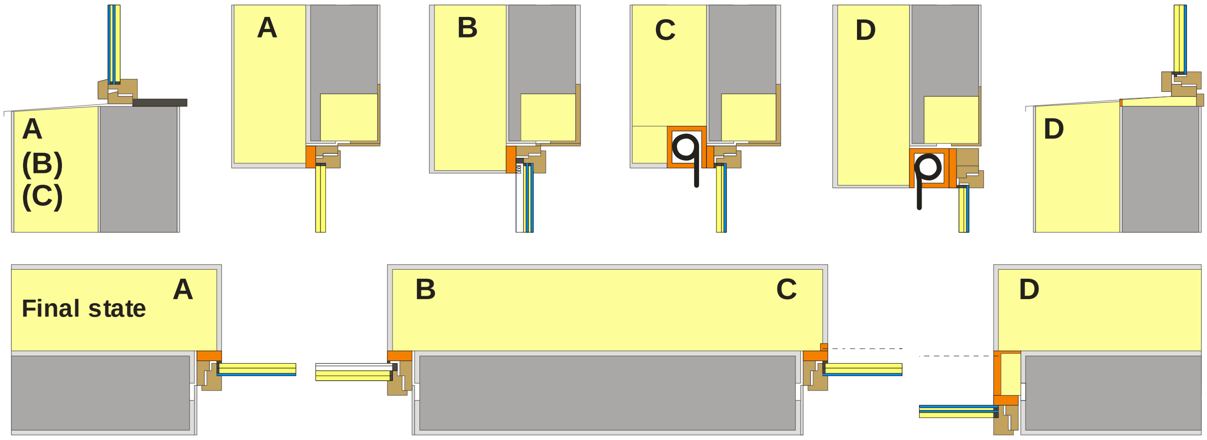

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INTELLIGENT ENERGY – EUROPE II

Energy efficiency and renewable energy in buildings

IEE/12/070

EuroPHit

[Improving the energy performance of step-by-step refurbishment and integration of renewable energies]

Contract N°: SI2.645928

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Project Coordinator	Jan Steiger Passive House Institute, Dr. Wolfgang Feist Rheinstrasse 44/46 D 64283 Darmstadt jan.steiger@passiv.de
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Co-author(s)	
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Abstract

Often, windows and walls are retrofitted separately. Nonetheless, good overall results are possible.

If the window is replaced first, it should be made flush with the old façade on the outside to have acceptable optics, thermal bridges, shadings, tightness situations and easy as well as cost efficient solutions in the first step and the second step, when the insulation of the wall will be applied.

The window should be at good thermal quality and best triple glazed (double-glazing is only recommended in Mediterranean areas. In arctic areas, quadruple glazing should be used).

Raff-stores, shutters or roller shutters should be replaced in the first step with the window. To avoid high thermal bridges, cold spots at the inner surface drafts and convective losses.

This solution was carried out as the most cost effective and easiest to apply in the Component Award 2015, co-founded by the EuroPHit project.

1 Passive House suitable windows

In a step-by-step retrofit where the windows are replaced first, and the insulation layer is added at a later stage, there are special considerations regarding the window connections. The new windows should work well both in the first stage, when they are installed in the old wall, and afterwards, when the insulation is added to the envelope.

Passive House suitability is verified using the U-value of the installed/uninstalled components and the temperature factor at the glazing edge or the installation situation as the coldest point of the component. These requirements are directly derived from Passive House criteria for hygiene and comfort as well as from feasibility studies.

1.1 Requirements

The requirements for transparent components are set according to the climate zone for which the component is designed. The criteria is included in Table 1.

The basis of this criteria, in terms of the functional requirement for hygiene is:

- **Maximum water activity (interior building components): $a_w \leq 0.80$**

  Water activity is the relative humidity either in a material's pores or directly on its surface. This requirement restricts the minimum temperature at the window surface for health reasons. Mold growth may occur if water activity exceeds 0.80. Such conditions should therefore be consistently avoided.

  The $f_{Rsi=0.25}$ temperature factors given in Table 1 result as acceptable certification criteria for different climates. This f_{Rsi} is the temperature factor at the coldest point of the window frame. Criteria for other climate zones are currently being determined.

Regarding comfort, the functional requirement is the following:

- **Minimum temperature of volume enclosing surfaces: $|\theta_{si}-\theta_{op}| \leq 4.2K$**

  This temperature difference requirement limits the minimum average temperature of a window for reasons of comfort; it may deviate by a maximum of 4.2K. A greater difference may lead to unpleasant cold air descent and perceptible radiant heat deprivation.

  The maximum thermal transmittance coefficients (U-values) of installed certified transparent Passive House building components under heating dominated situations are calculated from this temperature difference criterion. The heat transfer coefficients given in Table 1 result as acceptable certification criteria for different climates.

- **Limiting the risk of draughts: $v_{Air} \leq 0.1$ m/s**

  The air velocity in the living area must be less than 0.1m/s. This requirement restricts the air permeability of a building component as well as cold air descent.

Table 1: Adequate certification criteria and U-values of the reference glazing

Climate zone	**Hygiene criterion** $f_{Rsi=0.25\ m^2K/W} \geq$	**Orientation**	**Component U-value** [W/(m²K)]	**U-value installed** [W/(m²K)]	**Reference glazing**[1] [W/(m²K)]
1 Arctic	0.80	**Vertical**	**0.40**	**0.45**	**0.35**
		Inclined (45°)	0.50	0.50	Actual U-value[2]
		Horizontal	0.60	0.60	
2 Cold	0.75	**Vertical**	**0.60**	**0.65**	**0.52**
		Inclined (45°)	0.70	0.70	Actual U-value
		Horizontal	0.80	0.80	
3 Cool-temperate	0.70	**Vertical**	**0.80**	**0.85**	**0.70**
		Inclined (45°)	1.00	1.00	Actual U-value
		Horizontal	1.10	1.10	
4 Warm-temperate	0.65	**Vertical**	**1.00**	**1.05**	**0.90**
		Inclined (45°)	1.10	1.10	Actual U-value
		Horizontal	1.20	1.20	
5 Warm	0.55	**Vertical**	**1.20**	**1.25**	**1.10**
		Inclined (45°)	1.30	1.30	Actual U-value
		Horizontal	1.40	1.40	
6 Hot	none	**Vertical**	**1.20**	**1.25**	**1.10**
		Inclined (45°)	1.30	1.30	Actual U-value
		Horizontal	1.40	1.40	
7 Very hot	none	**Vertical**	**1.00**	**1.05**	**0.90**
		Inclined (45°)	1.10	1.10	Actual U-value
		Horizontal	1.20	1.20	

1.2 Calculation method

The thermal transmittance coefficients (U-values) and the thermal bridge loss coefficients (ψ-values) are determined based on DIN EN ISO 10077, EN 673 and DIN EN 12631. Passive House suitability should be determined for the specified dimensions of the products to be certified. Verification of the hygiene criterion is provided using 2-dimensional heat flow calculations of the standard cross-sections.

The detailed information on the requirements and calculation can be found in the criteria for certified Passive House transparent components (click here).

[1] The U-values mentioned here are used as a reference value within the framework of certification in order to allow comparison of the quality of the window frames within a climatic category. The actually installed glazing may be different. Excellent quality low-e quadruple glazing or multiple vacuum glazing is recommended in the arctic climate zone, while low-e quadruple glazing or excellent quality low-e triple glazing, possibly with hard coating on the outside, is recommended for cold climate zones. Low-e triple glazing is suitable for the cool-temperate climate zone, and triple glazing or excellent quality double glazing with hard coating on the outside is suitable for the warm-temperate climate. Low-e double glazing, possibly with a solar protection coating is recommended for warm climates. Double glazing should be used in hot climates, and solar control triple-glazing should be used in very hot climates, with both having a high degree of selectivity.

[2] With reference inclination, the actual U-values should be determined in accordance with DIN EN 673 or alternatively ISO 15099.

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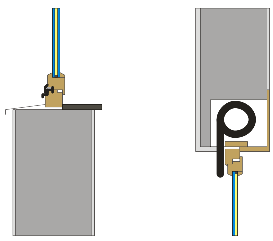
2 Design principles

In the case of retrofitting where the windows are installed before the insulation, the U-values of the new windows are automatically better than those of the original walls - U-value= 1.4 W/(m²K). The windows are improved so much that the coldest point is no longer somewhere within the window but generally in the existing wall. Also, old windows are generally not airtight so there is uncontrolled air exchange and. While this results in decreased comfort and much higher energy losses (and unnecessary heating costs), the lack of airtightness also allows moisture to be transported out of the room, keeping indoor air relatively dry. If the old windows are replaced with airtight windows, air hygiene issues could actually worsen. Because the new windows reduce air exchange, users must increase ventilation in order to remove humidity from the room – but they don't always change their ventilation behavior when faced with this new situation. As a result, humidity increases, leading to conditions that are problematic for health, including condensation at the coldest points in a room. The actual problem here is the change in how ventilation is managed, not the thermal quality of the windows. The process of replacing windows must include information on a new ventilation concept, or at least users and building owners must be made aware of the issue. Options such as increasing ventilation by cutting out gaskets or installing window-integrated ventilation systems without heat recovery or controls is far from an ideal solution, in part because they increase heat losses. Ideally, a ventilation system with heat recovery should be installed, since it reliably solves the air hygiene problem and improves indoor air quality without high energy costs.

When planning the replacement of windows, several concepts should be taken into account, including airtightness and thermal bridges generated during the transition period and after the insulation layer is installed. Therefore, the location of the window should be carefully chosen. Regarding the airtightness, the window has to be connected to the airtightness layer of the building. The connection could be done by plaster able airtightness adhesive tapes, approved compression tapes or a permanent-elastic joint-connection sealing.

2.1 Starting point

Generally, new windows are installed in the position of the old ones. This approach lowers investment costs because windowsills and any shading fixtures used do not need to be changed; the process goes quickly, and users are not bothered much. There are, however, high follow-up costs. In the end, once the wall is insulated, it will have thermal bridges from installation, and solar gains are lower because of reveal shading. Additional insulation of the window reveals raises costs further; the application of exterior wall insulation and lower exterior aperture sizes due to reveal insulation can easily lead to an ‘embrasure’ effect, especially when windows are small.



Initial situation

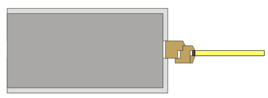


Figure 1: Initial situation: Old window in not refurbished facade. Bottom, side and top section of the window with roller shutter box.

2.2 Proposed solution

For the EuroPHit project's 2015 Component Award "Windows in step-by-step retrofits", the focus was on solutions that are as affordable and functional as possible over the window's lifecycle with consideration of investment and energy costs for the entire service life.

The result is surprisingly simple: The window, preferably with an integral frame (where the frame covers the casement), is installed flush with the exterior masonry, and the resulting gap is carefully sealed with a permanently elastic sealing agent (Figure 1). Well insulated Passive House frames are required for this situation; if standard frames are used, the temperatures at the interior window connection can be critical. Later, when the façade is renovated, the window frame can easily have insulation added to it. All other solutions turned out to be detrimental: If the frame is installed deeper in the reveal, the installation thermal bridge in the final state is much greater. Insulation of the reveal adds costs and increases reveal shading. A position within the future insulation level may be good in terms of installation thermal bridges and reveal shading, but installation in front of the wall leads to additional costs, and sealing off the resulting bays turns out to be difficult. In addition, the jury for the 2015 Component Award found this "bay solution" to be unacceptable in terms of design.

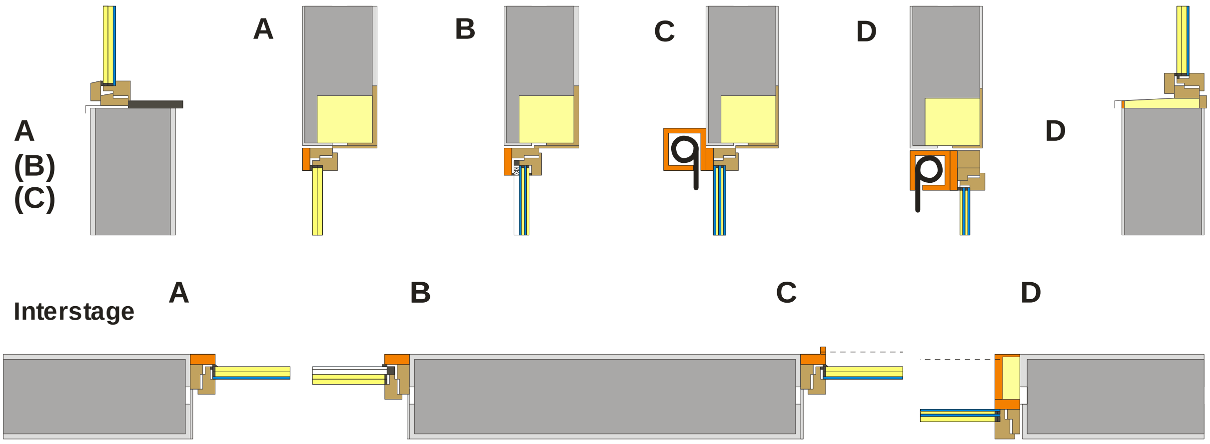


Figure 2: Interstage: Several solutions for the bottom, side and top section with- and without shading elements, frame is mounted in flush with the exterior plaster. Accurate sealing as a weather protection is crucial.

A: Without shading.

B: With air-gap integrated shading (recommended solution, see also Design Brief D5.1.3 Glazing Integrated Shading).

C: With roller shutter box in the future insulation layer. Extra care should be taken regarding the weather protection sealing at the joint between the wall and the shutter box.

D: Shutter box in flush with the exterior plaster: Solution should be avoided if possible because of thermal bridges and reveal shading. In addition, the glazed area is smaller due to higher frames (additional profile at the top section and additional insulation at the bottom profile to reduce the thermal bridge), which means less solar gains and less light.

2.3 Shading/Blinds

Roller shutter boxes are one of the major weak points in a building envelope. Generally, roller shutter boxes are not airtight, and it is hard to make them so in existing buildings. The result is high heat losses, even when the roller shutter box is insulated. Because the roller shutter box contains more or less cold outdoor air, insulating the box in the outside does not have a significant effect.

It is therefore recommended that the old roller shutter be removed along with the window; the roller shutter box should then be filled with insulation, made airtight and a new darkening/shading option should be provided. A front-mounted box or blinds that can be integrated in the new insulation later are a good option. In these cases, the frame and the front-mounted box should be thermally separated to reduce installation thermal bridges.

An even better option shown at the 2015 Component Award is shading in an air gap between an exterior single window pane and interior insulating glazing unit. The award showed that the investment costs for such shading are less than half those of blinds. Additional benefits include weather protection for shading/ darkening, lower thermal bridges and simpler, faster installation. The drawback is that the slats or the screen can slightly enlarge the visible frame width at the top, and dirt may collect on the panes in the air gap, which would then require cleaning. If this additional cleaning is to be avoided, filters can be used. This solution, called “composite windows”, is generally only offered operable windows. However, some manufacturers are working on solutions for stationary glazing as well (see also Design Brief D5.1.3 Glazing Integrated Shading).

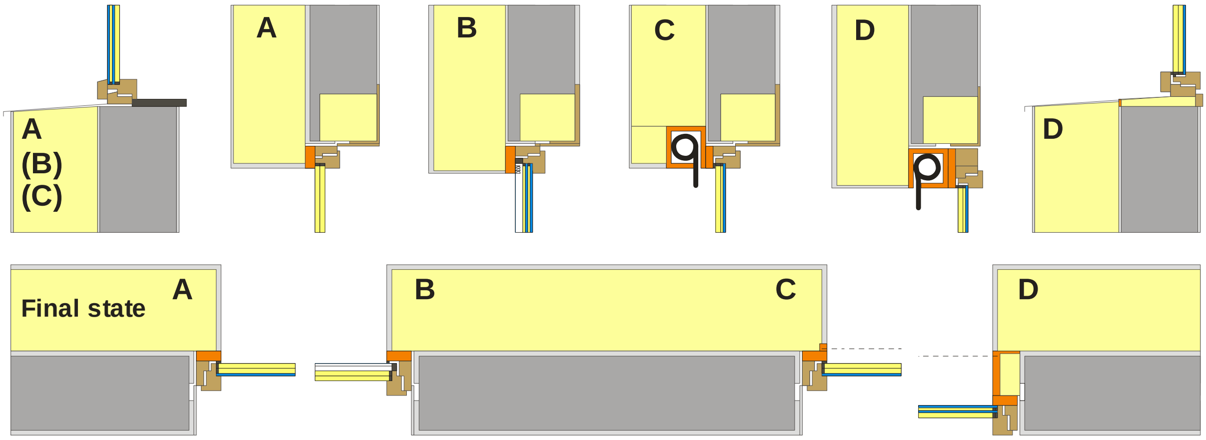


Figure 3: Final state: Several solutions for the bottom, side and top section with- and without shading elements, Frame is mounted in flush with the exterior plaster and over covered with insulation (side- and bottom profile).

A: Without shading.

B: With air-gap integrated shading (recommended solution, see also Design Brief D5.1.3 Glazing Integrated Shading).

C: With roller shutter box in the future insulation layer.

D: Shutter box in flush with the old exterior plaster: Solution should be avoided if possible because of thermal bridges and high reveal shading.

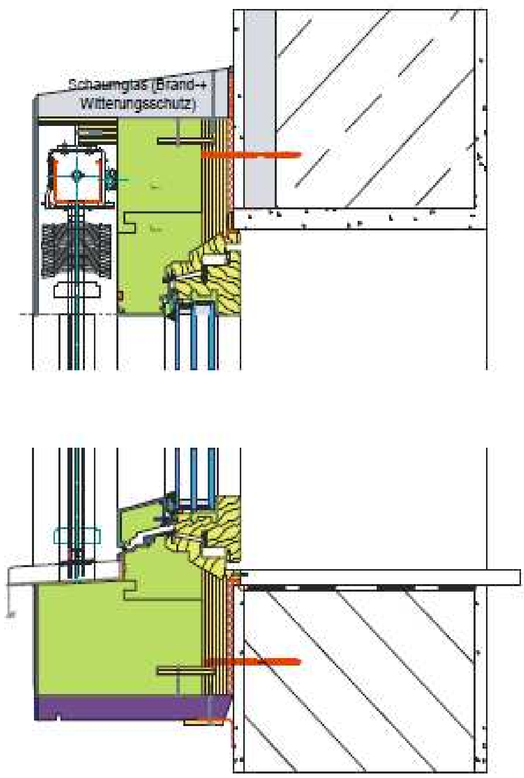
3 Solutions from the Component Award 2015 (samples)

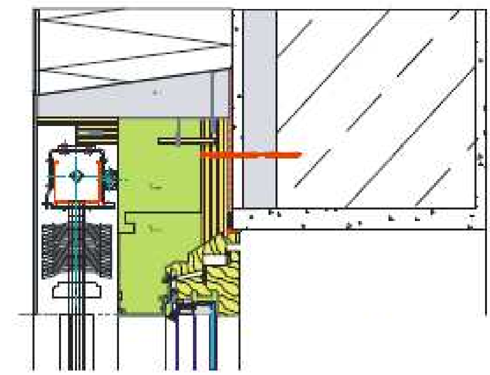
3.1 Installation solutions

Several installation solutions exist in which the window connections work both with and without the new insulation layer. Installation in the position of the old window is not recommended since it would lead to massive thermal bridges when the insulation layer is added and the window will be shaded by the deep reveal.

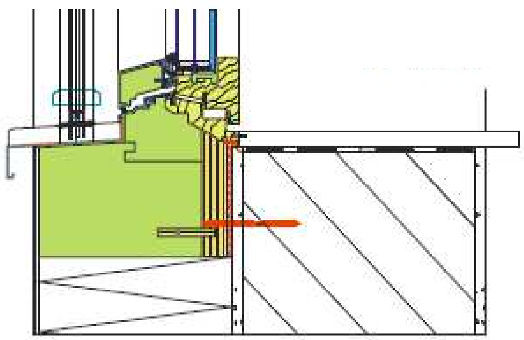
3.1.1 In front of the façade

Windows are installed in insulated frames in front of the façade, and the insulation is added later around the window. This solution has the advantage of extremely low thermal bridges. But issues with this kind of installation may be durability of the airtightness layer, possible issues with noise and weather protection, and aesthetics of the façade.





Source: dPHt



Stage 1: Window is installed in front of the old wall

Stage 2: Insulation is added around the window

Figure 4 – Window Installation in front of the Façade

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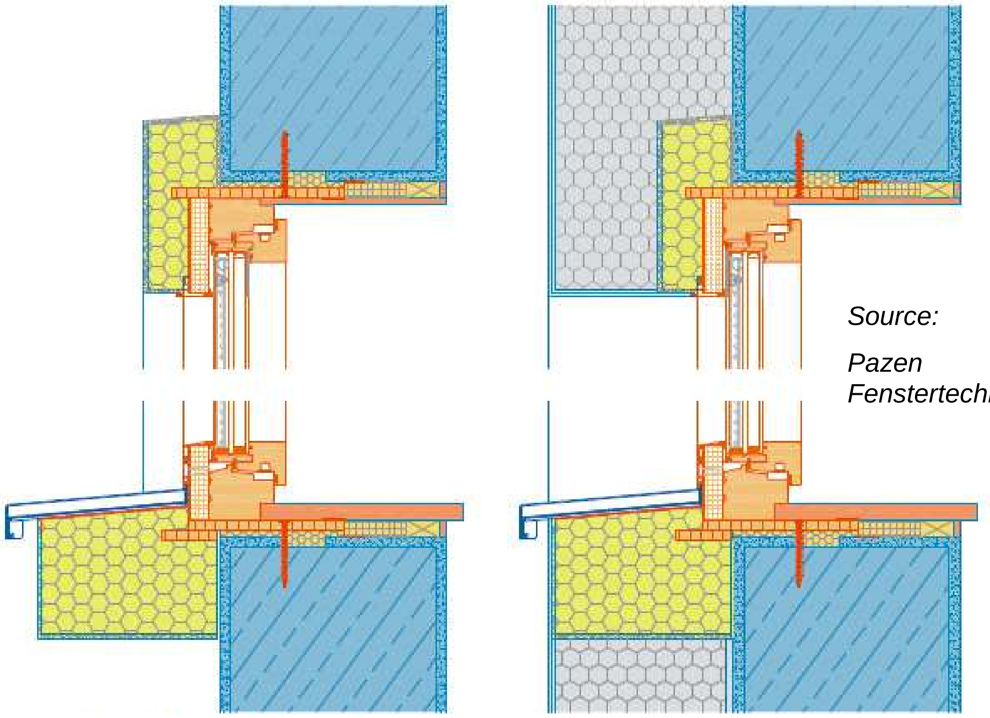
3.1.2 Partially in front of the façade

Windows are attached to the wall, but partially exposed to the exterior. When the next step of the retrofit occurs, the insulation layer is added around the protruding frame. It should be noted that very high thermal bridges may occur with this installation solution during the first stage. Additional insulation may be added to prevent temperatures around the reveal to drop too much. Other concerns were resistance to weather and aesthetics.



Source:

Pazen Fenstertechnik

Stage 1: The new window is installed, some insulation is added around the frame.

Stage 2: The insulation layer is added with no changes to the window.

Figure 5 – Window installation partially in front of the façade

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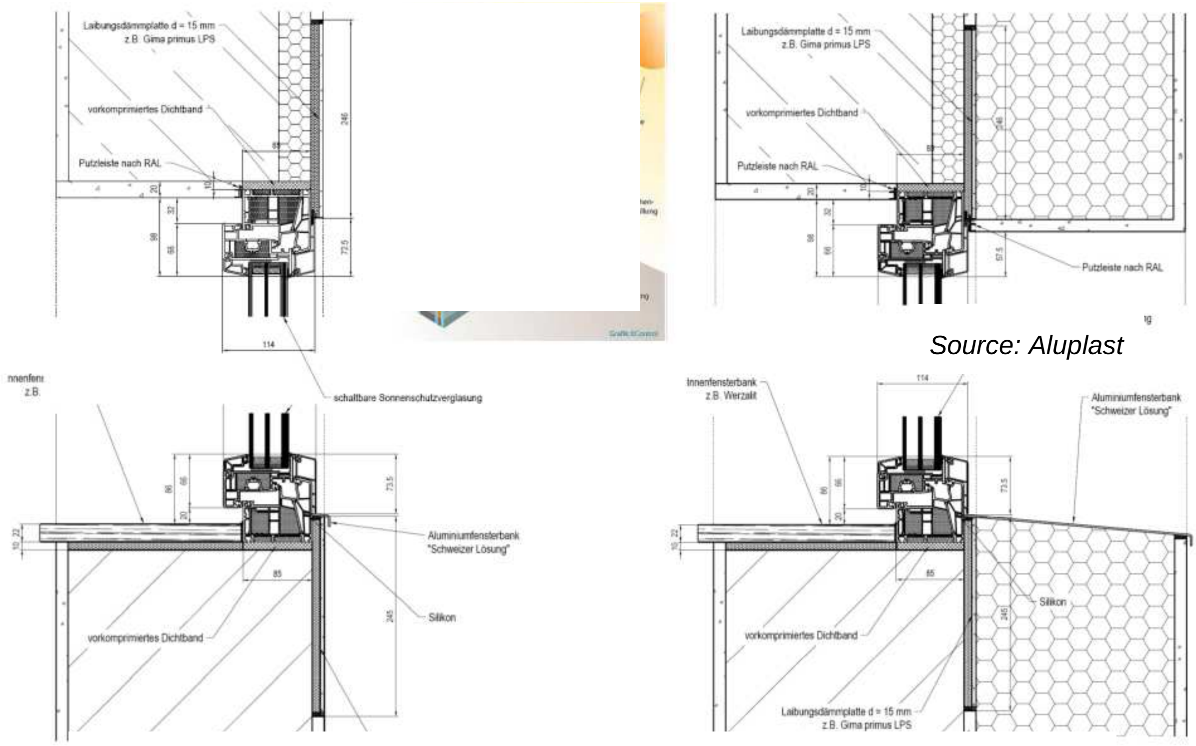
3.1.3 At the edge of the wall

The plaster around the window opening is removed and replaced with an insulated jamb panel that extends into the window opening. It is used as a bearing and insulating surface for the window, which is installed at the edge of the wall. The insulation layer is then added over the plaster board. This solution is relatively inexpensive compared to the other ones, but may result in a massive thermal bridge in the first stage. This may be reduced with the insulated plasterboard, which also improves weather protection.



Source: Aluplast

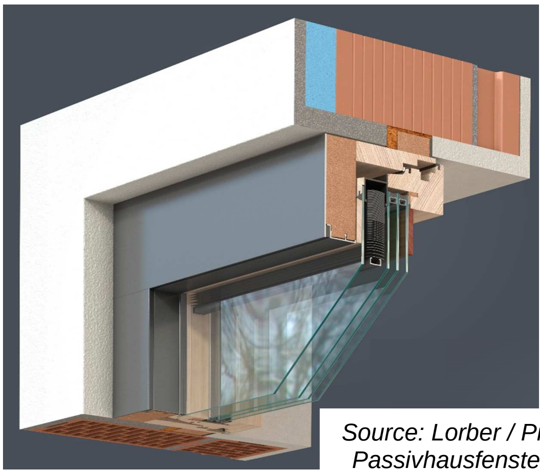
Stage 1: The new window is installed with the insulated jamb panel.

Stage 2: The insulation layer is added over the plaster board.

Figure 6 – Window installation in existing wall, with insulated jamb panel.

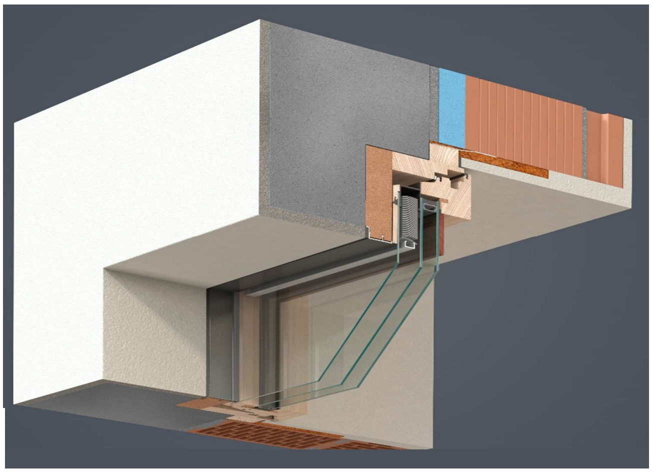
3.1.4 Moving windows

Another option is to install the new window in the same location of the old one, and, when the insulation layer is added, the window is relocated to the ideal installation situation. The advantages of this solution are that during both stages, there are low thermal bridges, there is more daylight and adequate weather protection.



Source: Lorber / Pro Passivhausfenster

Stage 1: The new window is installed in a similar location to the old one.



Stage 2. The window is relocated when the insulation layer is added.

Figure 7 – Moving windows

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Passive House Institute

4 Similar products

As part of the EuroPHit project, the Passive House Institute focused its 2015 Component Award on energy efficient windows for retrofits. The main challenge was that the product had to be flexible enough to work both during the transition period and when the insulation was put in place and that it was cost-effective, considering the life cycle costs. The solutions presented here, illustrations included, were presented by the participants. More information on the competition and the winners can be found here.

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