Energy and CO_2 savings through the use of blaugelb Trio**therm⁺** compared with steel mounting angles and with window installation flush with the exterior wall

Short study by the Passive House Institute on behalf of
Meesenburg Großhandel KG

Report

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1 Introduction

Saving energy in order to reduce climate-harming CO_2 emissions and reduce the pressure on renewable energy sources is one of the most important tasks of our age. For the building sector, the passive house has for decades performed a pioneering role in this regard because it demonstrates how saving energy and costs can routinely go hand in hand with increased living comfort.

One important aspect is easy-to-implement solutions, including in detail. One such solution is the blaugelb Trio**therm⁺**, with which windows can be installed quickly, reliably and neatly in the insulation layer of the façade.

This study, conducted by Passivhaus Institut GmbH on behalf of Meesenburg Großhandel KG, investigates the energy savings achieved with blaugelb Trio**therm⁺** compared with standard steel angles and with installation flush with the exterior wall.

2 Method

First the thermal characteristic values of a plastic window with triple glazing were determined by means of two-dimensional heat flow simulation. Then, using the same method, the built-in thermal bridge loss coefficients of the window were calculated in front of and in a concrete wall in the thermal insulation composite system. A distinction was made between installation with blaugelb Trio**therm⁺**, installation using steel angles and installation flush with the exterior wall. The thermal bridge loss coefficients were first determined without the steel angles. The additional losses as a result of the steel angles were determined using 3D heat flow simulation and added to the losses.

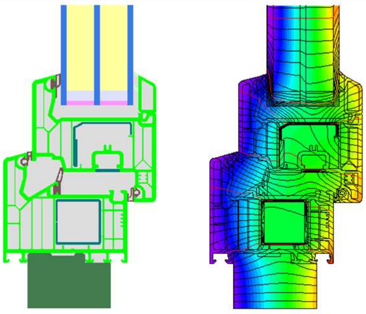
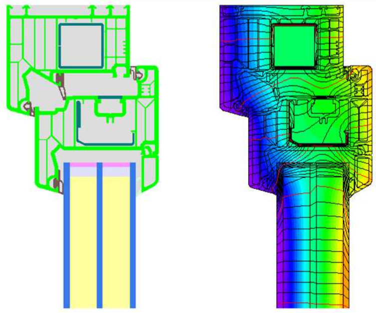
Then the annual energy and CO_2 savings for various climates were calculated from the characteristic values determined in this way.

2.1 Determination of the thermal characteristic values of the window

A conventional plastic window frame with triple glazing was taken as the reference frame. For 3D heat flow simulation, this was modelled more simply but with the same thermal characteristic values (cf. Table 1).

All 2D calculations were performed with Infomind Flixo 8.1 pro, cf. Annex 1. The 3D calculations were performed with Physibel Solido.

Table 1: Thermal characteristic values of the window frame used and the simplified model. U_W refers to a window size of 1.23 x 1.38 m.

Model			
Frame section	Bottom Model | Isotherm view	Top Model | Isotherm view	Simplified model
b_f [mm]	154	124	124
U_f [W/(m²K)]	1.08	1.15	1.15
Ψ_g [W/(mK)]	0.025	0.025	
U_g [W/(m²K)]	0.52		
U_W [W/(m²K)]	0.795		

2.2 Determination of the thermal characteristic values of the installation situation

Figure 1 shows the installation situations specified by the client. The wall consists of 20 cm reinforced concrete with 20 cm of insulation made from EPS (0.032 W/(mK)). The U value is 0.15 W/(m²K). For the bottom installation situation with blaugelb Trio**therm⁺**, a thermal bridge loss coefficient of 0.029 W/(mK) was determined, and 0.004 W/(mK) for the top installation situation. These good characteristic values are achieved thanks to the low thermal conductivity of blaugelb Trio**therm⁺** and the good position of the window in the insulation layer. The thermal transmittance value of the installed window is thus 0.82 W/(m²K). The comfort criterion of 0.85 W/(m²K) required for passive house windows for the cool-temperate climate zone is achieved.

The thermal insulation needs to be notched for the crimped steel angle. This was taken into account in modelling. The resulting air cavity worsens the thermal bridge loss coefficients at the top to 0.019 W/(mK). At the base, the cavity created can be partially filled with polyurethane foam; the thermal bridge loss coefficient then improves to 0.021 W/(mK), in each case before the steel angles have been taken into consideration.

Installation situations flush with the masonry are still widespread today. As the calculations show, they are a big disadvantage thermally. A thermal bridge loss coefficient of 0.162 W/(mK) was determined for the base installation situation. This is therefore almost six times higher than with blaugelb Trio**therm⁺**. The reason for this is that the highly thermally conductive masonry below the window sill can cool off markedly. A massive thermal bridge is also formed there. In the chosen position, the insulation layers of the wall and the window no longer overlap. This geometric effect also increases the thermal loss, as can also be observed at the upper connection. Despite the insulation over the window frame, the thermal bridge here is 0.058 W/(mK) and is therefore more than 14 times higher than with blaugelb Trio**therm⁺**. The thermal transmittance value of the installed window is thus 1.04 W/(m²K). The comfort criterion of 0.85 W/(m²K) required for passive house windows for the cool-temperate climate zone is missed by a significant margin.

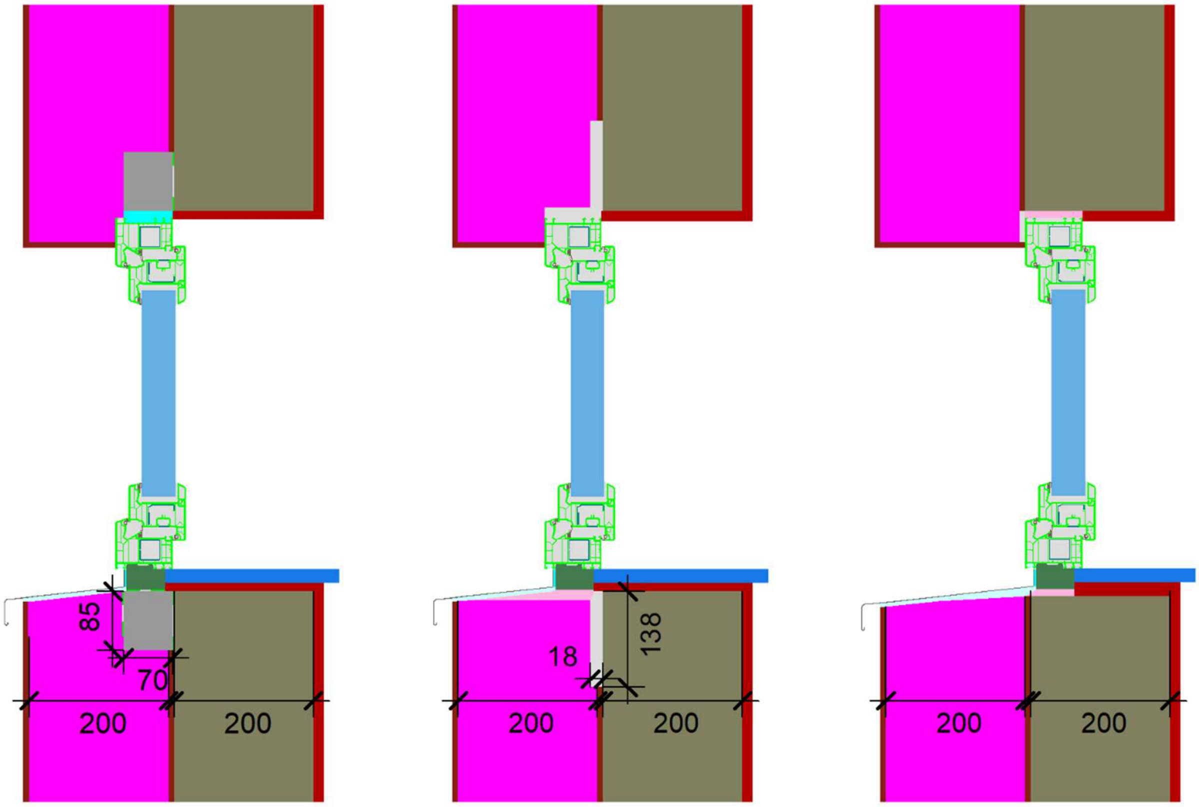


Figure 1: 2D models of the installation situations. Left, with blaugelb Trio**therm**+. Centre, for installation with steel angles. Right, flush with the wall.

In the case of installation with steel angles, the window is held by three steel angles at the base and three at the side, as well as by two at the top. Figure 2 shows the assumed angle (material thickness 2 mm, rabbet depth 12 mm, shank length 140/60 mm, width 80 mm). These angles constitute punctual thermal bridges that can be determined using 3D heat flow simulation. A punctual thermal bridge loss coefficient of 3.96 mW/K was calculated for the bottom angle, and 3.97 mW/K for those at the sides and top. Based on the number and spacing of the angles, this produces an additional linear thermal bridge of 0.0097 W/(mK) at the base and 0.0076 W/(mK) at the sides and top.

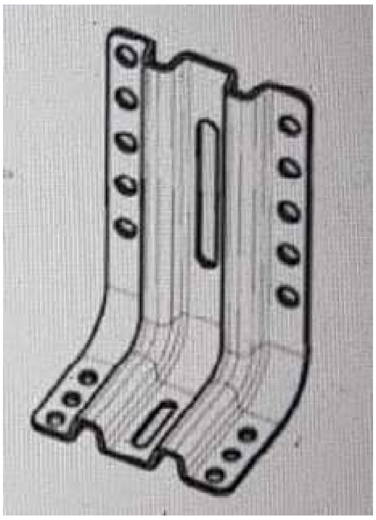


Figure 2: Assumed steel angle

This leads to an overall thermal bridge of 0.031 W/(mK) for the base connection and 0.027 for the top connection. The thermal transmittance value of the installed window is thus 0.88 W/(m²K). The use of the steel angle instead of the blaugelb Trio**therm+** results in a rise in the U value for the window in its installed state of 0.06 W/(m²K). The comfort criterion of 0.85 W/(m²K) required for passive house windows for the cool-temperate climate zone is missed. Table 2 summarises the results. Figure 3 and Figure 4 show the models for 3D heat flow simulation.

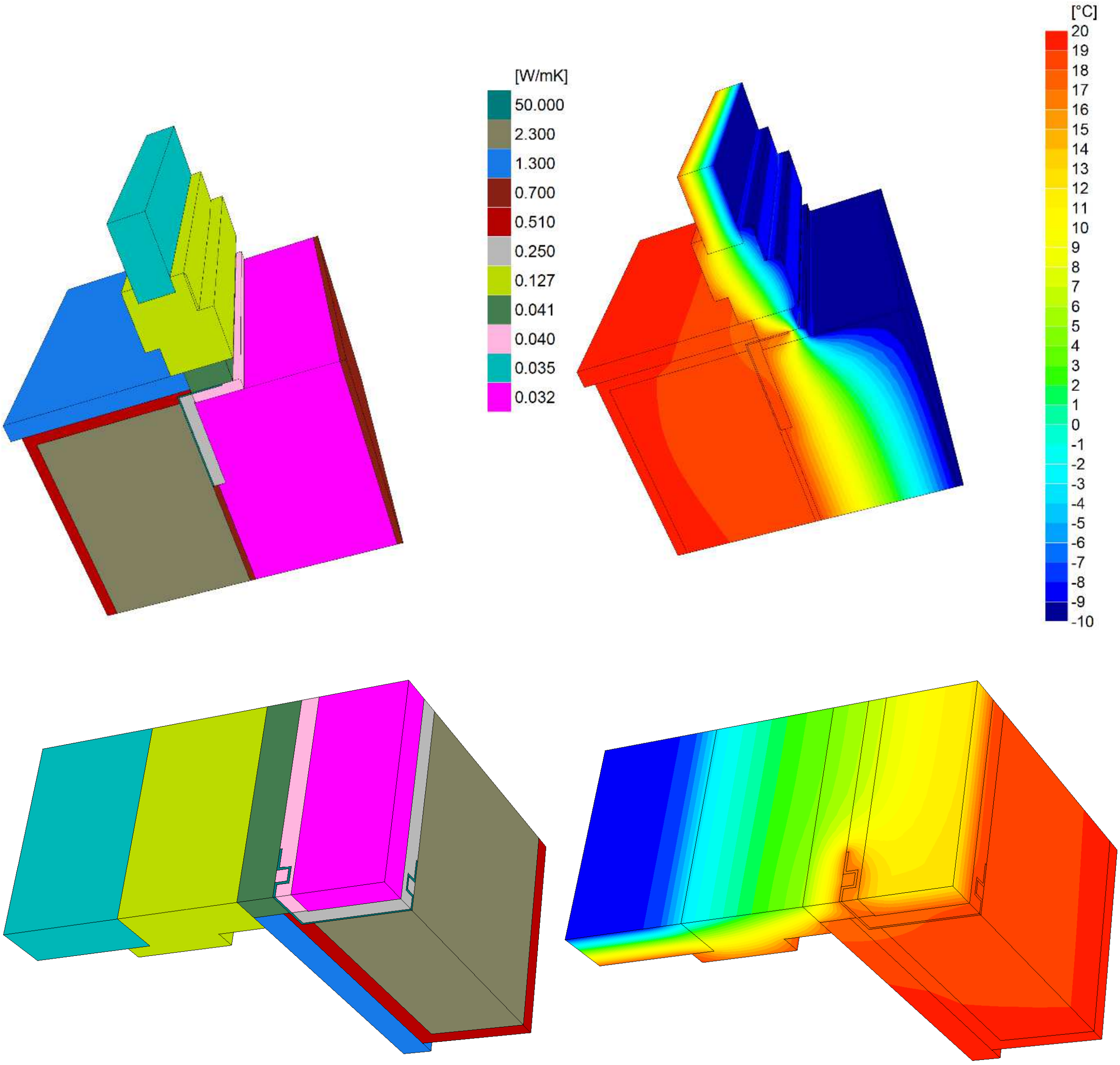


Figure 3: Bottom connection: extracts from the 3D models. Left: materials, right: isotherm view.

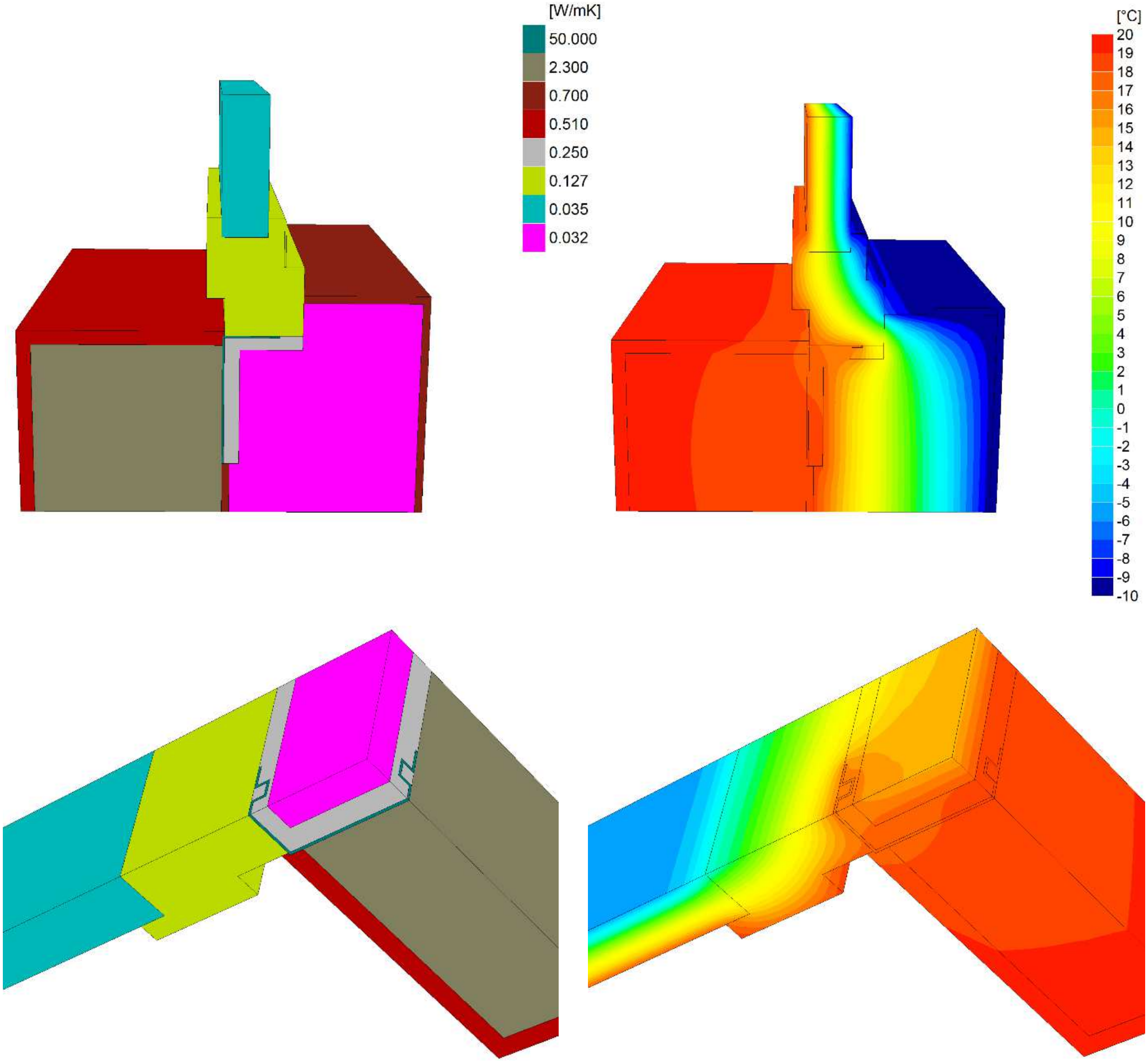


Figure 4: Side and top connection: extracts from the 3D models. Left: materials, right: isotherm view.

2.3 *Calculation of the energy and CO_2 saving*

To calculate the energy saving, the average thermal bridge loss coefficients were multiplied by the degree day for the location in question and the difference is then formed.

To calculate the CO_2 saving, this value was multiplied by the CO_2 factor for the energy source gas (250 g CO_2eq/kWh$_{End}$ acc. to GEMIS) and a system energy expenditure value of 1.2.

3 Results

Table 2 shows the results of the heat flow calculations. Whereas the U value of the window from the installation thermal bridge rises by only 0.03 W/(m²K) from 0.79 W/(m²K) to 0.82 W/(m²K) when blaugelb Trio**therm⁺** is used, it rises by 0.09 W/(m²K) to 0.88 W/(m²K) with the steel angles. If the window is installed flush with the exterior wall (a design still frequently encountered today), the thermal transmittance value actually rises by 0.24 W/(m²K) to 1.04 W/(m²K). The installation thermal bridges are transferable to other thermally equivalent window frames if there is no metal covered by insulation on the outside.

Table 2: Results of the heat flow calculations

Description	Uf value [W/(m²K)]		Frame Width [m]		Glazing Edge Ψ-value [W/(mK)]		Temperature factor (min)	U_W @U_g=0,52	Installation Ψ-value [W/(mK)]		$U_{W,}$ installed
	Side, head	Sill	Side, head	Sill	Side, head	Sill	$f_{Rsi=0,25}$ [-]	[W/(m²K)]	Sill	Side, head	[W/(m²K)]
1. PVC-window with blaugelb Triotherm+	1,15	1,08	0,124	0,154	0,025	0,025	0,70	0,79	0,029	0,004	**0,82**
2. PVC window with steel angle	1,15	1,08	0,124	0,154	0,025	0,025	0,70	0,79	0,031	0,027	**0,88**
3. PVC window in flush	1,15	1,08	0,124	0,154	0,025	0,025	0,70	0,79	0,162	0,058	**1,04**

Drawings and material data were provided by the manufacturer. The sole responibility for the provided information lies with the manufacturer.
* Ψ-values and temperature factors were carried out @ Ug = 0,52 W/(m²K)

Description and evaluation

PVC window frame with Swisspacer Ultimate, Ug = 0,52 W/(m²K) installed in an EIFS-wall.
1. Fixed by Meesenburg blaugelb Triotherm+ 70*85 system. The combination fullfills the certification criteria for cool, temperate climate.
2. Fixed by steel angels. The calculation (combination of 2D and 3D thermal heat flux analysis) is based on a practice-related installation with steel angels and the insulation under normal conditions. Under this circumstances, the criterion is missed.
3. Fixed in flush with the wall. This situation is common use, the thermal bridge is massive, the criterion is missed.

In Table 3, the heating energy and CO_2 savings for the locations Munich (Germany), Moscow (Russia), Beijing (China) and Almaty (Kazakhstan) are shown.

Table 3: Presentation of the results. Savings per 1 m of installation joint.

Climate			**Munich DE**	**Moscow RU**	**Beijing CN**	**Almaty KZ**
Heating degree hours		kKh/a	92	116	75	91
Average Ψ value	blaugelb Trio**therm⁺**	W/(mK)	0.010			
	Steel angle		0.028			
	Flush		0.082			
Difference	blaugelb Trio**therm⁺** – steel angle	W/(mK)	0.018			
	blaugelb Trio**therm⁺** – flush		0.072			
Heating energy saving	blaugelb Trio**therm⁺** – steel angle	kWh/(ma)	1.64	2.07	1.34	1.62
	blaugelb Trio**therm⁺** – flush		6.62	8.34	5.39	6.55
CO_2 saving	blaugelb Trio**therm⁺** – steel angle	kg CO_2eq/(ma)	0.49	0.62	0.40	0.49
	blaugelb Trio**therm⁺** – flush		1.99	2.50	1.62	1.96