Energy, CO2 and cost savings through the use of plastic windows with different glazing

In comparison to the single glazed aluminium windows in the climate of New Delhi, India

Short study of the Passive House Institute on behalf of ALUPLAST INDIA

REPORT

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Table of content

1 Introduction

The saving of energy for the reduction of climate-damaging CO_2 emissions and the relief of the strain of renewable energy sources is one of the most important tasks of our time. In the area of energy efficiency in buildings, energy savings in heating climates are regularly accompanied by a reduction in the life cycle costs and other advantages. With the example of windows and glazing this becomes particularly clear.
In this study, conducted by the Passivhaus Institute Dr. Wolfgang Feist on behalf of Aluplast India, these effects could also be demonstrated for cooling climates using the example of New Delhi, India.

2 Method

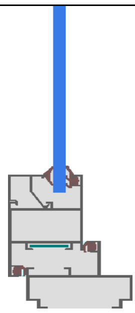
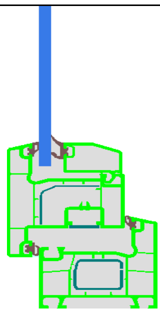
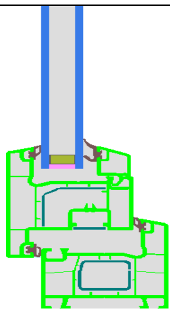
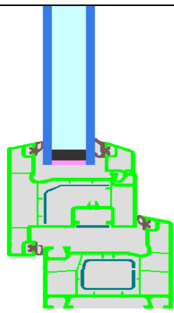
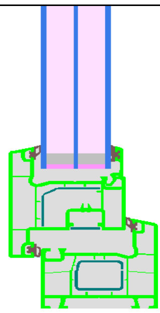
First, the thermal characteristics of an aluminium window with single glazing and an Aluplast Ideal 2000 window frame with 4 different glazing were determined. With these values, the energy performance of an example building was calculated in the second step using the Passive House Projecting Package (PHPP version 9.4). The savings in terms of energy requirements, energy costs and CO_2 in were determined. The energy costs, investment costs and all required design drawings were supplied by Aluplast India.

2.1 Determining the thermal characteristics

As a reference frame, single-glazed aluminium frame, which is typically in India, was used (see Table 1).

This window was compared with an Aluplast Ideal 2000 frame in the versions with single glazing, double glazing (without low-E coating with air filling in between the glass pane), with double and with triple low-E. In addition, the installation-thermal bridges for the aluminium frame and the plastic frame were determined. All calculations were carried out with Flixo 7 pro, see Annex 1. Table 1 shows the results.

Table 1: Thermal characteristics and investment costs of the analysed frame-glass combinations

Model					
Window	Standard Aluminium	Aluplast Ideal 2000	Aluplast Ideal 2000	Aluplast Ideal 2000	Aluplast Ideal 2000
b_f [mm]	88	107			
U_f [W/(m²K)]	6,52	1,64	1,60	1,59	1,56
Ψ_g [W/(mK)]	-0,015	-0,013	0,033	0,051	0,031
Glazing	Single	Single	Double	Double Low-e	Triple Low-e
U_g [W/(m²K)]	5,68		2,85	1,04	0,59
U_W [W/(m²K)]	5,83	3,92	2,43	1,45	1,11
g [-]	0,85		0,78	0,45	0,36
Invest [€/m²]	45	70	84	107	127
Ψ_i [W/(mK)]	0,111	0,044			

2.2 Building model and location

For the study the location New Delhi was chosen by the client in the very hot climate. The heating and cooling hours of the site are shown in Table 2.

The building, modeled in the Passive House Projecting Package project package, is based on a design of a typical new building in multi-storey housing construction in India, provided by the client. A representative section of a residential floor was modeled. The secondary heat emission (as a result of solar irradiation on the frame) was not inkluded. Due to the better U-value of the plastic frame, it is to be expected that the results would be altered by incorporating the secondary heat emissions in favor of the vinyl windows.

The building is cooled by a heat pump (SPF = 2,5). The internal temperature was set at 20 ° C all year round. There is no significant heating requirement. Thus, the building is monovalently powered by electricity. Figure 1 shows the building.

Figure 1: Analysed building

Table 2: Climate characteristics and component qualities of the reference building

Parameter	Einheit	**New Delhi**
Heating degree hours	kKh/a	4
Cooling degree hours	kKh/a	36
U-value roof & exterior wall	W/(m²K)	0,72
U-value basement ceiling	W/(m²K)	0,92

2.3 Determining the present value of the energy savings

In order to determine the present value of the energy saving, the following boundary conditions were applied: Period of use: 40 years. Nominal interest rate: 6.5%, inflation: 5%. Electricity price: 0,08 € / kWh (according to client). Divided by the Seasonal Performance Factor (SPF) of the heat pump, the useful cooling price (without depreciation and maintenance of the plant engineering) is determined to 0.032 € / kWh. The present value is determined according to the following equations.

$$K_e = k_j \cdot B_B$$

$$k_j = Q_{Energie} \cdot k_{Energie}$$

$$B_B = \frac{1-(1+p_{real})^{t_B \cdot -1}}{p_{real}}$$

K_e: Present value [€]
k_j: Annual energy costs [€]
B_B: Present value factor [-]
$Q_{Energie}$: Amount of energy [kWh]
$k_{Energie}$: Energy costs [€/kWh]
p_{real}: Real interest
t_B: Period of observation [a]

2.4 Determining the CO_2-savings

To determine the CO_2 savings, the final energy demand for heating and cooling (energy sources: electricity) is multiplied by the CO_2eq emission factor (also called global warming potential - GWP factor). This factor contains not only the CO_2 per kWh of final energy, but also includes the climate impact of other pollutants normalized to CO_2. The CO_2eq emission factor was calculated in this to 0.70 kgCO_2eq / kWh_{final}.

3 Results

This chapter presents the results of the short study in word and picture. A table of results can be found in Annex 2.

3.1 Cooling demand

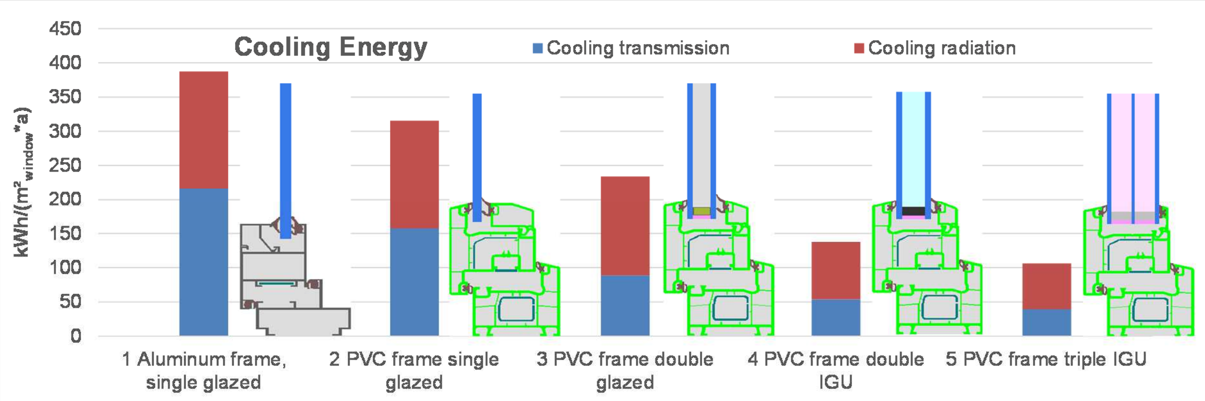


Figure 3: Cooling requirement for the tested variants

Figure 3 visualizes the cooling energy required by the windows, based on the square meter of the window area, separated in transmission and radiation in cooling energy. The transmission cooling demand is formed by the heat intruding through the frame and the glass, depending solely on the U-value of the windows. The better the window's U-value, the lower the cooling energy demand. The glazing surface and the total energy transmission factor of the glazing "g" are decisive for the heat intruding by radiation. The lower the g-value, the lower the thermal load. At this point too, the low-E coatings of the insulating glasses increasing the g-value have a positive effect on the energy balance. On closer inspection, it is noticeable that the heat loads of the single-glazed PVC window are somewhat lower than those of the aluminium window. This is due to the somewhat broader frame of the vinyl window, and therefore slightly smaller glass surface of the PVC window.

3.2 Electricity demand, GWP

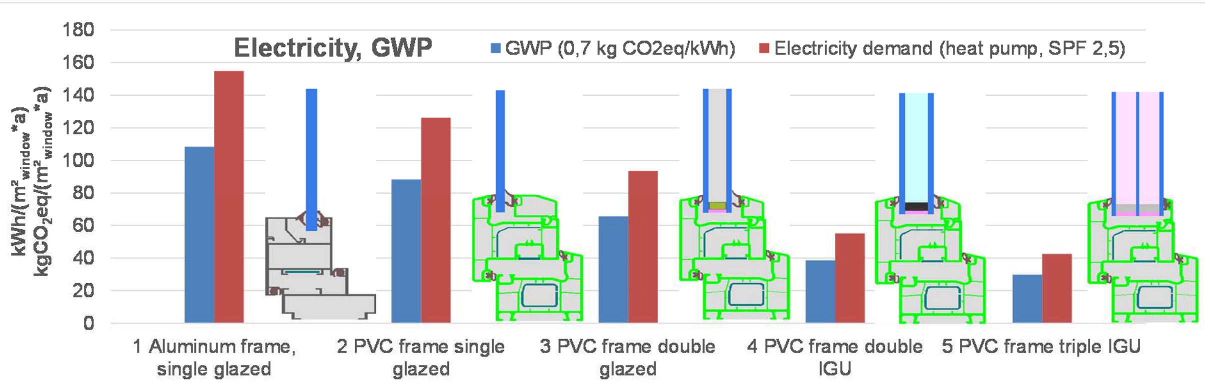


Figure 3: Demand for electrical energy for cooling and the resulting CO_2 emissions

The demand for electrical energy is directly linked to the cooling demand via the SPF

(Seasonal Performance Factor) - here 2.5. The lower the useful cooling demand, the lower the demand for (electrical) energy to be paid. The same applies to the Global Warming Potential GWP. The saving potential in comparison between the aluminium window and the PVC window with triple glazing is almost at 80 kg of CO_2eq per square meter of window area per year, corresponding to approximately 660 km kilometres driven with a Golf VI 1.6 TDI

3.3 Life cycle cost (LCC)

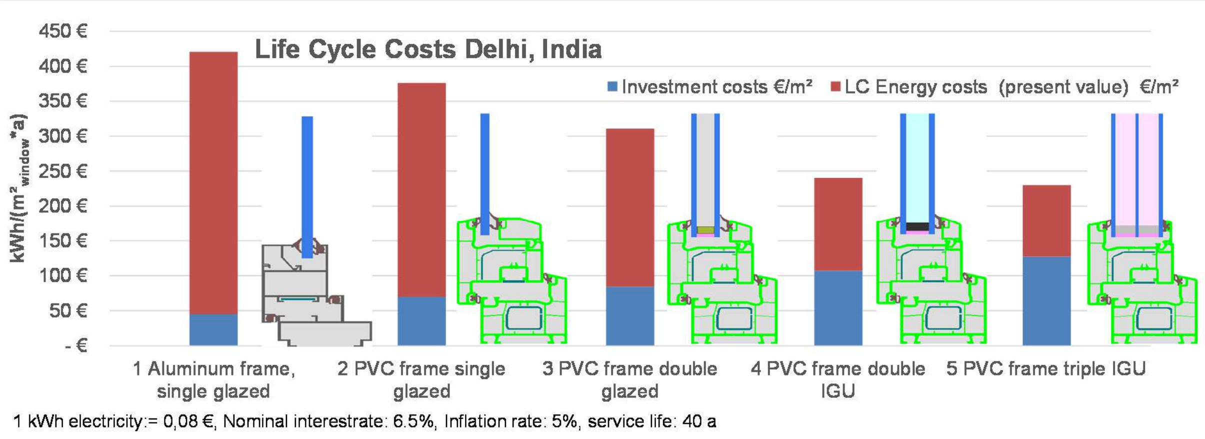


Figure 3: Life cycle costs (40 years) of the tested variants

The higher investment costs of thermally improved products are faced with significantly reduced energy costs over the entire service life of the components (in this case 40 years). With regard to Figure 3, it can be seen that the thermally highest-quality component with a slight lead to the thermally second-most window in this study performs with the lowest life cycle costs. The most obvious are the jumps between the single and double glazed, as well as the double- and the double low-E glazed PVC frame. It can be inferred from this that in conjunction with PVC frames, heat protection glazing should always be used. In addition to the cost advantage, the user also benefits from a better sound insulation and better thermal comfort due to the double- and triple glazing.

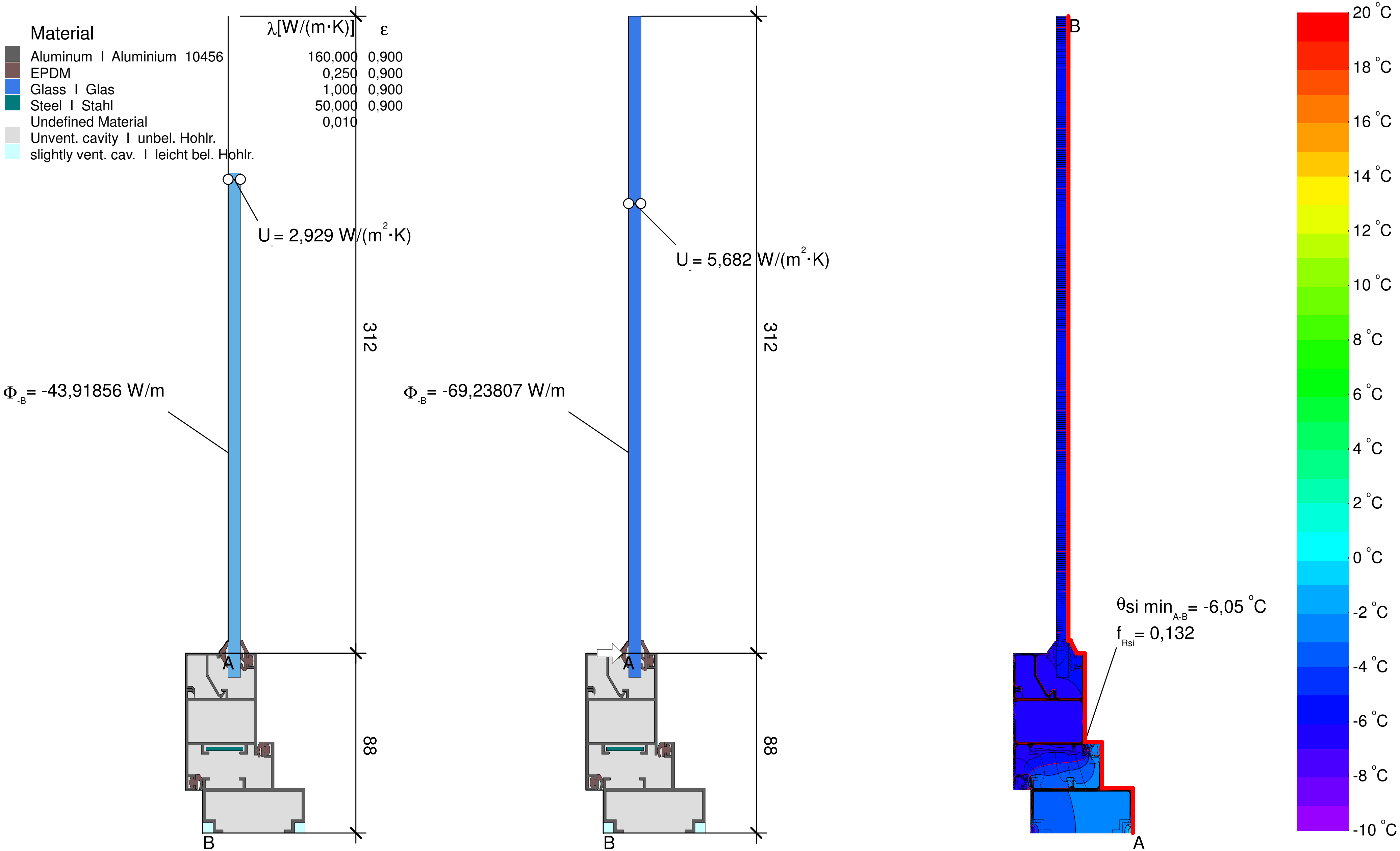
4 Summary

The present study has shown that the use of vinyl windows leads to significant savings in electricity and CO_2, as well as in economic terms.

This is particularly clear in combination with double- or even triple low-E glazing.

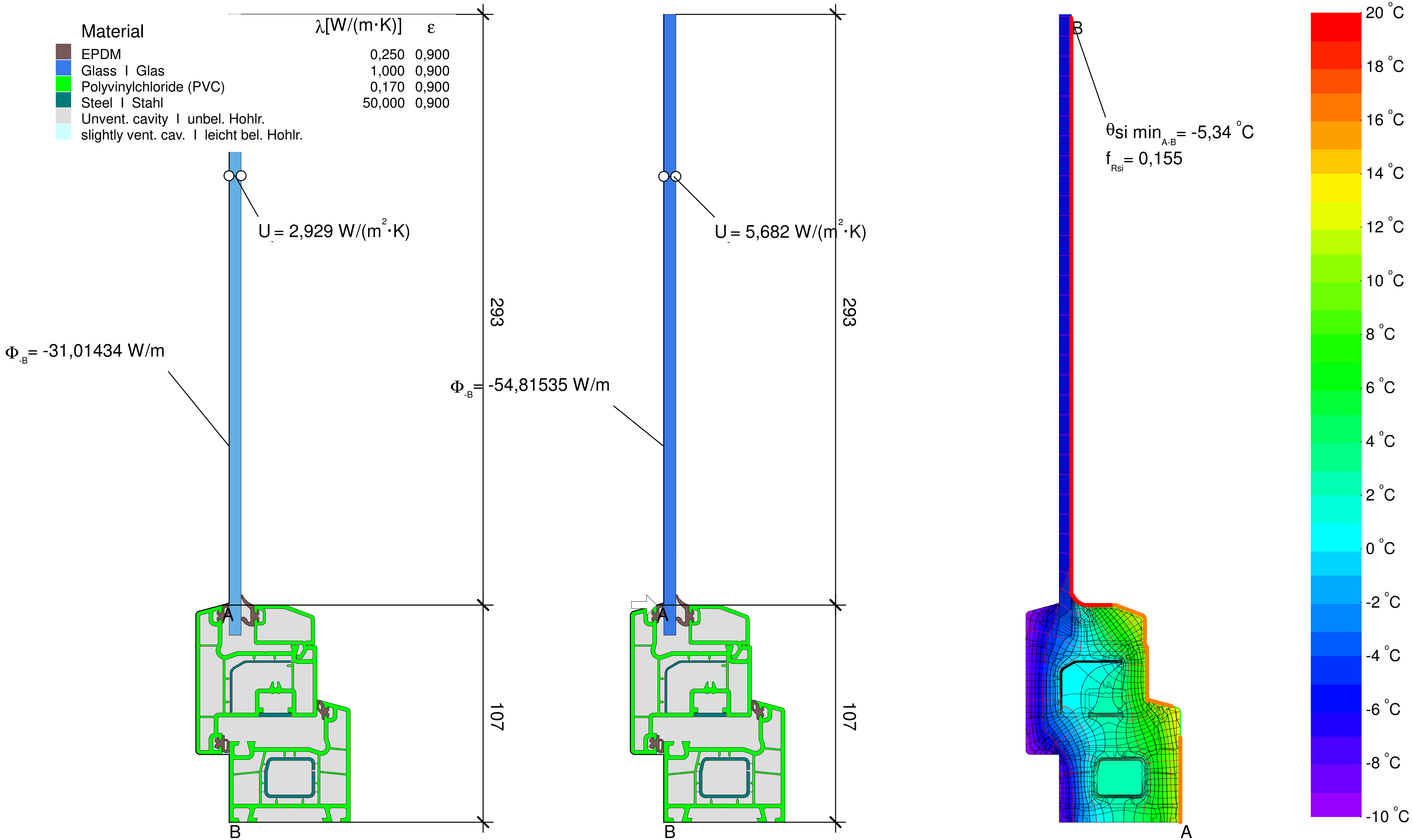
The annual avoidable amount of CO_2 per square meter of window area comparing the single-glazed aluminium window and the triple glazed PVC window corresponds to 660 km driven with a Golf VI 1.6 TDI.

In addition to the cost advantage, the user also benefits from a better sound insulation and better thermal comfort due to the multiple glazing.



$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{43,919}{30,000} - 2,929 \cdot 0,312}{0,088} = 6,252\ \mathrm{W/(m^2 \cdot K)}$$

$$\psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{69,238}{30,000} - 5,682 \cdot 0,312 - 6,252 \cdot 0,088 = -0,015\ \mathrm{W/(m \cdot K)}$$

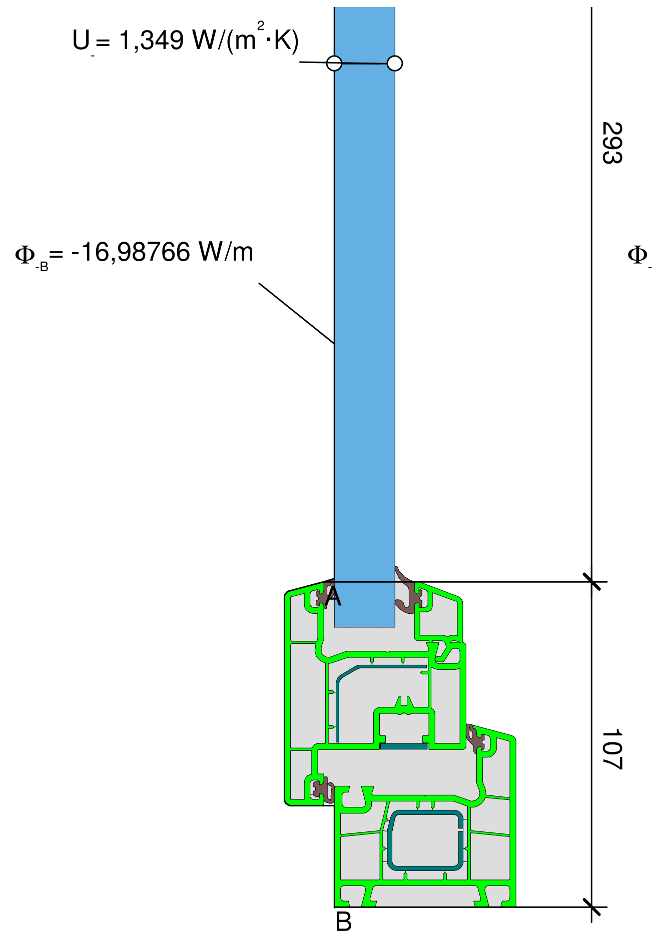


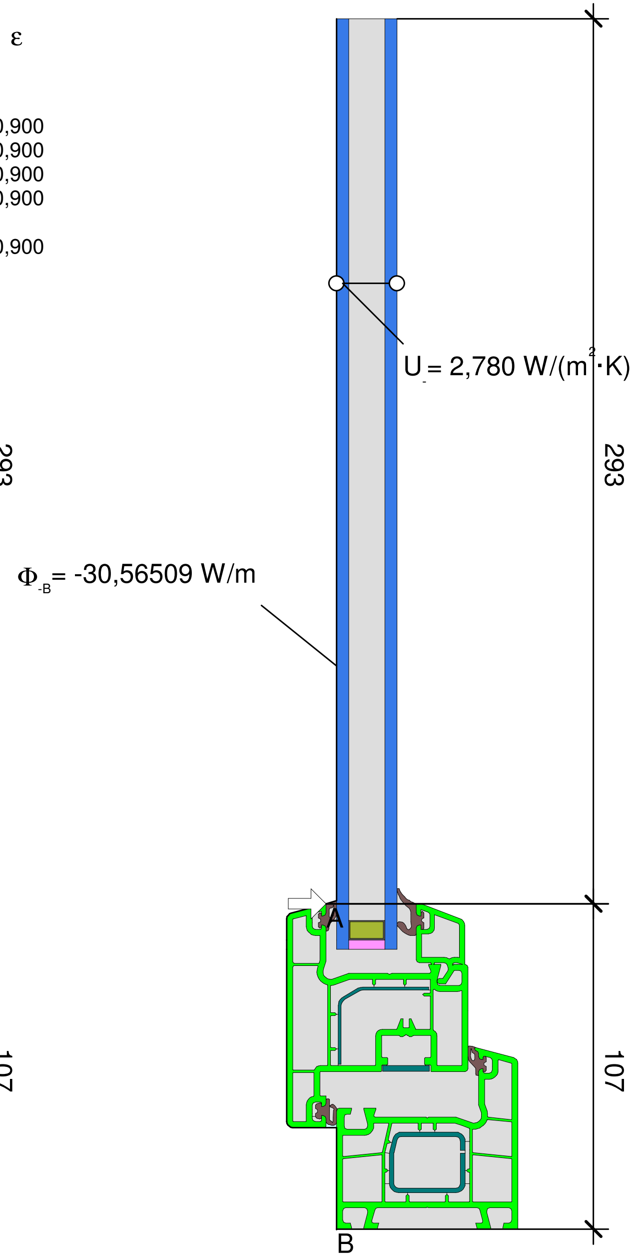
$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{31{,}014}{30{,}000} - 2{,}929 \cdot 0{,}293}{0{,}108} = 1{,}648\ W/(m^2 \cdot K)$$

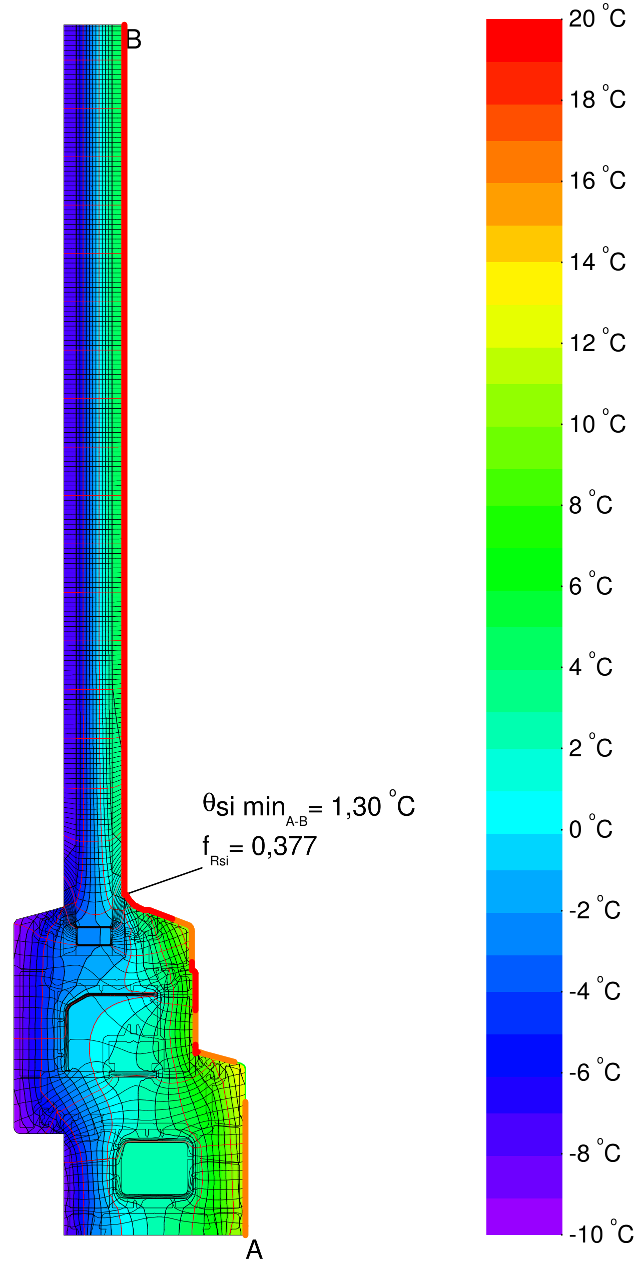
$$\psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{54{,}815}{30{,}000} - 5{,}682 \cdot 0{,}293 - 1{,}648 \cdot 0{,}108 = -0{,}012\ W/(m \cdot K)$$

PVC window with single glazing

Material	λ[W/(m·K)]	ε
Air 12 in 20 mm 2.78	0,066	
Aluminum I Aluminium 10456	160,000	
EPDM	0,250	0,900
Glass I Glas	1,000	0,900
Polysulfide I Polysulfid	0,400	0,900
Polyvinylchloride (PVC)	0,170	0,900
Silicagel (Trockenmittel) (1)	0,130	
Steel I Stahl	50,000	0,900
Unvent. cavity I unbel. Hohlr.		
slightly vent. cav. I leicht bel. Hohlr.		



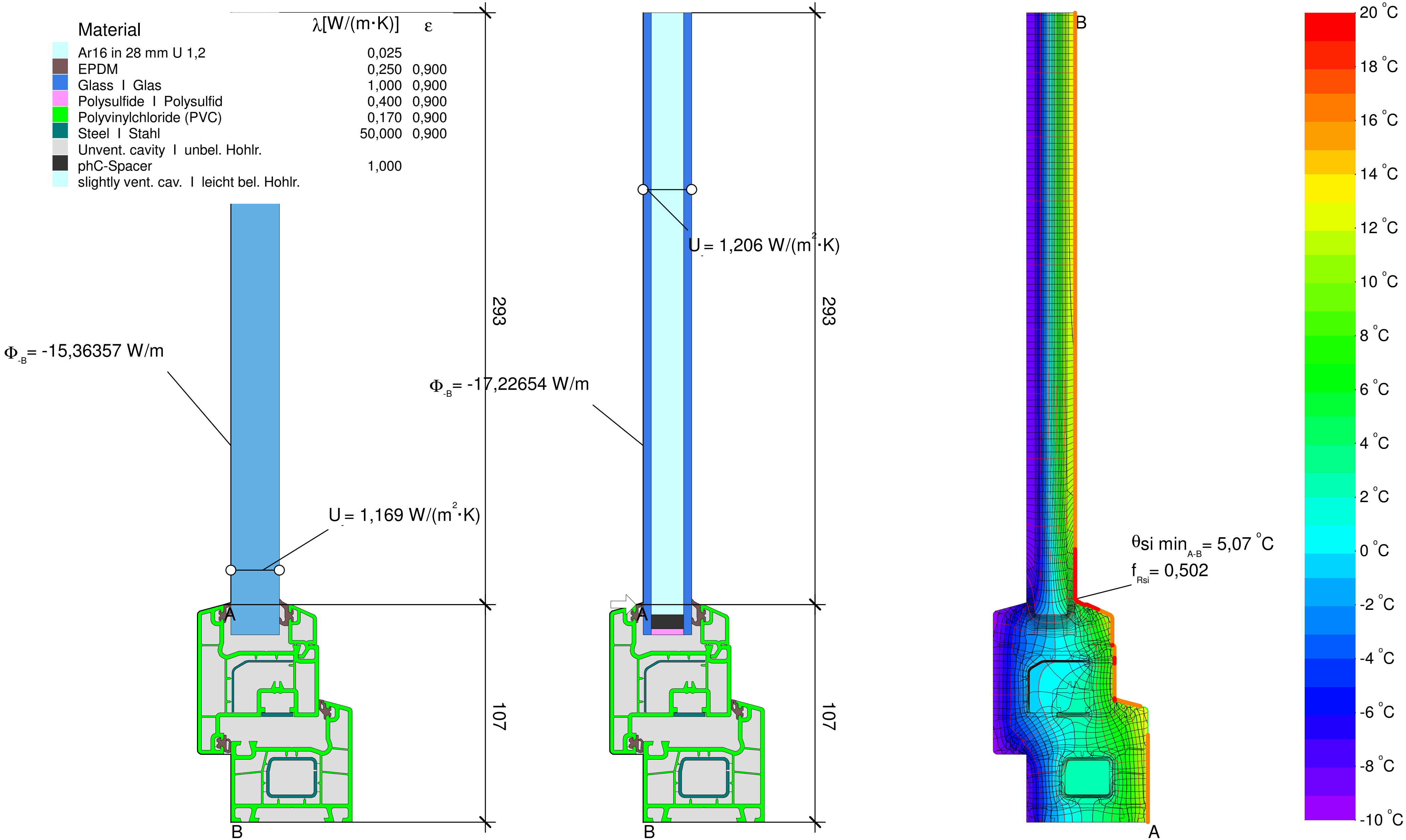




$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{16,988}{30,000} - 1,349\cdot 0,293}{0,108} = 1,598\ \text{W/(m}^2\cdot\text{K)}$$

$$\Psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{30,565}{30,000} - 2,780\cdot 0,293 - 1,598\cdot 0,108 = 0,034\ \text{W/(m}\cdot\text{K)}$$

Material	λ[W/(m·K)]	ε
Ar16 in 28 mm U 1,2	0,025	
EPDM	0,250	0,900
Glass I Glas	1,000	0,900
Polysulfide I Polysulfid	0,400	0,900
Polyvinylchloride (PVC)	0,170	0,900
Steel I Stahl	50,000	0,900
Unvent. cavity I unbel. Hohlr.		
phC-Spacer	1,000	
slightly vent. cav. I leicht bel. Hohlr.		

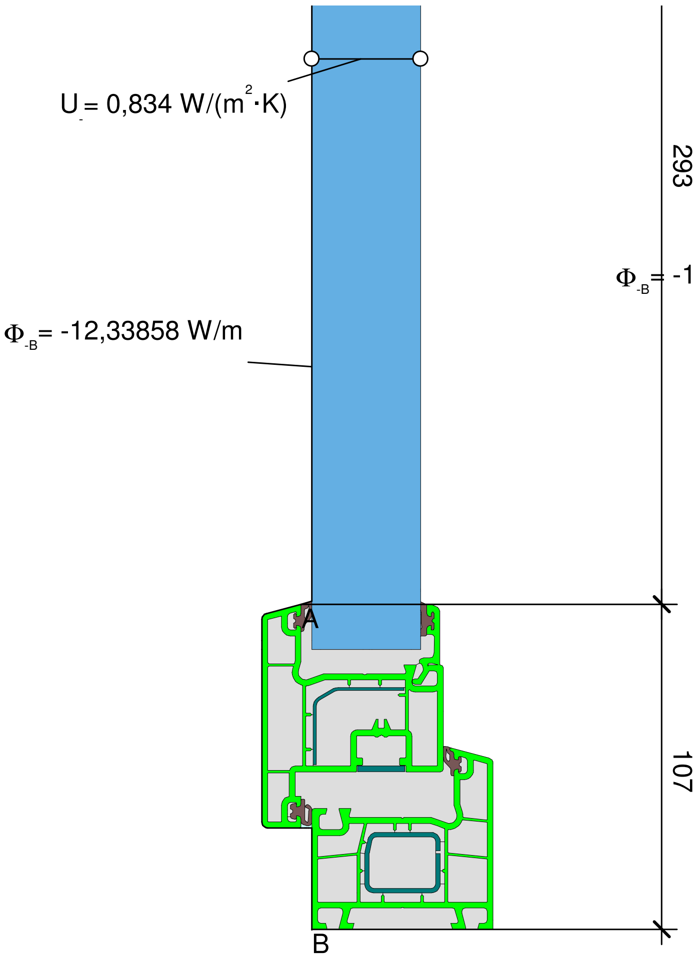


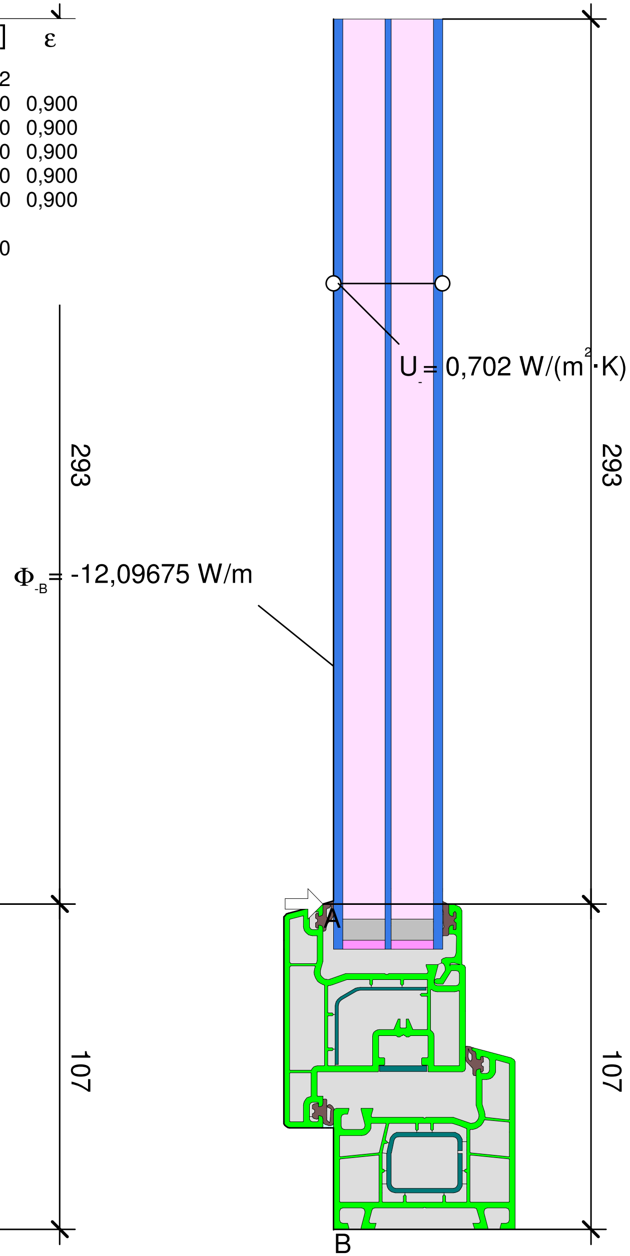
$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{15,364}{30,000} - 1,169 \cdot 0,293}{0,108} = 1,584\ W/(m^2 \cdot K)$$

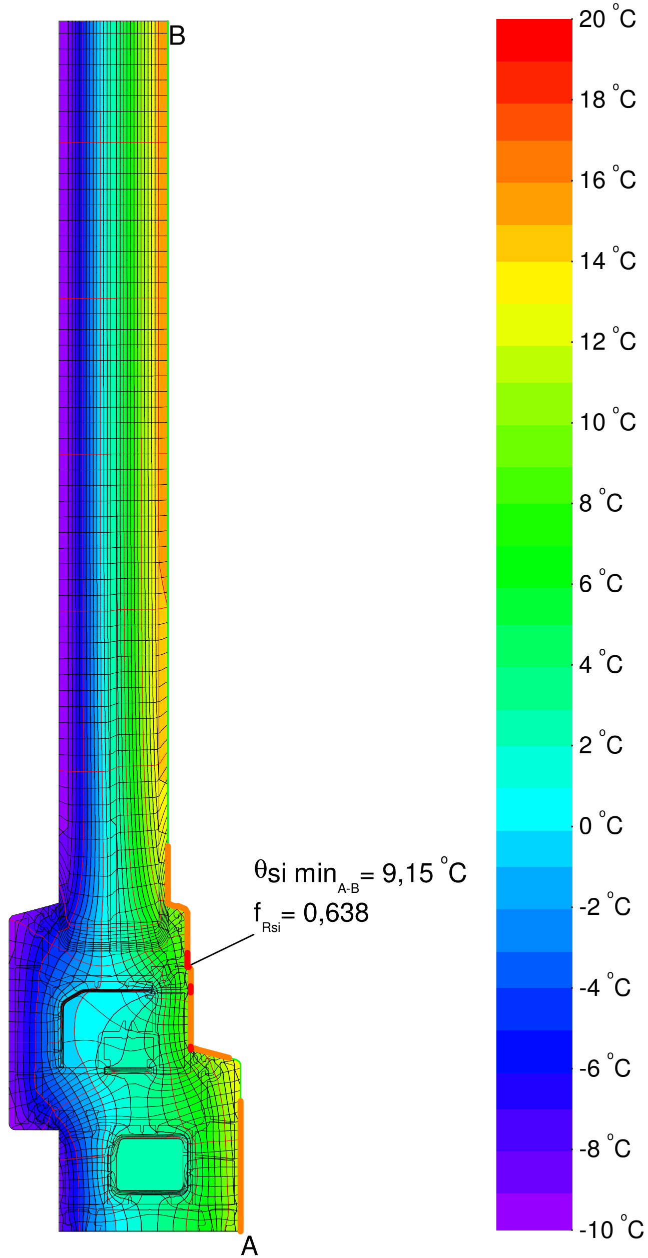
$$\Psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{17,227}{30,000} - 1,206 \cdot 0,293 - 1,598 \cdot 0,108 = 0,050\ W/(m \cdot K)$$

PVC window with double low-E glazing

Material	λ[W/(m·K)]	ε
Ar14 in 40 mm U 0,7	0,022	
EPDM	0,250	0,900
Glass I Glas	1,000	0,900
Polysulfide I Polysulfid	0,400	0,900
Polyvinylchloride (PVC)	0,170	0,900
Steel I Stahl	50,000	0,900
Unvent. cavity I unbel. Hohlr.		
phA-Spacer	0,200	
slightly vent. cav. I leicht bel. Hohlr.		

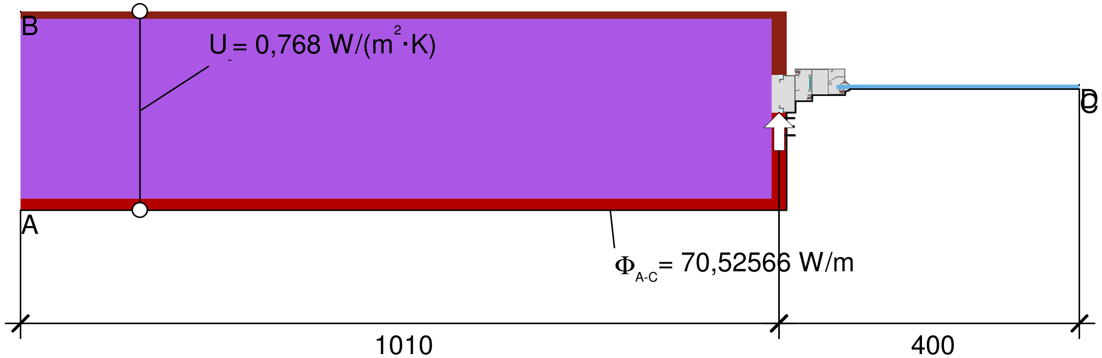






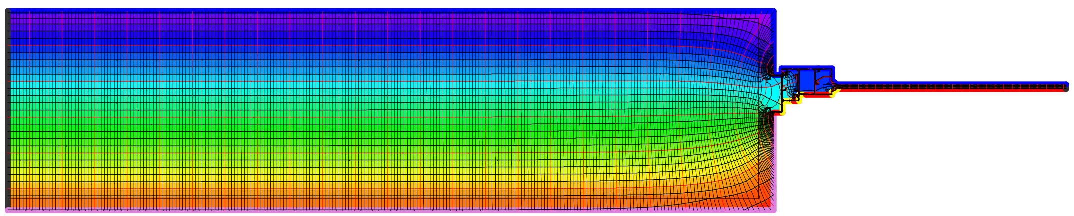
$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{12,339}{30,000} - 0,834 \cdot 0,293}{0,108} = 1,556\ W/(m^2 \cdot K)$$

$$\psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{12,097}{30,000} - 0,702 \cdot 0,293 - 1,556 \cdot 0,108 = 0,031\ W/(m \cdot K)$$

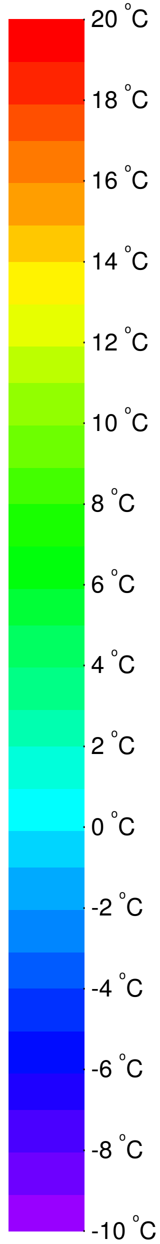


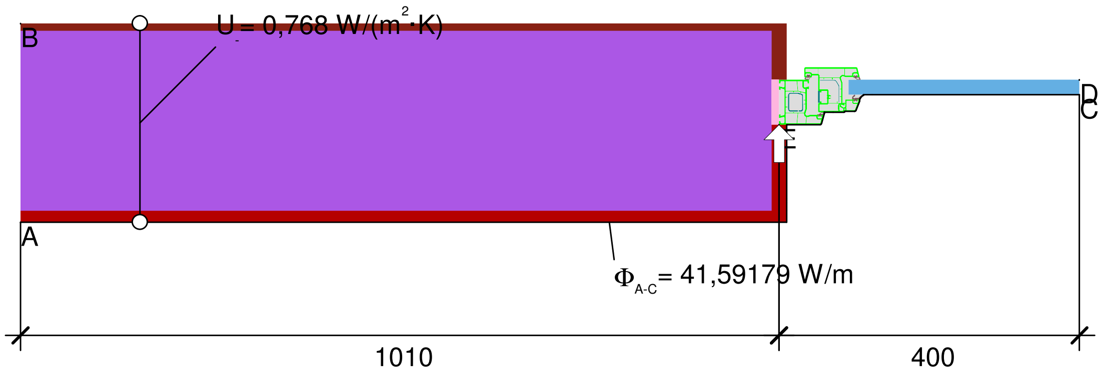
$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{70{,}526}{30{,}000} - 0{,}768 \cdot 1{,}010 - \frac{43{,}919}{30{,}000} = 0{,}111 \text{ W/(m·K)}$$

Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160,000	0,900
EPDM	0,250	0,900
Interior plaster I Gipsputz 10456	0,570	0,900
Organic compound plaster I Kunstharzputz 4108-4	0,700	0,900
Panel I Maske	0,035	0,900
Steel I Stahl	50,000	0,900
Undefined Material	0,010	
Unvent. cavity I unbel. Hohlr.		
Vollblöcke aus Leichtbeton mit LM21/DM, 450	0,220	0,900
slightly vent. cav. I leicht bel. Hohlr.		



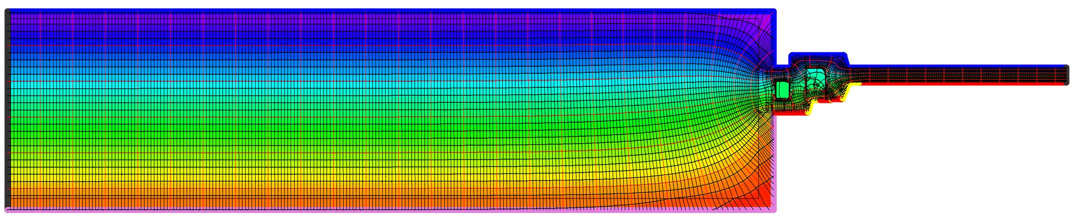
Randbedingung	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic | Adiabat	0,000			
Exterior | Außen		-10,000	0,040	
Interior | Innen		20,000	0,130	
Interior, frame, normal		20,000	0,130	
Interior, frame, reduced		20,000	0,200	
e 0,9 Cavity I Hohlraum				0,900



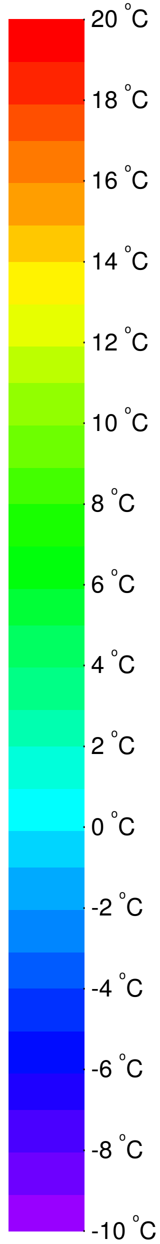


$$\Psi_{A\text{-}E\text{-}C,\cdot} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{41,592}{30,000} - 0,768 \cdot 1,010 - \frac{16,988}{30,000} = 0,044 \text{ W/(m·K)}$$

Material	λ[W/(m·K)]	ε
EPDM	0,250	0,900
Interior plaster I Gipsputz 10456	0,570	
Organic compound plaster I Kunstharzputz 4108-4	0,700	
PU in-situ foam I PU-Ortschaum 040	0,040	0,900
Panel I Maske	0,035	0,900
Polyvinylchloride (PVC)	0,170	0,900
Steel I Stahl	50,000	0,900
Unvent. cavity I unbel. Hohlr.		
Vollblöcke aus Leichtbeton mit LM21/DM, 450	0,220	
slightly vent. cav. I leicht bel. Hohlr.		



Randbedingung	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic | Adiabat	0,000			
Exterior | Außen		-10,000	0,040	
Interior | Innen		20,000	0,130	
Interior, frame, normal		20,000	0,130	
Interior, frame, reduced		20,000	0,200	
e 0,9 Cavity I Hohlraum				0,900



Appendix 2: Table of results

	1 Aluminum frame, single glazed	2 PVC frame single glazed	3 PVC frame double glazed	4 PVC frame double IGU	5 PVC frame triple IGU
Cooling transmission [kWh/(m^2_{window}*a)]	216	157	89	54	39
Cooling radiation [kWh/(m^2_{window}*a)]	171	158	145	84	67
Cooling summ [kWh/(m^2_{window}*a)]	387	316	234	138	106
El. demand (heat pump, SPF 2,5) [kWh/(m^2_{window}*a)]	155	126	94	55	43
GWP (0,7 kg CO_2eq/kWh) [CO_2eq/(m²window*a)]	108	88	66	39	30
Energy costs [€/(m^2_{window}*a)]	12,39 €	10,10 €	7,49 €	4,40 €	3,40 €
LC Energy costs (present value) [€/m^2_{window}]	375,59 €	306,18 €	227,01 €	133,42 €	103,08 €
Investment costs [€/m^2_{window}]	45,00 €	70,00 €	84,00 €	107,00 €	127,00 €
LC costs (40a) [€/m^2_{window}]	420,59 €	376,18 €	311,01 €	240,42 €	230,08 €