Report - Certified Passive House Component I Bericht - Zertifizierte Passivhaus Komponente

Passive House Institute

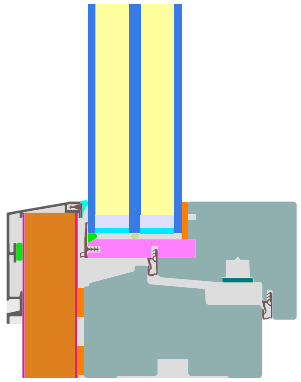
Window system
Fenstersystem

Passive House Institute
Rheinstraße 44/46
64283 Darmstadt
GERMANY

+49.6151.82699.0

mail@passiv.de
www.passiv.de

Product I Produkt:	**ENERsign plus**
Client I Auftraggeber:	**Pazen Fenster+Technik GmbH**
Spacer I Abstandhalter:	**SWISSPACER Ultimate**
Date I Datum:	**19.04.2016**
Author I Autor:	**Dr.-Ing. Benjamin Krick**



Because a separate heating system is not necessarily required in Passive Houses, high demands are placed on the quality of the building components used. The colder the climate, the higher the requirements for the components. To cover this, PHI has identified regions of similar requirements, and defined certification criteria. These criteria are available for free download at the website of the Passive House Institute.

If no radiator is placed under the window, its thermal transmittance U_W (U-value) may not exceed a climate-dependent value in order to prevent unpleasant radiation losses and cold down droughts. For a given quality of glazing, this results in restriction of the thermal losses of the window frame and the glass edge. In that context, the installation situation of the window in the wall is relevant. Because of that, a $U_{W,installed}$ exemplary tested for the certification has been defined.

Also the hygiene criterion must be met. For reasons of hygiene, this criterion limits the minimum individual temperature on window surfaces to prevent condensate and mold growth.

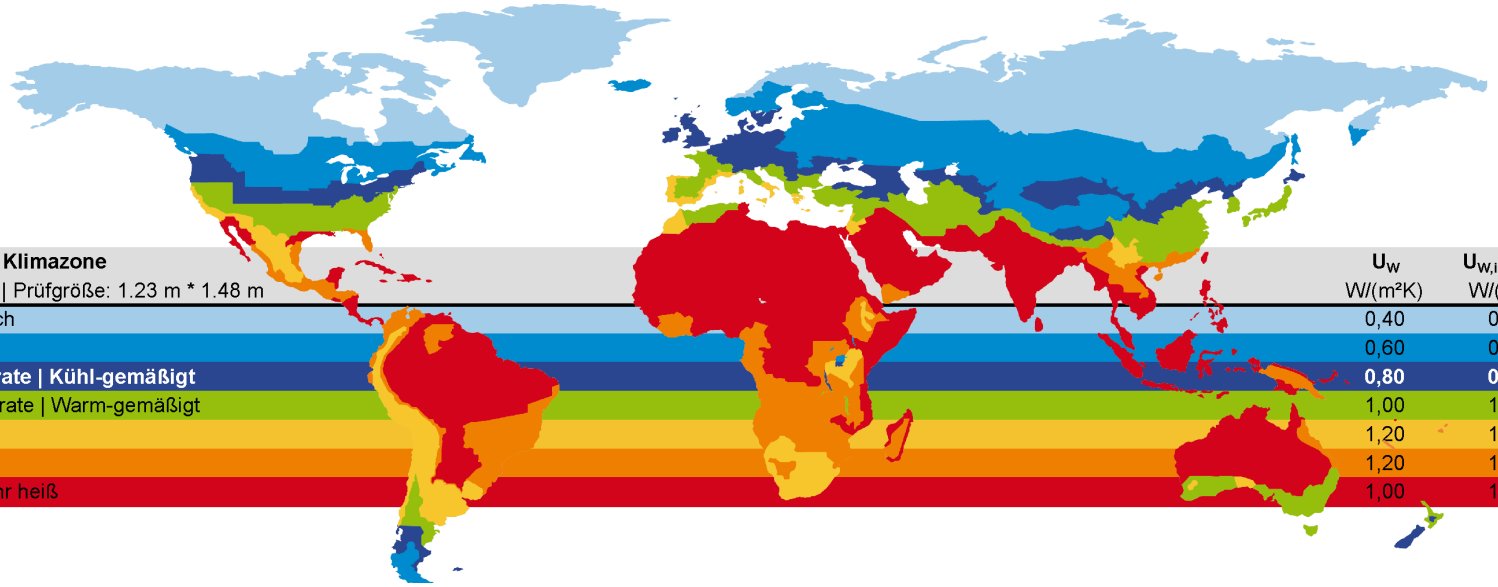
The below stated requirements for awarding the label "Certified Passive House Component" have been set by the Passive House Institute (PHI).

Passivhäuser stellen aufgrund der Möglichkeit, auf ein separates Heizsystem zu verzichten, hohe Anforderungen an die Qualität der verwendeten Bauteile. Dabei steigen die Anforderungen, je kälter das Klima ist. Darum hat das Passivhaus Institut Regionen gleicher Anforderung identifiziert und für diese Zertifizierungskriterien festgelegt. Die Kriterien sind auf der Homepage des Passivhaus Instituts als kostenfreier Download verfügbar.

Wird keine gezielte Heizwärmezufuhr unter den Fenstern vorgesehen, darf der Wärmedurchgangskoeffizient der verwendeten Fenster (Fenster-U-Wert) U_W einen vom Klima abhängigen Höchstwert nicht überschreiten, damit es nicht zu störendem Strahlungswärmeentzug und Kaltluftabfall am Fenster kommt. Daraus ergeben sich bei gegebener Verglasungsqualität Grenzen für den Wärmeverlust im Bereich des Fensterrahmens.In diesem Kontext ist die Einbausituation des Fensters relevant. Darum wurde auch für $U_{W,eingebaut}$ ein Maximalwert festgelegt, der im Rahmen der Zertifizierung beispielhaft geprüft wurde.

Des Weiteren ist das Hygienekriterium zu erfüllen. Dieses Kriterium begrenzt die minimale Einzeltemperatur an der Innenseite der Fensteroberfläche, um Tauwasserausfall und Schimmelbildung zu vermeiden.

Durch das Passivhaus Institut (PHI) wurden die unten stehenden Anforderungen zum Erlangen der Auszeichnung "Zertifizierte Passivhaus Komponente“ festgesetzt.



Climate zone | Klimazone Reference size | Prüfgröße: 1.23 m * 1.48 m	U_W W/(m²K)	$U_{W,installed}$ W/(m²K)	U_g for cert. W/(m²K)	$f_{Rsi=0,25\ m²K/W}$ -
1 Arctic | Arktisch	0,40	0,45	0,35	0,80
2 Cold | Kalt	0,60	0,65	0,52	0,75
3 Cool, temperate | Kühl-gemäßigt	**0,80**	**0,85**	**0,70**	**0,70**
4 Warm, temperate | Warm-gemäßigt	1,00	1,05	0,90	0,65
5 Warm | Warm	1,20	1,25	1,10	0,55
6 Hot | Heiß	1,20	1,25	1,10	-
7 Very hot | Sehr heiß	1,00	1,05	0,90	-

Certified windows are ranked by the thermal losses through the not transparent parts. These **efficiency classes** include the U-Value of the frame, the frame width, the Ψ-Value of the Glass edge and the length of the Glass edge.
Relevant for passive houses is the energy balance, the sum out of losses and gains. Because the solar gains are difficult to quote it is useful to rate the parts of the window, which do not allow solar gains. This is determined by Ψ_{opaque}.

The simulation of the thermal values of the frame sections are based on the regulations of the standard ISO 10077-1:2010 and 10077-2:2012. The thermal conductivities of the used materials refer to relevant standards, technical approvals or have been determined by measured values according to ISO 10077-2:2012, chapter 5.1. In case of one glazing, the models are to 40 cm height, in case of 2 glazing 60 cm in height.

The **spacers** were modeled according to the actual 2-Box-models of the working group “Warm Edge” of the Federal glass association (Bundesverband Flachglas) of Germany. Thermal bridge coefficients were calculated for typical **installation situations**. These values may be used in case of identical installations only in energy balance calculations. The wall-models are 1.41 m in height, glass and frame are 40 cm height, the installation gap is 1 cm.

For modeling and simulations, the software Flixo 7 of Infomind was used. For the used **boundary conditions**, please have a look at following drawings and tables.

Die Fenster werden abhängig von den Wärmeverlusten durch den opaken Teil in **Effizienzklassen** eingestuft. In diese Wärmeverluste gehen die Rahmen-U-Werte, die Rahmenbreiten, die Glasrand-Ψ-Werte und die Glasrandlängen ein. Für das Passivhaus ist die Bilanz aus Wärmeverlusten und Wärmegewinnen relevant. Da die solaren Gewinne schwer fassbar sind, ist es zweckmäßig, die Verluste über die Bereiche zu quantifizieren und zu einer Bilanzierung heran zu ziehen, über die keine solaren Gewinne möglich sind. Dies leistet Ψ_{opak}.

Die **Berechnung der thermischen Kennwerte** der Rahmenschnitte erfolgte auf der Grundlage der ISO 10077-1:2010 und 10077-2:2012. Die Wärmeleitfähigkeiten stammen aus einschlägigen Normen, bauaufstichtlichen Zulassungen oder wurden anhand von messwerten nach den Regeln der ISO 10077-2:2012 Abschnitt 5.1 determiniert. Dabei sind die Modelle mit einem Glasteil stets 40 cm, Modelle mit 2 Glasteilen stets 60 cm hoch.

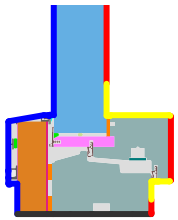
Zur Abbildung der **Abstandhalter** wurde auf die jeweils aktuellen 2-Box-Modelle des Arbeitskreises Warme Kante des Bundesverbandes Flachglas zurückgegriffen.

Die **Wärmebrückenverlustkoeffizienten** wurden beispielhaft für typische **Wandaufbauten** berechnet. Diese dürfen in der Gebäudeenergiebilanzierung nur bei identischer Konstruktion zum Ansatz gebracht werden. Die Modelle für Wandaufbauten sind stets 1,41 m hoch, wobei die Höhe des Glases und Rahmens 40 cm beträgt. Es wird eine Einbaufuge von 1 cm angesetzt.

Zur Berechnung der Bildung der Modelle und zur Berechnung der Wärmeströme wurde das Programm Flixo 7 Professional der Firma Infomind genutzt. Die Randbedingungen wurden wie unten gezeigt angesetzt.

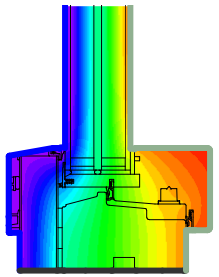
$$\Psi_{opak} = \Psi_{g} + \frac{U_{f} \cdot A_{f}}{l_{g}}$$

max. Ψ_{opak} [W/(mK)]	**Efficiency class Effizienzklasse**	**Name Bezeichnung**
0,065	phA+	Very advanced component
0,110	phA	Advanced component
0,155	phB	Basic component
0,200	phC	Certifiable component



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic	0.000			
Exterior I Außen		-10.000	0.040	
Interior, frame, normal		20.000	0.130	
Interior, frame, reduced		20.000	0.200	
e 0,9 Cavity I Hohlraum				0.900

Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic	0.000			
Exterior I Außen		-10.000	0.040	
e 0,9 Cavity I Hohlraum				0.900
fRsi: Interior I Innen		20.000	0.250	

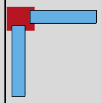


frame values | Rahmenwerte

Pazen Fenster+Technik GmbH

ENERsign plus

Spacer I Abstandhalter:
SWISSPACER Ultimate

		bo Bottom	to Top	s Side	bof Bottom fixed	tof Top fixed	sf Side fixed	th Thres-hold	sh Side door	fm Flying mullion	m2 Mullion	m1 Mullion	m Mullion fixed	ec Corner	t2 Transom	t1 Transom	t Transom fixed
		Unten	Oben	Seitl.	Unten fest	Oben fest	Seitl. fest	Schwe-lle	Seite Tür	Stulp	Pfosten	Pfosten	Pfosten fest	Ecke	Kämpfer	Kämpfer	Kämpfer fest
																	
Temperaturefactor Temperaturfaktor	$f_{Rsi=0,25m^2k/W}$	0,77	0,77	0,77	0,78	0,78	0,78	0,73	0,74	0,75	0,77	0,76	0,77			0,76	0,77
Frame width Rahmenbreite	b_f [mm]	94	94	94	94	94	94	125	165	0,1	148	114	114			114	114
U-value frame Rahmen-U-Wert	**Uf** [W/(m²K)]	0,59	0,59	0,59	0,58	0,58	0,58	0,84	0,70	0,73	0,61	0,63	0,63			0,65	0,63
Ψ-glass edge Glasrand-Ψ-Wert	**Ψg** [W/(mK)]	0,020	0,020	0,020	0,023	0,023	0,023	0,021	0,02105	0,020	0,021	0,022	0,023			0,022	0,023
U-value window Fenster-U-Wert	**Uw** [W/(m²K)] @U_g = 0,70 W/(m²K)	**0,590**			**0,596**												
Ψ_{opaque} Ψ_{opak}	Ψ_{opaque} W/(mK)	**0,080**			**0,082**												
Passive House effiziency class Passivhaus Effizienzklasse		**phA**			**phA**												

Installation | Einbau

EIFS | WDVS U-Wall = 0,13 W/(m²K)

$\Psi_{install}$ [W/(mK)]	0,009	-0,003	-0,003	0,009	-0,004	-0,004	-0,006	
$U_{W,\ installed}$ [W/(m²K)]	0,59			0,59				

Lightwight timber construction | Holzleichtbau U-Wall = 0,13 W/(m²K)

$\Psi_{install}$ [W/(mK)]	0,019	0,011	0,011	0,019	0,012	0,012		
$U_{W,\ installed}$ [W/(m²K)]	0,63			0,64				

Formwork blocks | Betonschalungsstein U-Wall = 0,15 W/(m²K)

$\Psi_{install}$ [W/(mK)]	0,008	0,001	0,001	0,008	0,001	0,001		
$U_{W,\ installed}$ [W/(m²K)]	0,60			0,60				

Ventillated facade | Vorhangfassade U-Wall = 0,13 W/(m²K)

$\Psi_{install}$ [W/(mK)]								
$U_{W,\ installed}$ [W/(m²K)]								

Cavity wall | Zweischaliges Mauerwerk U-Wall = 0,13 W/(m²K)

$\Psi_{install}$ [W/(mK)]								
$U_{W,\ installed}$ [W/(m²K)]								

Contact person | Ansprechpartner

Pazen Fenster+Technik GmbH, Günter Pazen
+ 49 (0)6571 95398 11 g.pazen@enersign.com

Construction:
Aluminium cladded timber frame (0,11 W/(mK)), insulated by XPS-Foam (0,028 W/(mK)). The glazing is carried by ENERcell (0,06 W/(mK)). Q100 = 0,16 m³/(hm) testet at a window with flying mullion Stulpfenster (2,26 * 2,51 m).

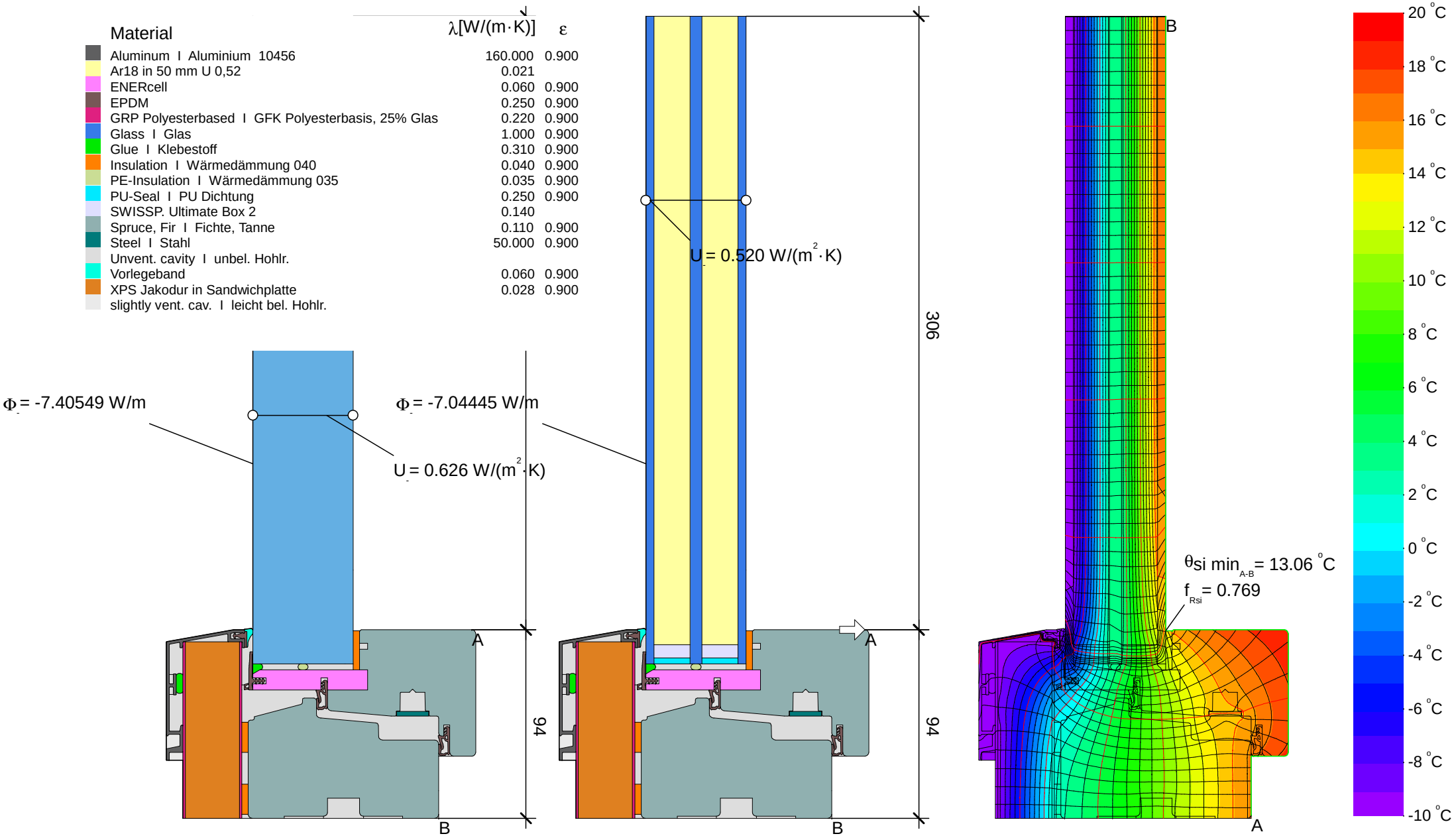
Konstruktion:
Holz-Aluminium Integralrahmen (Fichte/Tanne 0,11 W/(mK)) mit Dämmung aus XPS (0,028 W/(mK)). Das Glas wird durch ENERcell (0,06 W/(m²K)) getragen. Q100 = 0,16 m³/(hm) bezogen auf ein Stulpfenster (2,26 * 2,51 m).

Calculation I Berechnung

Passivhaus Institut Darmstadt

19.04.2016

Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Ar18 in 50 mm U 0,52	0.021	
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glass I Glas	1.000	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU-Seal I PU Dichtung	0.250	0.900
SWISSP. Ultimate Box 2	0.140	
Spruce, Fir I Fichte, Tanne	0.110	0.900
Steel I Stahl	50.000	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		



$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{7.405}{30.000} - 0.626 \cdot 0.306}{0.094} = 0.590\ \mathrm{W/(m^2 \cdot K)}$$

$$\psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{7.044}{30.000} - 0.520 \cdot 0.306 - 0.590 \cdot 0.094 = 0.020\ \mathrm{W/(m \cdot K)}$$

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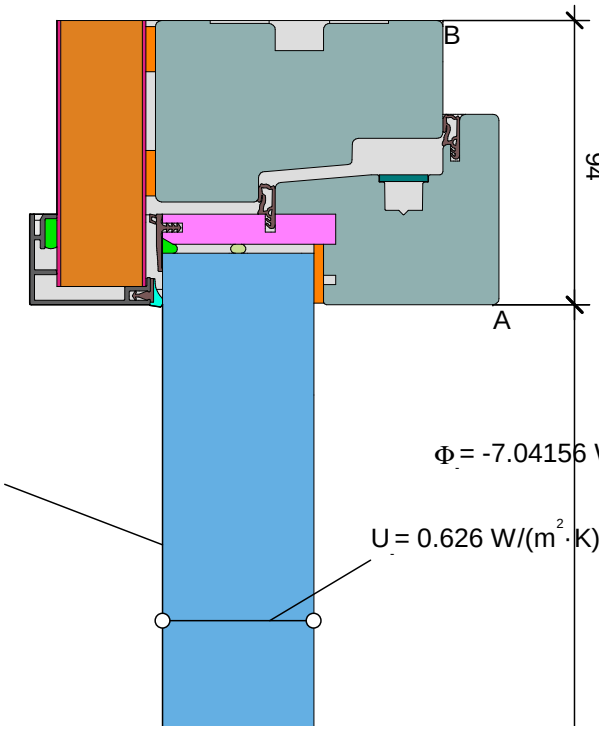
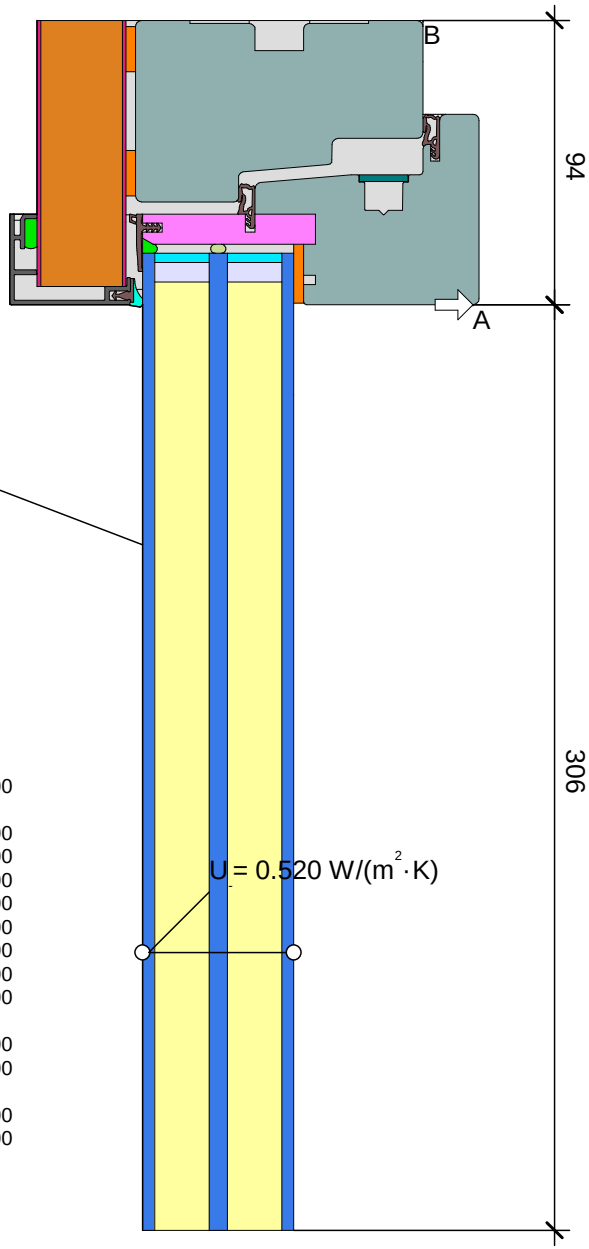
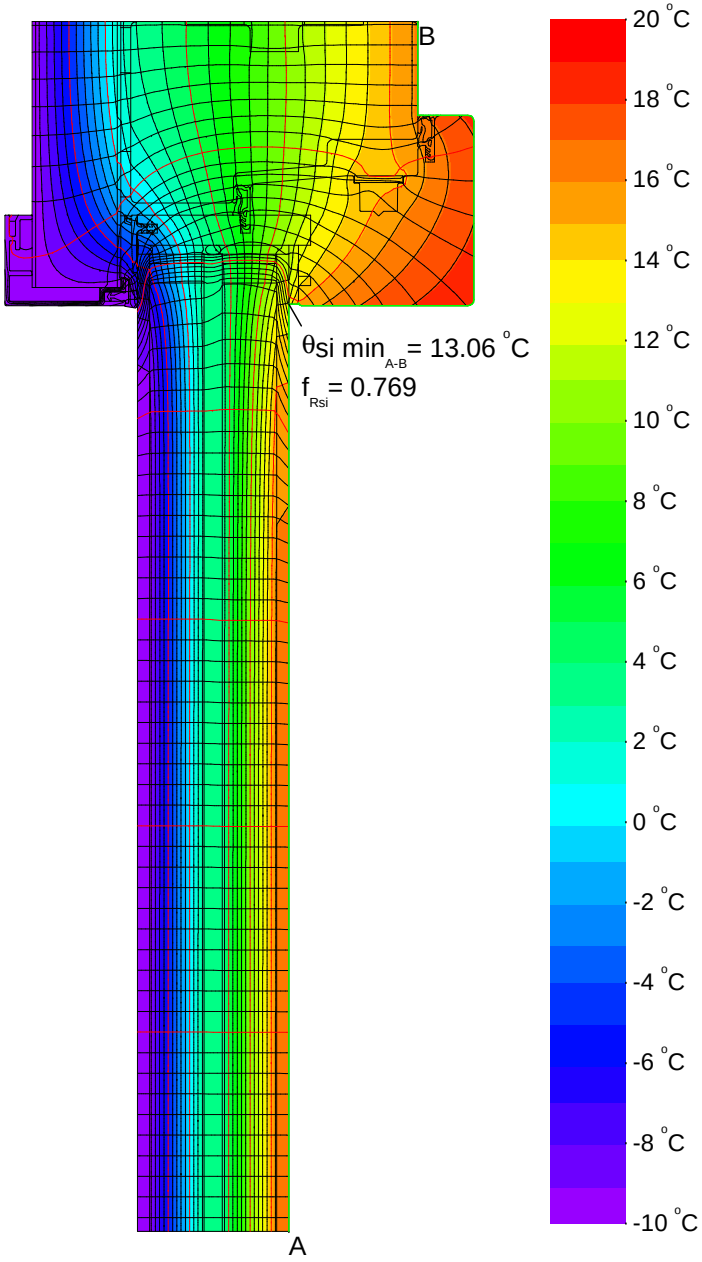




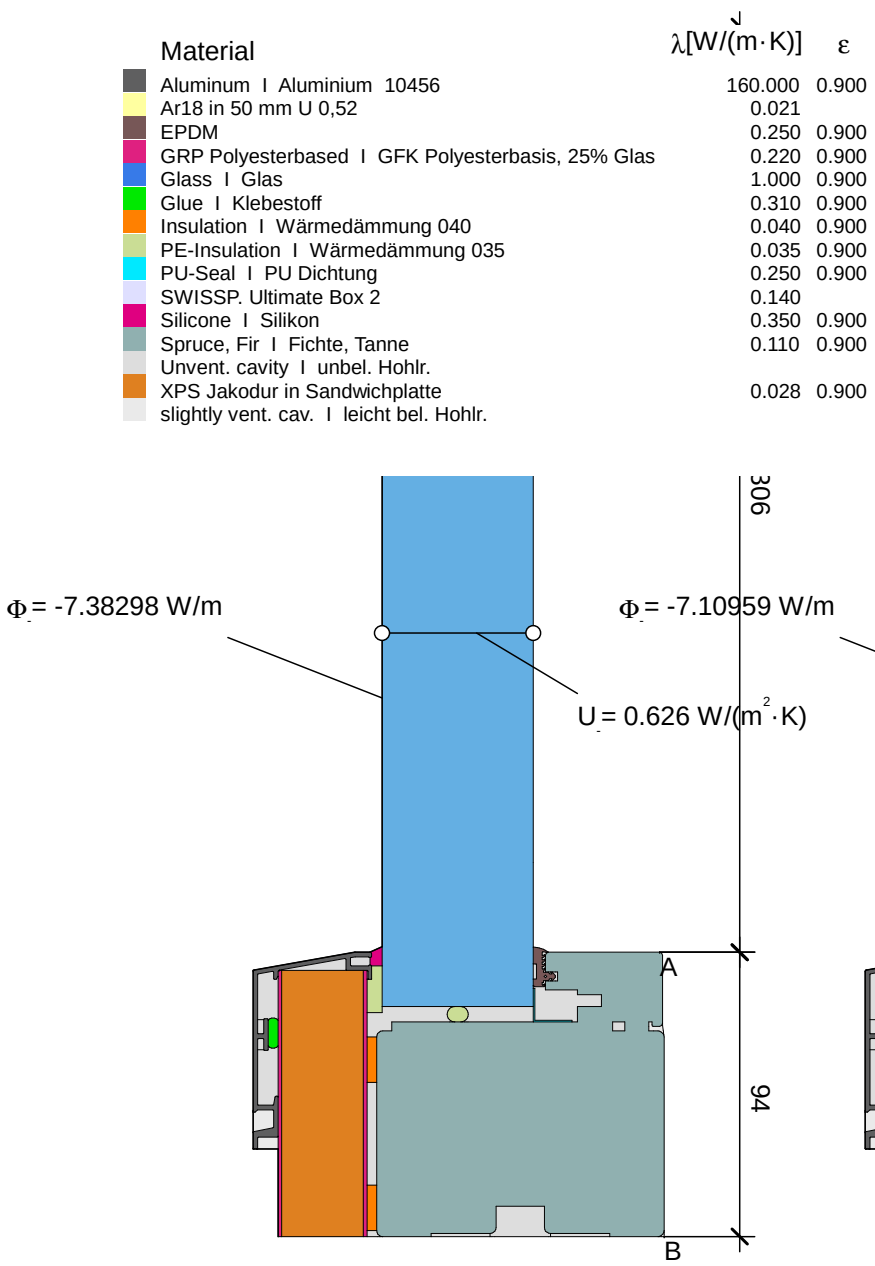


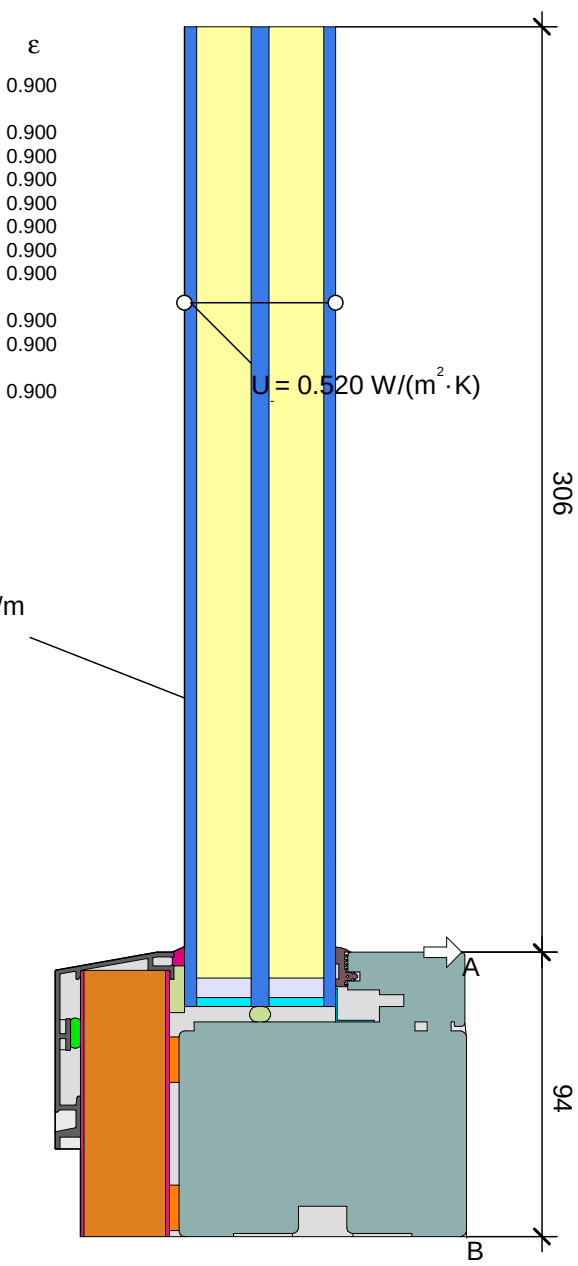
Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Ar18 in 50 mm U 0,52	0.021	
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glass I Glas	1.000	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU-Seal I PU Dichtung	0.250	0.900
SWISSP. Ultimate Box 2	0.140	
Spruce, Fir I Fichte, Tanne	0.110	0.900
Steel I Stahl	50.000	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

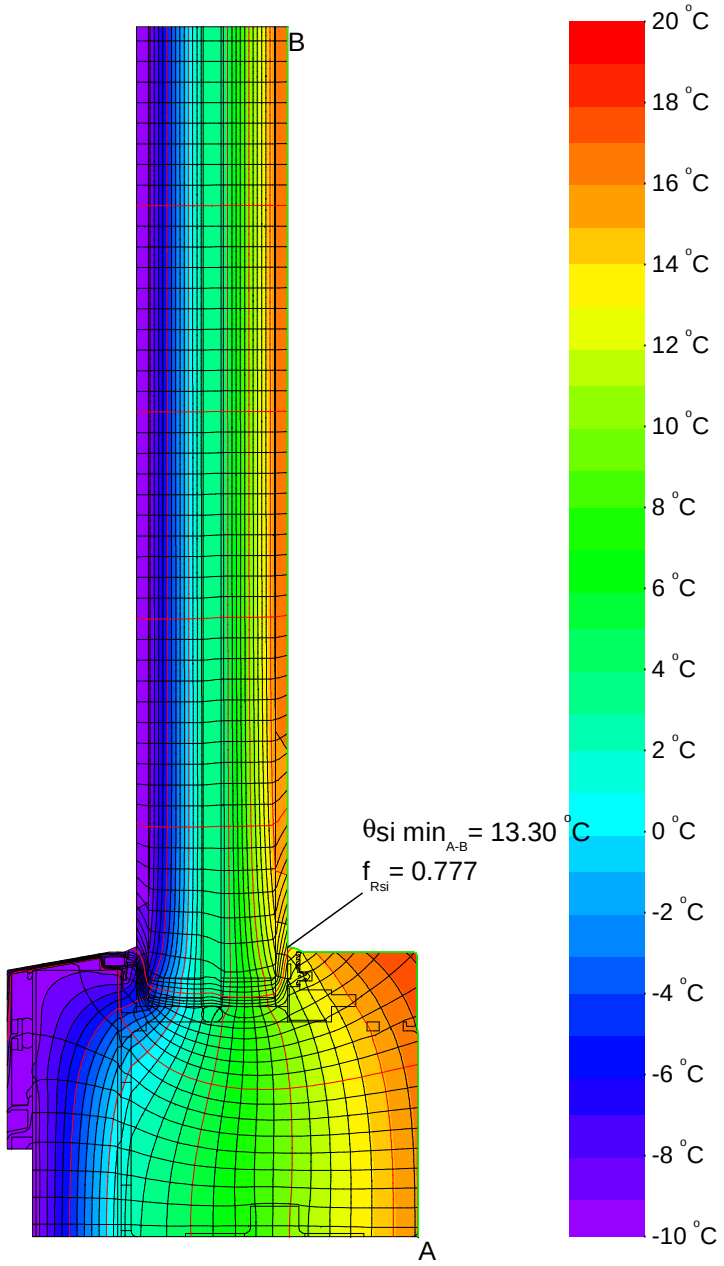
$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{7.402}{30.000} - 0.626 \cdot 0.306}{0.094} = 0.589\ \mathrm{W/(m^2 \cdot K)}$$

$$\psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{7.042}{30.000} - 0.520 \cdot 0.306 - 0.589 \cdot 0.094 = 0.020\ \mathrm{W/(m \cdot K)}$$

Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Ar18 in 50 mm U 0,52	0.021	
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glass I Glas	1.000	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU-Seal I PU Dichtung	0.250	0.900
SWISSP. Ultimate Box 2	0.140	
Silicone I Silikon	0.350	0.900
Spruce, Fir I Fichte, Tanne	0.110	0.900
Unvent. cavity I unbel. Hohlr.		
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

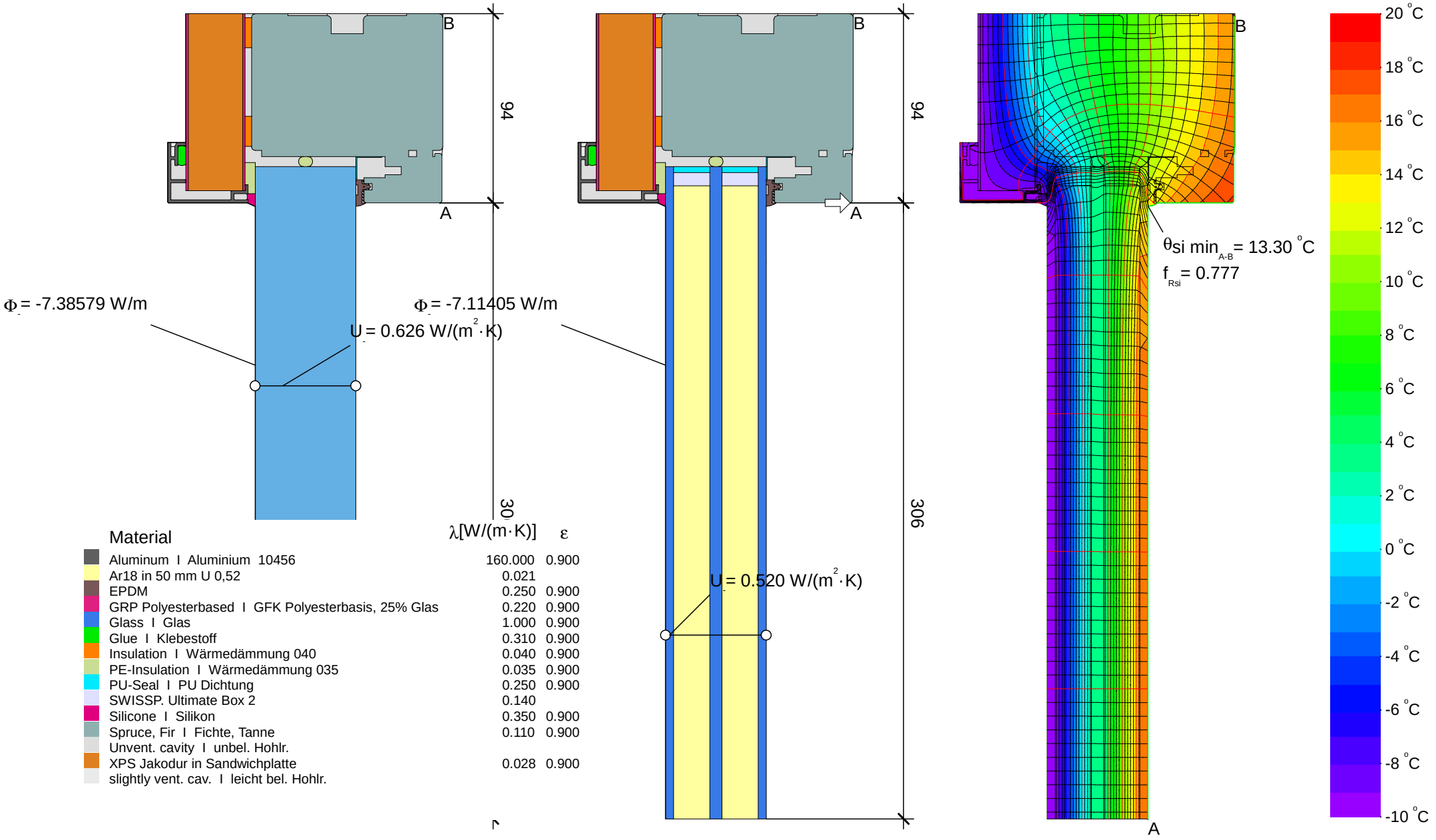






$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{7.383}{30.000} - 0.626 \cdot 0.306}{0.094} = 0.582\ \mathrm{W/(m^2 \cdot K)}$$

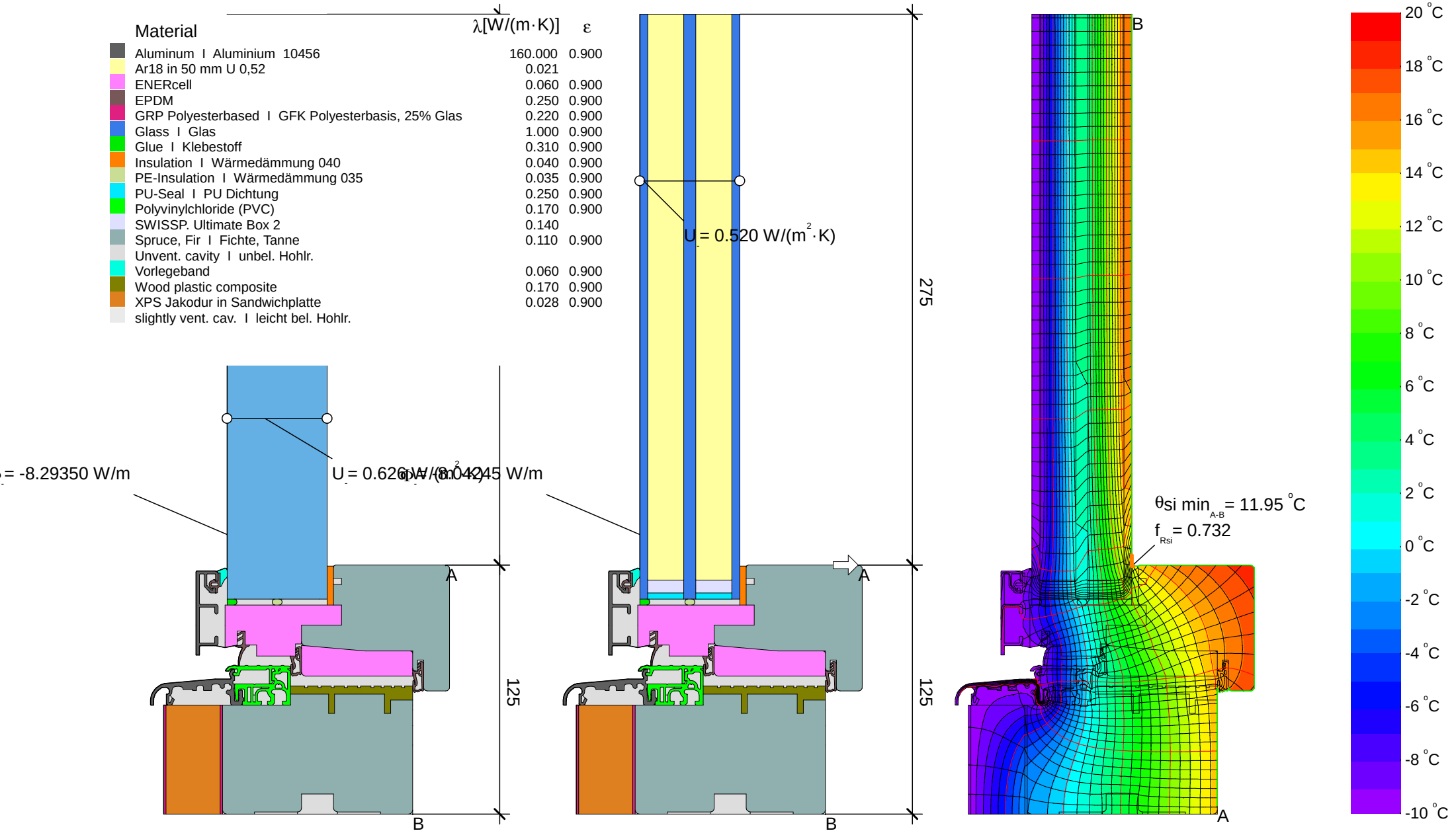
$$\psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{7.110}{30.000} - 0.520 \cdot 0.306 - 0.582 \cdot 0.094 = 0.023\ \mathrm{W/(m \cdot K)}$$



Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Ar18 in 50 mm U 0,52	0.021	
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glass I Glas	1.000	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU-Seal I PU Dichtung	0.250	0.900
SWISSP. Ultimate Box 2	0.140	
Silicone I Silikon	0.350	0.900
Spruce, Fir I Fichte, Tanne	0.110	0.900
Unvent. cavity I unbel. Hohlr.		
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{7.386}{30.000} - 0.626 \cdot 0.306}{0.094} = 0.583\ \text{W/(m}^2\cdot\text{K)} \qquad \psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{7.114}{30.000} - 0.520 \cdot 0.306 - 0.583 \cdot 0.094 = 0.023\ \text{W/(m·K)}$$

Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Ar18 in 50 mm U 0,52	0.021	
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glass I Glas	1.000	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU-Seal I PU Dichtung	0.250	0.900
Polyvinylchloride (PVC)	0.170	0.900
SWISSP. Ultimate Box 2	0.140	
Spruce, Fir I Fichte, Tanne	0.110	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
Wood plastic composite	0.170	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		



$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{8.293}{30.000} - 0.626 \cdot 0.276}{0.125} = 0.836\ W/(m^2 \cdot K)$$

$$\psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{8.042}{30.000} - 0.520 \cdot 0.276 - 0.836 \cdot 0.125 = 0.021\ W/(m \cdot K)$$

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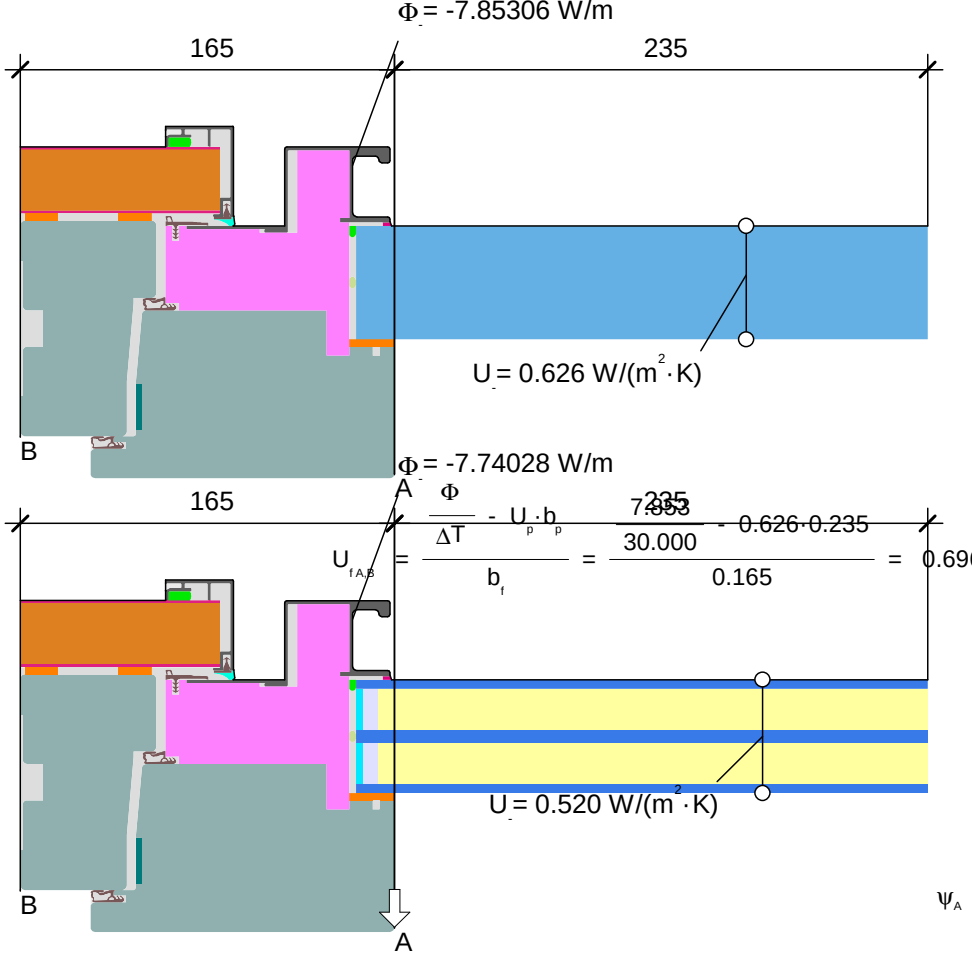
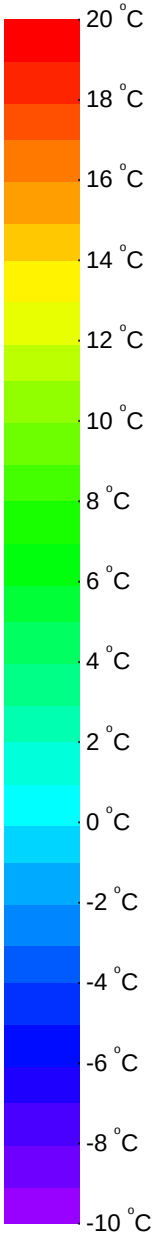
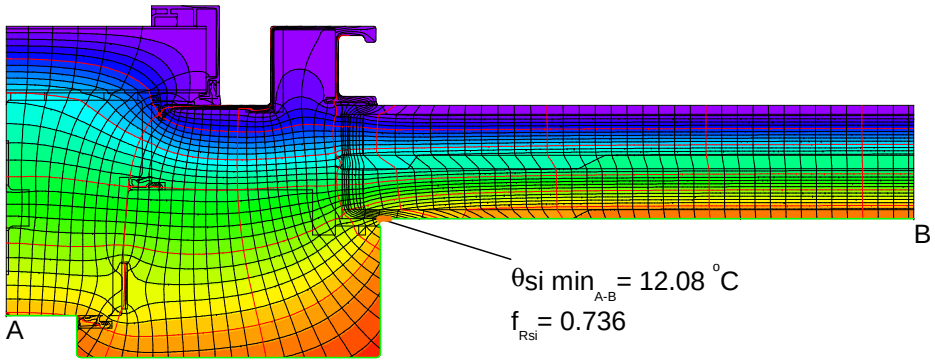


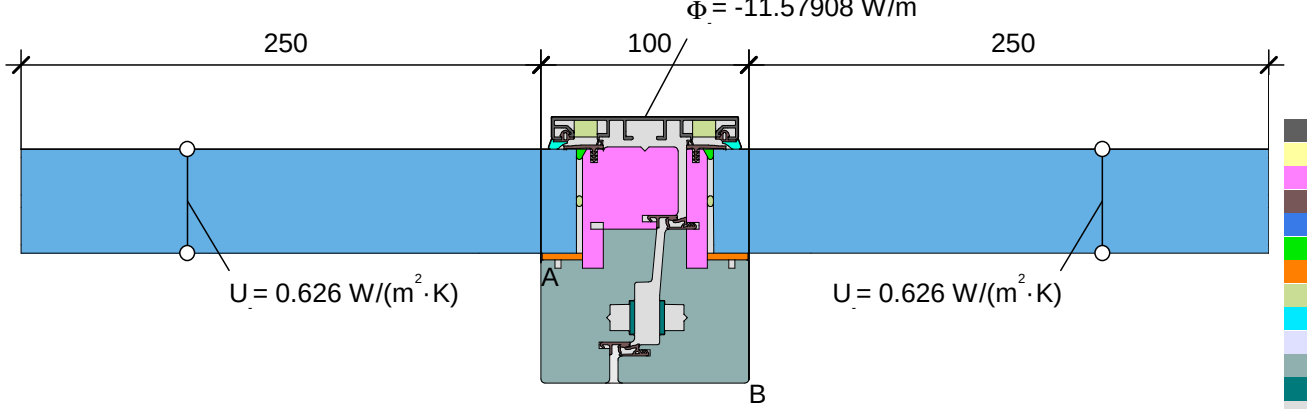
$$U_{f\,A\text{-}B} = \frac{\frac{\Phi}{\Delta T} - U_p \cdot b_p}{b_f} = \frac{\frac{7.853}{30.000} - 0.626 \cdot 0.235}{0.165} = 0.696\ \mathrm{W/(m^2 \cdot K)}$$

Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Ar18 in 50 mm U 0,52	0.021	
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glass I Glas	1.000	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU-Seal I PU Dichtung	0.250	0.900
SWISSP. Ultimate Box 2	0.140	
Silicone I Silikon	0.350	0.900
Spruce, Fir I Fichte, Tanne	0.110	0.900
Steel I Stahl	50.000	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

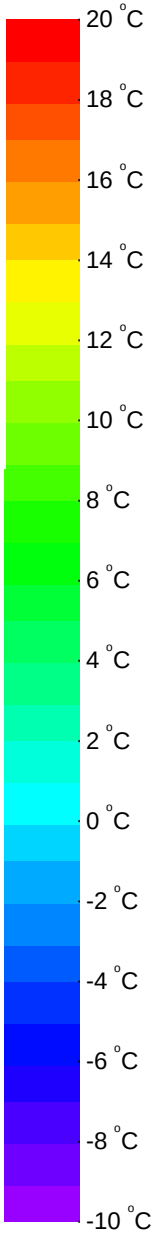


$$\psi_A = \frac{\Phi}{\Delta T} - U_g \cdot b_g - U_f \cdot b_f = \frac{7.740}{30.000} - 0.520 \cdot 0.235 - 0.696 \cdot 0.165 = 0.021\ \mathrm{W/(m \cdot K)}$$

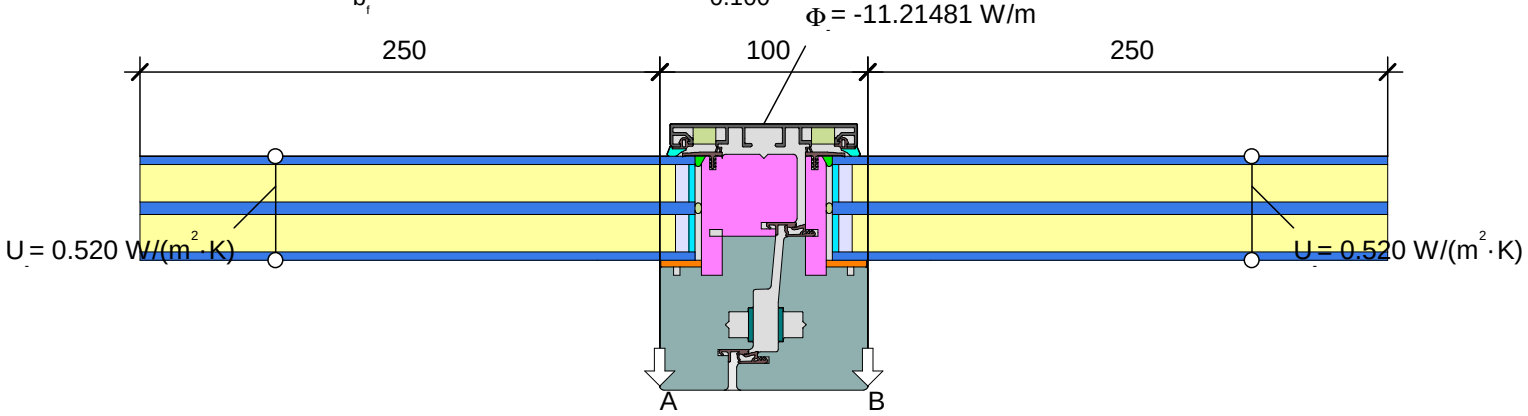




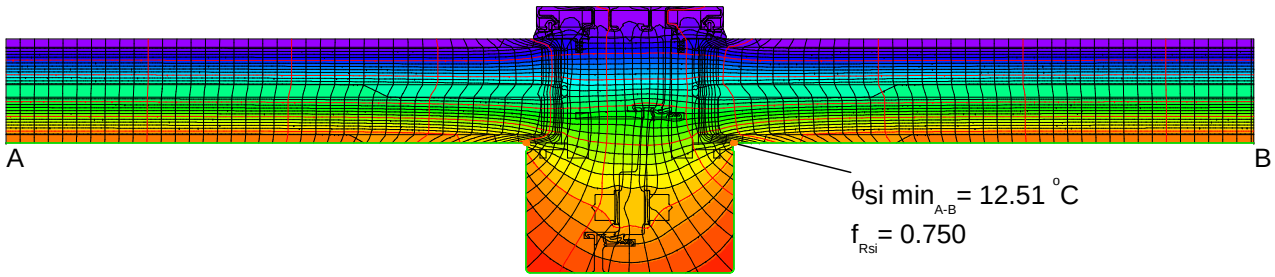
Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Ar18 in 50 mm U 0,52	0.021	
ENERcell	0.060	0.900
EPDM	0.250	0.900
Glass I Glas	1.000	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU-Seal I PU Dichtung	0.250	0.900
SWISSP. Ultimate Box 2	0.140	
Spruce, Fir I Fichte, Tanne	0.110	0.900
Steel I Stahl	50.000	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
slightly vent. cav. I leicht bel. Hohlr.		

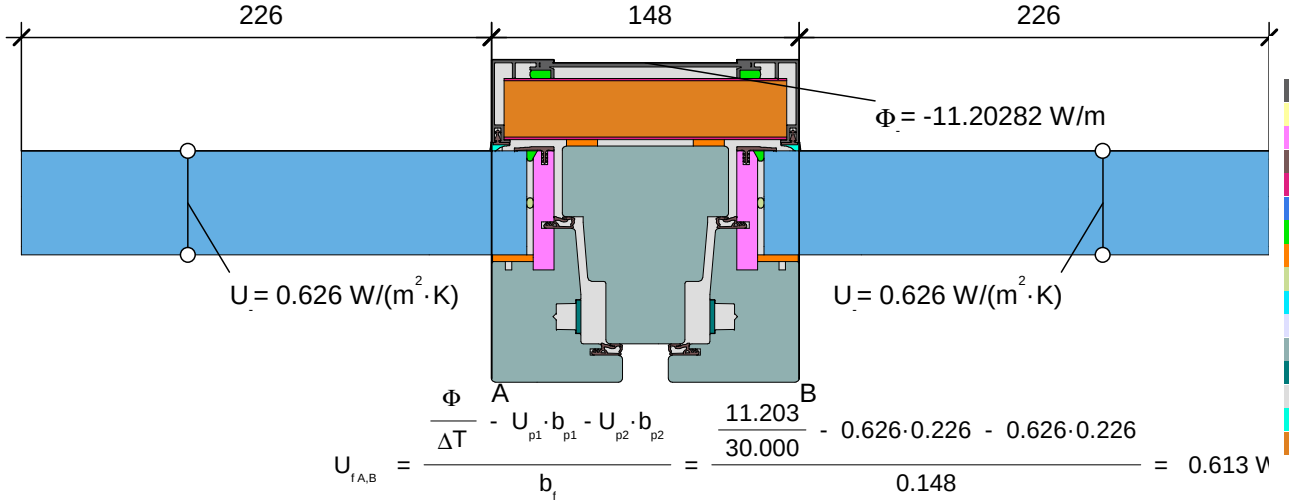


$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_{p1}\cdot b_{p1} - U_{p2}\cdot b_{p2}}{b_f} = \frac{\frac{11.579}{30.000} - 0.626\cdot 0.250 - 0.626\cdot 0.250}{0.100} = 0.732\ W/(m^2\cdot K)$$

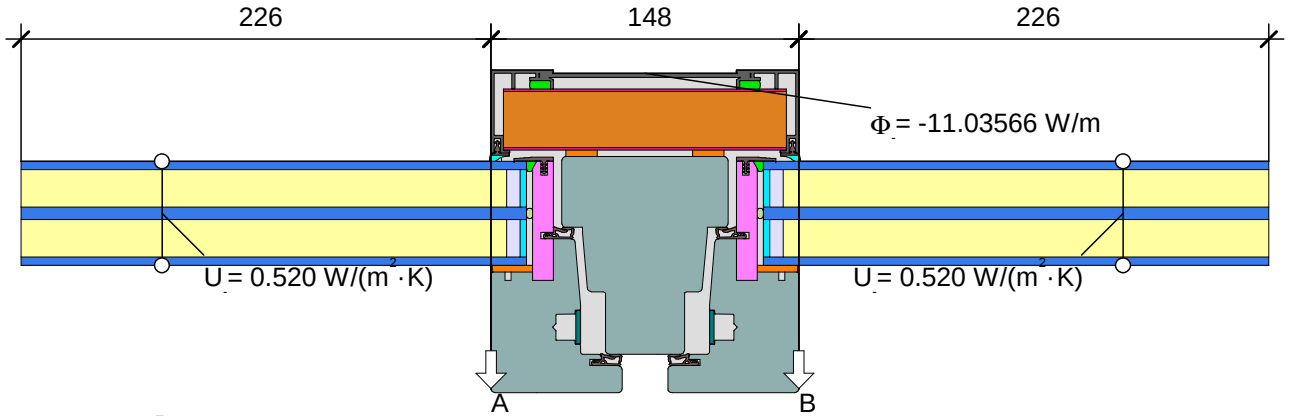


$$\psi_{A,B} = \frac{\frac{\Phi}{\Delta T} - U_{g1}\cdot b_{g1} - U_f\cdot b_f - U_{g2}\cdot b_{g2}}{2} = \frac{\frac{11.215}{30.000} - 0.520\cdot 0.250 - 0.698\cdot 0.100 - 0.520\cdot 0.250}{2} = 0.022\ W/(m\cdot K)$$

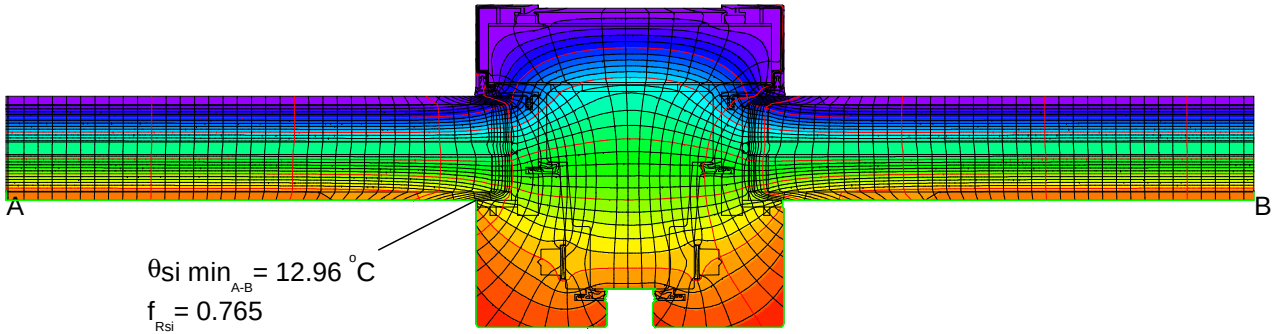




$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_{p1}\cdot b_{p1} - U_{p2}\cdot b_{p2}}{b_f} = \frac{\frac{11.203}{30.000} - 0.626\cdot 0.226 - 0.626\cdot 0.226}{0.148} = 0.613\ W$$

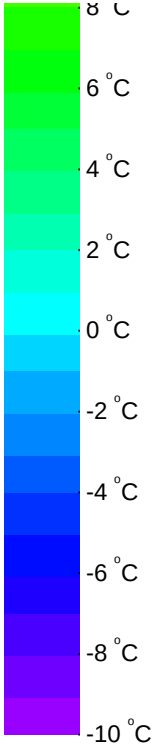


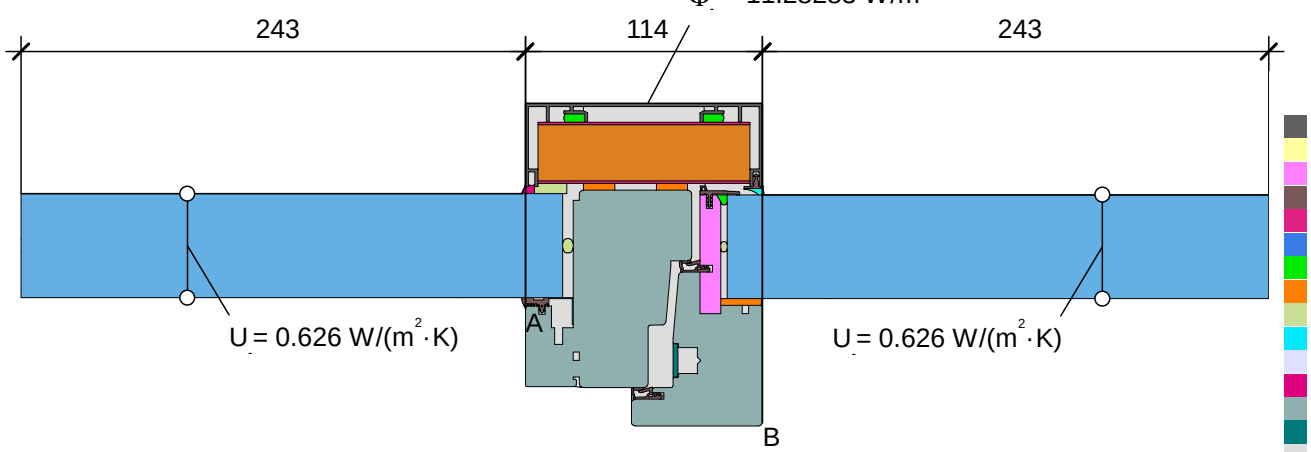
$$\psi_{A,B} = \frac{\frac{\Phi}{\Delta T} - U_{g1}\cdot b_{g1} - U_f\cdot b_f - U_{g2}\cdot b_{g2}}{2} = \frac{\frac{11.036}{30.000} - 0.520\cdot 0.226 - 0.613\cdot 0.148 - 0.520\cdot 0.226}{2} = 0.021\ W/(m\cdot K)$$

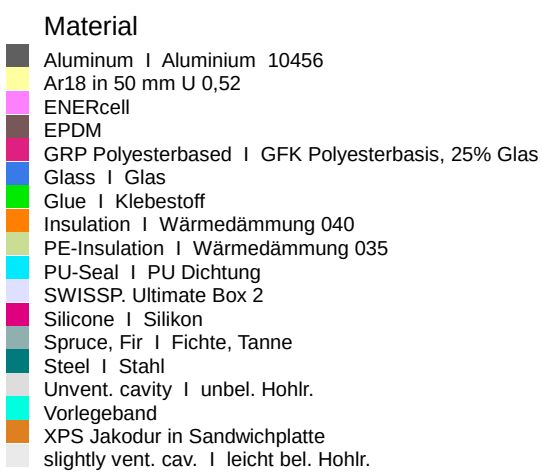


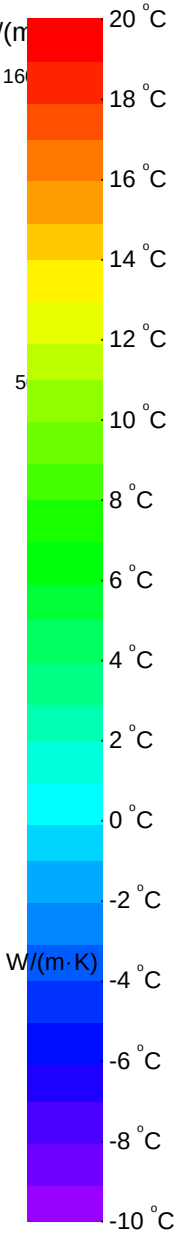
Material

Material	λ[W/(m·K)]	ε (20 °C)
Aluminum I Aluminium 10456	160.000	0.900
Ar18 in 50 mm U 0,52	0.021	
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glass I Glas	1.000	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU-Seal I PU Dichtung	0.250	0.900
SWISSP. Ultimate Box 2	0.140	
Spruce, Fir I Fichte, Tanne	0.110	0.900
Steel I Stahl	50.000	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900



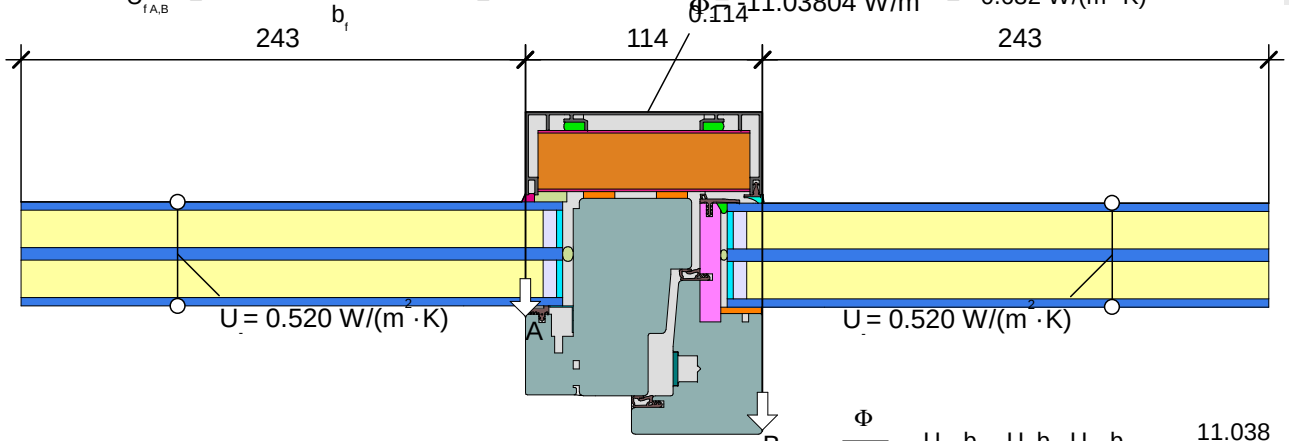




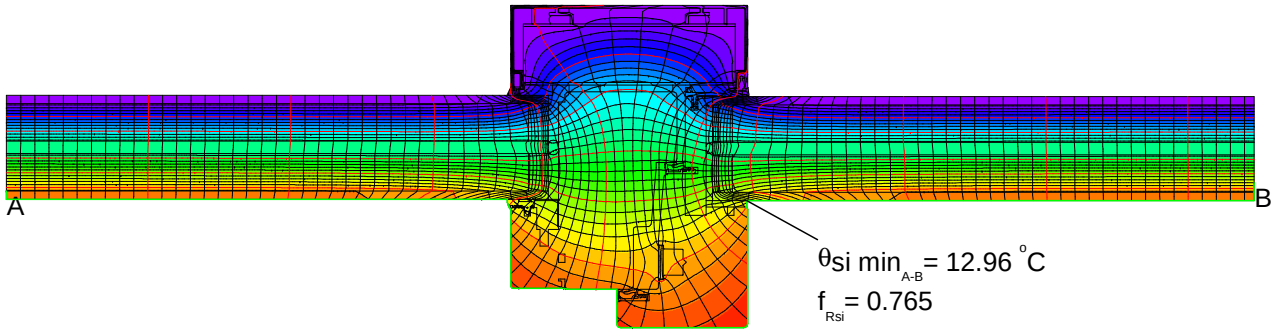


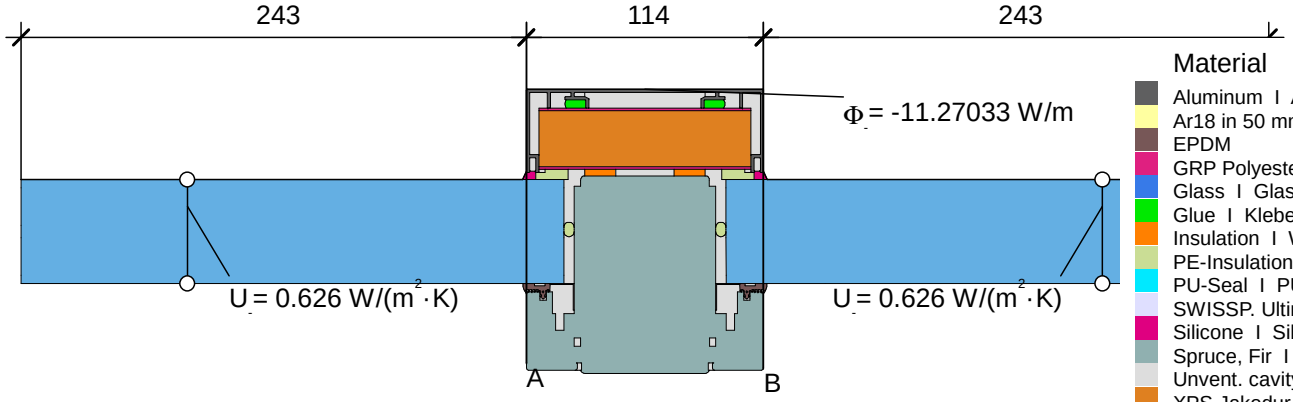
$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_{p1}\cdot b_{p1} - U_{p2}\cdot b_{p2}}{b_f} = \frac{\frac{11.283}{30.000} - 0.626\cdot 0.243 - 0.626\cdot 0.244}{0.114} = 0.632\ \mathrm{W/(m^2\cdot K)}$$

$\Phi = 11.03804$ W/m

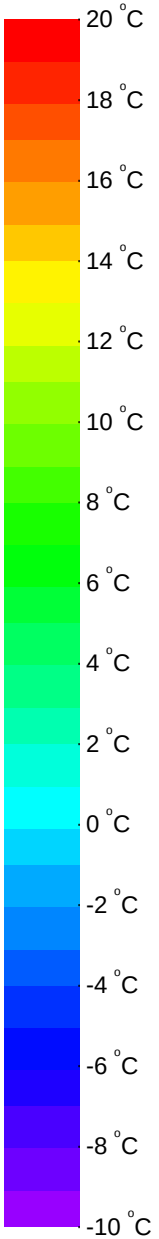


$$\psi_{A,B} = \frac{\frac{\Phi}{\Delta T} - U_{g1}\cdot b_{g1} - U_f\cdot b_f - U_{g2}\cdot b_{g2}}{2} = \frac{\frac{11.038}{30.000} - 0.520\cdot 0.243 - 0.632\cdot 0.114 - 0.520\cdot 0.244}{2} = 0.022\ \mathrm{W/(m\cdot K)}$$

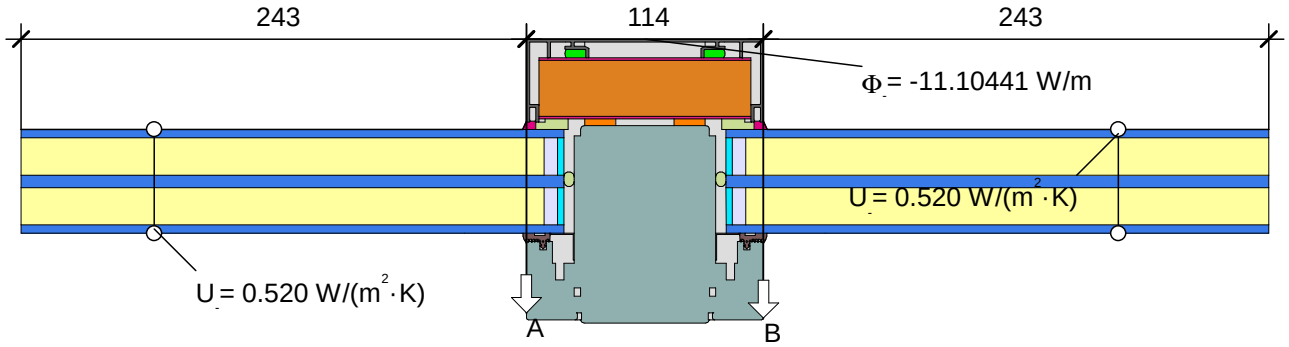




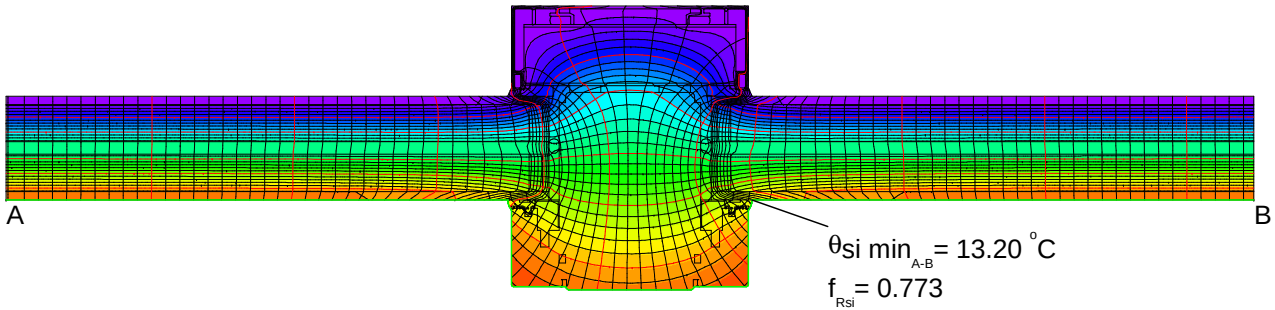
Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Ar18 in 50 mm U 0,52	0.021	
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glass I Glas	1.000	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU-Seal I PU Dichtung	0.250	0.900
SWISSP. Ultimate Box 2	0.140	
Silicone I Silikon	0.350	0.900
Spruce, Fir I Fichte, Tanne	0.110	0.900
Unvent. cavity I unbel. Hohlr.		
XPS Jakodur in Sandwichplatte	0.028	0.900



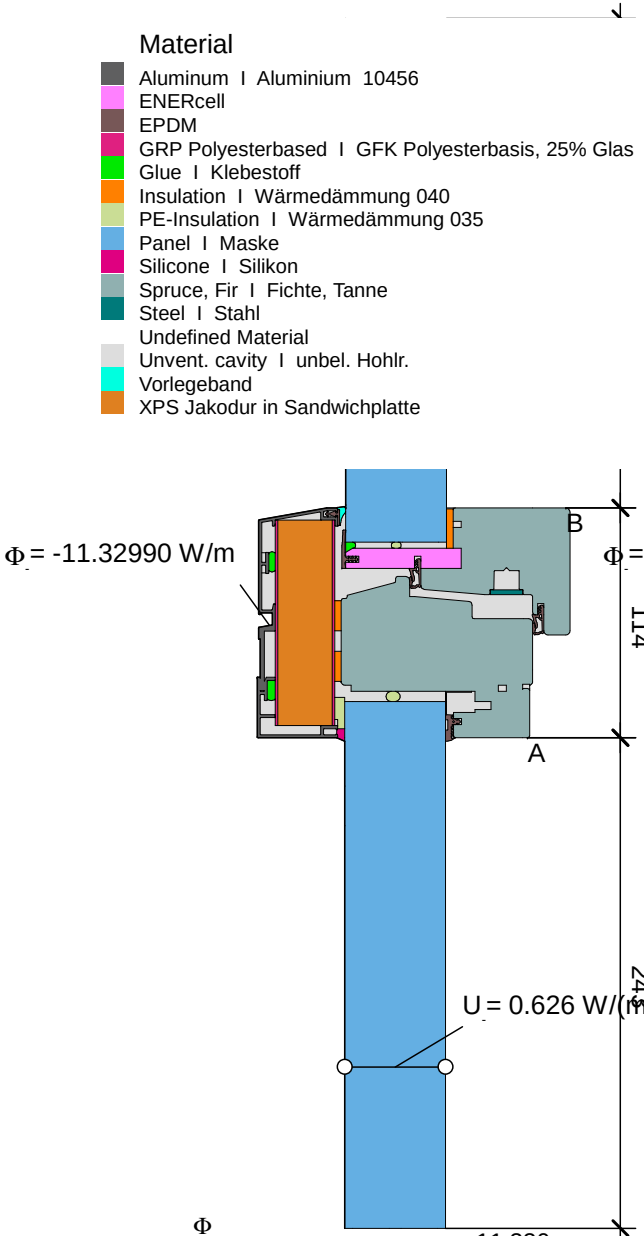
$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_{p1}\cdot b_{p1} - U_{p2}\cdot b_{p2}}{b_f} = \frac{\frac{11.270}{30.000} - 0.626\cdot 0.243 - 0.626\cdot 0.243}{0.114} = 0.629\ \mathrm{W/(m^2\cdot K)}$$

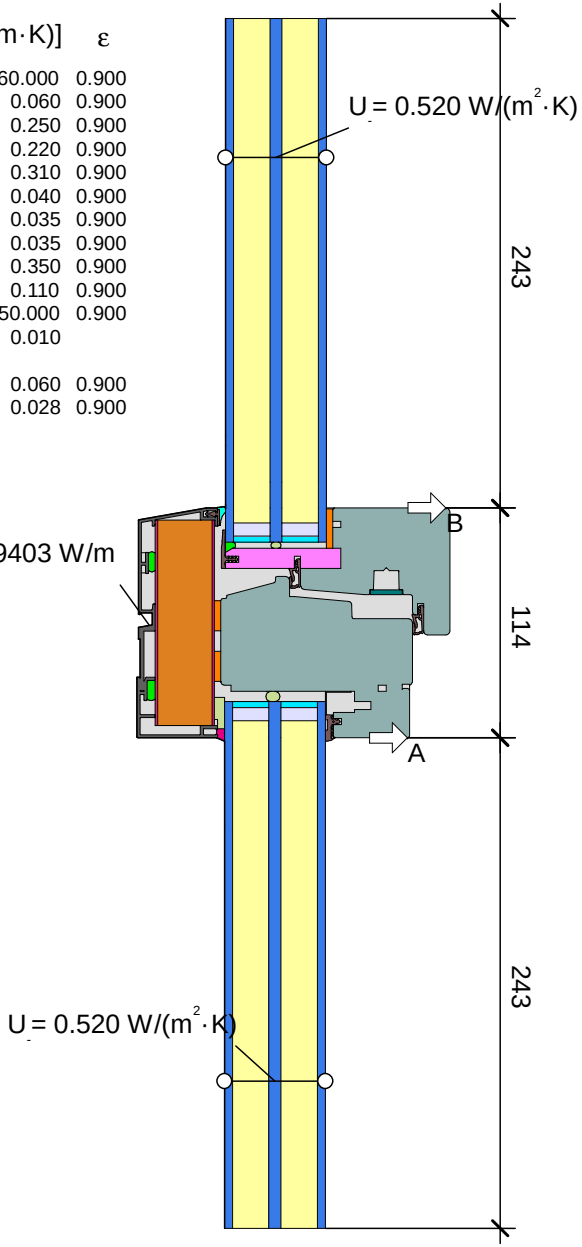


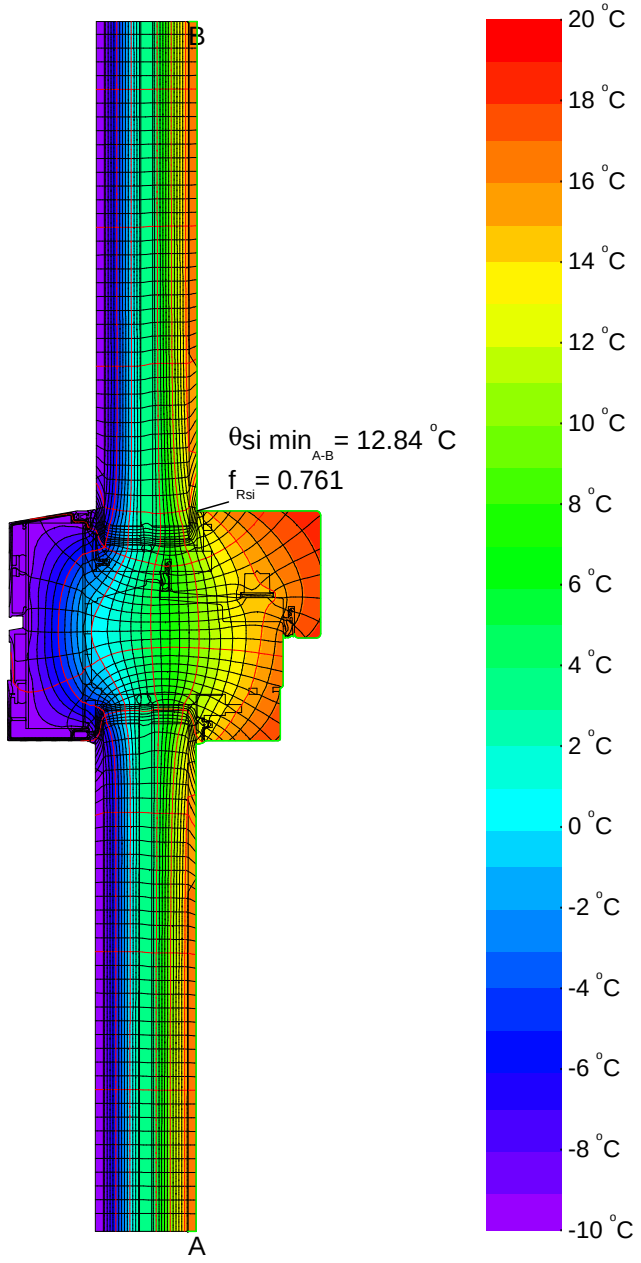
$$\psi_{A,B} = \frac{\frac{\Phi}{\Delta T} - U_{g1}\cdot b_{g1} - U_f\cdot b_f - U_{g2}\cdot b_{g2}}{2} = \frac{\frac{11.104}{30.000} - 0.520\cdot 0.243 - 0.629\cdot 0.114 - 0.520\cdot 0.243}{2} = 0.023\ \mathrm{W/(m\cdot K)}$$



Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
Panel I Maske	0.035	0.900
Silicone I Silikon	0.350	0.900
Spruce, Fir I Fichte, Tanne	0.110	0.900
Steel I Stahl	50.000	0.900
Undefined Material	0.010	
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900



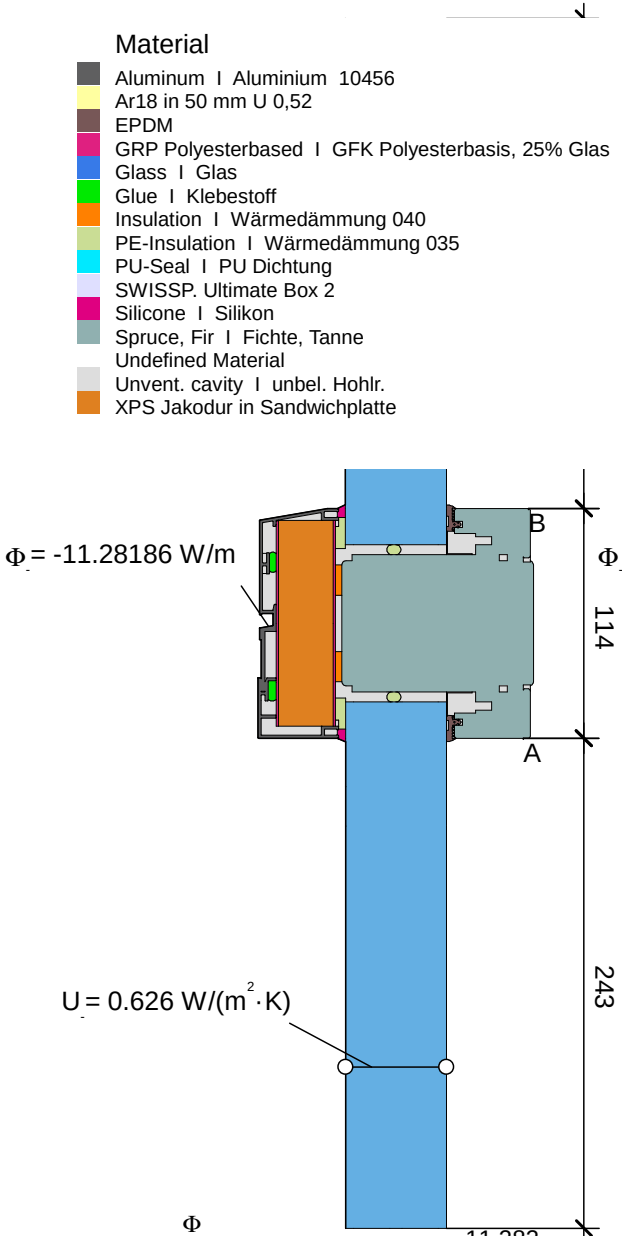


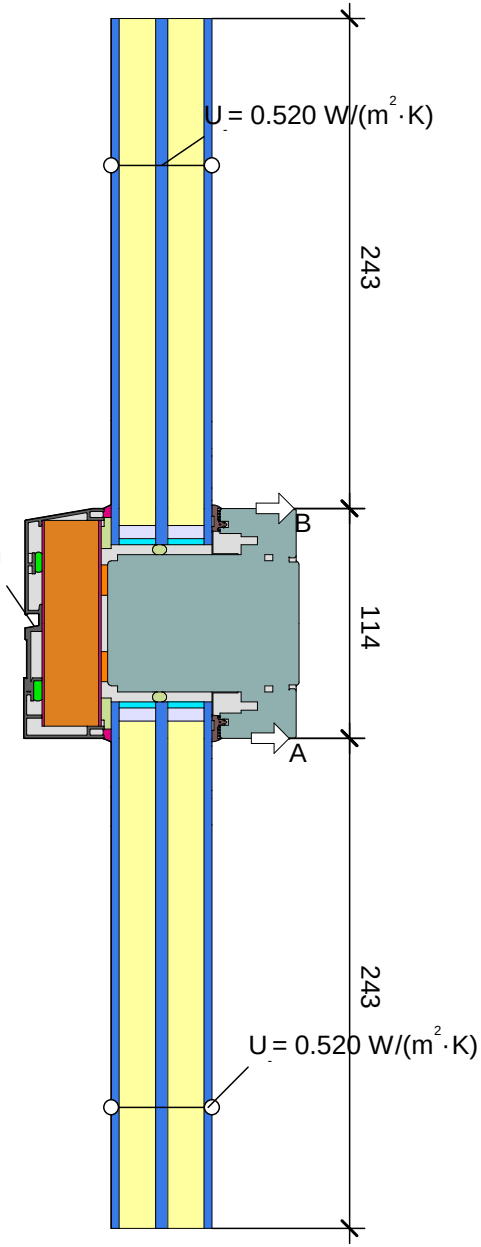


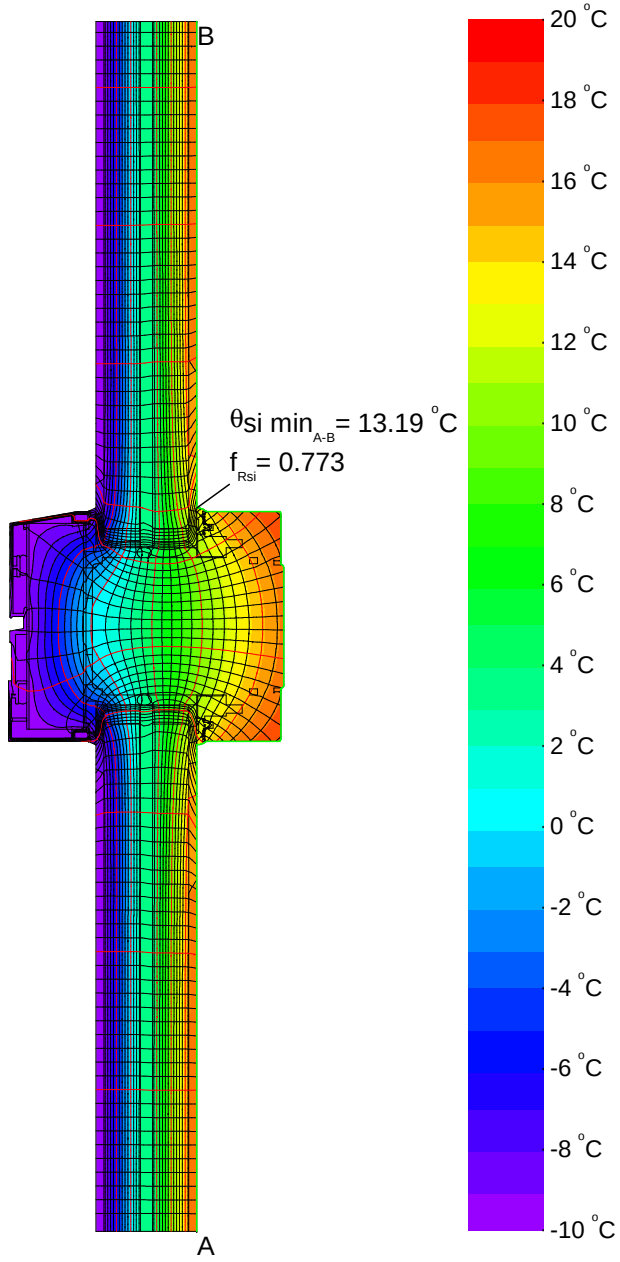
$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_{p1}\cdot b_{p1} - U_{p2}\cdot b_{p2}}{b_f} = \frac{\frac{11.330}{30.000} - 0.626\cdot 0.243 - 0.626\cdot 0.243}{0.114} = 0.646\ \mathrm{W/(m^2\cdot K)}$$

$$\psi_{A,B} = \frac{\frac{\Phi}{\Delta T} - U_{g1}\cdot b_{g1} - U_f\cdot b_f - U_{g2}\cdot b_{g2}}{2} = \frac{\frac{11.094}{30.000} - 0.520\cdot 0.243 - 0.646\cdot 0.114 - 0.520\cdot 0.243}{2} = 0.022\ \mathrm{W/(m\cdot K)}$$

Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Ar18 in 50 mm U 0,52	0.021	
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glass I Glas	1.000	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 040	0.040	0.900
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU-Seal I PU Dichtung	0.250	0.900
SWISSP. Ultimate Box 2	0.140	
Silicone I Silikon	0.350	0.900
Spruce, Fir I Fichte, Tanne	0.110	0.900
Undefined Material	0.010	
Unvent. cavity I unbel. Hohlr.		
XPS Jakodur in Sandwichplatte	0.028	0.900







$$U_{f\,A,B} = \frac{\frac{\Phi}{\Delta T} - U_{p1}\cdot b_{p1} - U_{p2}\cdot b_{p2}}{b_f} = \frac{\frac{11.282}{30.000} - 0.626\cdot 0.243 - 0.626\cdot 0.243}{0.114} = 0.632\ \mathrm{W/(m^2\cdot K)}$$

$$\psi_{A,B} = \frac{\frac{\Phi}{\Delta T} - U_{g1}\cdot b_{g1} - U_f\cdot b_f - U_{g2}\cdot b_{g2}}{2} = \frac{\frac{11.113}{30.000} - 0.520\cdot 0.243 - 0.632\cdot 0.114 - 0.520\cdot 0.243}{2} = 0.023\ \mathrm{W/(m\cdot K)}$$

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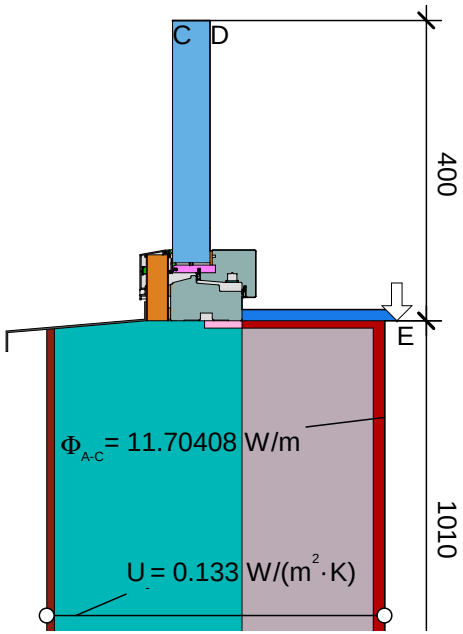
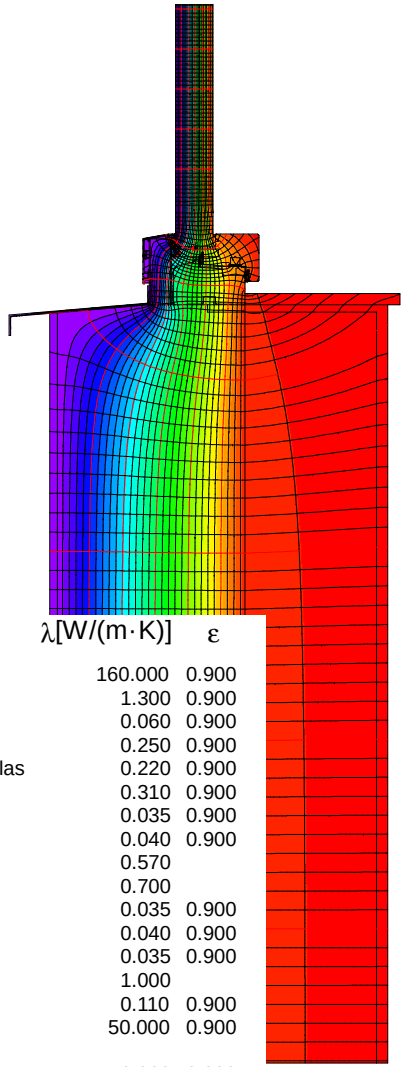
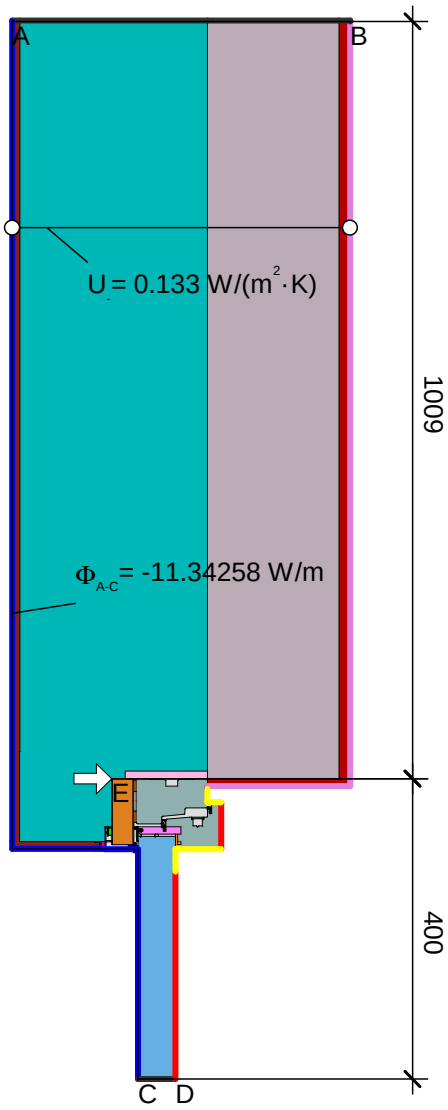
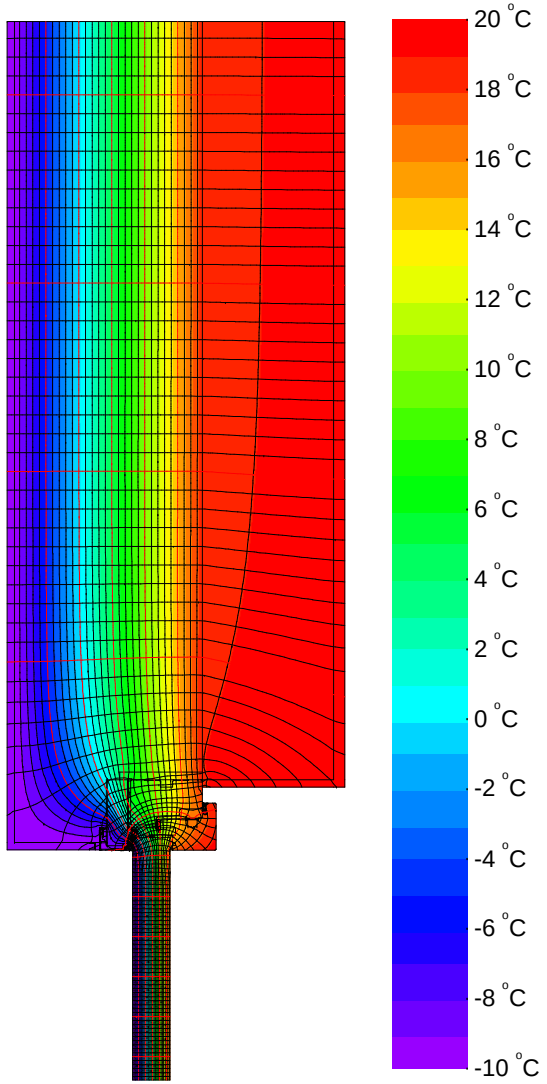




Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Artificial stone I Kunststein 10456	1.300	0.900
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 035	0.035	0.900
Insulation I Wärmedämmung 040	0.040	0.900
Interior plaster I Gipsputz 10456	0.570	
Organic compound plaster I Kunstharzputz 4108-4	0.700	
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU in-situ foam I PU-Ortschaum 040	0.040	0.900
Panel I Maske	0.035	0.900
Sand-lime stone I Kalksandstein 1745	1.000	
Spruce, Fir I Fichte, Tanne	0.110	0.900
Steel I Stahl	50.000	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

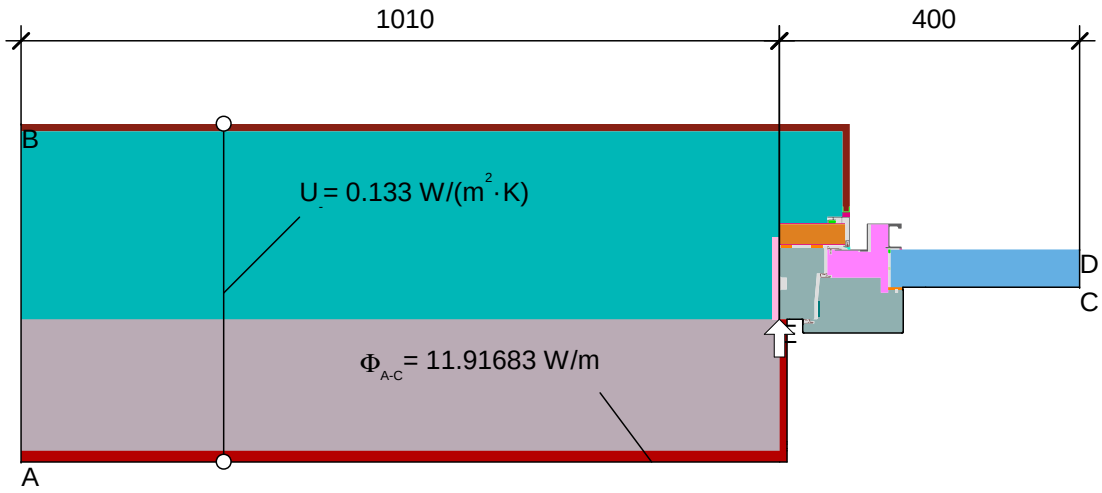
$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{11.704}{30.000} - 0.133 \cdot 1.010 - \frac{7.406}{30.000} = 0.009 \text{ W/(m·K)}$$



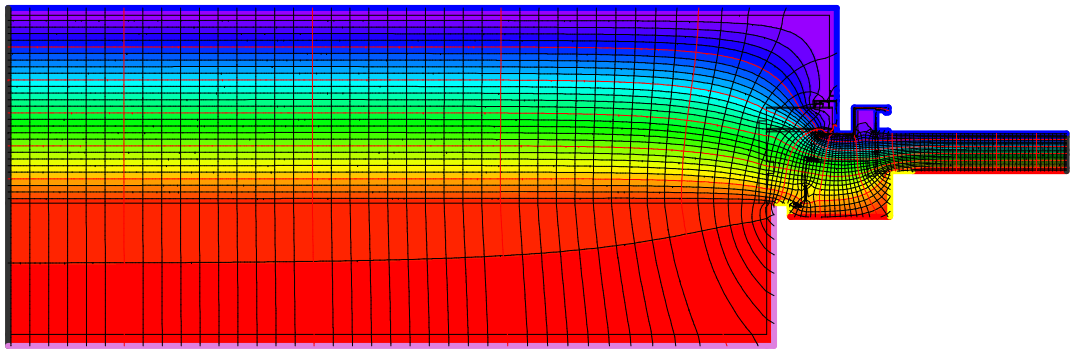


$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{11.343}{30.000} - 0.133 \cdot 1.009 - \frac{7.402}{30.000} = -0.003 \text{ W/(m·K)}$$

Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic	0.000			
Exterior I Außen		-10.000	0.040	
Interior I 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

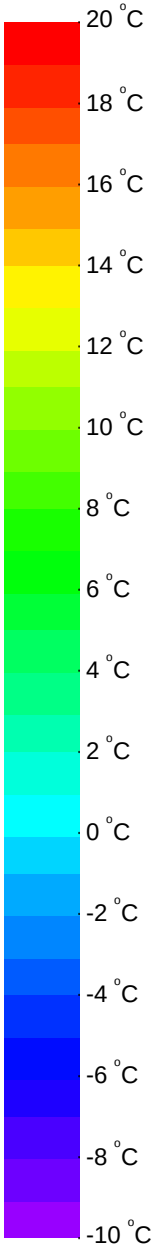


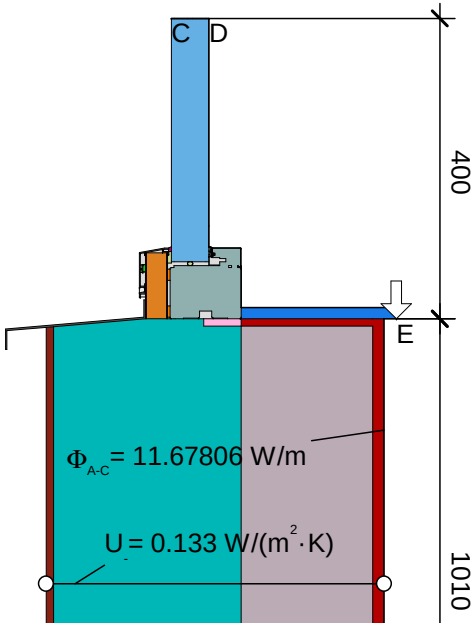
$$\psi_{A\text{-}E\text{-}C,\,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{11.917}{30.000} - 0.133 \cdot 1.010 - \frac{7.853}{30.000} = 0.001\ \text{W/(m·K)}$$

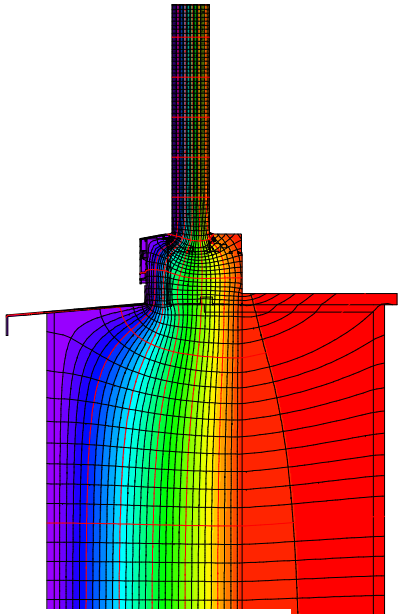


Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 035	0.035	0.900
Insulation I Wärmedämmung 040	0.040	0.900
Interior plaster I Gipsputz 10456	0.570	0.900
Organic compound plaster I Kunstharzputz 4108-4	0.700	
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU in-situ foam I PU-Ortschaum 040	0.040	0.900
Panel I Maske	0.035	0.900
Polyvinylchloride (PVC)	0.170	
Sand-lime stone I Kalksandstein 1745	1.000	0.900
Silicone I Silikon	0.350	0.900
Spruce, Fir I Fichte, Tanne	0.110	0.900
Steel I Stahl	50.000	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic	0.000			
Adiabatic | Adiabat	0.000			
Exterior I Außen		-10.000	0.040	
Innen Fensterrahmen Reduziert		20.000	0.200	
Innen Fensterrahmen Standard		20.000	0.130	
Interior | Innen		20.000	0.130	
e 0,9 Cavity I Hohlraum				0.900

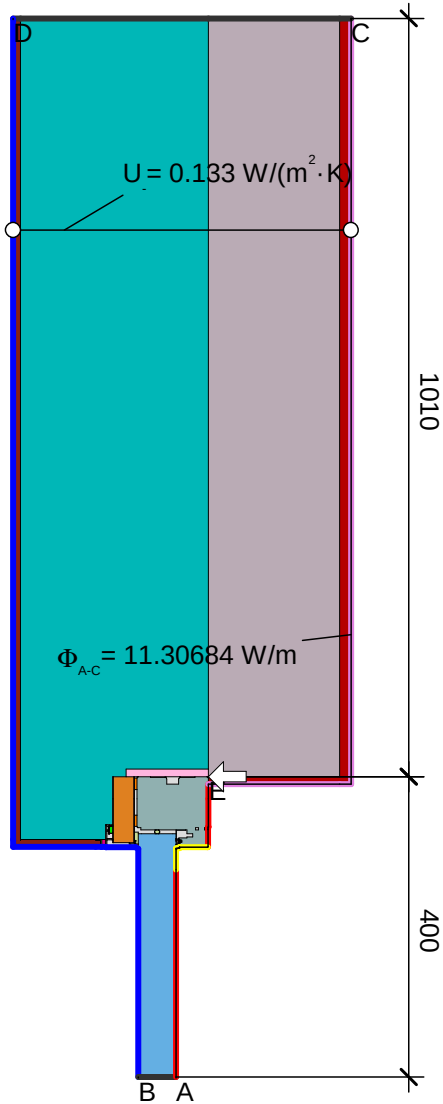


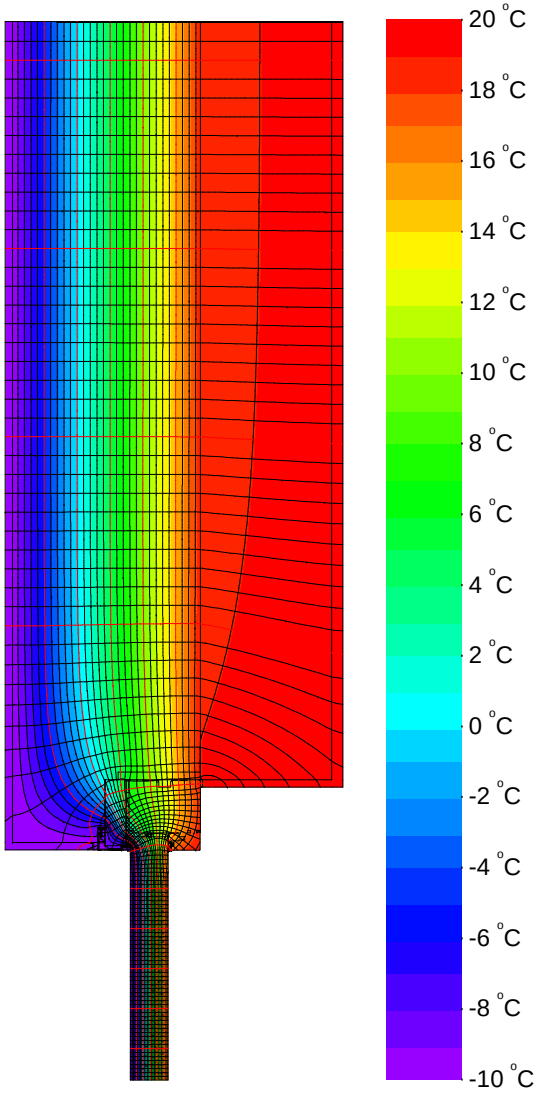




Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Artificial stone I Kunststein 10456	1.300	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 035	0.035	0.900
Insulation I Wärmedämmung 040	0.040	0.900
Interior plaster I Gipsputz 10456	0.570	
Organic compound plaster I Kunstharzputz 4108-4	0.700	
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU in-situ foam I PU-Ortschaum 040	0.040	0.900
PU-Seal I PU Dichtung	0.250	0.900
Panel I Maske	0.035	0.900
Sand-lime stone I Kalksandstein 1745	1.000	
Silicone I Silikon	0.350	0.900
Spruce, Fir I Fichte, Tanne	0.110	0.900
Unvent. cavity I unbel. Hohlr.		
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

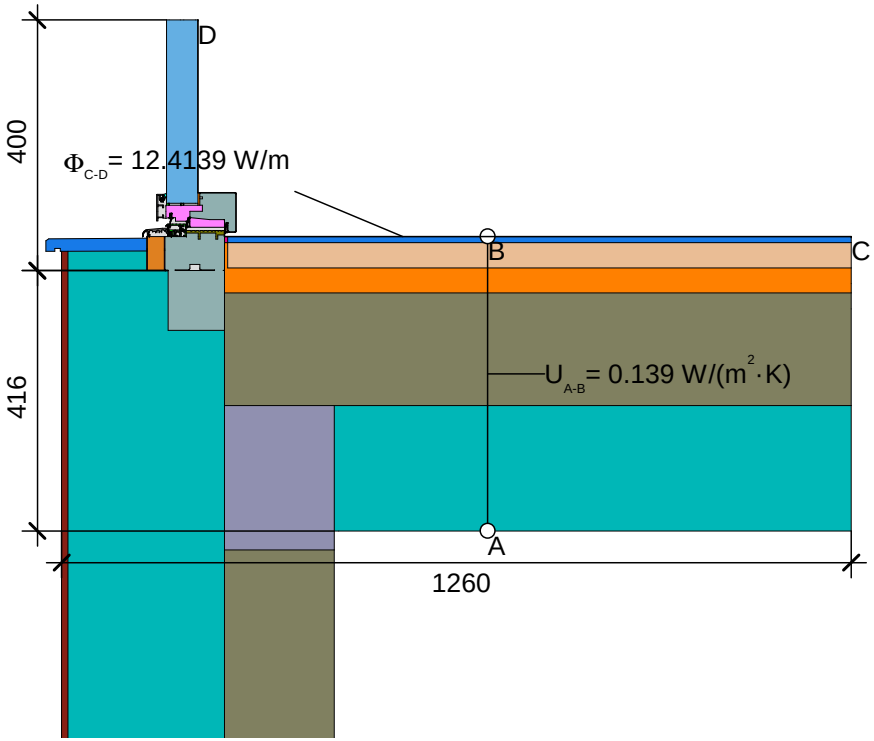
$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{11.678}{30.000} - 0.133 \cdot 1.010 - \frac{7.383}{30.000} = 0.009 \text{ W/(m·K)}$$

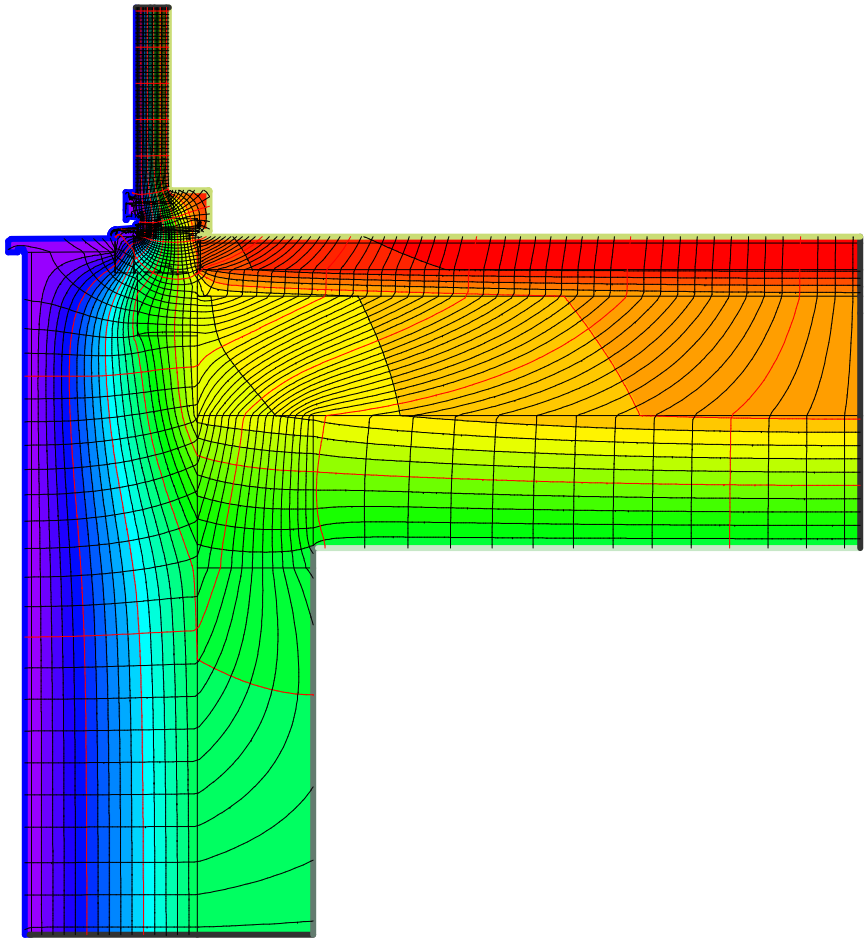


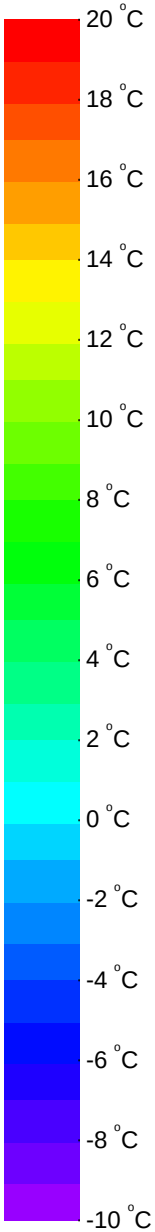


$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - \frac{\Phi_1}{\Delta T} - U_2 \cdot b_2 = \frac{11.307}{30.000} - \frac{7.386}{30.000} - 0.133 \cdot 1.010 = -0.003 \text{ W/(m·K)}$$

Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic	0.000			
Exterior I Außen		-10.000	0.040	
Interior I 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

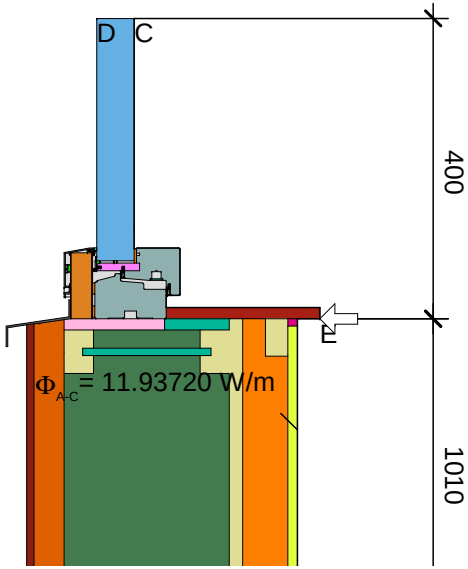


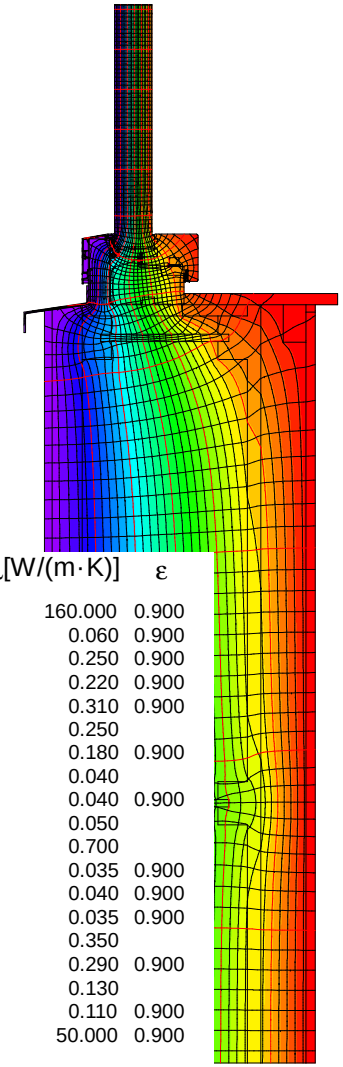




Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Artificial stone I Kunststein 10456	1.300	
Cement screed I Zement-Estrich 4108	1.400	
Concrete, 1% Steel I Beton, 1% Stahl 10456	2.300	
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Gas concrete I Porenbeton 750 4108	0.240	
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 035	0.035	0.900
Insulation I Wärmedämmung 040	0.040	0.900
Organic compound plaster I Kunstharzputz 4108-4	0.700	
PE-Insulation I Wärmedämmung 035	0.035	0.900
Panel I Maske	0.035	0.900
Polyvinylchloride (PVC)	0.170	0.900
Silicone I Silikon	0.350	
Spruce, Fir I Fichte, Tanne	0.110	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
Wood plastic composite	0.170	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

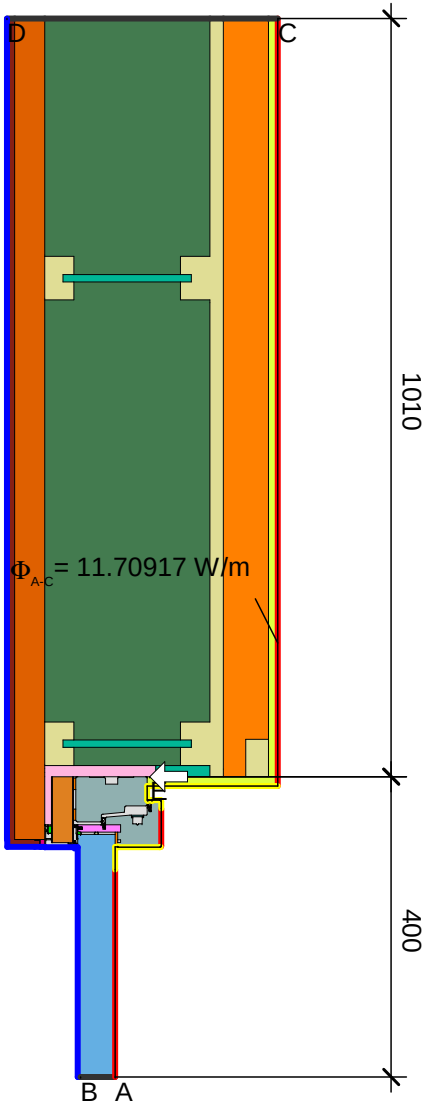
Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic	0.000			
Exterior I Außen		-10.000	0.040	
Int. flux down I Innen abwärts		20.000	0.170	
Int. unheated I Innen unbeheizt		5.000	0.130	
Int. unheated down I Innen unbeheizt abwärts		5.000	0.170	
e 0,9 Cavity I Hohlraum				0.900

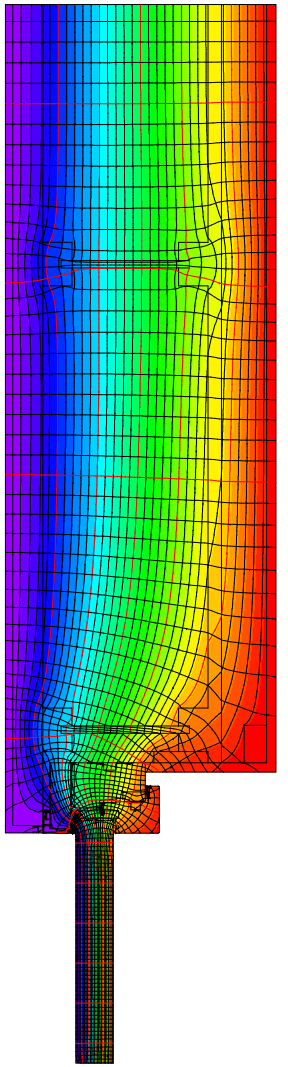


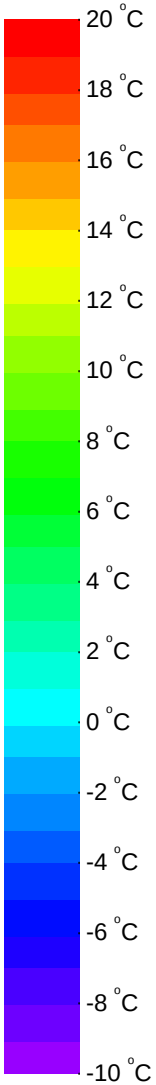


Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glue I Klebestoff	0.310	0.900
Gypsum board I Gipskartonplatten 900 kg/m3 10456	0.250	
Hardwood I Hartholz 0.18 700 kg/m3 10456	0.180	0.900
Insulation I Dämmstoff 040	0.040	
Insulation I Wärmedämmung 040	0.040	0.900
Insulation I Wärmedämmung 050	0.050	
Organic compound plaster I Kunstharzputz 4108-4	0.700	
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU in-situ foam I PU-Ortschaum 040	0.040	0.900
Panel I Maske	0.035	0.900
Silicone I Silikon	0.350	
Softwood flow parallel I Weichholz Q parallel	0.290	0.900
Softwood, OSB I Weichholz, OSB 10456	0.130	
Spruce, Fir I Fichte, Tanne	0.110	0.900
Steel I Stahl	50.000	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{11.937}{30.000} - 0.131 \cdot 1.010 - \frac{7.406}{30.000} = 0.019 \text{ W/(m·K)}$$







$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - \frac{\Phi_1}{\Delta T} - U_2 \cdot b_2 = \frac{11.709}{30.000} - \frac{7.402}{30.000} - 0.131 \cdot 1.010 = 0.011 \text{ W/(m·K)}$$

Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic	0.000			
Exterior I Außen		-10.000	0.040	
Interior, frame, normal		20.000	0.130	
Interior, frame, reduced		20.000	0.200	
e 0,9 Cavity I Hohlraum				0.900

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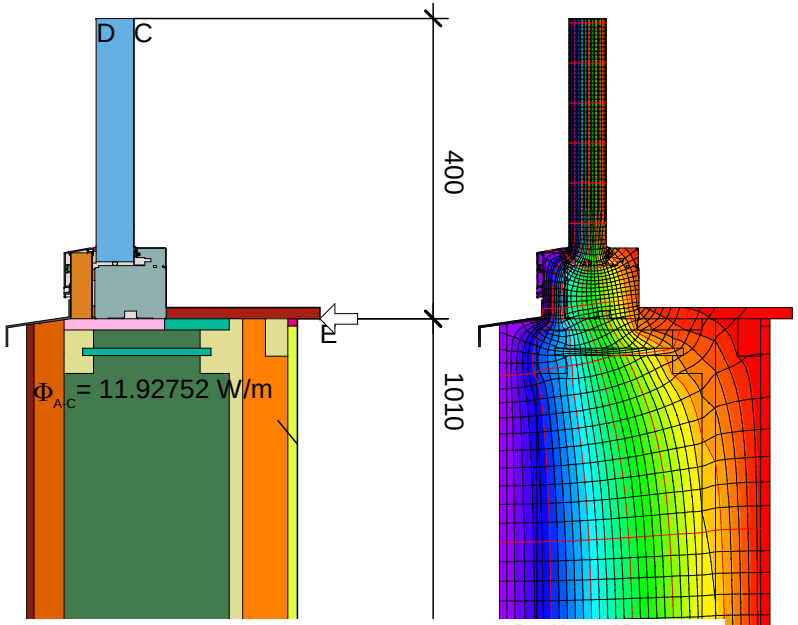
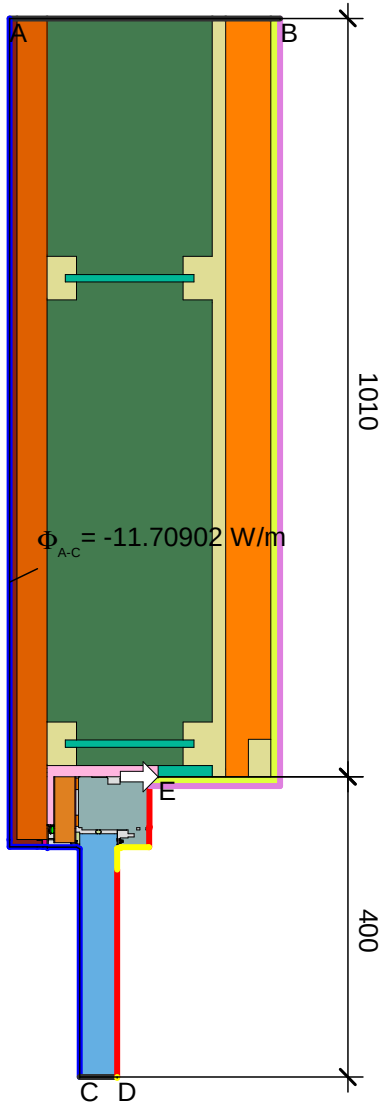
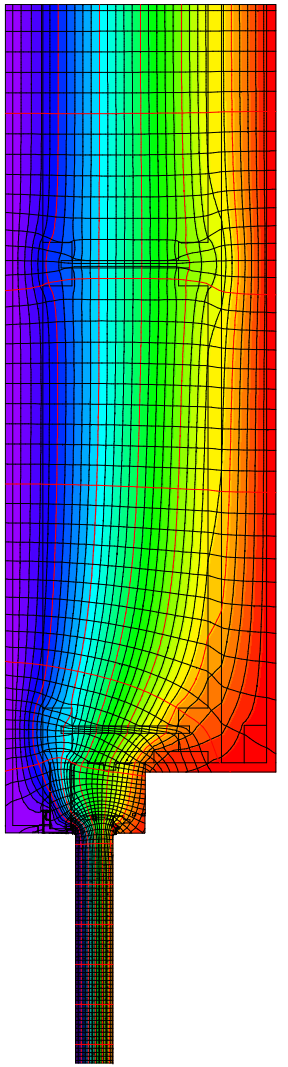
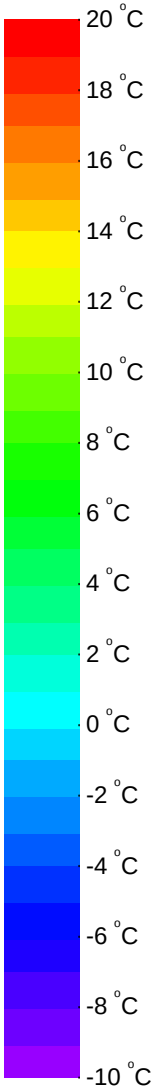


Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glue I Klebestoff	0.310	0.900
Gypsum board I Gipskartonplatten 900 kg/m3 10456	0.250	
Hardwood I Hartholz 0.18 700 kg/m3 10456	0.180	0.900
Insulation I Dämmstoff 040	0.040	
Insulation I Wärmedämmung 040	0.040	0.900
Insulation I Wärmedämmung 050	0.050	
Organic compound plaster I Kunstharzputz 4108-4	0.700	
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU in-situ foam I PU-Ortschaum 040	0.040	0.900
PU-Seal I PU Dichtung	0.250	0.900
Panel I Maske	0.035	0.900
Silicone I Silikon	0.350	0.900
Softwood flow parallel I Weichholz Q parallel	0.290	0.900
Softwood, OSB I Weichholz, OSB 10456	0.130	
Spruce, Fir I Fichte, Tanne	0.110	0.900
Unvent. cavity I unbel. Hohlr.		
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{11.928}{30.000} - 0.131 \cdot 1.010 - \frac{7.383}{30.000} = 0.019 \text{ W/(m·K)}$$







$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{11.709}{30.000} - 0.131 \cdot 1.010 - \frac{7.386}{30.000} = 0.012 \text{ W/(m·K)}$$

Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic	0.000			
Exterior I Außen		-10.000	0.040	
Interior I 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

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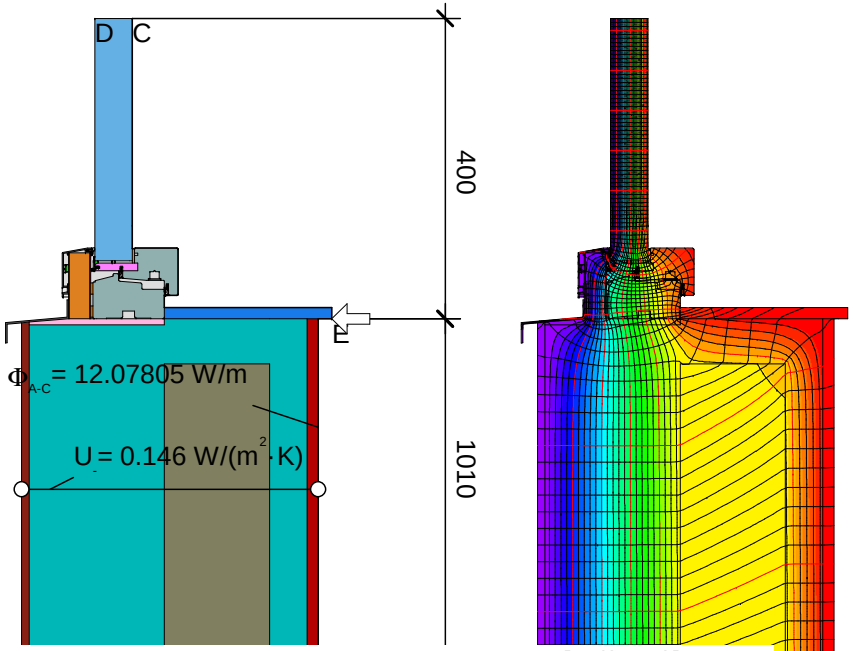
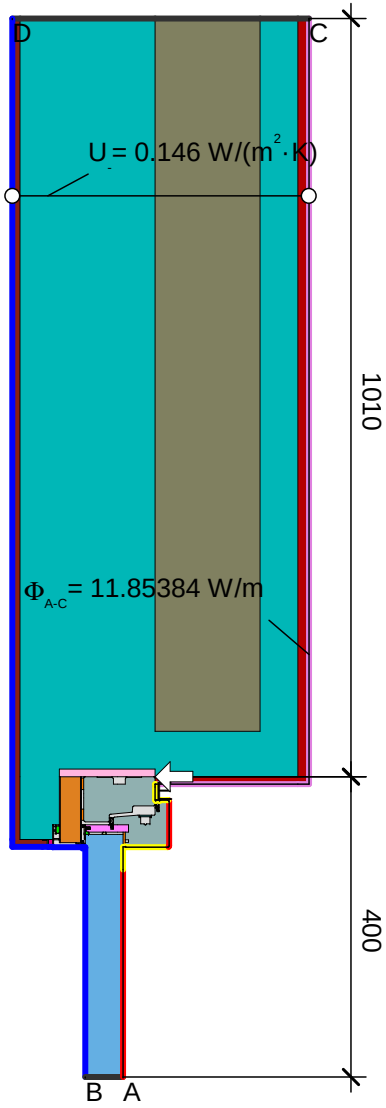
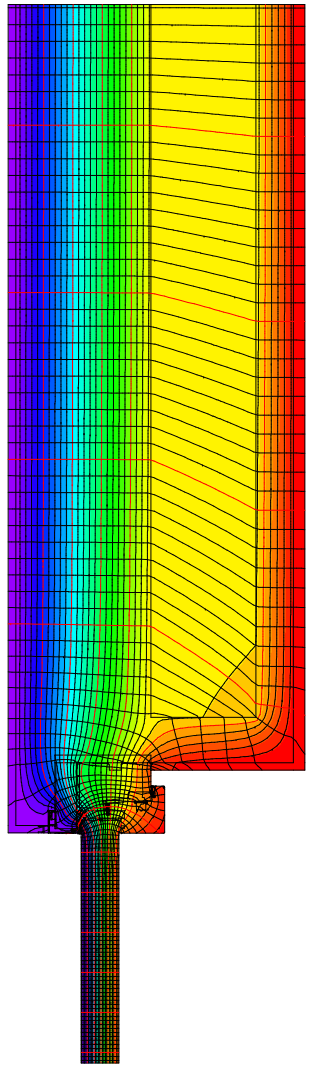
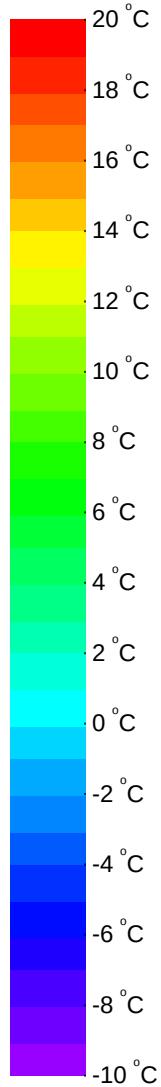


Material	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Artificial stone I Kunststein 10456	1.300	0.900
Concrete, 1% Steel I Beton, 1% Stahl 10456	2.300	
ENERcell	0.060	0.900
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 035	0.035	
Insulation I Wärmedämmung 040	0.040	0.900
Interior plaster I Gipsputz 10456	0.570	
Organic compound plaster I Kunstharzputz 4108-4	0.700	
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU in-situ foam I PU-Ortschaum 040	0.040	0.900
Panel I Maske	0.035	0.900
Spruce, Fir I Fichte, Tanne	0.110	0.900
Steel I Stahl	50.000	0.900
Unvent. cavity I unbel. Hohlr.		
Vorlegeband	0.060	0.900
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{12.078}{30.000} - 0.146 \cdot 1.010 - \frac{7.406}{30.000} = 0.008 \text{ W/(m·K)}$$



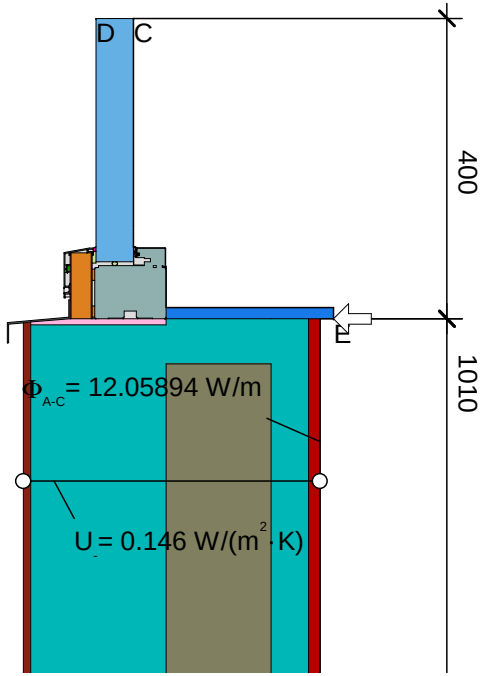


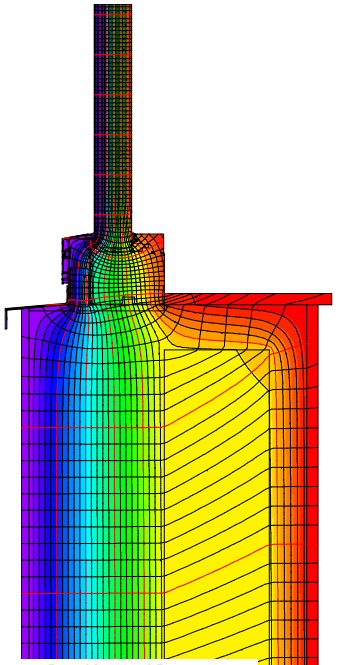


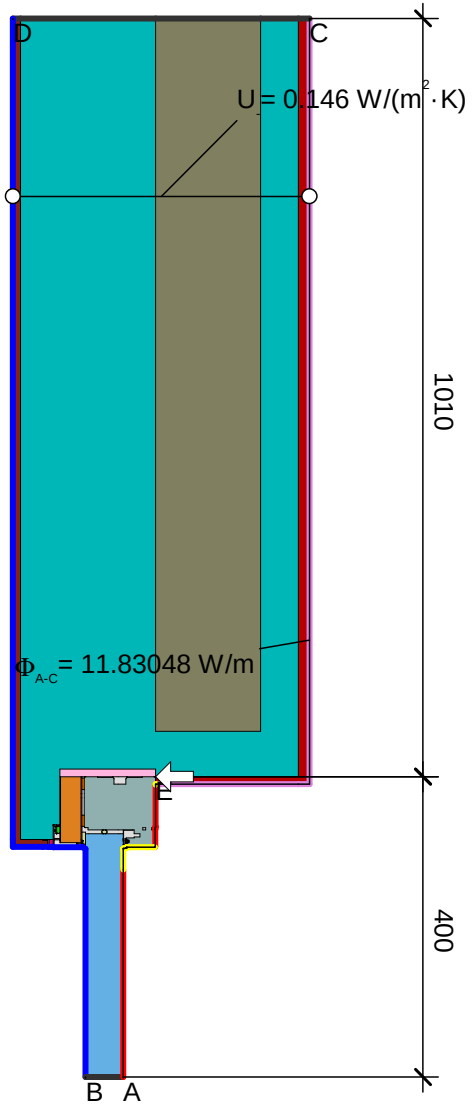
$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - \frac{\Phi_1}{\Delta T} - U_2 \cdot b_2 = \frac{11.854}{30.000} - \frac{7.402}{30.000} - 0.146 \cdot 1.010 = 0.001 \text{ W/(m·K)}$$

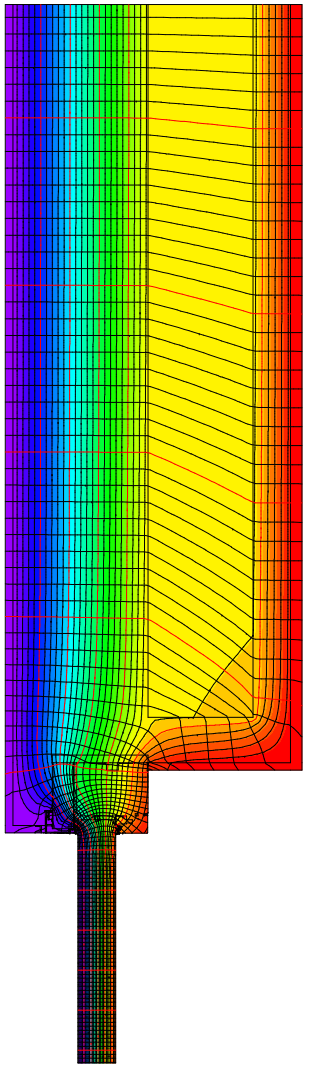
Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic	0.000			
Exterior I Außen		-10.000	0.040	
Interior I Innen		20.000	0.130	
Interior, frame, normal		20.000	0.130	
Interior, frame, reduced		20.000	0.200	
e 0,9 Cavity I Hohlraum				0.900

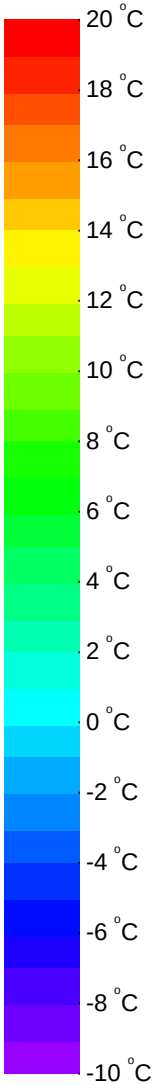
Passive House Institute











Material

	λ[W/(m·K)]	ε
Aluminum I Aluminium 10456	160.000	0.900
Artificial stone I Kunststein 10456	1.300	0.900
Concrete, 1% Steel I Beton, 1% Stahl 10456	2.300	
EPDM	0.250	0.900
GRP Polyesterbased I GFK Polyesterbasis, 25% Glas	0.220	0.900
Glue I Klebestoff	0.310	0.900
Insulation I Wärmedämmung 035	0.035	
Insulation I Wärmedämmung 040	0.040	0.900
Interior plaster I Gipsputz 10456	0.570	
Organic compound plaster I Kunstharzputz 4108-4	0.700	
PE-Insulation I Wärmedämmung 035	0.035	0.900
PU in-situ foam I PU-Ortschaum 040	0.040	0.900
PU-Seal I PU Dichtung	0.250	0.900
Panel I Maske	0.035	0.900
Silicone I Silikon	0.350	0.900
Spruce, Fir I Fichte, Tanne	0.110	0.900
Unvent. cavity I unbel. Hohlr.		
XPS Jakodur in Sandwichplatte	0.028	0.900
slightly vent. cav. I leicht bel. Hohlr.		

$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - \frac{\Phi_2}{\Delta T} = \frac{12.059}{30.000} - 0.146 \cdot 1.010 - \frac{7.383}{30.000} = 0.008 \text{ W/(m·K)}$$

$$\psi_{A\text{-}E\text{-}C,*} = \frac{\Phi}{\Delta T} - \frac{\Phi_1}{\Delta T} - U_2 \cdot b_2 = \frac{11.830}{30.000} - \frac{7.386}{30.000} - 0.146 \cdot 1.010 = 0.001 \text{ W/(m·K)}$$

Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε
Adiabatic	0.000			
Exterior I Außen		-10.000	0.040	
Interior I 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