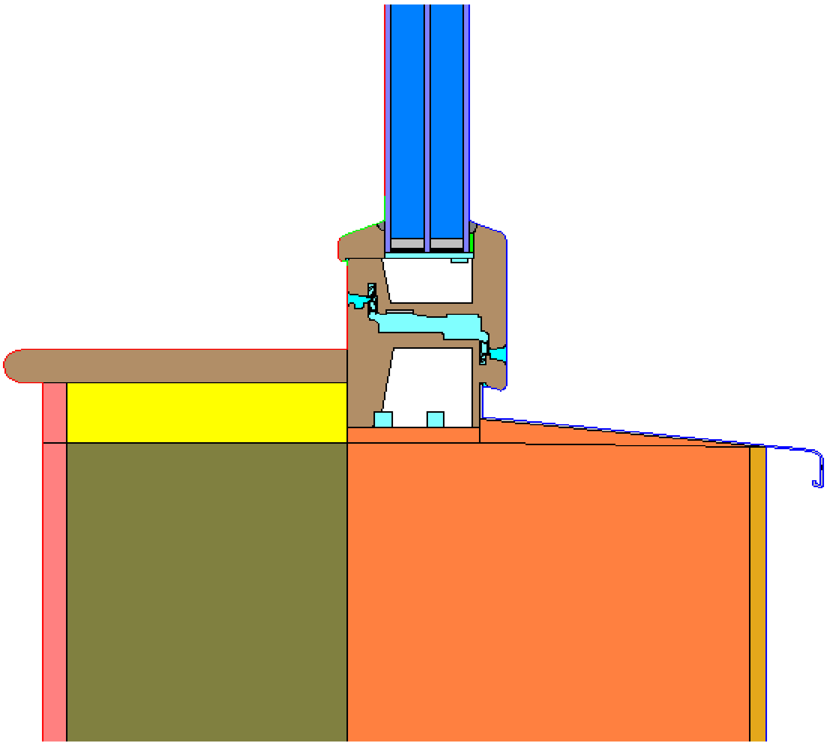
Thermal bridge calculation for the window frame and installation of Ecocontract ULTRA insulated frame opening window as a Certified Passive House Component

for
Green Building Store
Heath House Mill, Heath House Lane, Golcar
Huddersfield HD7 4JW UK



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Summary

The Ecocontract ULTRA insulated frame opening window from the Green Building Store company has been analyzed and this report contains the data needed to use this window in PHPP for the design of a Passivhaus, including various installation situations.

The enclosed table of Values (Section 9) has been designed to cut and paste directly into PHPP, to quickly enable designers to accurately model one of these windows.

This window meets the Comfort part of the certification criteria for a Passivhaus certified window.

Similarly, this window passes the Hygiene requirements for a Passivhaus certified window.

The choice of the spacer as Swisspacer Ultimate is an important part of reaching the criteria.

In conclusion, This window is suitable for use in Passivhaus construction in the Cool temperate climate as defined by the Passivhaus Institut.

During the construction care should be taken that the windows are installed as stated in the report, otherwise the thermal bridge heat loss coefficient for the installation may be considerably worse. Significantly different situations will require remodelling.

Table of contents

1. Introduction to Passivhaus window analysis

Because a separate heating system is not necessarily required in Passive Houses, high demands are placed on the quality of the building components used. If no radiator under the windows is planned, the thermal transmittance U_W (U-value) of the window used may not exceed 0.80 W/(m²K), in order to prevent unpleasant radiant heat deprivation and cold air descent at the window. For a given quality of glazing, this results in restriction of the thermal bridge loss coefficient for window frames.
The following requirements for the certificate "Certified Passive House Component - window frame" have been set by the PHI:

$$\mathbf{U_W \leq 0.80\ W/(m^2K)}$$

U_W is the average thermal transmittance for the whole window. The criterion must be met with U_g = 0.70 W/(m²K) and with a window size of 1.23 m x 1.48 m.

$$\mathbf{U_{W,installed} \leq 0.85\ W/(m^2K)}$$

$U_{W,installed}$ is the U-Value of the installed window. The criterion must be met in minimum three installation situations using the same sized frame as above.

Also the hygiene criterion must be met. For reasons of hygiene, this criterion limits the minimum individual temperature on window surfaces to prevent mould growth. Criterion for cool, temperate climate is:

$$\mathbf{f_{Rsi\_0.25\ m^2K/W} \geq 0.70}$$

At -5°C ambient temperature, 20°C interior temperature and 50% relative humidity the minimum temperature of the surface therefore is limited to 12.6 °C.

In addition, certified windows will be ranked by the thermal losses through the not transparent parts, represented by Ψ_{opaque}. 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:

The energy balance of Passivhauses, the sum out of losses and gains, is very important. 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 done by calculating $\Psi_{opaque.}$

Table 1: Passive house efficency classes

Ψ_{opaque}	**Passive house efficiency class**	**Name**
≤ 0.110 W/(mK)	$_{ph}$**A**	Advanced component
≤ 0.155 W/(mK)	$_{ph}$**B**	Basic component
≤ 0.220 W/(mK)	$_{ph}$**C**	Certifiable component

2. Guidelines for thermal bridge calculation for windows

On behalf of the Green Building Store company in Huddersfield, WARM has calculated the thermal characteristics for a window based on the regulation EN ISO 10077 (standard size 1.23 m * 1.48 m), with a window frame Ecocontract ULTRA insulated frame.

The calculations were carried out using the heat flow software THERM V6.3.46.0 by the American LBNLaboratory

2.1 Description of the window frame

The frame is constructed with laminated softwood with a wedge shaped "Compacfoam" insulated section.

2.2 Glass, Panel and Spacer

For triple glazing with low-e coating, generally a Glass U-value of U_g = 0.7 W/(m²K) is assumed for the calculations in the course of certification. In order to meet the certification criterion U_W = 0.80 W/(m²K), a frame (including spacer and edge bond) with the corresponding thermal quality is necessary

Table 2: Properties of the glazing and the panel.

Properties of the glazing	Edge-bond	Swisspacer Ultimate	
	Number of panes	3	
	Thickness of the panes	4/4/4	mm
	Thickness of the gas gap	20 / 20	mm
	Glazing	52	mm
	Conductivity of gas gap	0.0321	W/(mK)
	Additional air gap	-	mm
	Thickness of additional pane	-	mm
	conductivity of air gap	-	W/(mK)
	thickness of the total glazing	52	mm
	U-Value of the glazing	0.700	W/(m²K)
Properties of the panel	Conductivity of the panel	0.035	W/(mK)
	U-Value of the panel	0.673	W/(m²K)

In many edge bond constructions, very thin (about 0.025 to 0.1 mm) films are incorporated, the materials of which have a high thermal conductivity. The true-scale representation of the spacer in the calculation model could only be resolved with a very large numerical effort.
Instead of a high resolution representation of the spacer Swisspacer Ultimate a simplified, but thermally equivalent, replacement was therefore used. This allows a simpler mesh in the calculation model and therefore a viable computational effort.

2.3 Boundary conditions

The boundary conditions for the calculations were chosen to reflect the actual circumstances, i.e. with an external temperaure of –10°C, an interior temperature of +20°C and the corresponding heat transfer coefficient at the surfaces (see table below). A reduced inner heat transfer coefficient of Rs_i = 0.20 (m²K/W) was assumed at the inner surfaces of the window corners, in accordance with DIN EN 10077-2.

Table 3: Heat transfer resistances and surface temperatures.

Surface	Temperature θ [°C]	Heat-transfer resistance R_{SI} [m²K/W]
to ambient	-10	0.04
to ambient with air gap		0.13
to interior	20	0.13
to interior in edges		0.20
to ambient for calculation of f_{Rsi}	-5	0.04
to interior for calculation of f_{Rsi}	20	0.25

2.4 Used materials and thermal conductivities

In the following table the materials used in the calculation are listed with their thermal conductivities. The thermal conductivities are based on information provided by the company or on established standards. The equivalent thermal conductivity of hollow spaces was determined in accordance with DIN EN 10077-2.

Table 4: Thermal conductivities representing the materials used for the calculation model and their colours as they appear in the THERM model diagrams

Window Frame

Name	Conductivity W/m-K	Emissivity
CEN Polysulphide	0.400	0.9
AA SPR Swisspacer Ultimate	0.140	0.9
CEN Glass	1.000	0.9
CEN PH Glazing	0.0321	0.9
AA INS k046 Compacfoam CF200	0.046	0.9
CEN EPDM	0.250	0.9
AA TIM General Timber	0.130	0.9
AA INS k034 Elastomeric Foam	0.050	0.9
CEN Silicone Pure 0k35	0.350	0.9
AA Steel Plate in central cavity	50.0	0.9

The Compacfoam CF200 and the elastomeric foam are unusual materials - see appendices
The following materials were used in the installation of the walls

Cavity Wall		
AA MAS Concrete Block Heavyweight	1.600	0.90
AA INS k0.037	0.032	0.90
Stone	1.500	0.90
AA FIN Plaster	0.250	0.90
AA MAS Reinforced Concrete	2.100	0.90
Timber Frame		
AA FIN Plasterboard & Skim	0.210	0.90
AA TIM General Timber	0.130	0.90
AA TIM Plywood Osb heat flow along p	0.208	0.90
AA INS k022	0.022	0.90
AA INS k040	0.040	0.90
AA INS k039 Gutex	0.039	0.90
AA MAS Render	0.700	0.90
CEN Service Void	Calculated	0.90
Externally Insulated Wall		
AA MAS Med Conc Block High Cond	0.850	0.90
AA INS k037	0.037	0.90
AA MAS Render	0.700	0.90
AA FIN Plaster	0.250	0.90

3. Results of the heat-flow-calculation

The heat flow rate L_{2D} was calculated for each sectional drawing following DIN EN 10077–1 and 2 using the two-dimensional heat flow software programme THERM. For each section, two calculations were carried out, one with the installed glazing and one with a calibration panel (lamda-value of 0,035 W/(m²K)) in place of the glazing. The depth of the edge and thickness of the calibration panel correspond with those of the glazing. Each of the calculated L_{2D} values in W/mK are documented with the respective dimensions of the sections in Table 5. These intermediate results form the basis for the calculation of the U-values and the Ψ-values.

The height of the calculation models is 0.4 m in models with one glazed part and 0.6 m in models with two glazed parts(eg mullion). For installation situations at least 1m or 3 times the wall thickness is added to typically produce 1.4m.

Table 5: Results of the heat flow calculations for all sections [W/mK].

Name			Ecocontract ULTRA insulated frame opening window				
Frame with panel	Cill		0.2716				
	Head		0.2699				
	Jamb		0.2699				
	Mullion		0.3961				
Edge bond							
Frame with glass	Cill		0.3188				
	Head		0.3196				
	Jamb		0.3196				
	Mullion		0.4857				
Cavity wall	Cill		0.4452				
	Head		0.5239				
	Jamb		0.5239				
Timber frame	Cill		0.4562				
	Head		0.4379				
	Jamb		0.4379				
Externally insulated wall	Cill		0.4726				
	Head		0.4670				
	Jamb		0.4670				

4. Overview of calculation results

Table 6: Overview of calculation results.

Name		Passivhaus Transparent Component Certification Crieteria	Ecocontract ULTRA insulated frame opening window				
frame width b_f [m]	Cill		0.138				
	Head		0.120				
	Jamb		0.120				
	Mullion		0.136				
U-value of the frame U_f [W/(m²K)]	Cill		0.822				
	Head		0.841				
	Jamb		0.841				
	Mullion		0.853				
Edge bond							
th. bridge of edge bond Ψ_g [W/(mK)]	Cill		0.0221				
	Head		0.0228				
	Jamb		0.0228				
	Mullion		0.0225				
Minimum Internal Temps [C]	Cill		13.90				
	Head		13.80				
	Jamb		13.80				
	Mullion		13.80				
Lowest Min Int Temp [C]		12.6	13.8				
Frsi based on -5 C		0.70	0.75				
Hygiene satisfied above ext. temp of:		-5	-10				
Window-U-value U_W [W/(m²K]		**0.80**	**0.80**				
Comfort satisfied above ext. temp of:		-16	-16				
Ψ_{opaque} [W/(mK)]			**0.133**				
Passive House Efficiency class			**phB**				
Thermal installation bridge $\Psi_{install}$ [W/(mK)] und $U_{W,installed}$ [W/(m²K)]							
Cavity wall	Cill		0.0059				
	Head		0.0017				
	Jamb		0.0017				
	$U_{W,installed}$	**0.85**	**0.809**				
Timber frame	Cill		0.0094				
	Head		-0.0098				
	Jamb		0.0049				
	$U_{W,installed}$	**0.85**	**0.808**				
Externally insulated wall	Cill		0.0226				
	Head		0.0086				
	Jamb		0.0086				
	$U_{W,installed}$	**0.85**	**0.836**				

5. Window construction

In the following figures, the colour coded construction is shown on the left, with the heat flux results in the middle, and the isothermal figures on the right.

Figure 1 shows the sections head/jamb and cill of the window with a 52 mm wide glazing and the spacer Swisspacer Ultimate.

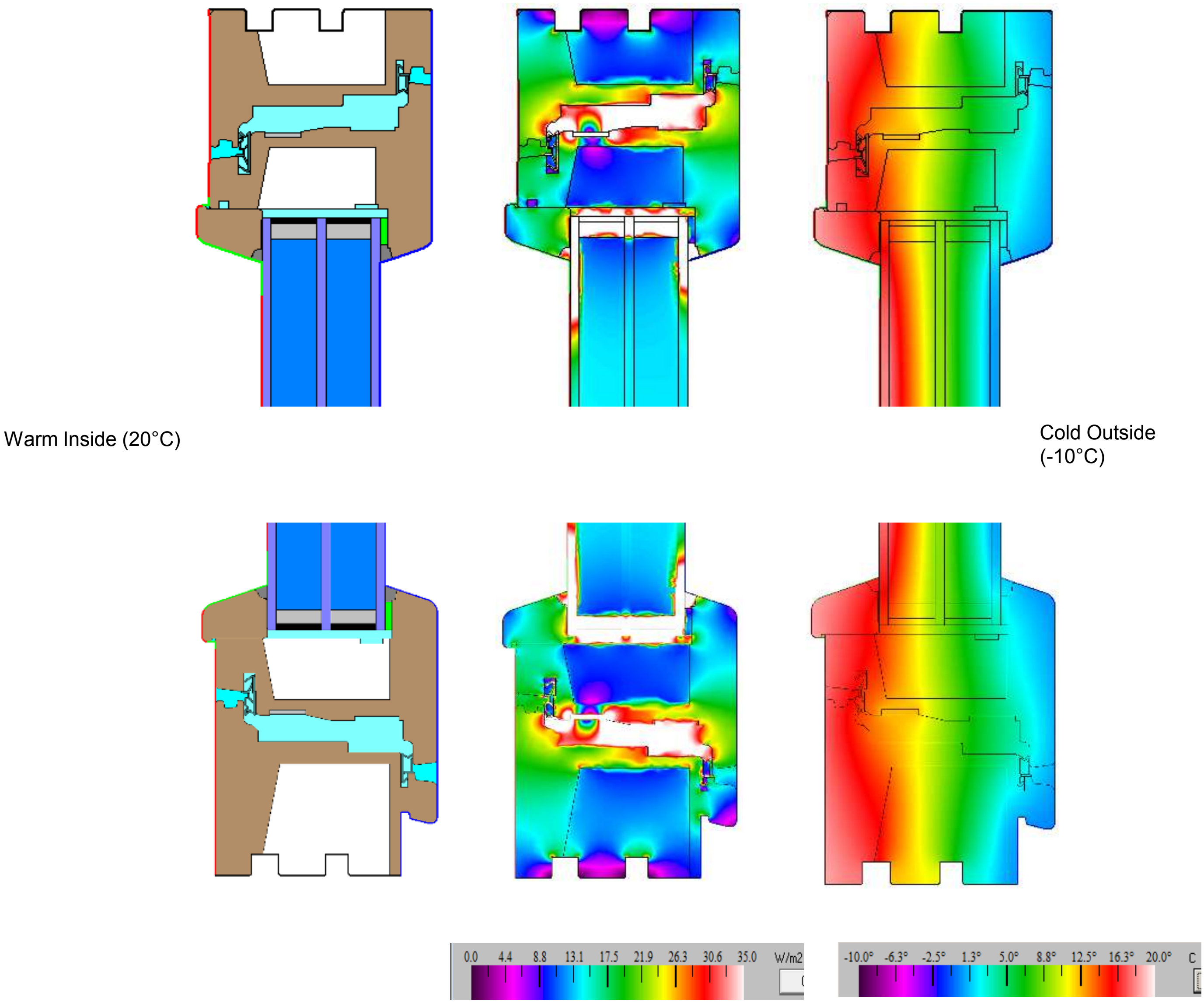


Figure 1: : Section 'head/jamb' and 'cill' with the respective heat flux and isothermal graphics.

5.1 Mullion

Figure 2 shows the section of a Mullion of the certified window system with a 52 mm wide glazing and the spacer Swisspacer Ultimate.
The thermal properties of this section are given for information only. They are not part in the calculation of the window U-value. However, they can be used to determine the correct PHPP data for windows with Mullions

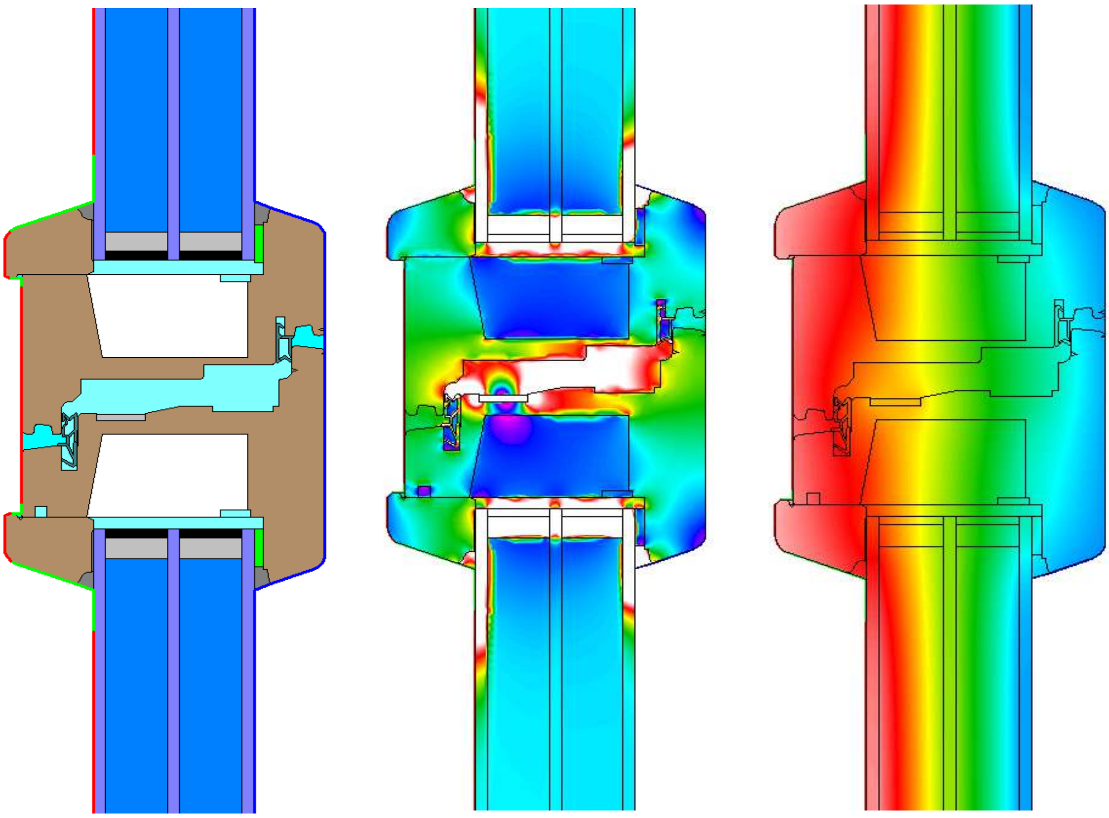


Figure 2: Section of the Mullion of the window system with respective isothermal and heat flux graphics.

6. Window U-values for different window sizes

The U-value U_W of an uninstalled window of any size can be determined using the following equation:

$$U_W = \frac{A_g \cdot U_g + A_f \cdot U_f + l_g \cdot \Psi_g}{A_g + A_f}$$

where:	A_g	Glazing area [m²]	U_g	Average glazing U-value [W/(m²K]
	A_f	Frame area [m²]	U_f	Average frame U-value [W/(m²K]
	l_g	Length of edge bond [m]	Ψ_g	Av. th. bridge of edge bond [W/(mK)]

7. Installation

Besides the heat transfer through window frames and glazing, the connection of the frame to a suitable Passivhaus wall construction is of considerable importance for the whole system (the U-value of the wall must be less than 0.15 W/(m ^{2}K)). Therefore, three typical installation situations (the specific arrangement of which were given by the manufacturer) were tested for their suitability.

The results are shown in table 5 and 6. For the calculation models and the respective isothermal graphics, see the following pages.

The U-value of an installed window of any size can be determined using the following equation:

$$U_{W,installed} = \frac{A_W \cdot U_W + l_{instal.} \cdot \Psi_{instal.}}{A_W}$$

where:	A_W	Window area [m²]	U_W	Window-U-value [W/(m²K)]
	$l_{instal.}$	Length of installation [m]	$\Psi_{instal.}$	Av. th. installation bridge [W/(mK)]

7.1 Cavity wall

The following figure shows the installation of the Ecocontract ULTRA insulated frame 'side/top' and 'bottom' in a Cavity wall.

In the following figures, the heat flux results are shown on the left, with the respective isothermal figures are shown on the right. The construction details are in the appendicies.
In order to better represent the details, only relevant sections of the calculation model are shown.

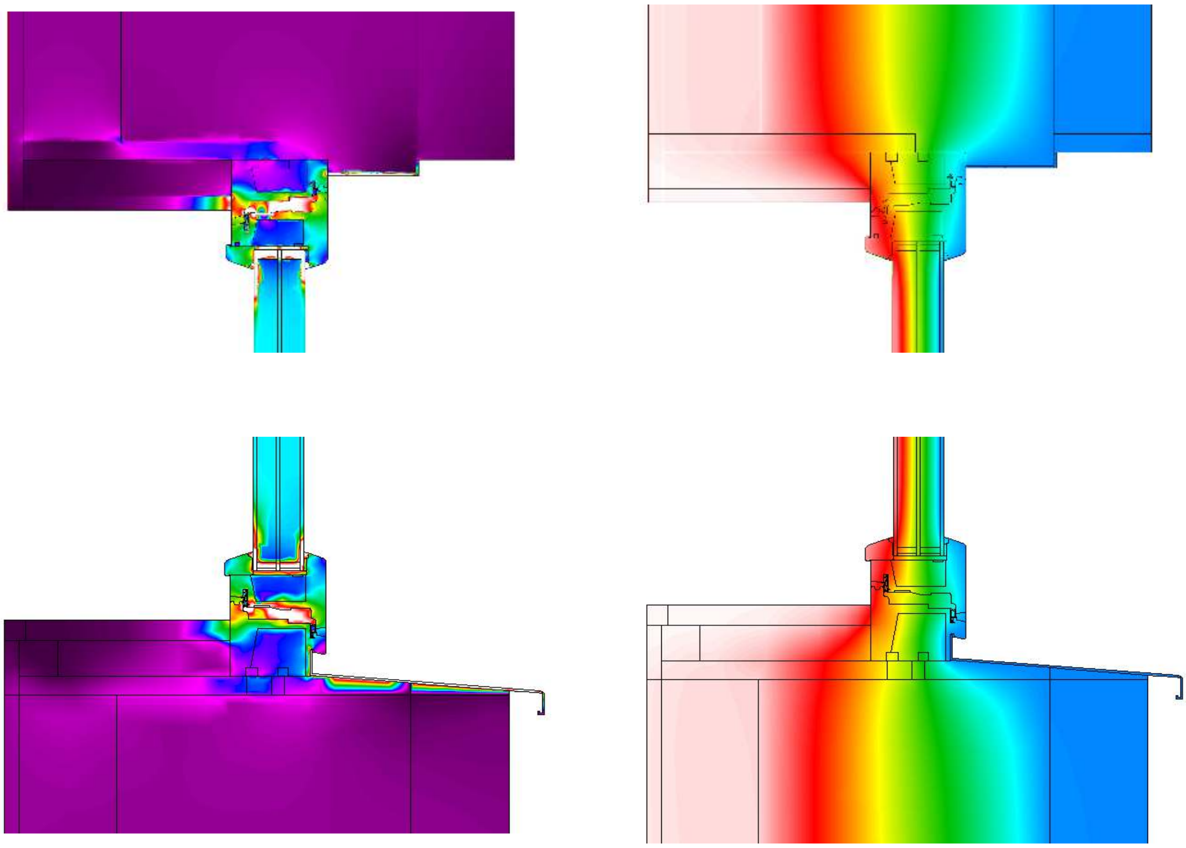


Figure 3: Installation head/jamb and cill in a Cavity wall with respective isothermal graphics

	U wall [W/(m²K)]	$\Psi_{instal., bottom}$ [W/(mK)]	$\Psi_{instal., s./top}$ [W/(mK)]	$U_{W,installed}$ [W/(m²K)]
	0.118	0.006	0.002	0.81

7.2 Timber frame

The following figure shows the installation of the Ecocontract ULTRA insulated frame 'top/side‘ and 'bottom' in a Timber frame.

In the following figures, the heat flux results are shown on the left, with the respective isothermal figures are shown on the right. The construction details are in the appendicies.

In order to better represent the details, only relevant sections of the calculation model are shown.

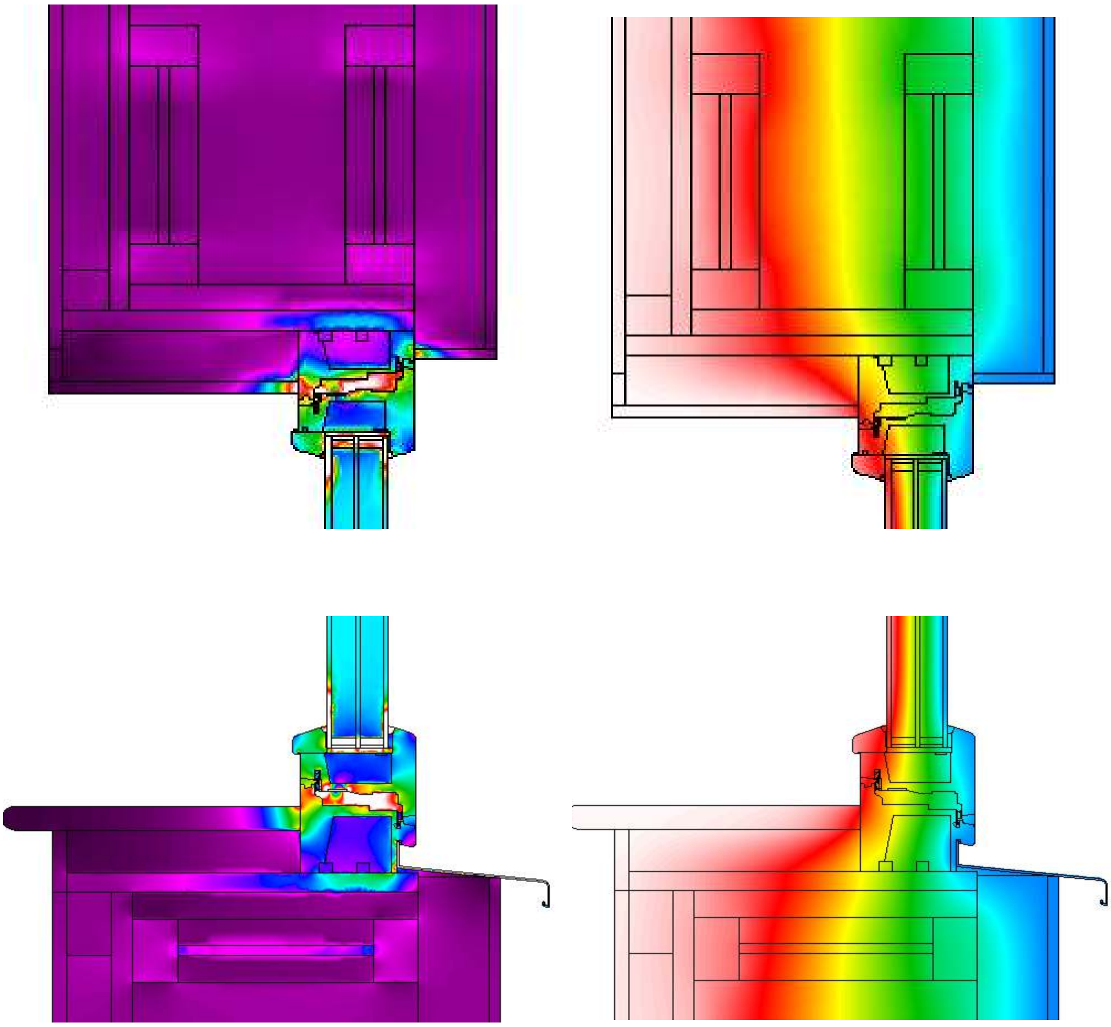


Figure 4: Installation 'bottom' and 'side/top' in a Timber frame with respective isothermal graphic

	U wall [W/(m²K)]	$\Psi_{instal., bottom}$ [W/(mK)]	$\Psi_{instal., top}$ [W/(mK)]	$\Psi_{instal., side}$ [W/(mK)]	$U_{W,installed}$ [W/(m²K)]
	0.126	0.009	-0.010	0.005	0.81

7.3 Externally insulated wall

The following figure shows the installation of the Ecocontract ULTRA insulated frame 'side/top' and 'bottom' in a Externally insulated wall.

In the following figures, the heat flux results are shown on the left, with the respective isothermal figures are shown on the right. The construction details are in the appendicies.

In order to better represent the details, only relevant sections of the calculation model are shown.

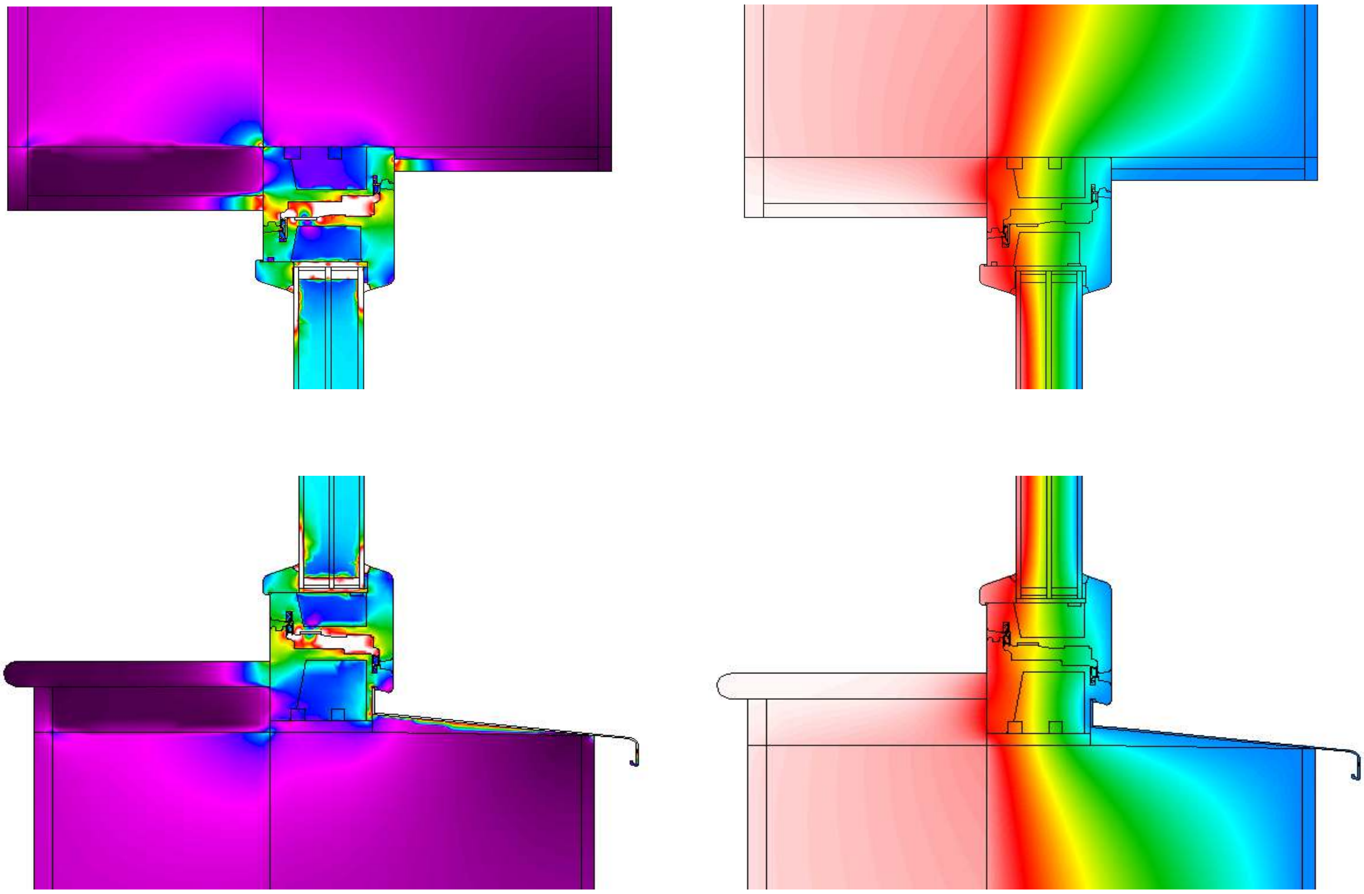


Figure 5: Installation 'bottom' and 'side/top' in a Externally insulated wall with respective isothermal graphic

	U wall [W/(m²K)]	$\Psi_{instal., bottom}$ [W/(mK)]	$\Psi_{instal., s./top}$ [W/(mK)]	$U_{W,installed}$ [W/(m²K)]
	0.14	0.023	0.009	0.84

8. Alternative Glasses offered by manufacturer

In deriving the performance of windows, the convention is to install a standard quality of glazing with a centre U value of 0.7 W/m2K to enable a fair comparison of the frames.

However, for analysis in PHPP it is important to know the properties of the actual glass to be offered by the manufacturer. These obviously include the Centre of glass U value of the glazed unit, but also the g value, which is the fraction of solar heat that passes through the glass at normal incidence.

These values commonly change if the glass is required to have security, safety, or obscured properties. Usually this is because as the glass thickness changes, the gas cavity also changes to maintain a fixed total sealed unit thickness. The g value can also change with some obscured or laminated glass types.

The following list has been provided by the manufacturer to help choose the correct properties in PHPP. This glazing data is incldued in the PHPP data value in the next section, but here we also show the PHI glazing rating, which is expressed as:

Ueq = Ug - 1.6 x g   where 1.6 is a climate factor for Cool temperate regions

PHI scale:	rating	Ueq W/m2K
	D	>=0
	C	>=-0.2 but <0
	B	>=-0.35 but <-0.2
	A	<-0.35

	g	Ug	
Standard_4-20-4-20-4 Guardian Climaguard Premium/Clear float/Guardian Climaguard Premium_Argon 90%	0.49	0.52	B
Safety_4-20-6.4-20-4 AGC Top N+T toughened/Clear laminated/AGC Top N+T toughened_Argon 90%	0.49	0.52	B
High g_4-20-4-20-4 Planitherm Lux/Clear float/Planitherm Lux_Argon 90%	0.63	0.61	A

9. PHPP Values

GLASS

Assem-bly No.	Type: Glazing	g-Value	U_g-Value
			W/(m²K)
1	Green Building Store Standard_4-20-4-20-4 Guardian Climaguard Premium/Clear float/Guardian Climaguard Premium_Argon 90%	0.49	0.52
2	Green Building Store Safety_4-20-6.4-20-4 AGC Top N+T toughened/Clear laminated/AGC Top N+T toughened_Argon 90%	0.49	0.52
3	Green Building Store High g_4-20-4-20-4 Planitherm Lux/Clear float/Planitherm Lux_Argon 90%	0.63	0.61

WINDOW FRAME PHPP V7 and V8

	Type	U_f-Value				Frame Dimensions				Thermal bridges								
Assem-bly No.	Window frame	Frame left	Frame right	Frame bottom	Frame top	Width - Left	Width - Right	Width - Below	Width - Above	Glazing edge thermal bridge				Installation thermal bridge				Curtain wall facades:
	Curtain wall facade	Post left	Post right	Beam bottom	Beam top	Post left	Post right	Beam bottom	Beam top	Ψ Glazing edge left	Ψ Glazing edge right	Ψ Glazing edge bottom	Ψ Glazing edge top	Ψ Installation left	Ψ Installation right	Ψ Installation bottom	Ψ Installation top	χ_{GC} - value Glass carrier
		W/(m²K)	W/(m²K)	W/(m²K)	W/(m²K)	m	m	m	m	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/K
1	Green Building Store Ecocontract ULTRA insulated frame opening window	0.84	0.84	0.82	0.84	0.120	0.120	0.138	0.120	0.023	0.023	0.022	0.023	0.040	0.040	0.040	0.040	
2	Green Building Store Ecocontract ULTRA insulated frame opening window in a Cavity wall (U= 0.12 W/m2K)	0.84	0.84	0.82	0.84	0.120	0.120	0.138	0.120	0.023	0.023	0.022	0.023	0.002	0.002	0.006	0.002	
3	Green Building Store Ecocontract ULTRA insulated frame opening window in a Timber frame (U= 0.13 W/m2K)	0.84	0.84	0.82	0.84	0.120	0.120	0.138	0.120	0.023	0.023	0.022	0.023	0.005	0.005	0.009	-0.010	
4	Green Building Store Ecocontract ULTRA insulated frame opening window in a Externally insulated wall (U= 0.14 W/m2K)	0.84	0.84	0.82	0.84	0.120	0.120	0.138	0.120	0.023	0.023	0.022	0.023	0.009	0.009	0.023	0.009	

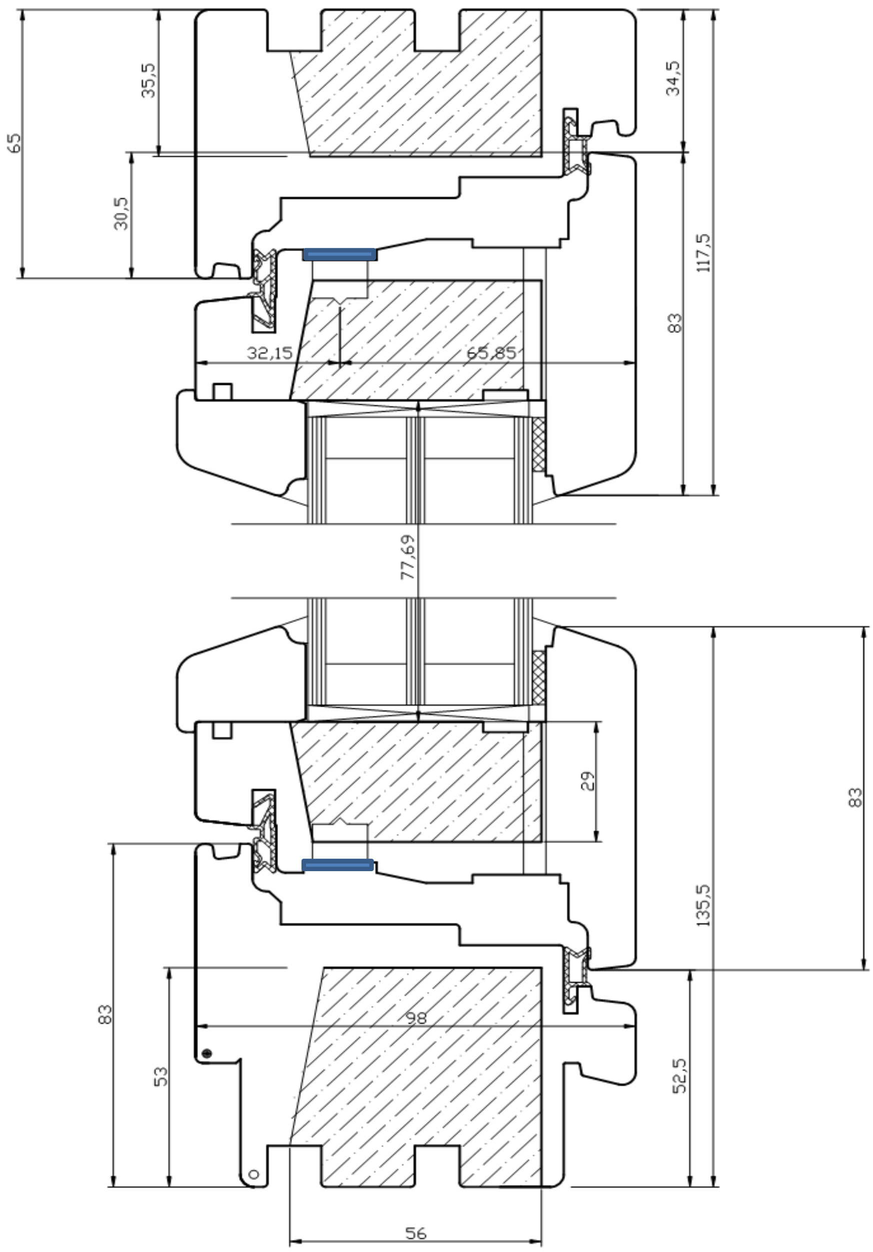
WINDOW FRAME PHPP 2007 V1.2 English

	Type	U_f-Value	Frame Dimensions				Thermal bridges	
Assem-bly No.	Window frame	Frame	Width Left	Width Right	Width Bottom	Width Top	Ψ glazing edge	Ψ installation
	Curtain wall system	Mullion / transom	1/2 Width mullion		1/2 Width transom		Ψ glazing edge	Ψ installation
		W/(m²K)	m	m	m	m	W/(mK)	W/(mK)
1	Green Building Store Ecocontract ULTRA insulated frame opening window	0.84	0.120	0.120	0.138	0.120	0.023	0.040
2	Green Building Store Ecocontract ULTRA insulated frame opening window in a Cavity wall (U= 0.12 W/m2K)	0.84	0.120	0.120	0.138	0.120	0.023	0.003
3	Green Building Store Ecocontract ULTRA insulated frame opening window in a Timber frame (U= 0.13 W/m2K)	0.84	0.120	0.120	0.138	0.120	0.023	0.003
4	Green Building Store Ecocontract ULTRA insulated frame opening window in a Externally insulated wall (U= 0.14 W/m2K)	0.84	0.120	0.120	0.138	0.120	0.023	0.012

Assem-bly No.	U_f-Value	Thermal Bridge	standard window size		U_f-Value			Ψ installation		
	frame	Ψ installation (averaged)	Height	Width	side	top	bottom	side	top	bottom
	W/(m²K)	W/(mK)	m	m	W/(m²K)	W/(m²K)	W/(m²K)	W/(mK)	W/(mK)	W/(mK)
1	0.84	0.040	1.48	1.23	0.84	0.84	0.82	0.040	0.040	0.040
2	0.84	0.003	1.48	1.23	0.84	0.84	0.82	0.002	0.002	0.006
3	0.84	0.003	1.48	1.23	0.84	0.84	0.82	0.005	-0.010	0.009
4	0.84	0.012	1.48	1.23	0.84	0.84	0.82	0.009	0.009	0.023

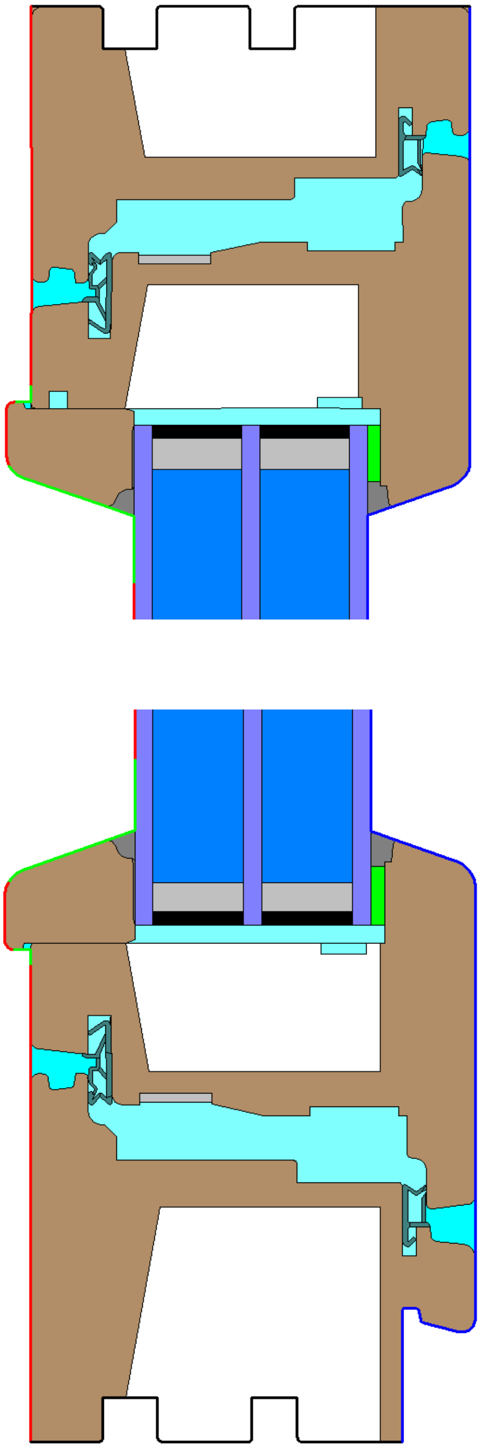
10. Appendix: Construction drawings - (Not to scale)

Ecocontract ULTRA insulated frame: Frame section - Head/jamb and Cill



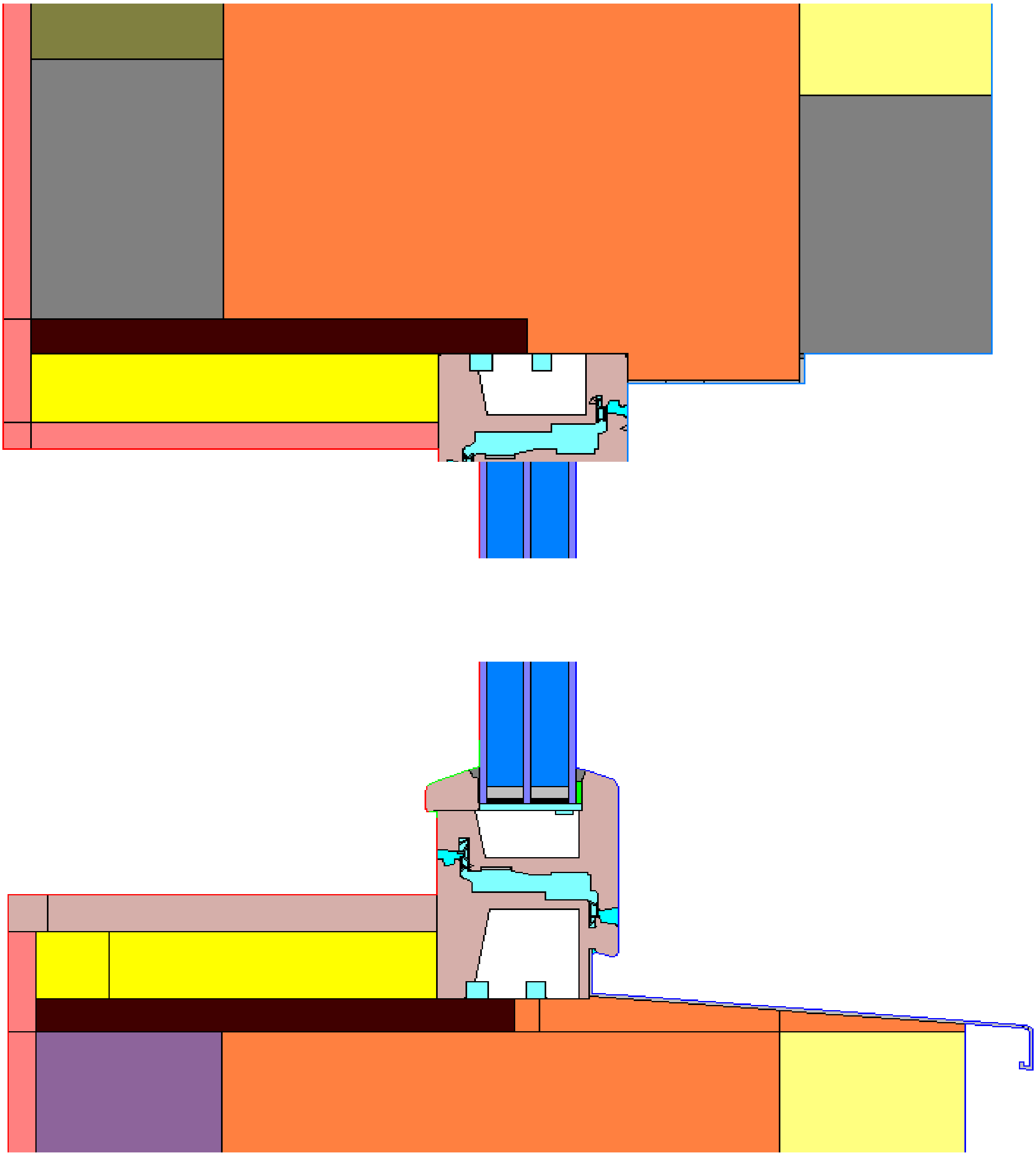
Note wedge shaped CF200 compacfoam insulation (k= 0.046 W/mK)
52mm glazing rebate

Ecocontract ULTRA insulated frame: Section of Window Head and Cill (not to scale)



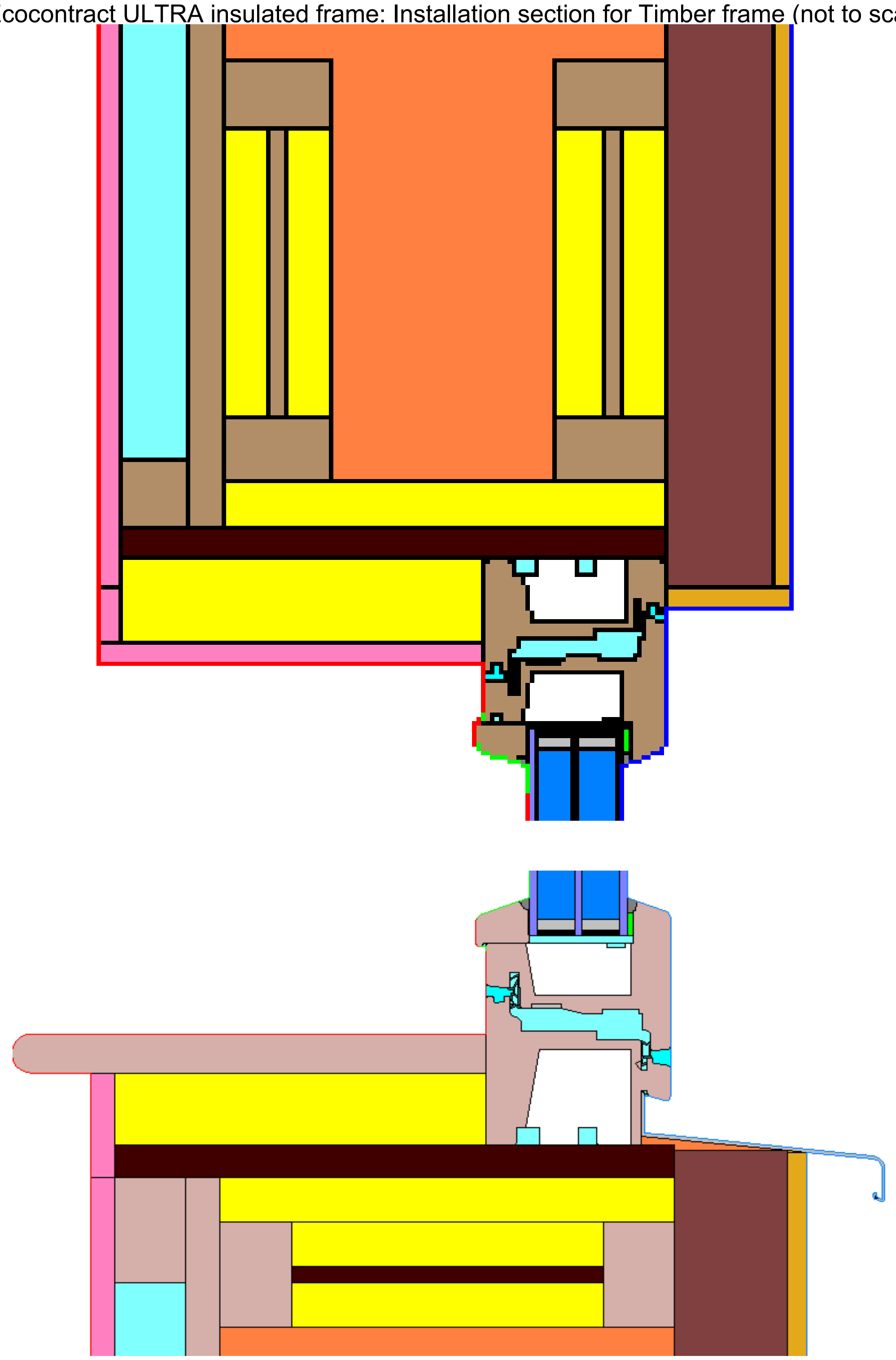
See page 7 for colour key

Ecocontract ULTRA insulated frame: Installation section for Cavity wall (not to scale)



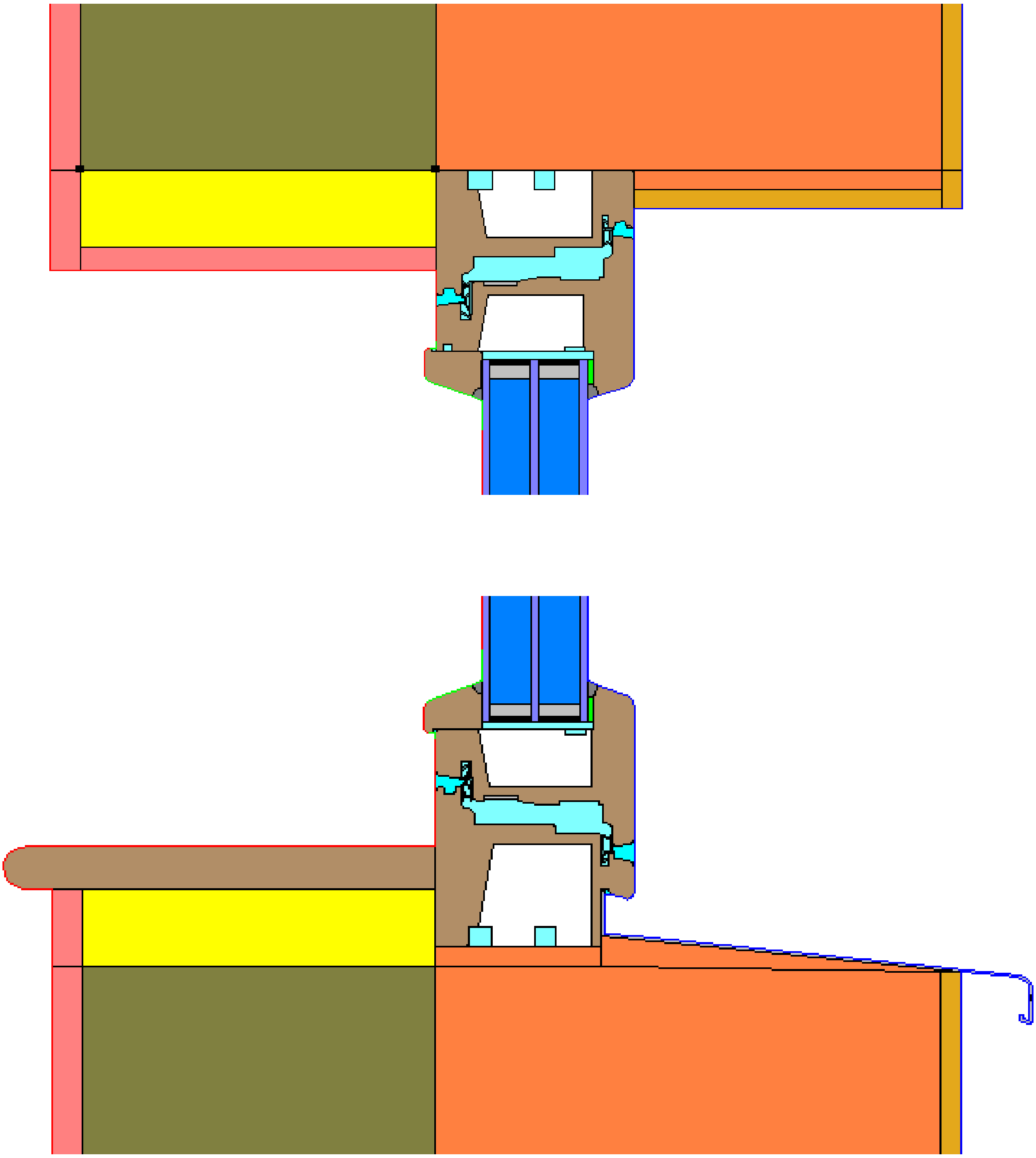
Cavity wall has a U-value of 0.118 Wm2K

Ecocontract ULTRA insulated frame: Installation section for Timber frame (not to scale)



Timber frame has a U-value of 0.126 Wm2K
See page 7 for colour key

Ecocontract ULTRA insulated frame: Installation section for Externally insulated wall (not to scale)



Externally insulated wall has a U-value of 0.139 Wm2K