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CLIENT REPORT

Energy performance assessment of Flutter Shutter

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Executive Summary

Flutter Shutter has commissioned BRE to assess the energy performance of their shutter and blind system using detailed calculation methods to determine U-values and resulting SAP performance.

The U-value assessments, to assess heat loss, were undertaken using Physibel Trisco software using the conventions given in:

- BR497 – Conventions for calculating linear thermal transmittance and temperature factors, Tim Ward, Graeme Hannah and Chris Sanders, BRE press, 2016.
- BS EN ISO 10077-1
- BS EN 673

The energy performance was assessed using RdSAP 2012 calculations on typical dwelling types.

The following results are provided:

- Predicted temperature profiles
- The U-values
- RdSAP performance

The results for the U-value of a standard single-glazed window measuring 1.23 m wide and 1.48 m tall are given in Table 3C and Table 3D. The key results are:

- For the unimproved single glazed window, the U-value is 5.4 W/m²K
- If the blind is present and if the shutter (tightness class 3) is closed for 50% of the time, the Uvalue of the single glazed window with Flutter Shutter is 2.1 W/m²K
- If the blind is present and if the shutter (tightness class 5) is closed for 50% of the time, the Uvalue of the single glazed window with Flutter Shutter is 1.9 W/m²K

The U-values have been calculated on the basis that the roller blind does not allow a significant quantity of long-wave infrared radiation to pass through it. This approach was confirmed as appropriate through correspondence with Lawrence Berkeley Laboratories and through some tests of the roller blind product.

This report includes a worksheet for calculating U-values of windows of a non-standard size.

Key drawings supplied by Flutter Shutter are reproduced in this report in addition to images of the thermal models. A description of the approach, together with results, are given in the sections that follow.

To determine the impact of Flutter Shutter on typical housing, a series of RdSAP 2012 calculations have been carried out and presented in this report. The most significant impact of Flutter Shutter occurs in older housing with single glazed windows. The biggest change can be seen in older housing (ca 1900) which displays an increase in the SAP score of 4.8. Flutter Shutter has the lowest impact on newer housing (1990s) with double glazed windows with an increase in the SAP score of around 2. Results of the RdSAP calculations are given in Tables 4A, 4B, 5, 6 and 7.

Guidance on how these results are to be used in an RdSAP 2012 calculation is given in Sections 3.4 and 3.5.

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1. Introduction

1.1 Background

Flutter Shutter Ltd. has commissioned BRE to assess the energy performance of their system incorporating a plastic blind and internal shutters/louvres.

This report presents the thermal performance assessment of a roller blind and shutter system supplied by Flutter Shutter, using detailed calculation methods to determine the U-values of the framing and the central-window U-value. The calculations are consistent with BR443 which sets out the conventions to calculate U-values as required for Part L of the Building Regulations for England and Wales. The system includes a shutter and transparent plastic blind over an existing window.

The transparent blind is guided to run alongside the existing window frame to create a relatively airtight space between the glass and the blind to reduce air leakage. In addition, the shutters provide an airspace between the blind and the interior of the dwelling which reduce heat loss.

The assessments were undertaken using Physibel Trisco software using the conventions given in:

BR497 – Conventions for calculating linear thermal transmittance and temperature factors, Tim Ward, Graeme Hannah and Chris Sanders, BRE press, 2016.

BS EN ISO 10077-1 and BS EN ISO 10077-2 BR443 – Conventions for calculating U-values

Thermal properties of materials and air spaces are based on:

- Manufacturer's declared values
- Values given in conventions document and standards
- The method in BS EN 673 to determine the central window U-value

Key drawings are reproduced in this report in addition to images of the thermal models. A description of the approach, together with results, are given in the chapters that follow.

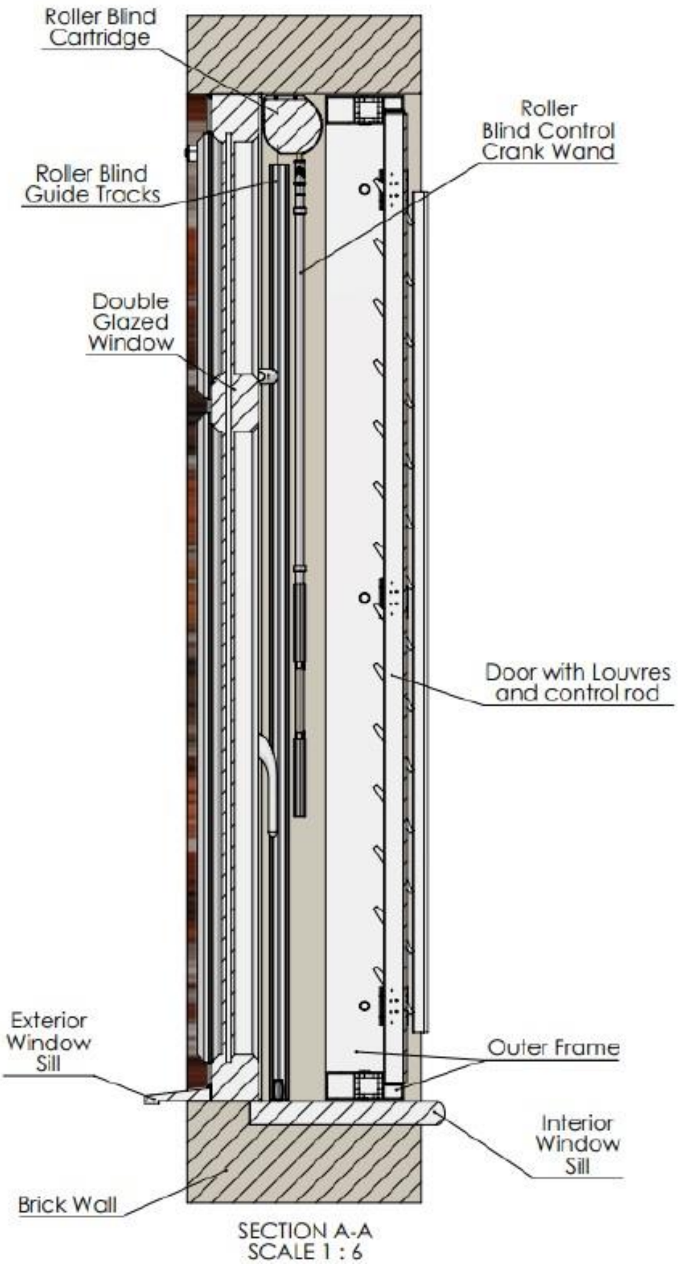
Based upon the calculated U-values, and upon a set of housing archetypes, a series of RdSAP 2012 calculations were carried out to assess the energy impact of the Flutter Shutter system. The RdSAP calculations took into account the shutters being open for part of the time and closed for part of the time.

The report concludes by describing how the product's performance can be recognised in EPCs and ECO4.

1.2 The shutter and blind system

Figure 1 shows an illustration of the Flutter Shutter blind system. Figures 2, 3 and 4 show elements of the Flutter Shutter system in more detail.

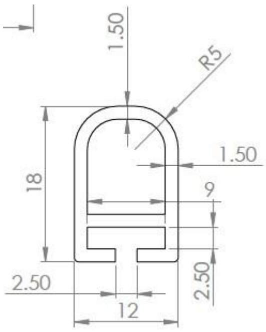
Figure 1: The blind system (cross-sectional view)



Source: IDS-306 Master Drawing, provided by Flutter Shutter

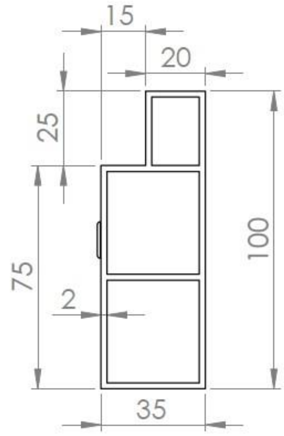
The roller blind, which is located close to the existing window, is about 1 mm thick and composed of crystal-clear thermal grade PVC.

Figure 2: A cross section of a control rod for holding the roller blind in place



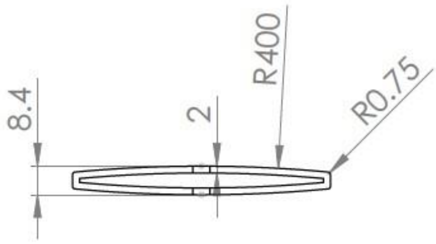
Source: Drawing provided by Flutter Shutter

Figure 3: Dimensions of the Flutter Shutter framing



Source: Drawing provided by Flutter Shutter

Figure 4: Cross-section of a shutter louvre



Note: The shutter louvre is composed of wood with a polypropylene coating finished with a UV lacquer.

Source: Drawing provided by Flutter Shutter

2. Description of the project

The aim of the project was to evaluate the energy performance of a window incorporating the Flutter Shutter and roller blind system using detailed calculation methods to determine their U-values.

2.1 Basis of the calculations

Detailed thermal modelling software has been used to model the heat transfer through the glass, blind and framing. The assessment took into account typical material properties as listed in ISO 10456. The airspace between the blind and the existing glass was assessed using BS EN 673. The impact of the shutters was assessed using the method in BS EN ISO 10077-1.

Calculations were conducted using guidance published in BR497 and other relevant standards. The calculations were carried out using Physibel Trisco software. The thermal values that were assigned to the materials are given in Table 1, which indicates the thermal conductivity of each material together with the reference sources. Table 2 indicates the temperatures and surface thermal resistances that were used in the calculations.

Once the U-values had been calculated, RdSAP 2012 calculations were carried out on typical house designs in order to determine the overall impact of the Flutter Shutters.

The RdSAP 2012 calculations were carried out on the basis that the shutters/louvres were open for 50% of the time (to represent daytime use) and closed for 50% of the time (to represent nighttime use).

2.2 Properties of materials and air spaces

Table 1 gives properties of materials used in the thermal simulations. Table 2 gives boundary conditions used in the calculations.

Table 1: Thermal conductivity of each material used in the thermal model

Material	Thermal conductivity W/m·K	Source
Roller blind, crystal clear PVC	0.17	BS EN ISO 10077-2, Annex D
Wooden window frame	0.13	BS EN ISO 10456
Flutter shutter frame	0.17	BS EN ISO 10077-2, Annex D
Glass, existing window	1.0	BS EN ISO 10077-2, Annex D

Table 2: Boundary conditions used in the thermal modelling

	Value	Source
Internal temperature	20°C	-
External temperature	0°C	-
Internal surface resistance	0.13 m²K/W	BS EN ISO 10077-2, Annex E
External surface resistance	0.04 m²K/W	BS EN ISO 10077-2, Annex E
Sheltered surface resistance	0.20 m²K/W	BS EN ISO 10077-2, Annex E

2.3 Classes of shutter

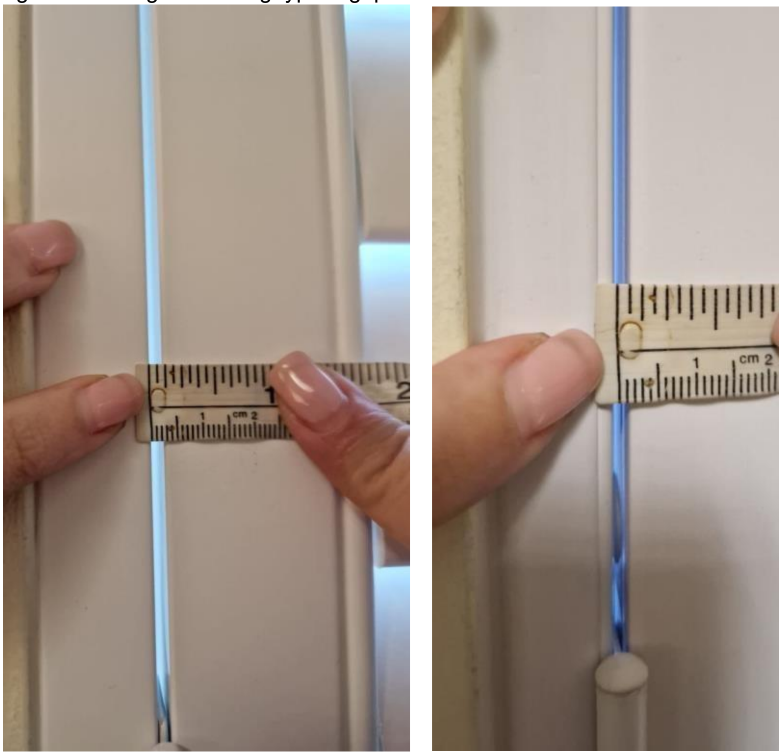
Annex G and Annex H of BS EN ISO 10077-1 describe how to assess the thermal resistance of shutters and of airspaces enclosed by shutters. As part of the calculation procedure, shutters are categorised into shutter classes, where the shutter class depends upon the air gaps above, below and at the sides of the shutter.

Flutter Shutter's observations are that the typical gap size around the shutter is in the range 1mm to 3mm. This would imply that the b_{sh}-value (discussed in Annex H of ISO 10077-1) should be in the range 8 mm to 12 mm, implying a shutter permeability class of 3 or 5 (Shutter Class 5 being the more appropriate option). This gap size is confirmed by some images of typical gap sizes shown in Figure 4A.

Shutter permeability class (Annex H of ISO 10077-1)	Description	Thermal resistance
1	very high permeability	0.08 m²K/W
2	high air permeability	$0.25\ R_{sh} + 0.09$ m²K/W
3	average air permeability	$0.55\ R_{sh} + 0.11$ m²K/W
4	low air permeability	$0.80\ R_{sh} + 0.14$ m²K/W
5	tight	$0.95\ R_{sh} + 0.17$ m²K/W

Note: Table G.2 of ISO 10077-1 gives a value of 0.20 m²K for the R_{sh}-value of wooden shutters

Figure 4A: Images showing typical gap sizes around the shutters



2.4 The layers of the window

Table 3 shows the layers of the window and their assigned thermal conductivity values.

Table 3: Layers of the window (for use in the thermal modelling)

	thickness, mm	thermal conductivity, W/m.K	emissivity
existing glass	4	1.0	0.89

gap between existing glass and roller blind, below central divider, R=0.19, BS EN 673 assumes PVC is opaque to long wave infrared	73	0.384	-
gap between existing glass and roller blind, above central	123	0.647	-
divider, R=0.19, BS EN 673 assumes PVC is opaque to long wave infrared			
gap between existing glass and shutter, below central divider, if roller blind is absent, R=0.11 if shutter class 3 R=0.17 if shutter class 5	198	1.165 (if shutter class 5) 1.800 (if shutter class 3)	
gap between existing glass and shutter above central divider, if roller blind is absent, R=0.11 if shutter class 3 R=0.17 if shutter class 5	248	1.459 (if shutter class 5) 2.248 (if shutter class 3)	
clear PVC roller blind	1	0.17	0.90
gap between roller blind and shutter, R=0.11 if shutter class 3 R=0.17 if shutter class 5, BS EN ISO 10077-1	124	0.729 (if shutter class 5) 1.127 (if shutter class 3)	-
Shutter (25 mm wood) R = 0.95 * 0.20 if shutter class 5 R = 0.55 * 0.20 if shutter class 3 0.20 taken from ISO 10077-1	25	0.132 (if shutter class 5) 0.227 (if shutter class 3)	0.90
TOTAL thickness, below central divider	227	-	-
TOTAL thickness, above central divider	277	-	-

2.5 Thermal resistance of the air gap between the glass and the roller blind

Figure 5 shows a calculation by the BRE U-value calculation software to BS EN 673. It provides a thermal resistance for the 73 mm air space between the existing glass and the PVC roller blind. It indicates that the thermal resistance of this air space is 0.190 m²K/W. In these calculations, the PVC roller blind was assumed to have an emissivity of 0.9 and to be opaque to long-wave infrared radiation. Glass (e.g. the glass of the existing window) is assigned an emissivity of 0.89.

The calculations have been carried out on the basis that the PVC roller blinds do not allow significant quantities of long-wave infrared radiation to pass through them. This approach was based on advice from Lawrence Berkeley Laboratories (LBL), USA, that thin films used with glazing have generally been found to be impervious to long-wave infrared. [Ref. 8]

In order to provide further justification for this approach, some tests were carried out, which are described in Appendix B. These tests supported the advice from LBL that PVC film is largely impervious to longwave infrared radiation.

A thermal imaging camera was used to view some hot and cold objects, where the PVC film was placed between the thermal imaging camera and the hot/cold objects. The PVC film was positioned so that it covered only half of these objects. This enabled a side-by-side comparison between the infrared radiation coming directly from the objects and the infrared radiation coming if the PVC film was in the way. A film which is transparent to infrared radiation would not affect the thermal images of the hot and cold objects, but a film which is opaque to infrared radiation would prevent the infrared camera from seeing the hot and cold objects.

Figure B3, B.6, B.7 and B.8 show views of the hot objects, where the PVC roller blind covers roughly half of the objects. These hot objects are of a temperature close to 100°C (cups containing very hot water). The images show that the infrared camera is unable to see through the PVC film, while the ordinary camera is able to see through the PVC.

Figures B.4, B.9, B.10 show views of the cold objects, where again the PVC roller blind covers roughly half of the objects. These cold objects are at a temperature of around 10°C (cups containing cold water). The images show that the infrared camera is unable to see through the PVC film, while the ordinary camera can see through the PVC.

These tests, therefore, showed that the PVC film, supplied by Flutter Shutter, is impervious to long wave infrared radiation. The fact that the PVC film prevents infrared radiation from passing through it, leads to less heat loss by radiation, thereby leading to a lower (i.e. better) U-value than that which would be achieved if the film allowed infrared radiation to pass through it.

Figure 5: An image from the BRE U-value calculation software being used to assess glazing

Single
Double
Triple
Quad

Layer	Description	d (mm)	λ glass	ε1	ε2	Gas	% fill	R layer
	Rsi							0.13
1	Shutter	25	0.132					0.189
2	Gas space	124		0.9	0.9	Air		0.185
3	PVC	1	0.17					0.006
4	Gas space	73		0.9	0.89	Air		0.190
5	Glass	4	1					0.004
	Rse							0.04

Same gas space — Total thickness: 227 — Total resistance: 0.744

Calculate glazing U-value — Centre-pane U-value: 1.344

If the thickness of the air space between the glass and the roller blind is considered to be 73 mm, then its equivalent thermal conductivity is 0.3842 W/m·K [i.e. 0.073 m ÷ 0.190 m²K/W].

Although the above calculation also gives a thermal resistance for the 124 mm air space between the shutter and the roller blind, the thermal resistance for the 124 mm space is not valid because it neglects the air permeability of the shutter. The 124 mm space is therefore assessed using the method in Annex G and H of BS EN ISO 10077-1 as described below.

2.6 Thermal resistance of the shutters and the air space behind the shutters

Annex G of BS EN ISO 10077-1 gives guidance on the thermal resistance effects of closed shutters. This Annex also recommends, in table G.2, a value of 0.20 m²K/W for R_{sh} for timber shutters of thickness 25 mm.

Annex H of 10077-1 gives guidance on assessing the permeability of shutters. Since the typical gap size around the shuttering is 1 – 3 mm, the shutter is likely to be considered ‘tight’ (Class 4 or 5) according to the criteria of this Annex. The relationship between the gaps around the top, sides and bottom of the shutter arrangement and the shutter tightness classes is described in Table H.1 of ISO 10077-1:2005 and also in Section 4.1 of EN 13125:2001.

The thermal resistance attributable to the shutter and air gap together was determined to be:

- (0.55 × 0.20 m²K/W) + 0.11 m²K/W = 0.22 m²K/W, if shutter is class 3 (‘average’ permeability, with gaps around the shuttering of approximately 3 mm)
- (0.95 × 0.20 m²K/W) + 0.17 m²K/W = 0.36 m²K/W, if shutter is class 5 (‘tight’ shutters)

With regard to thermal modelling, the shutters are considered to have the following thermal resistances:

- For Shutter Class 3, the thermal resistance of the 25 mm wooden shutter is considered to be
  0.55 × 0.20 m²K/W, and for a thickness of 25 mm this corresponds to a thermal conductivity of 0.227 W/m.K. [i.e. 0.025 / (0.55 × 0.20 m²K/W)]
- For Shutter Class 5, the thermal resistance of the 25 mm wooden shutter is considered to be 0.95 × 0.20 m²K/W, and for a thickness of 25 mm this corresponds to a thermal conductivity of
  0.1316 W/m·K [i.e. 0.025 m ÷ (0.95 × 0.20 m²K/W)].

The assumptions in the above calculations are as follows:

- The shutters/louvres, when closed, are considered ‘average’ or ‘tight’ (corresponding to Shutter Class 3 or Shutter Class 5 in Annex H of BS EN ISO 10077-1)
- The shutters are predominantly composed of PVC.

In the RdSAP 2012 calculations, for assessing the overall energy performance of typical dwellings, the shutters were considered to be open for 50% of the time and closed for 50% of the time.

2.6.1. Additional note on Shutter Airtightness Class 5

It is possible to justify a higher airtightness class for the shutters, as Annex G of BS EN ISO 10077-1 also provide an alternative approach: “An alternative method to establish that a shutter is class 5 is to verify by measurement that the air flow through the shutter does not exceed 10 m³/(h.m²) under a pressure drop of 10 Pa”.

2.7 The U-value of the central part of the window with blind and shutters closed

On the basis of these calculations, the U-value at locations close to the centre of the window would be expected, on the basis of the above calculation methods, to be

- 1 ÷ (0.04 + {0.004÷1.0} + 0.190 + {0.001÷0.17} + 0.22 + 0.13), or <u>1.70 W/m²K</u>, for shutter class 3 (‘average’)
- 1 ÷ (0.04 + {0.004÷1.0} + 0.190 + {0.001÷0.17} + 0.36 + 0.13), or <u>1.37 W/m²K</u>, for shutter class 5 (‘tight’)

2.8 The thermal models where shutters and roller blinds are both used

Thermal modelling has been carried out based on the internal application of the Flutter Shutter plastic blind to a typical single-glazed solid timber frame sash window. This thermal modelling was aimed at determining a U-value for the central part of the window for a single-glazed window of standard size measuring 1.23 m by 1.48 m with a horizontal divider. Appendix A shows a selection of the thermal models for these cases (applicable when the shutters are closed).

2.9 The thermal models where shutters are used but not roller blinds

Thermal modelling has been carried out based on the internal application of the Flutter Shutter system <u>without</u> the plastic blind to a typical single-glazed solid timber frame sash window. This thermal modelling was aimed at determining a U-value for the central part of the window for a window of standard size measuring 1.23 m by 1.48 m with a horizontal divider. Appendix A shows the thermal models for these cases as well as the cases where both shutters and roller blinds are used (applicable when the shutters are closed).

2.10 Effective U-value to allow for curtains in RdSAP calculations

The RdSAP methodology indicates that effective U-values are to be used to allow for curtains, as follows:

> The effective window, roof window or rooflight U-value to be used in worksheet (27) and (27a) takes account of the assumed use of curtains/blinds; it is calculated using the formula:
>
> $$U_{w,effective} = \frac{1}{\frac{1}{U_w} + 0.04} \qquad (2)$$
>
> where U_w is the window U-value calculated or measured without curtains/blinds. This correction is based on a curtain/blind resistance of 0.08, but this is halved on the assumption that curtains/blinds will be open approximately half the time.

The U-values reported here do <u>not</u> include the effect of curtains, but the RdSAP calculations do.

3. Findings

3.1 Results

The following results are provided:

- Predicted temperature profiles (in Appendix A)
- The U-value of a window of standard size
- A method for calculating U-values of windows of other sizes
- Typical impacts on RdSAP ratings for a set of housing archetypes
- Verification that the PVC roller blind does not allow longwave infrared radiation to pass through (in Appendix B)

3.2 U-values

3.2.1. Results for the central portion of the window

The central portion of the window includes glazing and may include a closed shutter and/or a closed blind. The U-value here will depend on whether the shutters and blind are open or closed. The U-value of the central portion of the window is given in Table 3A. The U-values of the framing are given in Table 3B.

Table 3A The U-value of the central portion of window, taking account of blind and shutters

Glazing of existing window	Blind	Shutter	U-value of central portion of window if Shutter Class is 3	U-value of central portion of window if Shutter Class is 5
Single	Closed	Closed	1.6945	1.3700
Single	Open	Closed	2.5373	1.8730
Single	Closed	Open	2.7025	2.7025
Single	Open	Open	5.7458	5.7458
Double	Closed	Closed	1.3726	1.1517
Double	Open	Closed	1.8779	1.4875
Double	Closed	Open	1.9669	1.9669
Double	Open	Open	3.2008	3.2008

Table 3B The U-value of the framing of the window, taking account of blind and shutters

Glazing of existing window	Blind	Shutter	U-value of window head	U-value of window jambs	U-value of transom	U-value of window sill
Single	Closed	Closed, class 3	1.0963	0.9396	1.3083	1.2288
Single	Closed	Closed, class 5	1.0504	0.8421	1.1100	1.1700
Single	Closed	Open	1.6200	1.6125	1.7088	1.9125

3.2.2. Results for a standard window measuring 1.23 m wide and 1.48 m tall

The results for the U-values are given in Table 3C and Table 3D for a standard single-glazed or doubleglazed window measuring 1.23 m wide and 1.48 m tall, where the U-values are based on a retrofit to a single-glazed or double-glazed window. Some examples of U-value calculations are given in Appendix C.

Table 3C: A table of U-values, based on shutter class 3 (‘average’ permeability)

Blind	Shutter	U-value (W/m^2.K) if applied to single glazed window of standard size	U-value (W/m^2.K) if applied to double glazed window of standard size
Open	Open	5.429	3.100
Open	Closed 50% of the time	3.921*	2.542
Open	Closed	2.413	1.809
Closed	Open	2.559	1.890
Closed	Closed 50% of the time	2.084	1.618
Closed	Closed	1.609	1.316

*The U-value is midway between the U-value for the case where the blinds are closed all the time and the U-value for the case where the blinds are open all of the time.

Note: the U-value for a case involving double glazing (U_d) can be derived from the U-value for the corresponding case involving single glazing (U_s) by the following formula: $U_d = 1 \div [(1 \div U_s) + 0.1384]$

Table 3D: A table of U-values, based on shutter class 5 (‘tight’ shutters)

Blind	Shutter	U-value (W/m^2.K) if applied to single glazed window of standard size	U-value (W/m^2.K) if applied to double glazed window of standard size
Open	Open	5.429	3.100
Open	Closed 50% of the time	3.615*	2.410
Open	Closed	1.800	1.441
Closed	Open	2.559	1.890
Closed	Closed 50% of the time	1.938*	1.528
Closed	Closed	1.316	1.113

*The U-value is midway between the U-value for the case where the blinds are closed all the time and the U-value for the case where the blinds are open all of the time.

Note: the U-value for a case involving double glazing (U_d) can be derived from the U-value for the corresponding case involving single glazing (U_s) by the following formula: $U_d = 1 \div [(1 \div U_s) + 0.1384]$

Note: The U-values in the above tables do not include the effect of curtains as the reduced heat loss due to curtains is normally taken into account within the RdSAP methodology.

Note: The U-values have been calculated on the basis that the roller blinds do not allow significant quantities of infrared radiation to pass through. This is justified both by correspondence with Lawrence Berkeley Laboratories and by tests which are described in Appendix B.

3.2.3. A worksheet for windows of a non-standard size

Table 3C and Table 3D are based on windows of a standard size, measuring 1480 mm high by 1230 mm wide. For windows of other sizes, the following worksheet may be used to calculate the U-value of the overall window: Examples of worksheets which have already been filled in are given in Appendix C.

Worksheet for calculating U-value of window (for any window size)

Height of window, m					
Width of window, m					
Area of window, m²	(1)	×	(2)	=	
Width of frame, mm	(typically 40 mm)				
Width of frame, m	(4)	÷	1000	=	
Area of window head	[(2) - (5)]	×	(5)		

(1) (2) (3) (4) (5)

(6)
(7)

(8)

(9)

Area of window jambs	[(1) - (5)]	×	2 × (5)		
Width of transom, mm	(typically 40 mm)				
Width of transom, m	(8)	÷	1000	=	
Area of transom, m2	(2) – [2 × (9)]	×	(9)	=	
Area of sill	[(2) – (5)]	×	(5)	=	
Glazed area	(3) – (6) – (7) – (10) – (11)			=	
U-value of window head	See Table 3B				
U-value of window jambs	See Table 3B				
U-value of transom	See Table 3B				
U-value of window sill	See Table 3B				
U-value of glazed area	See Table 3A				
U*area of window head	(6)	×	(13)	=	
U*area of window jambs	(7)	×	(14)	=	
U*area of transom	(10)	×	(15)	=	
U*area of sill	(11)	×	(16)	=	
U*area of glazed area	(12)	×	(17)	=	
Heat loss per degree	(18) + (19) + (20) + (21) + (22)			=	
U-value of window	(23)	÷	(3)	=	

(10) (11) (12) (13)

(14)

(15) (16) (17)

(18)

(19)

(20) (21) (22)

(23)
(24)
Note: the U-value for a case involving double glazing (U_d) can be derived from the U-value for the corresponding case involving single glazing (U_s) by using the following formula: $U_d = 1 \div [(1 \div U_s) + 0.1384]$

3.2.4. Resulting U-value

The above worksheet can be used to calculate the U-value of a whole window, with or without the components of Flutter Shutter, for any of the configurations listed in Table 3D. If the shutters are, however, open for 50% of the time and closed for 50% of the time then the U-value will be midway between the U-value for the shutters being closed and the corresponding U-value for the shutters being open.

3.3 RdSAP/EPC review

The increase in RdSAP rating resulting from the use of Flutter Shutter will depend on a number of factors, including the following:

- The window area of the property
- The size and built form of the property (e.g. mid-terraced, semi-detached/end-terraced, detached)
- The age band of the property (age bands are discussed in Appendix S of SAP 2012)
- The heating system (mains gas non-condensing boiler might be typical)
- Whether the walls have been insulated (e.g. cavity wall insulation) after the property was built
- The existing glazing (e.g. single glazing, double glazing)
- The proportion of the time for which the shutters/louvres and blinds are closed

The RdSAP cases were selected, in consultation with Flutter Shutter, after consideration of the most typical age bands, the most typical house types and glazing.

The cases that were studied were:

- The base case, with uninsulated cavity walls and single glazing, where the dwelling has a semidetached/mid-terraced design, where U-value of roof = 0.13 W/m²K (i.e. 300 mm loft insulation), ground floor area of 22 m², and exposed perimeter of 18 metres
- A dwelling similar to the base case but mid-terraced house (to assess impact of built form and the higher glazing/wall ratio associated with mid-terraced housing)
- A dwelling similar to the base case but detached (to assess impact of built form and the impact of a large wall area)
- A dwelling similar to the base case but cavity is considered to be insulated as a retrofit, still single glazed, semi-detached [impact of insulation, but without double glazing]
- A dwelling similar to the base case but double glazed, still no cavity insulation, semi-detached (to assess impact of double glazing, but without changes to insulation)
- A dwelling similar to the base case, but older property, single glazed, semi-detached/mid-terraced

(to assess impact of age / insulation with reference to dwelling age)

- A dwelling similar to the base case, but 1990's property, cavity insulated, double-glazed (to assess impact of existing double glazing and insulation)

The above cases were used as the basis of the RdSAP2012 calculations presented in Table 4A and Table 4B. The RdSAP2012 calculations, shown in Tables 4A and 4B, were carried out on the basis that the shutters/louvres were open for 50% of the time and closed for 50% of the time.

Table 4A: RdSAP 2012 calculations – Shutter Class 3

case:	1	2	3	4	5	6	7
feature being examined:	base case	built form	built form	cavity insul.	double glazed	pre war	1990s
built form	semi	mid-terr	detach	semi	semi	semi	semi
year of construction	1950	1950	1950	1950	1950	1900	1993
ground floor area, m²	22	40	50	22	22	22	22
U-value of ground floor	0.900	0.423	0.750	0.900	0.900	0.900	0.45
Uwall*	1.5	1.5	1.5	0.7	1.5	1.7	0.45
type of glazing	single	single	single	single	double	single	double
Uwindows (no shutters, no blind)	5.429	5.429	5.429	5.429	3.1	5.429	3.1
g-value	0.85	0.85	0.85	0.85	0.76	0.85	0.76
RdSAP rating (no shutters, no blind)	47.7	68.22	53.17	55.77	50.93	46.16	63.42
Uwindows (shutters, class 3, closed 50% of the time, blind closed)	2.084	2.084	2.084	2.084	1.618	2.084	1.618
g-value	0.76	0.76	0.76	0.76	0.68	0.76	0.68
RdSAP rating (shutters, class 3	51.77	72.31	56.54	59.92	52.75	50.74	65.33
case:	1	2	3	4	5	6	7
closed 50% of the time, blind closed)							
Annual bill, £	880.85	590.81	1121.97	731.95	862.92	898.90	633.11
Space heating cost	574.2	310.88	778.05	424.67	556.21	592.32	324.88

Table 4B: RdSAP2012 calculations – Shutter Class 5

case:	1	2	3	4	5	6	7

feature being examined:	base case	built form	built form	cavity insul.	Double glazed	pre war	1990s
built form	semi	mid-terr	detach	semi	semi	semi	semi
year of construction	1950	1950	1950	1950	1950	1900	1993
ground floor area, m²	22	40	50	22	22	22	22
U-value of ground floor	0.900	0.423	0.750	0.900	0.900	0.900	0.45
Uwall	1.5	1.5	1.5	0.7	1.5	1.7	0.45
type of glazing	single	single	single	single	double	single	double
g-value	0.85	0.85	0.85	0.85	0.76	0.85	0.76
Uwindows (no shutters, no blind)	5.429	5.429	5.429	5.429	3.1	5.429	3.1
RdSAP rating (no shutters, no blind)	47.7	68.22	53.17	55.77	50.93	46.16	63.42
Uwindows (shutters, class 5, closed 50% of the time, blind closed)	1.938	1.938	1.938	1.938	1.528	1.938	1.528
g-value	0.76	0.76	0.76	0.76	0.68	0.76	0.68
RdSAP rating (shutters, class 5 closed 50% of the time, blind closed)	51.97	72.52	56.71	60.14	52.88	50.97	65.47
Annual bill, £	877.20	586.25	1117.46	728.02	860.48	895.02	630.53
Space heating cost	570.54	306.29	773.54	420.72	553.76	588.44	322.28

Notes to Table 4: Designs are based on standard examples of house designs provided by colleagues. RdSAP 2012 Appendix S (Tables S1 and S6) gives U-values of walls for properties of various age bands, and these tables were used as the basis for assessing U-values of walls.

The following conditions were used for the RdSAP calculations:

- Regular non-condensing boiler, post-1998, mains gas, efficiency from Table 4b of SAP 2012
- Programmer, room thermostat and TRVs
- Water heating from main boiler
- Secondary heating by electric room heaters
- Roofs have a U-value of 0.13 W/m²K (i.e. 300 mm of loft insulation)
- Floors are slab-on-ground solid floors
- SAP default levels of thermal bridging at junctions

- Doors are solid with a U-value of 3.0 W/m²K
- Natural ventilation with intermittent extract fans
- Existing single glazed windows should NOT be considered draught-proofed
- Blinds are assumed to have an impact on the solar g-factors of the windows equivalent to a single pane of glass

- The above U-values do not include the effect of curtains, however this is not a problem because RdSAP includes a correction for the use of curtains

The typical impacts on the RdSAP rating of the Flutter Shutter system for various situations are shown in Table 5.

Table 5: Typical impact of Flutter Shutter (shutters and blinds combined) on RdSAP rating

	Typical increase due to Flutter Shutter and blinds combined	
	Shutters close 50% of the time and blind closed compared with initial window Table 4A (Shutter Class 3)	Shutters close 50% of the time and blind closed compared with initial window Table 4B (Shutter Class 5)
Base case	4.07	4.27
Mid-terraced house	4.09	4.3
Detached house	3.37	3.54
Cavity wall insulation	4.15	4.37
Double glazing	1.82	1.95
Older housing (ca 1900)	4.58	4.81
Newer housing (1990s)	1.91	2.05

Note: The typical increase in RdSAP rating is based on the Flutter Shutter system being added to single glazed windows, except in the “Double glazing” case, which gives a typical increase in RdSAP where the existing windows are double glazed.

Table 5 shows the impact Flutter Shutter can have on increasing RdSAP scores in older housing. The greatest impact occurs in older housing with single glazed windows. The biggest change can be seen in older housing (ca 1900) which has an increase in the RdSAP score of about 4.8. Flutter Shutter has the lowest impact on Case 5 with double glazed windows with an increase in the RdSAP score of about 2.

Table 6: Typical impact of Flutter Shutter (shutters and blinds combined) on RdSAP 2012 annual bill

	Typical increase due to Flutter Shutter and blinds combined	
	Shutters close 50% of the time and blind closed compared with initial window Table 4A (Shutter Class 3)	Shutters close 50% of the time and blind closed compared with initial window Table 4B (Shutter Class 5)
Base case	£71.63	£75.28
Mid-terraced house	£87.21	£91.77
Detached house	£86.96	£91.47
Cavity wall insulation	£75.75	£79.68
Double glazing	£32.83	£35.27
Older housing (ca 1900)	£81.99	£85.87

Newer housing (1990s)	£34.85	£37.43

Note: The typical increase in RdSAP rating is based on the Flutter Shutter system being added to single glazed windows, except in the “Double glazing” case, which gives a typical increase in RdSAP where the existing windows are double glazed.

Table 7: Typical impact of Flutter Shutter (shutters and blinds combined) on RdSAP 2012 space heating cost

	Typical increase due to Flutter Shutter and blinds combined	
	Shutters close 50% of the time and blind closed compared with initial window Table 4A (Shutter Class 3)	Shutters close 50% of the time and blind closed compared with initial window Table 4B (Shutter Class 5)
Base case	£71.6	£75.26
Mid-terraced house	£87.55	£92.14
Detached house	£87.11	£91.62
Cavity wall insulation	£76.1	£80.05
Double glazing	£32.93	£35.38
Older housing (ca 1900)	£82.22	£86.1
Newer housing (1990s)	£34.91	£37.51

Note: The typical increase in RdSAP rating is based on the Flutter Shutter system being added to single glazed windows, except in the “Double glazing” case, which gives a typical increase in RdSAP where the existing windows are double glazed.

3.4 Incorporating results into RdSAP calculations for EPC purposes

RdSAP2012 contains default U-values for windows that DEAs (Domestic Energy Assessors) use when producing EPCs. SAP Conventions, specifically 3.10 in this case, allows these defaults to be overwritten provided a BFRC (British Fenestration Rating Council) Energy Rating or manufacturer’s data is available. The U-value data given in this report can be used by DEAs when undertaking RdSAP calculations.

Specifically, DEAs should use the highlighted U-values from Table 3D or a Class 5 shutter (tight permeability) where the blind is closed, and the shutter is open 50% of the time. The appropriate solar gvalues (see Table 4B) should also be used.

To comply with SAP Conventions, DEAs need to identify what they found in the dwelling during the survey. The Flutter Shutter product needs to be identified by a clear feature like a label, etc. DEAs will need to photograph the feature (label or other identifier) and attach it to the documentation forwarded to the Accreditation scheme for QA. If a DEA is uncertain then the default U-values should be used. The Flutter Shutter product meets glazing indicators therefore should be implemented as such under secondary glazing as it is an independent, fixed measure.

3.5 Guidance for ECO4

For the inclusion of innovative measures in ECO4, the ECO4 scheme states:

“ECO4 includes a mechanism designed to support the delivery of innovative measures where benefits and improvements may not otherwise be captured through current partial project and full project scores, via the 'New Measures and Products (NMAP)’ routes.”

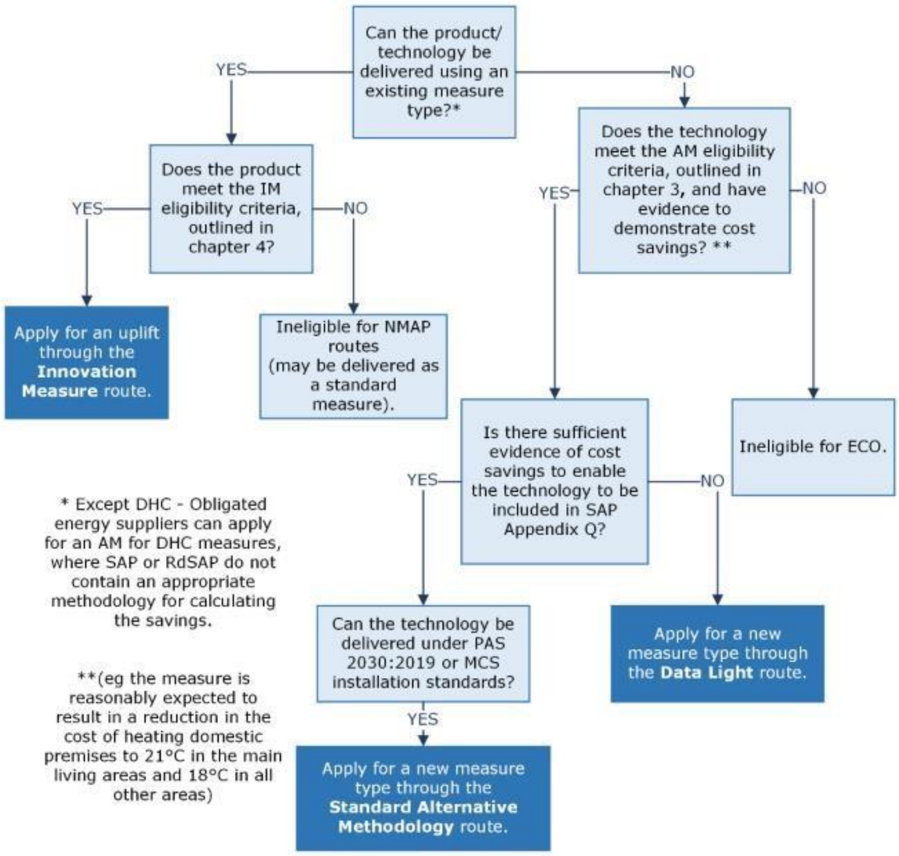
There are three routes for innovative measures to become approved for ECO4:

- Standard Alternative Methodology (SAM) route
- Data Light Measures (DLM) route
- Innovation Measures (IM) route

For all routes, evidence is required about the energy saving potential of the innovative measure. Evidence similar to that required for SAP Appendix Q is likely to be sufficient. The Data Light Measures (DLM) route has less stringent evidence requirements.

In their guidance document, Ofgem provide this Eligibility Flowchart, to help to decide which route to take.

Figure 1: Eligibility flowchart for NMAP routes



3.5.1. Standard Alternative Methodology (SAM) route

This is a route for awarding a new measure type, and not currently recognised in SAP nor deliverable on the scheme under an existing standard measure type.

The ECO4 scheme states: “The evidence of cost savings must be of a similar level as required for inclusion in SAP Appendix Q as a space heating measure.”

This implies that if the innovative measure undergoes analysis and validation which is similar to that required for SAP Appendix Q, the evidence will be sufficient for the ECO4 scheme. However, the decision to accept or reject the measure for inclusion in ECO4 is at the discretion of the ECO4 scheme.

The ECO4 scheme also states: “A successful application will result in a new measure type and partial project score being created.”

After the innovation measure is granted a successful application, it is recognised in the ECO4 scheme. The partial project score (PPS) is used to award credit to energy suppliers, in the situation where a retrofit project has only been partially delivered. The PPS is based on modelled energy savings for the measure, and Ofgem would arrange for a consultancy such as BRE to provide the modelling of the energy savings. Where there are bundled energy saving measures in a “full project”, the partial project score is not used, instead a full project score is calculated based on improvements to the SAP rating after the full project retrofit is completed.

3.5.2. Data Light Measures (DLM) route

This requires a lower level of evidence, but is capped at 1,250 measures per annum.

3.5.3. Innovation Measures (IM) route

This route is meant for innovative measures that can demonstrate an improvement over comparable measures currently deliverable under ECO4. To incentivise energy supplier uptake of innovative measures, the measure is awarded an uplift to its ECO4 score, either 25% (standard) or 45% (substantial) uplift.

Relevant aspects for Flutter Shutter could be these selected requirements:

- Be deliverable under an existing ECO4 measure type (this may be under upgrades to double glazing, or under improved double glazing: the ECO4 scheme would determine if it is eligible).
- Be energy-saving
- Be listed in Annex A to PAS 2030:2019, and not be a heat generator.

After a measure is approved, Ofgem will publish a description of the innovation measure, the date on which it was approved, and whether it is a standard or substantial innovation measure.

3.5.4. Further information

Further information about ECO4 New Measures can be found on the Ofgem website. See references below.

ECO4 Innovation: New Measures and Products https://www.ofgem.gov.uk/eco4-innovation-new-

measures-and-products

ECO Guidance for New Measures and Products

“The ECO4 Guidance: New Measures and Products (NMAP) provides guidance on the Innovation Measure, Standard Alternative Methodology, and Data light Measure routes.”

https://www.ofgem.gov.uk/publications/energy-company-obligation-2022-26-eco4-guidance-newmeasures-and-products

4. Conclusion and recommendations

Flutter Shutter has commissioned BRE to assess the thermal performance of the blind system, with and without a roller blind, using detailed calculation methods to determine their U-values and RdSAP energy performance.

The U-value assessments were undertaken using Physibel Trisco software using the conventions given in:

- BR497 – Conventions for calculating linear thermal transmittance and temperature factors, Tim Ward, Graeme Hannah and Chris Sanders, BRE press, 2016.
- BS EN ISO 10077-1
- BS EN 673

The energy performance was assessed using RdSAP 2012 calculations on typical dwelling types.

The following results are provided:

- Predicted temperature profiles
- The U-values
- RdSAP performance

The results for a standard single-glazed window measuring 1.23 m wide and 1.48 m tall are given in Table 3B and Table 4D. The key results are:

- For the unimproved single glazed window, the U-value is 5.4 W/m²K
- If the blind is present and if the shutter (tightness class 3) is closed for 50% of the time, the Uvalue of the single glazed window with Flutter Shutter is 2.1 W/m²K
- If the blind is present and if the shutter (tightness class 5) is closed for 50% of the time, the Uvalue of the single glazed window with Flutter Shutter is 1.9 W/m²K

The U-values have been calculated on the basis that the roller blind does not allow a significant quantity of long-wave infrared radiation to pass through it – this approach has been confirmed by testing a sample of the product.

The U-values have been calculated on the basis that the roller blind does not allow a significant quantity of long-wave infrared radiation to pass through it. This approach was confirmed as appropriate through correspondence with Lawrence Berkeley Laboratories and through some tests of the roller blind product which are presented in Appendix B.

This report includes a worksheet for calculating U-values of windows of a non-standard size.

Key drawings supplied by Flutter Shutter are reproduced in this report in addition to images of the thermal models. A description of the approach, together with results, are given in the chapters that follow.

To determine the impact of Flutter Shutter on typical housing, a series of RdSAP calculations have been carried out and presented in this report. The calculations were carried out on the basis that the blinds were open for 50% of the time (to represent daytime use) and closed for 50% of the time (to represent nighttime use). The most significant impact of Flutter Shutter occurs in older housing with single glazed windows. The biggest change can be seen in older housing (ca 1900) which displays an increase in the RdSAP score of 4.8. Flutter shutter has the lowest impact on newer housing (1990's) with double glazed windows with an increase in the RdSAP score of 2. Additional information is in Table 5.

To recognise Flutter Shutter in EPC assessments, DEAs should use the highlighted U-values from Table 3B for a Class 5 shutter (tight permeability) where the blind is closed, and the shutter is open 50% of the time. A U-value of 1.938 W/m²K is applicable if the Flutter Shutter system has been applied to a single-glazed window and a U-value of 1.528 W/m²K is applicable if it has been applied to a double-glazed window. Results of the RdSAP calculations are given in Tables 4A, 4B, 5, 6 and 7.

To comply with SAP Conventions, DEAs need to identify what they found in the dwelling during the survey. The Flutter Shutter product needs to be identified by a clear feature like a label, etc. DEAs will need to photograph the feature (label or other identifier) and attach it to the documentation forwarded to the Accreditation scheme for QA. If a DEA is uncertain then the default U-values should be used. See Section 3.4.

Guidance on ECO4 is given in Section 3.5.

5. References

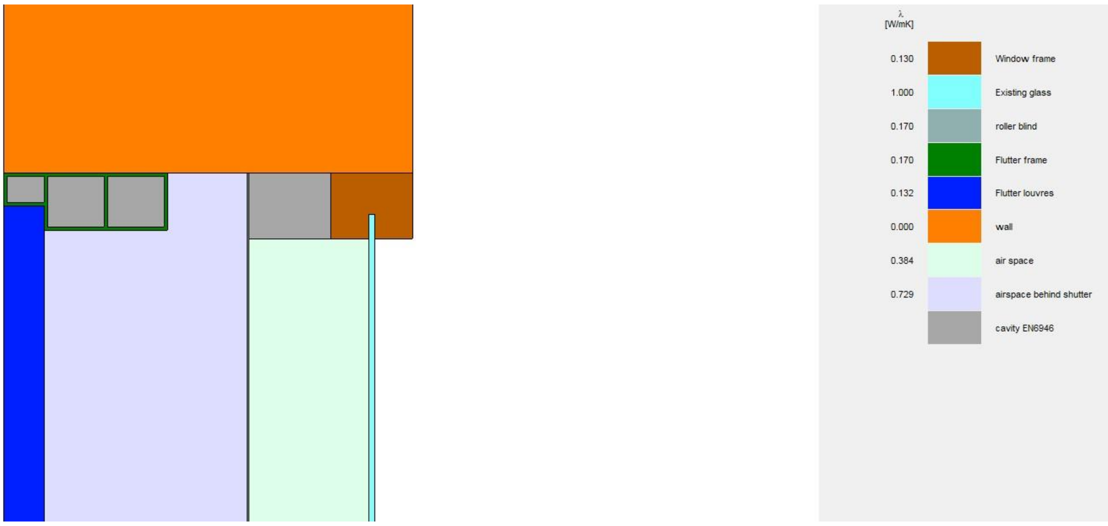
1. BS EN ISO 10077-1: Thermal performance of windows, doors and shutters — Calculation of thermal transmittance — Part 1: General, BSI, 2005
2. BS EN ISO 10077-2:2017 – Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical method for frames. BSI, 2017
3. BS EN ISO 10456:2007 – Building materials and products — Hygrothermal properties - Tabulated design values and procedures for determining declared and design thermal values. BSI, 2007
4. Assessing the effects of thermal bridging at junctions and around openings. T Ward, *BRE Information Paper* IP 1/06. Garston, BRE Press, 2006.
5. BR 497 – Conventions for calculating linear thermal transmittance and temperature factors, T Ward and C Sanders, IHS BRE Press 2007 & 2016.
6. BS EN 673:2011, BSI, 2011
7. SAP 2012, The Government's Standard Assessment Procedure for Energy Rating of Dwellings, 2012 Edition, published 2014
8. Richard Versluis, Lawrence Berkeley National Laboratories, USA, private communication, advice concerning the transmission of long-wave infrared radiation through thin plastic films associated with glazing.

Appendix A – Results of thermal models

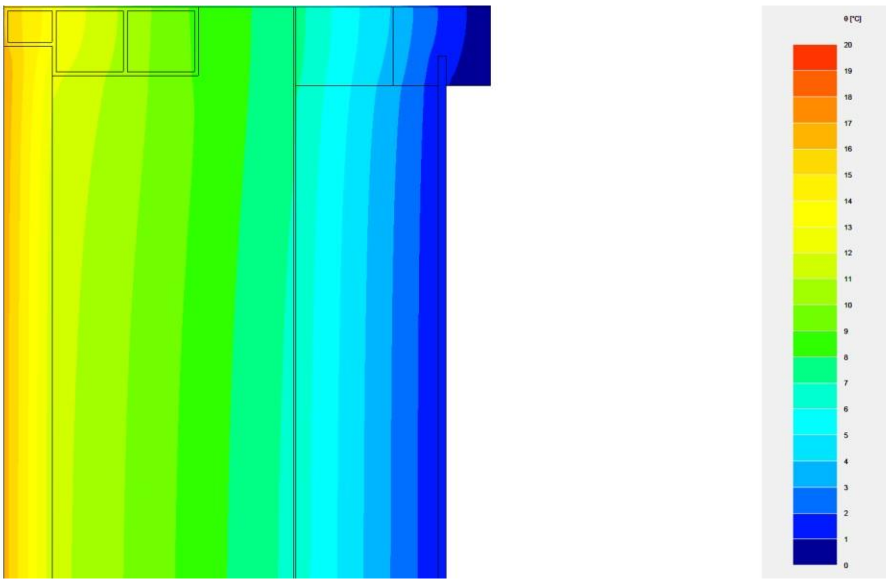
For the windows with the roller blind and shutter

Shutters (class 5) and blind present, window head detail

Materials

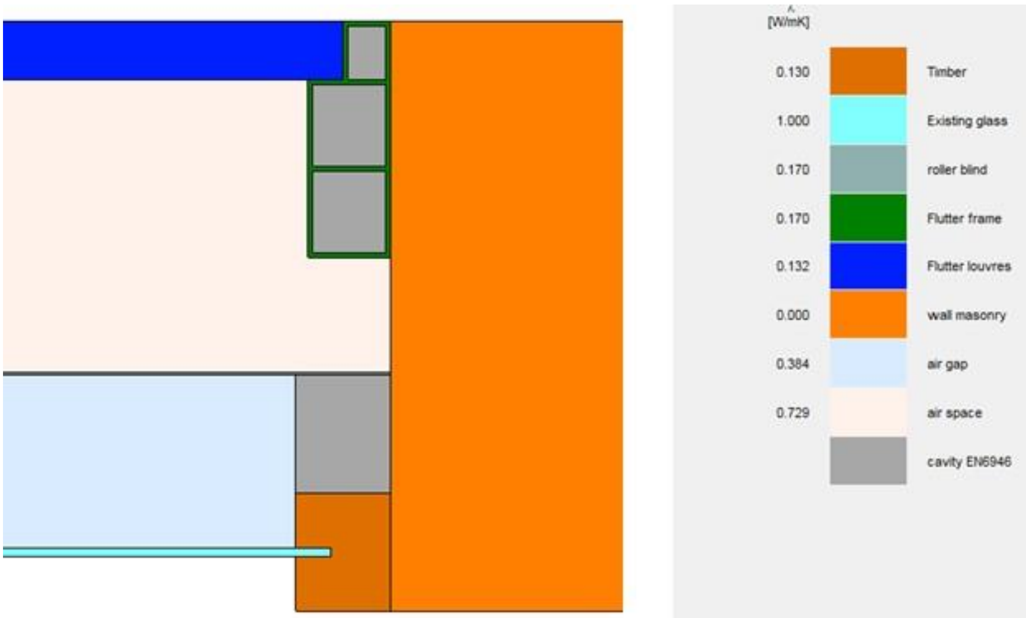


Temperature



Shutters (class 5) and blind present, window jamb detail

Materials



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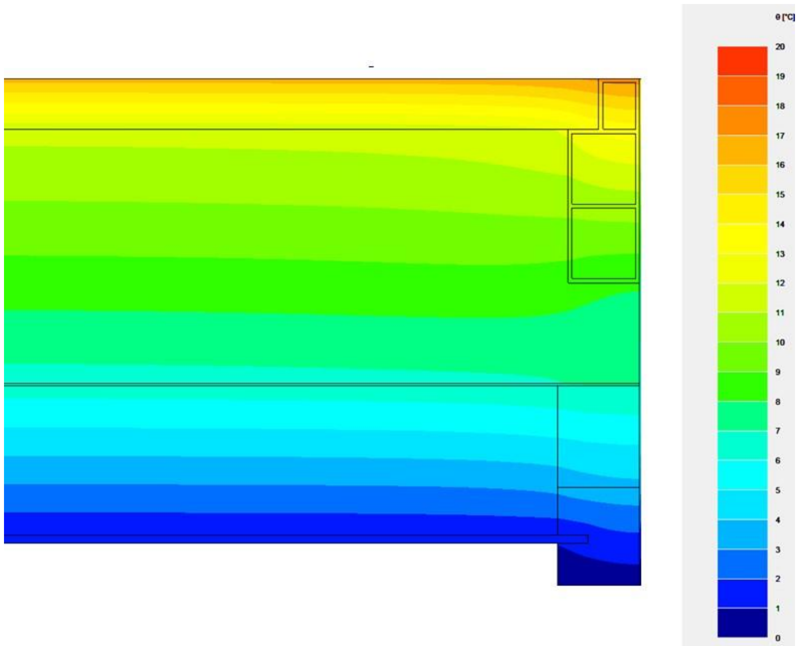
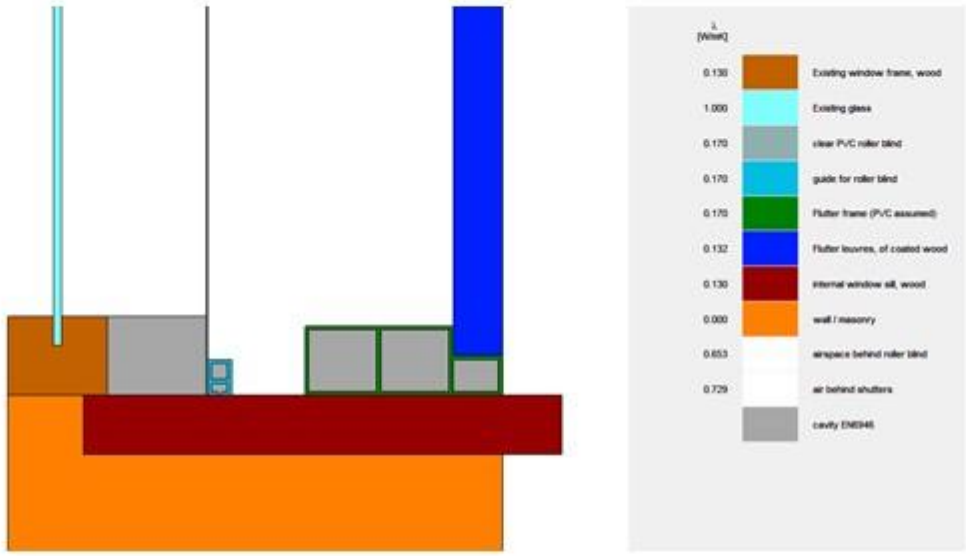
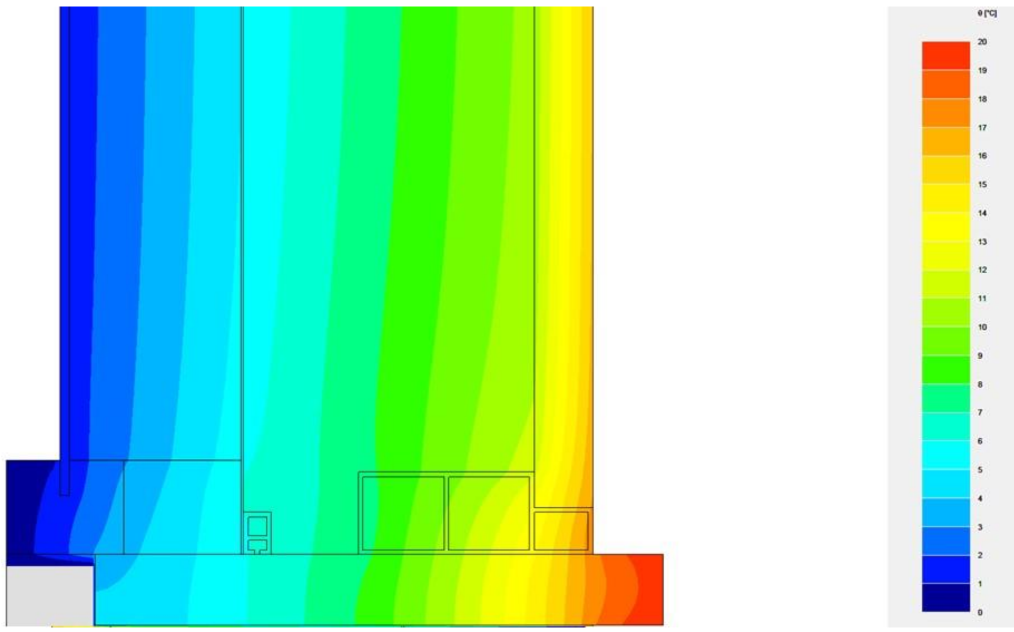


Shutters (class 5) and blind present, window sill detail

Materials

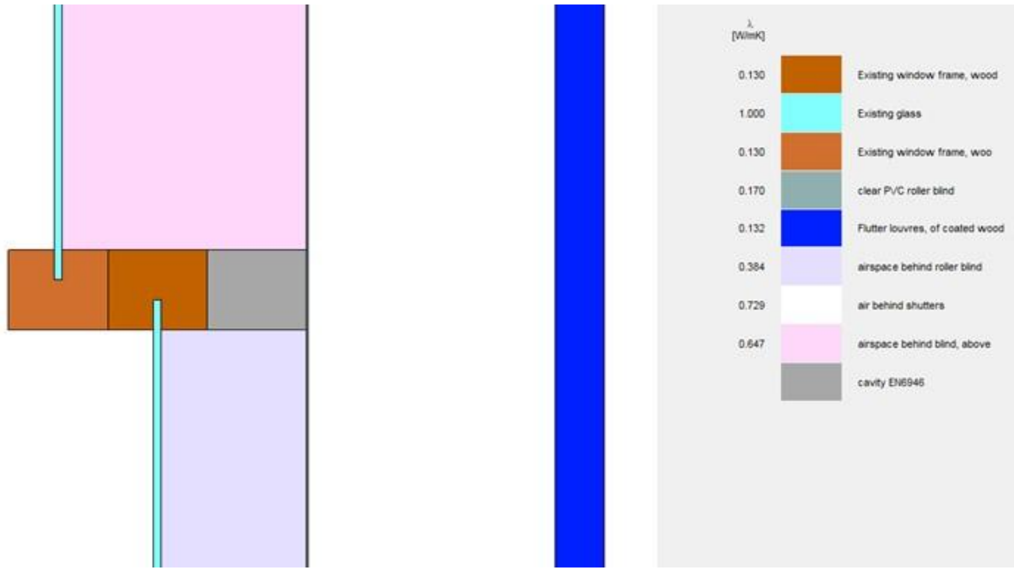


Temperature

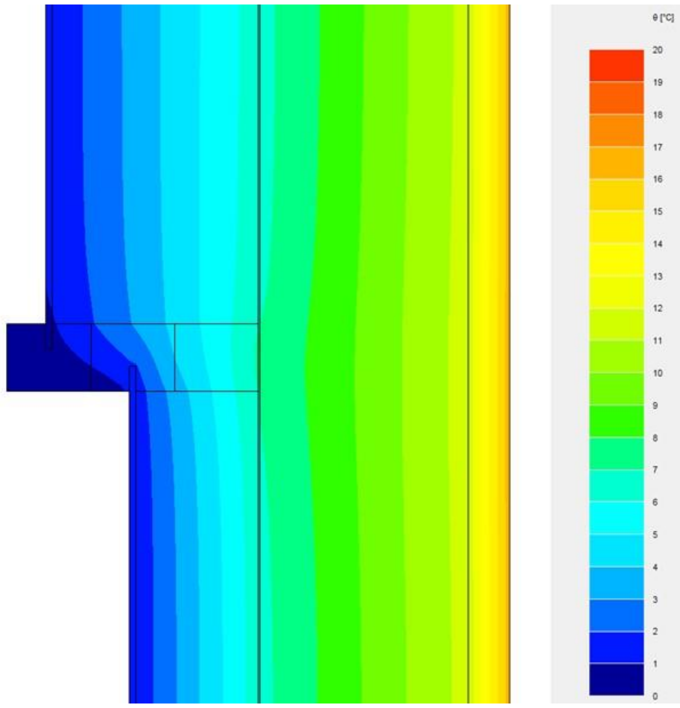


Shutters (class 5) and blind present, window transom detail

Materials

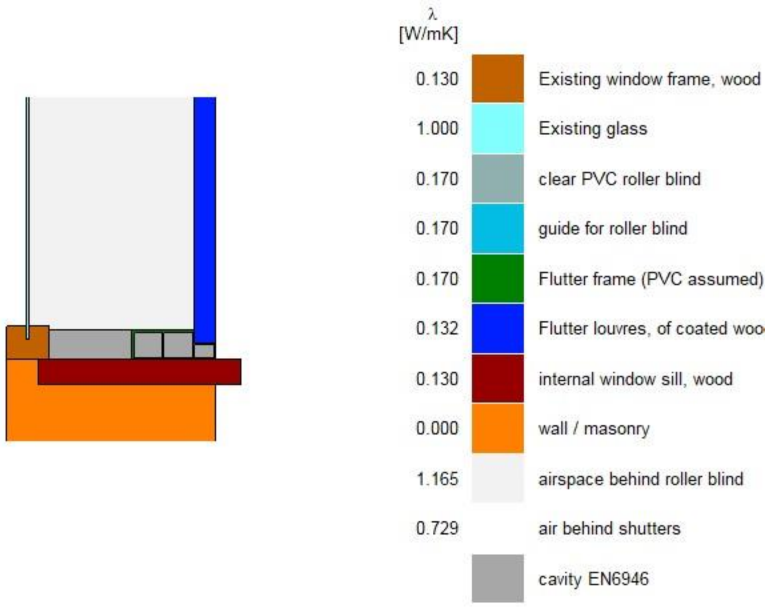


Temperature

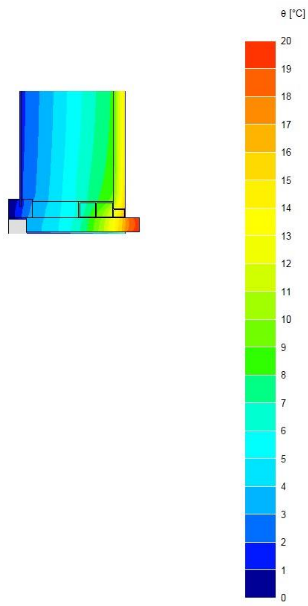


For the windows with the shutter but no blind

Window sill, with the shutters (class 5) but without the blind
Materials

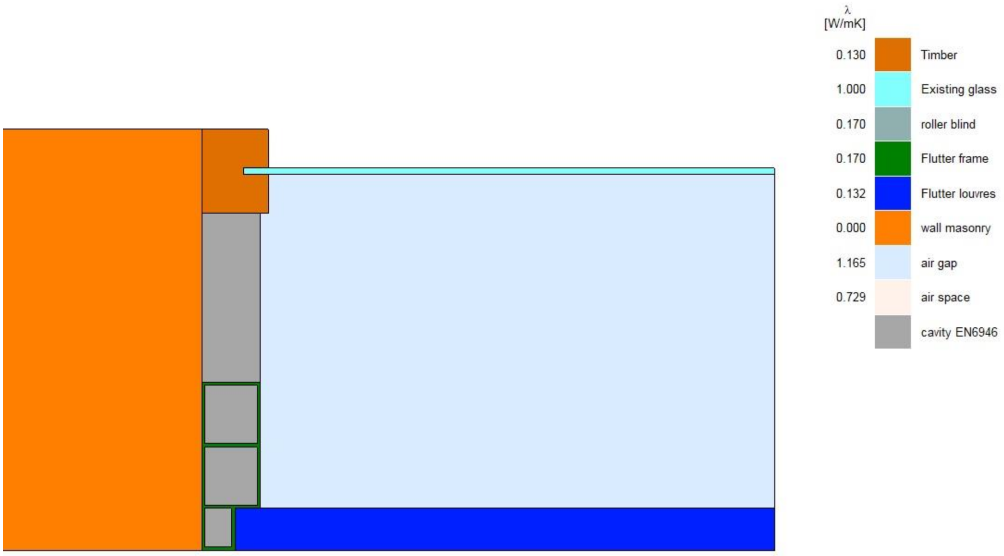


Temperature

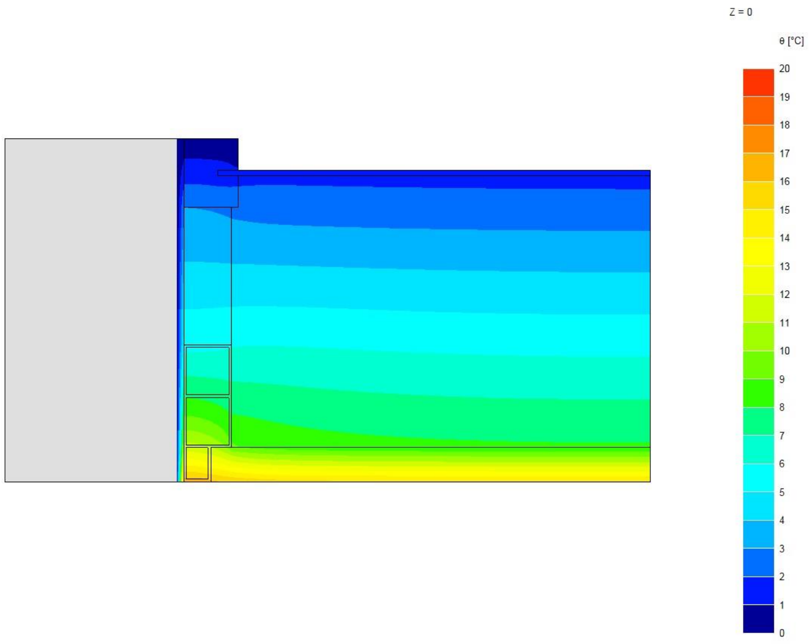


The window jamb with the shutters (class 5) but without the blinds

Materials

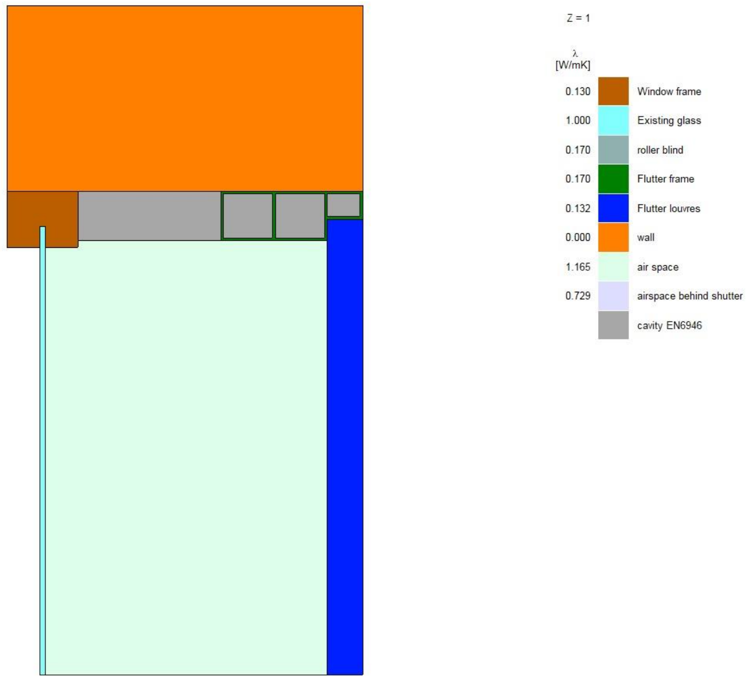


Temperature

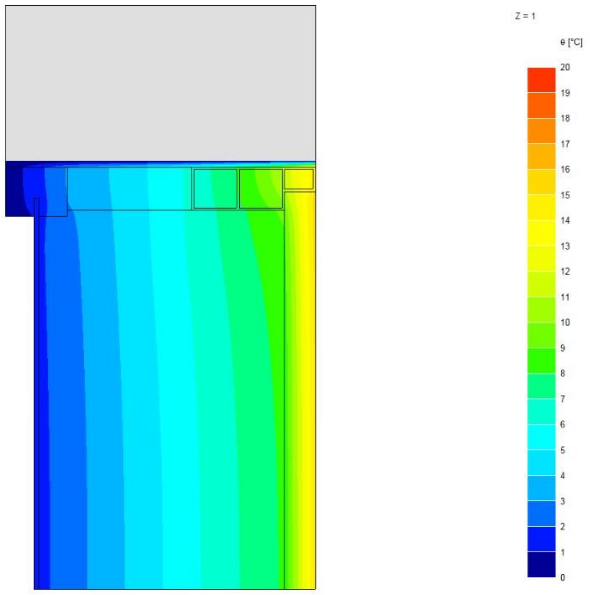


Window head, with the shutters (class 5) but without the blinds

Materials

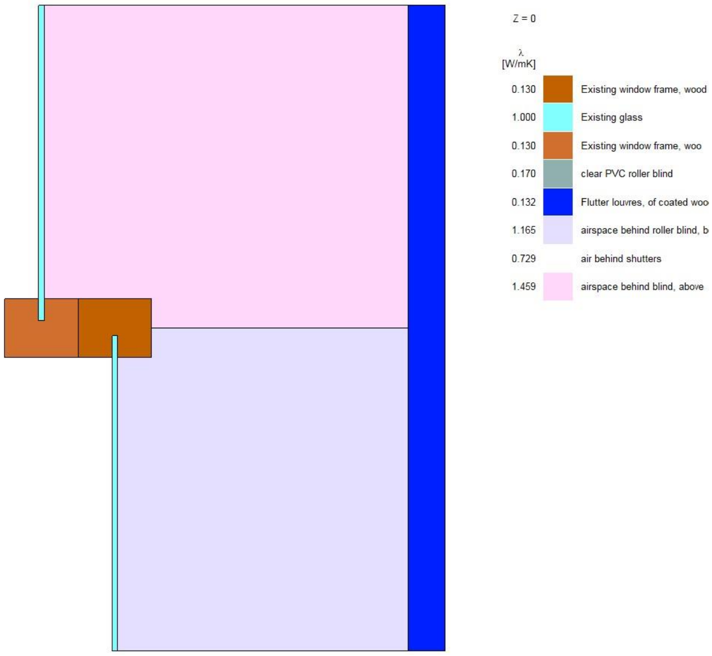


Temperature

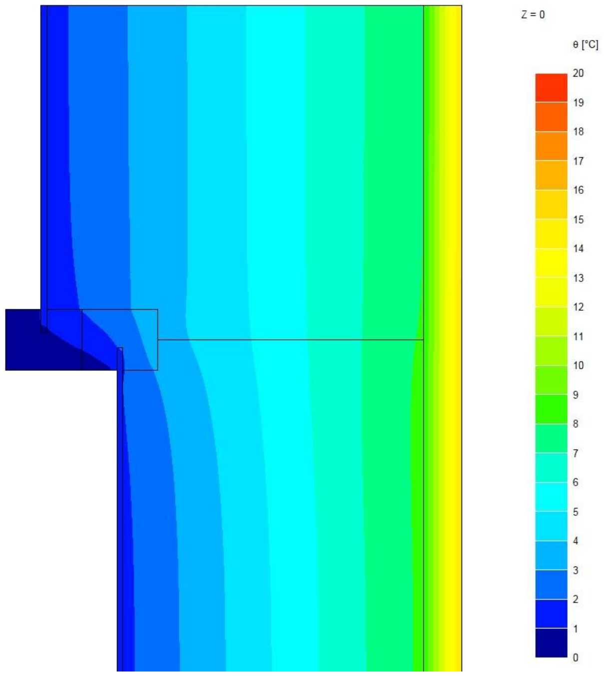


Central divider with the shutters (class 5) but without the blind

Materials



Temperature



Appendix B – Infra red tests

Flutter Shutter provided a sample of the PVC roller blind so that BRE could conduct tests to evaluate its infrared properties. The sample of PVC roller blind was laid upon 6 supports, as shown in Figure C.1, to create a gap of approximately 110 mm between the PVC sample and the surface of a desk. Two mugs were placed on the desk, one containing hot water and the other containing cold water. Tea plates were placed over the mugs to prevent water vapour from interfering with the measurement.

The mugs with tea plates over them were placed near the edge of the PVC sample, so that one half of each tea plate could be viewed directly by the infrared camera and the other half could be viewed only through the PVC film. Both visual and infrared images were taken simultaneously. The gap between the tea plates and the PVC film during the tests was approximately 20 mm, allowing air to circulate freely under the PVC.

The results shown in the figures below, indicated that although the PVC was transparent to visible light the PVC allowed little or no long-wave infrared radiation to pass through. The conclusion from this is that the PVC allows little or no longwave infrared radiation to pass through and therefore the calculation method in BS EN 673 is permissible for assessing the gap between the existing window and the PVC roller blind.

Figure B.1: An overview of the testing arrangement

In Figures B.2 and B.3 we can see that the infrared radiation from the side of the tea plate which is covered by PVC is less than the radiation from the side that is uncovered, indicating that the PVC is transparent to visible light but is not transparent to long-wave infrared.

Figure B.2: The tea plate over the mug containing hot water

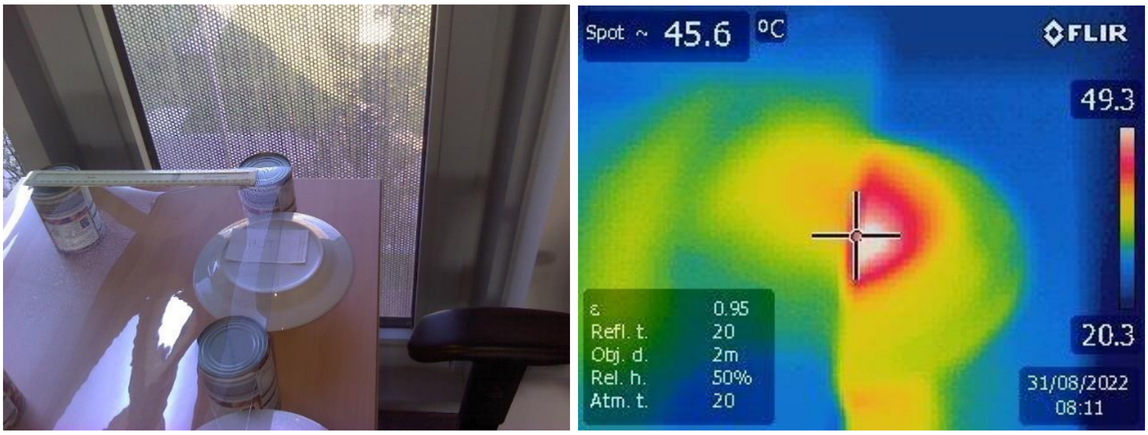


Figure B.3: The tea plate over the hot mug

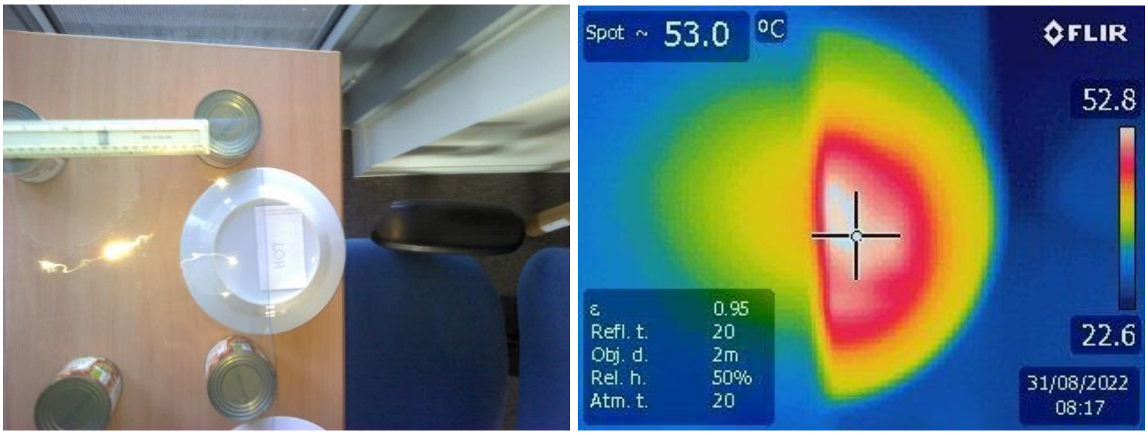
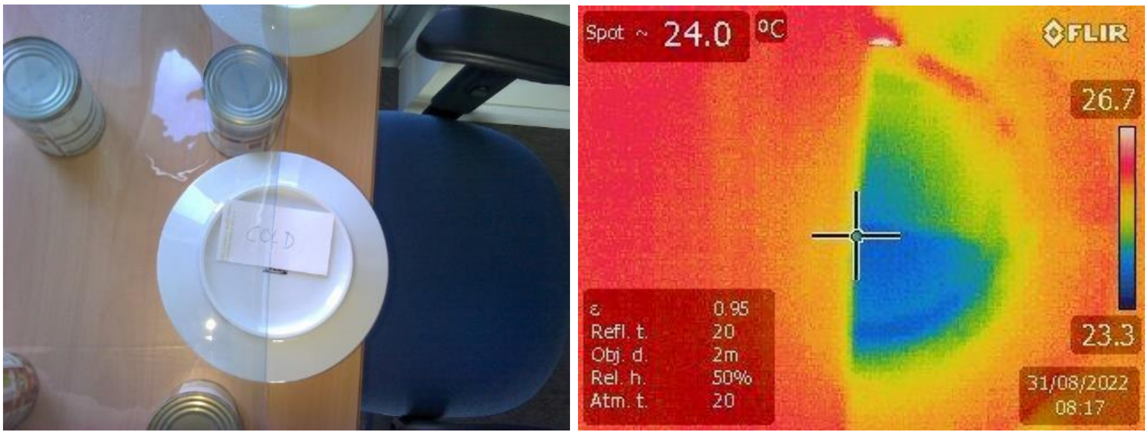


Figure B.4: The tea plate over the cold mug



Note: As with the hot tea plate, the infrared camera is only able to sense the temperature of the tea plate on the side which is uncovered by the PVC.

Figure B.5: The hot and cold tea plates side by side

Figure B.6: The hot tea plate

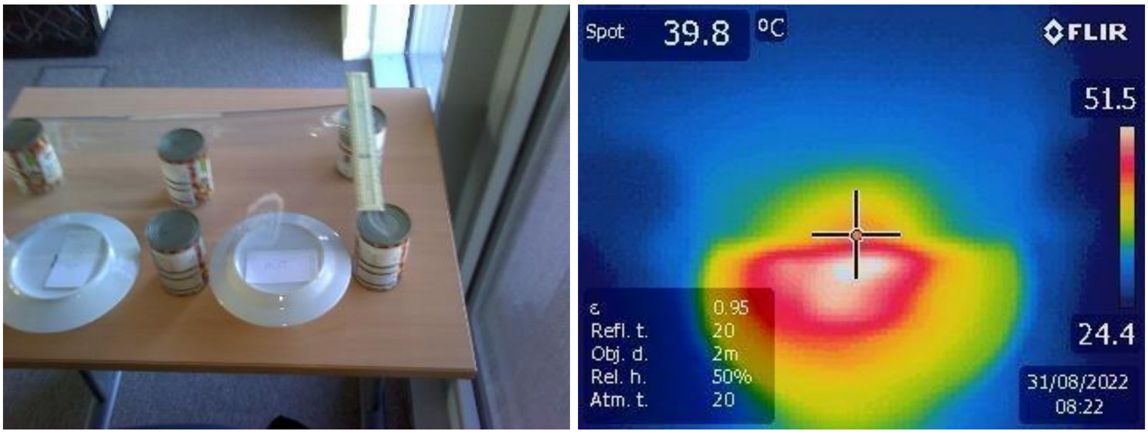


Figure B.7: The hot tea plate

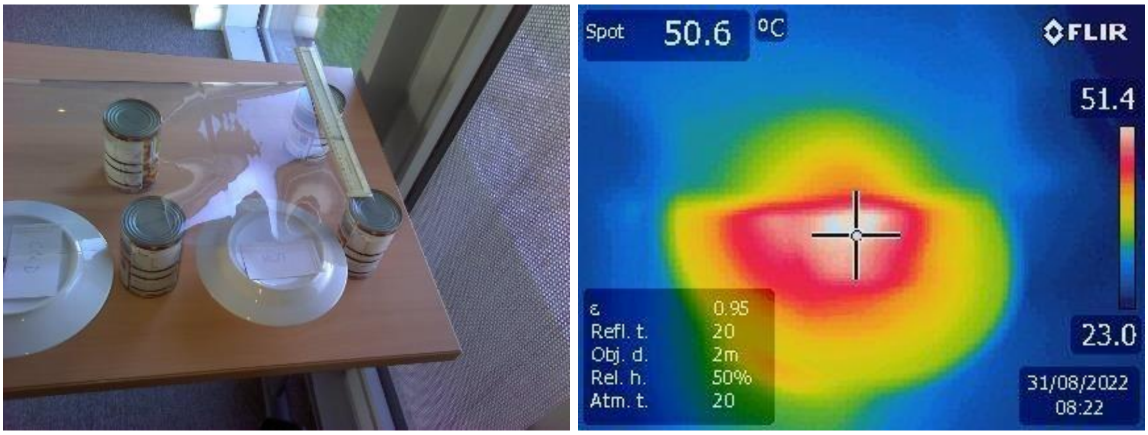


Figure B.8: The hot tea plate

Figure B.9: The cold tea plate

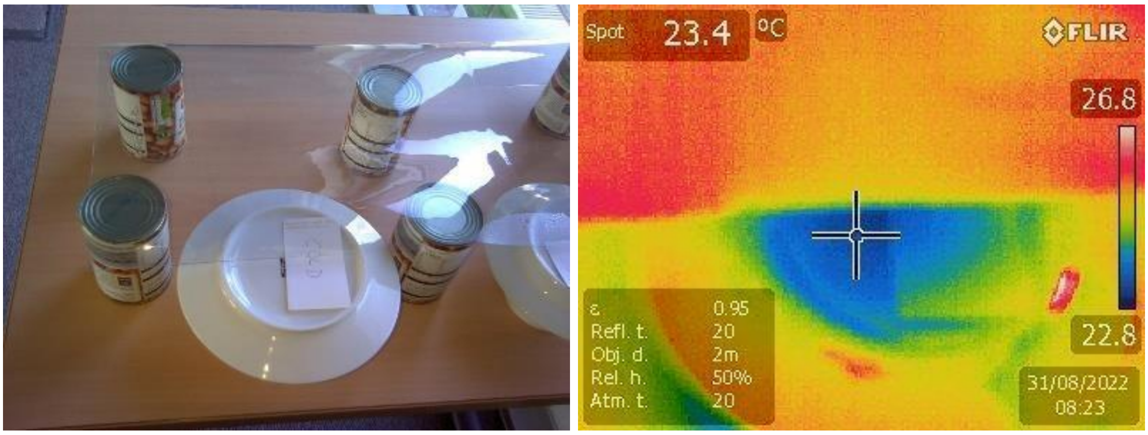


Figure B.10: The cold tea plate

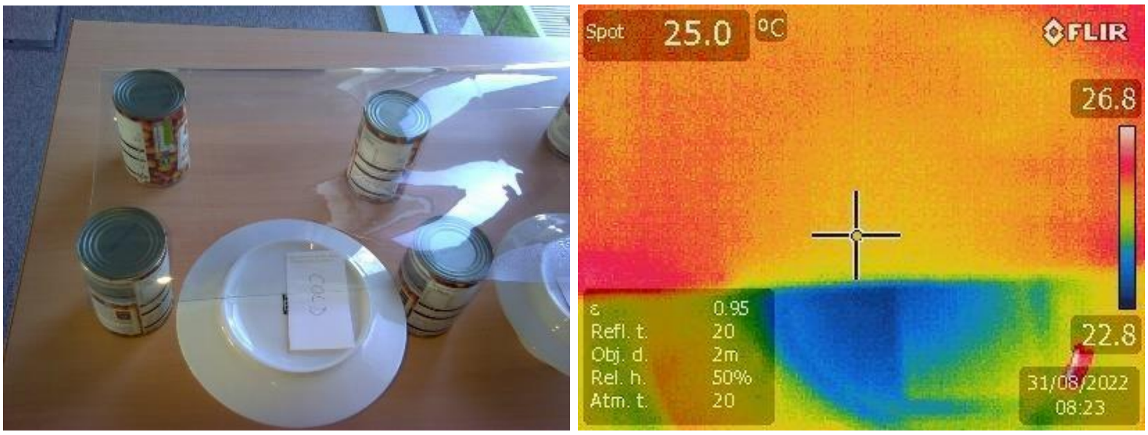
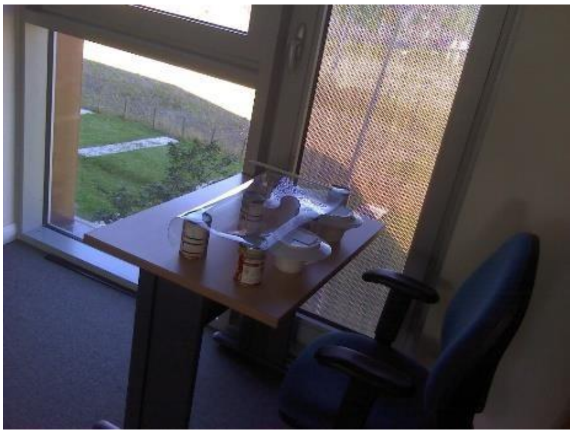
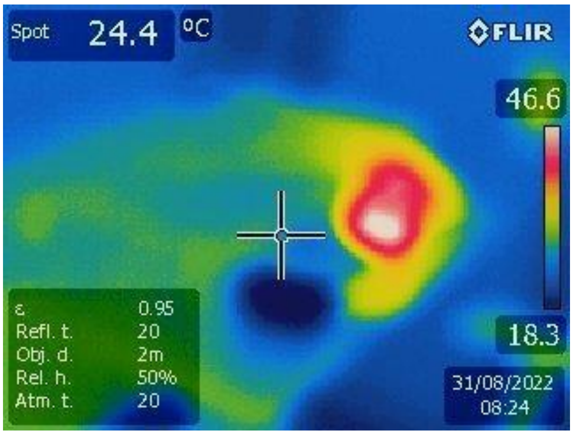


Figure B.11: An overview of the testing arrangement




Spot 24.4 °C
FLIR
46.6
18.3
ε 0.95
Refl. t. 20
Obj. d. 2m
Rel. h. 50%
Atm. t. 20
31/08/2022
08:24

Appendix C – U-value calculations

Below are some U-value worksheets that have been filled in for windows of standard size to serve as examples of U-value calculations.

U-value calculation where existing window is single glazed, with blind and shutters both closed (shutter class 3)

Height of window, m					1.480
Width of window, m					1.230
Area of window, m²	(1)	×	(2)	=	1.8204
Width of frame, mm					40
Width of frame, m	(4)	÷	1000	=	0.040
Area of window head	[(2) - (5)]	×	(5)		0.0476
Area of window jambs	[(1) - (5)]	×	2 × (5)		0.1152
Width of transom, mm					40
Width of transom, m	(8)	÷	1000	=	0.040
Area of transom, m2	(2) – [2 × (9)]	×	(9)	=	0.046
Area of sill	[(2) – (5)]	×	(5)	=	0.0476
Glazed area	(3) – (6) – (7) – (10) – (11)			=	1.564
U-value of window head	1.0963 if roller blind closed and shutters of class 3 closed				1.0963
U-value of window jambs	0.9396 if roller blind closed and shutters of class 3 closed				0.9396
U-value of transom	1.3083 if roller blind closed and shutters of class 3 closed				1.3083
U-value of window sill	1.2288 if roller blind closed and shutters of class 3 closed				1.2288
U-value of glazed area	See Table 3A				1.6945
U × area of window head	(6)	×	(13)	=	0.05218
U × area of window jambs	(7)	×	(14)	=	0.10824
U × area of transom	(10)	×	(15)	=	0.0602
U × area of sill	(11)	×	(16)	=	0.05849
U × area of glazed area	(12)	×	(17)	=	2.6502
Heat loss per degree	(18) + (19) + (20) + (21) + (22)			=	2.929
U-value of window	(23)	÷	(3)	=	1.609

(1) (2) (3) (4) (5) (6) (7)

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(20) (21) (22)

(23)
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U-value calculation where existing window is single glazed, with blind and shutters both closed (shutter class 5)

Height of window, m					1.480
Width of window, m					1.230
Area of window, m²	(1)	×	(2)	=	1.8204
Width of frame, mm					40
Width of frame, m	(4)	÷	1000	=	0.040
Area of window head	[(2) - (5)]	×	(5)		0.0476
Area of window jambs	[(1) - (5)]	×	2 × (5)		0.1152
Width of transom, mm					40
Width of transom, m	(8)	÷	1000	=	0.040
Area of transom, m2	(2) – [2 × (9)]	×	(9)	=	0.046
Area of sill	[(2) – (5)]	×	(5)	=	0.0476
Glazed area	(3) – (6) – (7) – (10) – (11)			=	1.564
U-value of window head	1.0504 if roller blind closed and shutters of class 5 closed				1.0504
U-value of window jambs	0.8421 if roller blind closed and shutters of class 5 closed				0.8421
U-value of transom	1.1100 if roller blind closed and shutters of class 5 closed				1.1100
U-value of window sill	1.1700 if roller blind closed and shutters of class 5 closed				1.1700
U-value of glazed area	See Table 3A				1.6945
U × area of window head	(6)	×	(13)	=	0.0500
U × area of window jambs	(7)	×	(14)	=	0.09701
U × area of transom	(10)	×	(15)	=	0.05106
U × area of sill	(11)	×	(16)	=	0.05569
U × area of glazed area	(12)	×	(17)	=	2.14268
Heat loss per degree	(18) + (19) + (20) + (21) + (22)			=	2.39644
U-value of window	(23)	÷	(3)	=	1.316

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U-value calculation where existing window is single glazed, with blind closed, shutters open

Height of window, m					1.480
Width of window, m					1.230
Area of window, m²	(1)	×	(2)	=	1.8204
Width of frame, mm					40
Width of frame, m	(4)	÷	1000	=	0.040
Area of window head	[(2) - (5)]	×	(5)		0.0476
Area of window jambs	[(1) - (5)]	×	2 × (5)		0.1152
Width of transom, mm					40
Width of transom, m	(8)	÷	1000	=	0.040
Area of transom, m2	(2) – [2 × (9)]	×	(9)	=	0.046
Area of sill	[(2) – (5)]	×	(5)	=	0.0476
Glazed area	(3) – (6) – (7) – (10) – (11)			=	1.564
U-value of window head	1.6200	if roller blind closed and shutters open			1.6200
U-value of window jambs	1.6125	if roller blind closed and shutters open			1.6125
U-value of transom	1.7088	if roller blind closed and shutters open			1.7088
U-value of window sill	1.9125	if roller blind closed and shutters open			1.9125
U-value of glazed area		See Table 3A			2.7025
U × area of window head	(6)	×	(13)	=	0.07711
U × area of window jambs	(7)	×	(14)	=	0.1858
U × area of transom	(10)	×	(15)	=	0.0786
U × area of sill	(11)	×	(16)	=	0.09104
U × area of glazed area	(12)	×	(17)	=	4.2267
Heat loss per degree	(18) + (19) + (20) + (21) + (22)			=	4.6593
U-value of window	(23)	÷	(3)	=	2.559

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(18)

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(20) (21) (22)

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