Salford Energy House Thermal Performance of Blinds and Shutters Testing

Initial Report v2

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BBSA BRITISH BLIND & SHUTTER ASSOCIATION

ENERGY HOUSE LABS

Introduction

This report provides the initial results[1] from the Salford Energy House Thermal Performance of Blinds and Shutters Testing project. It was undertaken by an Energy House Labs research team at the University of Salford (UoS) Energy House research facility and was commissioned and funded by the British Blind and Shutter Association (BBSA).

The purpose of the testing was to measure under controlled conditions the impact blinds and shutters has on the heat loss through a window. This data will be used to validate the accuracy of modelling software used by the BBSA, to assess the heat loss performance of varying designs of window coverings on different specifications of glazing.

Facility

The University of Salford Energy House is a full-scale replica of a pre-1920s solid wall end terrace house, built using reclaimed brick and traditional construction methods of its time. Adjoining the Energy House is a neighbouring property, the Conditioning Void (CV), built of similar construction, and is primarily used to replicate neighbouring heat gains for the Energy House. The CV has one double glazed window located on the first-floor rear of the property, which was used for the BBSA testing. Double glazing (4 mm + 16 mm space + 4 mm), with low emissivity coating in position 3 (outer surface of the inner pane), space filled with 90 % argon in a PCVu frame.

These properties are located within an environmental chamber, allowing both dynamic and steady state control of the temperature (-12°C to +30°C), and systems to replicate rain, wind, and solar gain.

Methodology

All U-Value measurements were made following ISO 9869:1, using a single heat flux plate (HFP) located at the centre on the glazing panel. Each system was tested for a minimum of 72h, with the stated U-value being based on the final 24h period.

The tests were conducted under steady-state conditions. Internally, the temperature was set at 20°C, using an electric resistance heater connected to a PID temperature controller. Between the heater and glazing, shielding was placed to reduce radiative heat gain incident on the glazing panel and HFPs (Figure 1). To further increase the temperature control, a partition was created within the CV around the window test area, as to limit temperature fluctuations resulting from equipment located on the first floor. The external chamber temperature was set to achieve 4.5°C using the chamber blast chiller system.

Test Setup

Measurement Equipment

Internal and external temperature measurements were made using Campbell Scientific Hygrovue 10 sensors (±0.1 °C). Heat flux measurements were made using Hukseflux HFP01 (±3%). All data were collected at 1-minute interval using a Campbell CR1000X data logger.

Figure 1 – a) Internal test setup, with internal temperature sensor circled in yellow and centre pane HFP denoted by the blue arrow. b) Shows testing of external zip blind, external temperature sensor highlighted in yellow.

Results

Measured Centre Pane U-Value

In all tests, a reduction in U-Value was measured when compared to the glazing only (baseline) measurement. All results presented comply with ISO 9869 measurements and are based on the final 24h measurement period. Appendix A shows the full 72h U-value period for each system, and Appendix B shows the raw heat flux and temperature measurements.

ISO 9869:1 U-value uncertainty is typically between 14-28%. However, as measurements at the Energy House were conducted under steady state conditions, the uncertainty can be further reduced, and will be stated for each measurement in the final report.

Table 1 - Final 24h measured centre pane U-values

Blind Design	U-Value [W/(m².K)]	ΔU on baseline [W/(m².K)]	U % Change on baseline[1]
Glazing Only (baseline)	1.52	-	-
Roller (Free hanging)	1.32	-0.20	-13%
Zip (Flocke)	1.17	-0.35	-23%
Zip (Ultimetal)	0.96	-0.56	-37%
External Roller Blind / Flocke	1.20	-0.32	-21%
Honeycomb (Free hanging - foil insert)	1.09	-0.43	-28%
Fitted to Glass Honeycomb (foil insert)	1.00	-0.52	-34%
Shutter	1.06	-0.46	-30%
Honeycomb (Free hanging - no insert)	1.08	-0.44	-29%

[1] percentages apply to the combination of blind and glazing tested

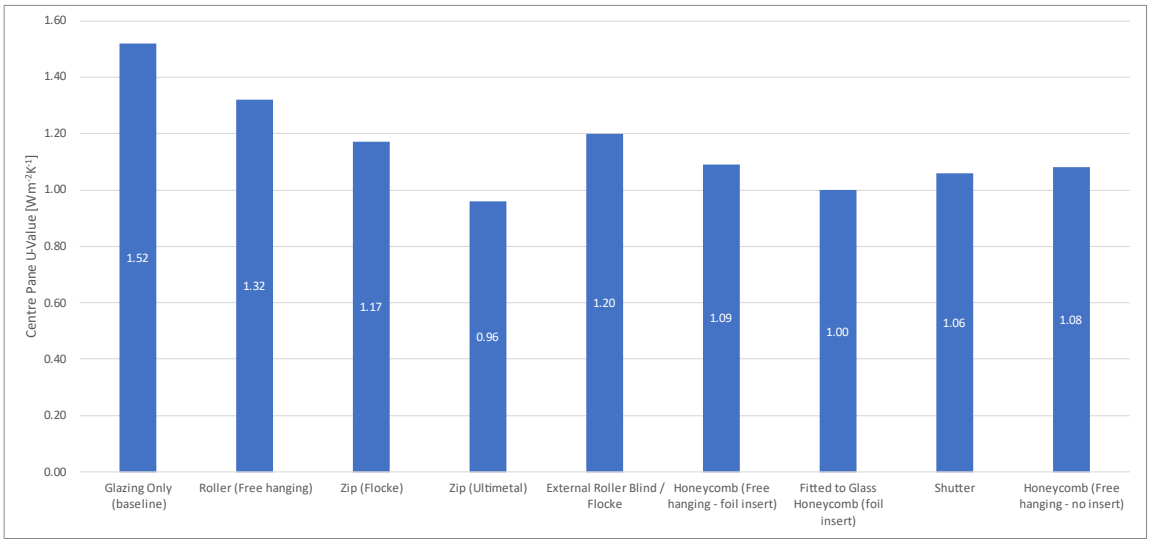


Figure 2 - Centre pane U-value measurements

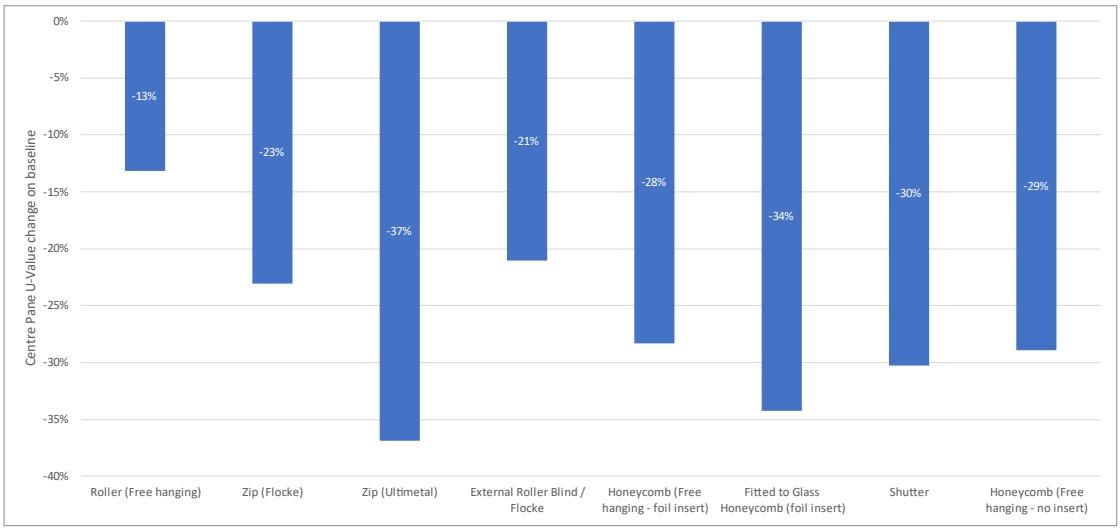


Figure 3 - Centre pane U-value change on baseline

"Corrected" Centre Pane U-Value

The BBSA specified *"Double Glazing in line with REF C Glazing according to BS EN 14501"*, which should give a U-Value of 1.20 $Wm^{-2}K^{-1}$. However, the glazing panel installed in the conditioning void has a measured centre pane U-Value of 1.52 $Wm^{-2}K^{-1}$ despite the composition of the glazing panel being the same as specified in the standard. 2022 changes to part L of the Building Regulations state a minimum U-Value of 1.40 $Wm^{-2}K^{-1}$ for existing dwelling retrofits and 1.60 $Wm^{-2}K^{-1}$ for new builds, which more closely aligns with the installed glazing.

A methodology for correcting for this difference in U-value was produced (detailed in Appendix C), and applied to the measurements. It is worth stressing that these *"corrected"* U-values are ultimately based upon its own physics model, and priority should be given to the *"measured"* U-values stated previously.

Table 2 - Baseline corrected centre pane U-Values

Blind Design	R_{GI} [(m².K)/W]	$R^*_{GI\_0}$ [(m².K)/W]	U^*_{Sys} [W/(m².K)]	ΔU* on baseline [W/(m².K)]	U* % Change on baseline[2]
Glazing Only (baseline)	0.43	0.48	1.40	-	-
Roller (Free hanging)	0.42	0.48	1.22	-0.18	-13%
Zip (Flocke)	0.42	0.48	1.09	-0.31	-22%
Zip (Ultimetal)	0.46	0.48	0.94	-0.46	-33%
External Roller Blind / Flocke	0.40	0.48	1.09	-0.31	-22%
Honeycomb (Free hanging - foil insert)	0.43	0.48	1.03	-0.37	-26%
Fitted to Glass Honeycomb (foil insert)	0.44	0.48	0.96	-0.44	-32%
Shutter	0.43	0.48	1.00	-0.40	-28%
Honeycomb (Free hanging - no insert)	0.42	0.48	1.01	-0.39	-28%

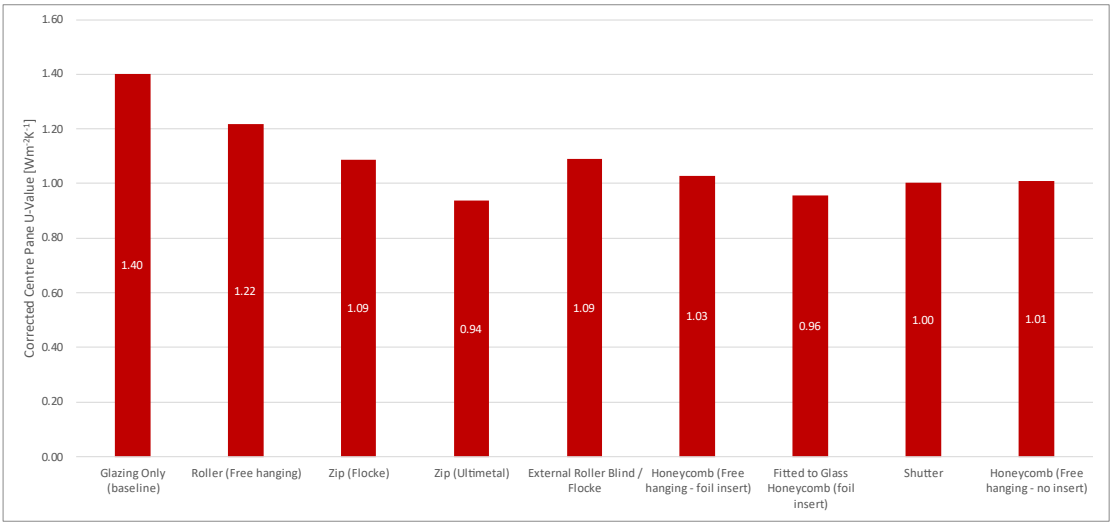


Figure 4 - Corrected centre pane U-values

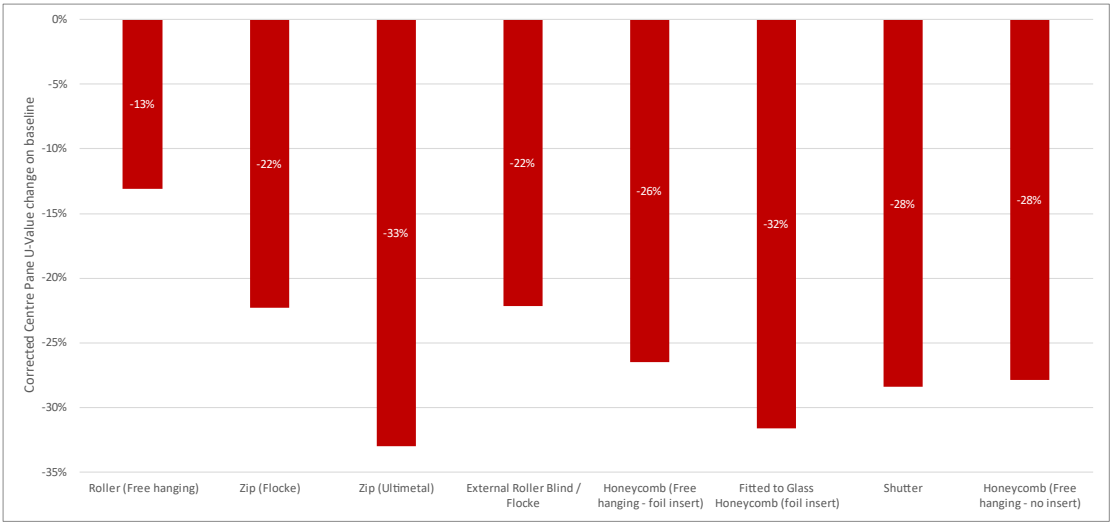


Figure 5 - Corrected centre pane U-value change on baseline

[2] percentages apply to the combination of blind and glazing tested

Conclusions and Recommendations

From the results, all forms of tested window covering caused a reduction in the U-value between 13-37%, and therefore a reduction in the heat loss through the glazing. However, systems that were designed to reduce air movement show a further reduction in U-value (see *Honeycomb (Free hanging – foil insert)* vs *Fitted to Glass Honeycomb (foil insert)*). Further, systems which implemented a metallic layer would usually show an additional U-value reduction when compared to their no insert counterparts (see *Zip (Flocke)* vs *Zip (Ultimetal)*).

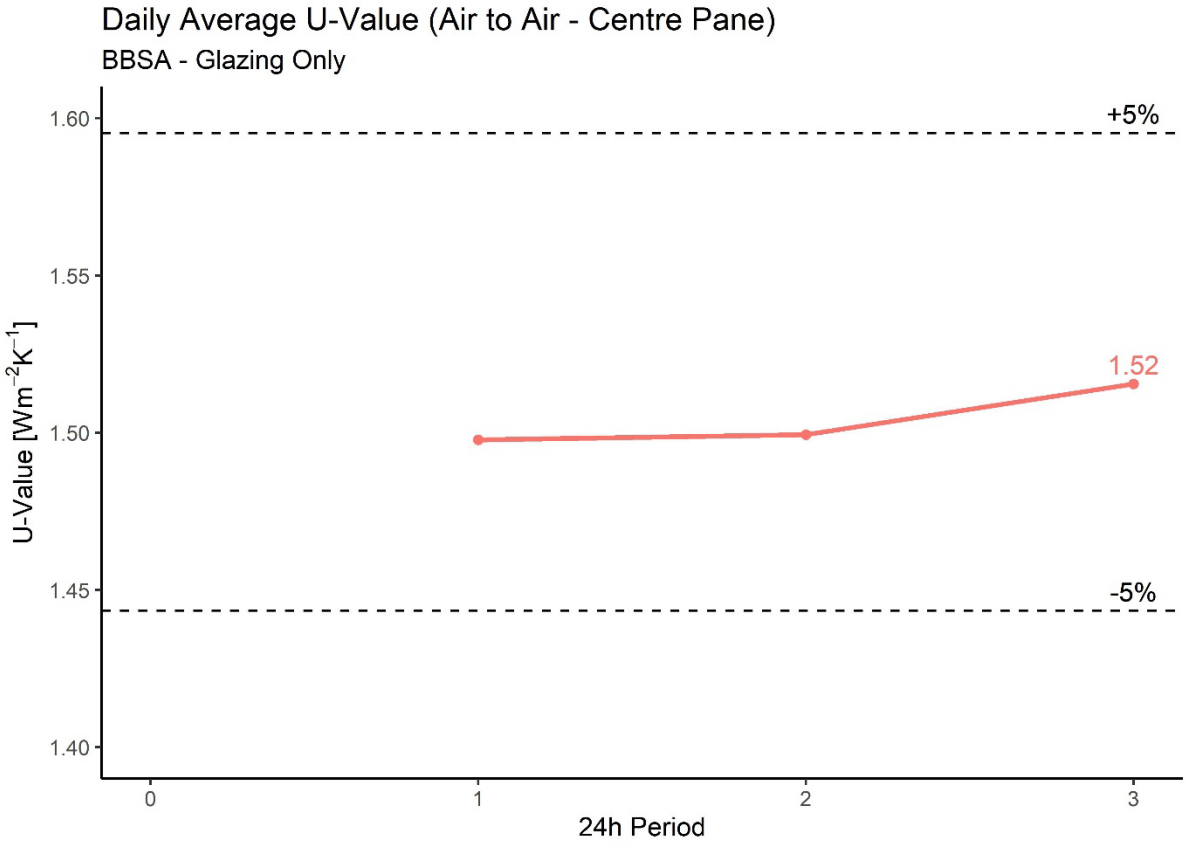
It is worth noting that this reduction due to a foil insert layer was not observed between the *Honeycomb (Free hanging – foil insert)* and the *Honeycomb (Free hanging – no insert)*. The reason for this is not known, and the requires further investigation.

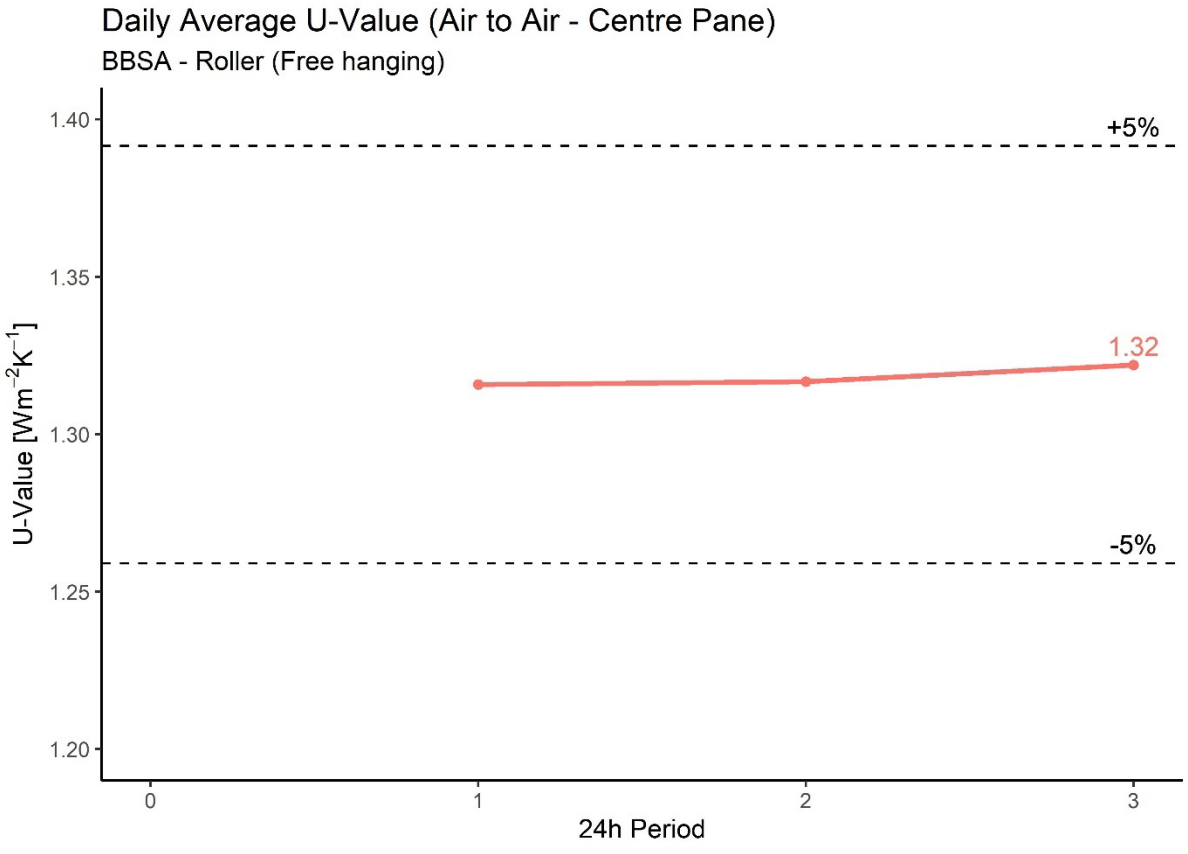
Further research may focus on:

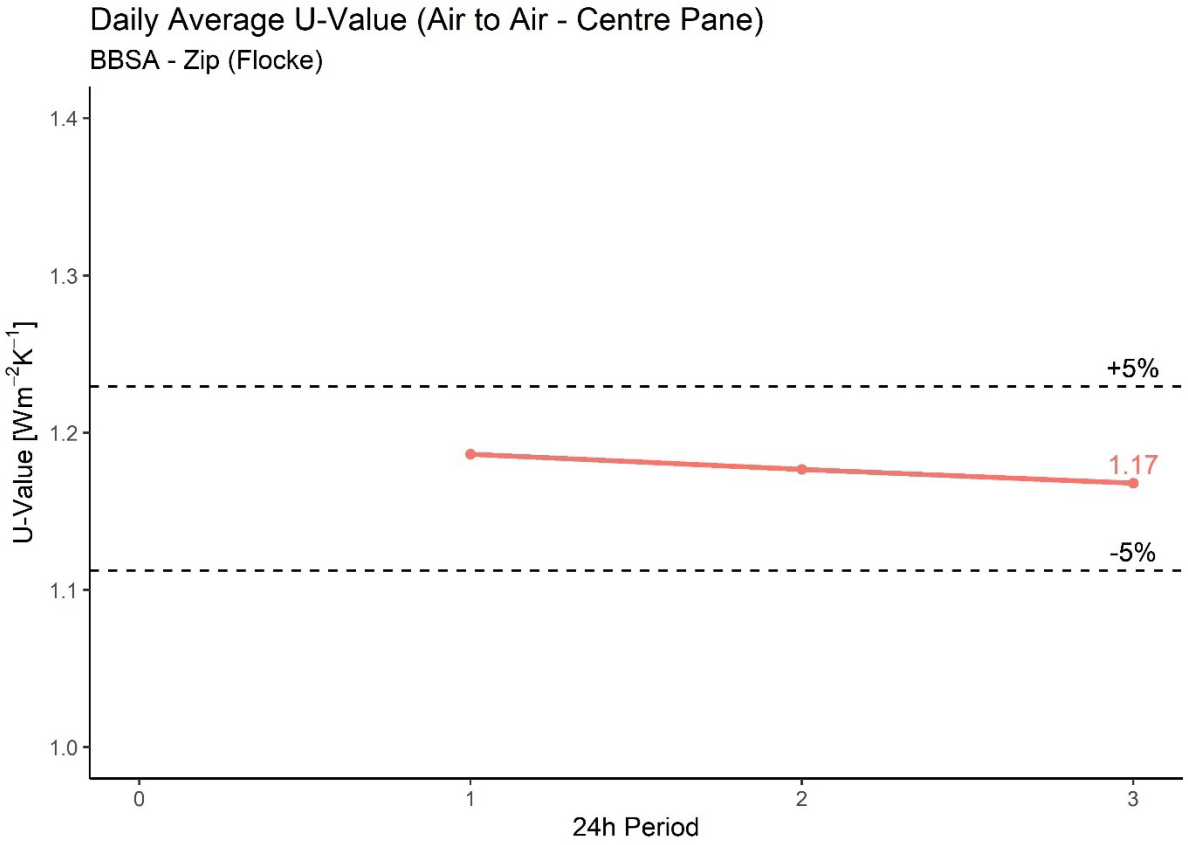
- how centre pane U-values relate to whole window heat loss
- additional measurements be made to quantify how air movement/tightness around the window is affected by the window coverings
- Further investigation of honeycomb testing
- Testing with single or clear double glazing
- heater placement in relation to the window
- direction in which a venetian blind/ shutter is closed

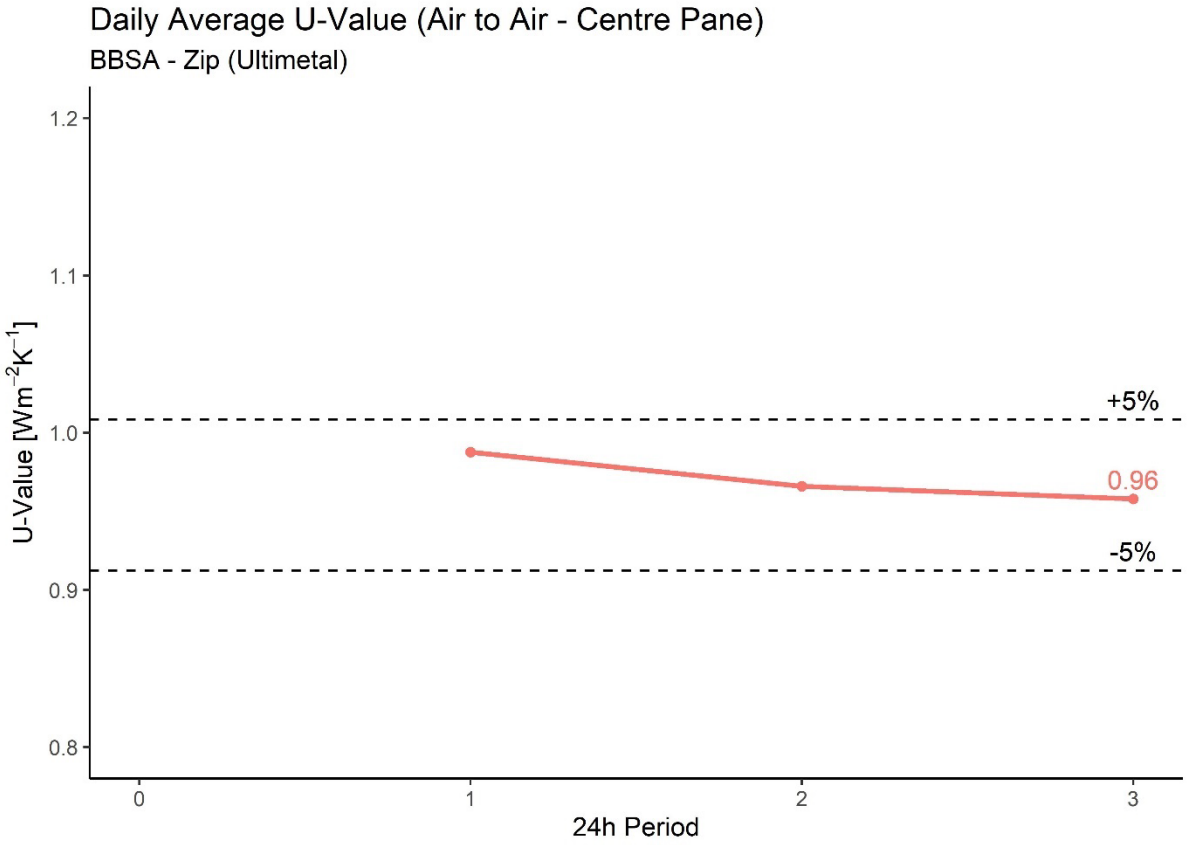
Appendix A - 24h Average Centre Pane U-Value

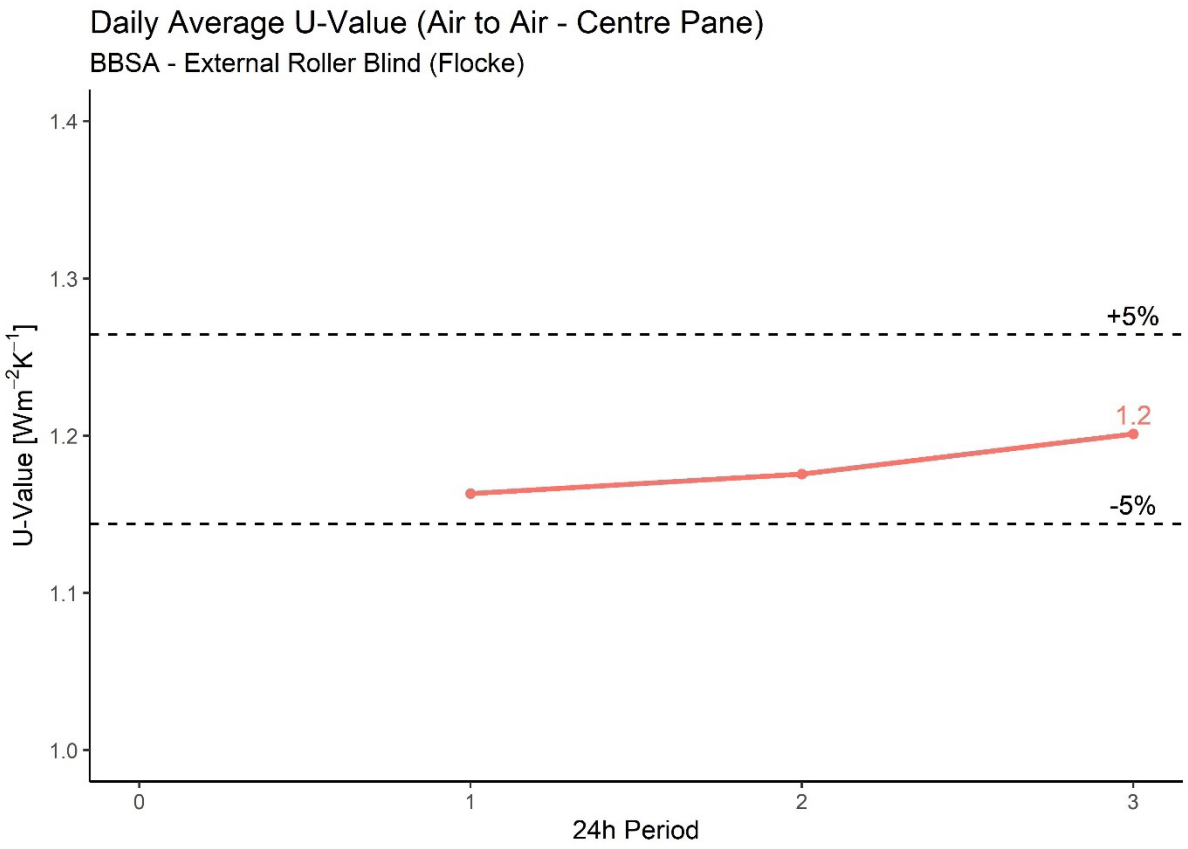
±5% lines are to show conformity to part of the criteria stated in ISO9869:1.

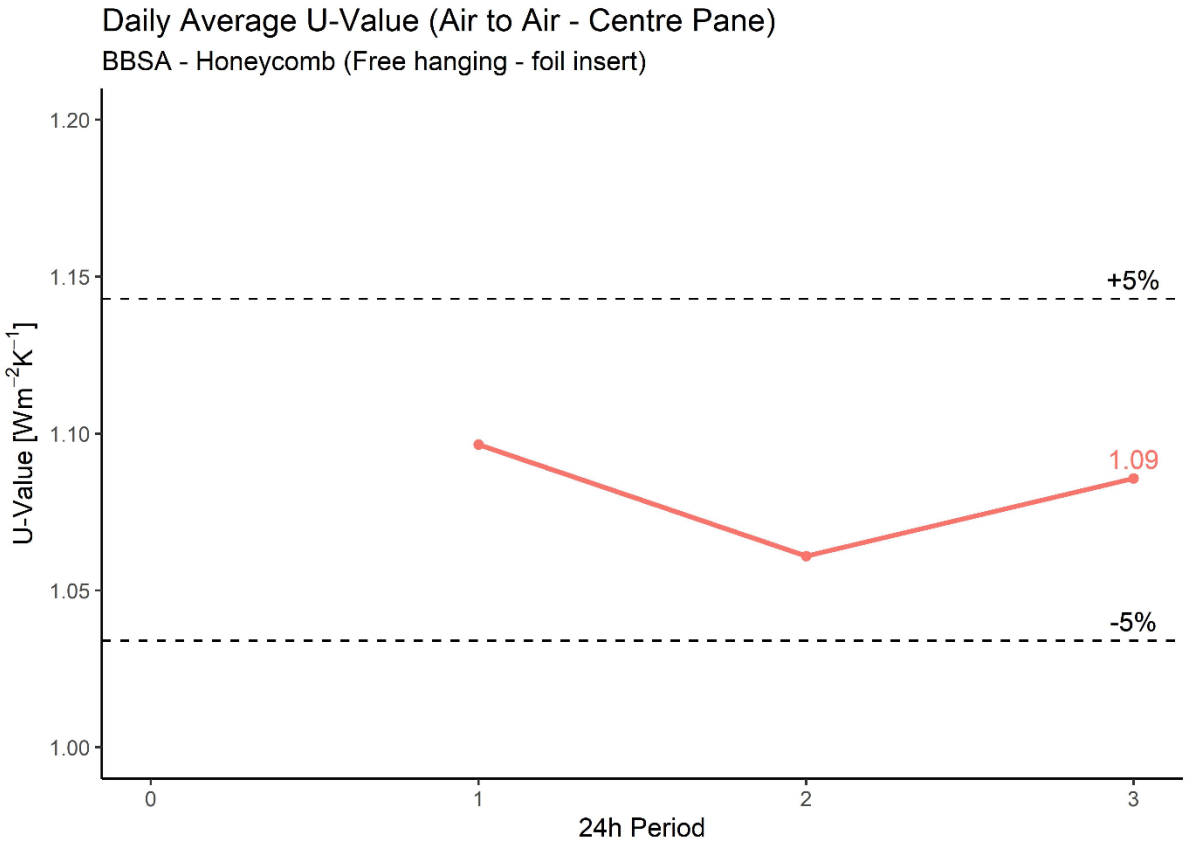


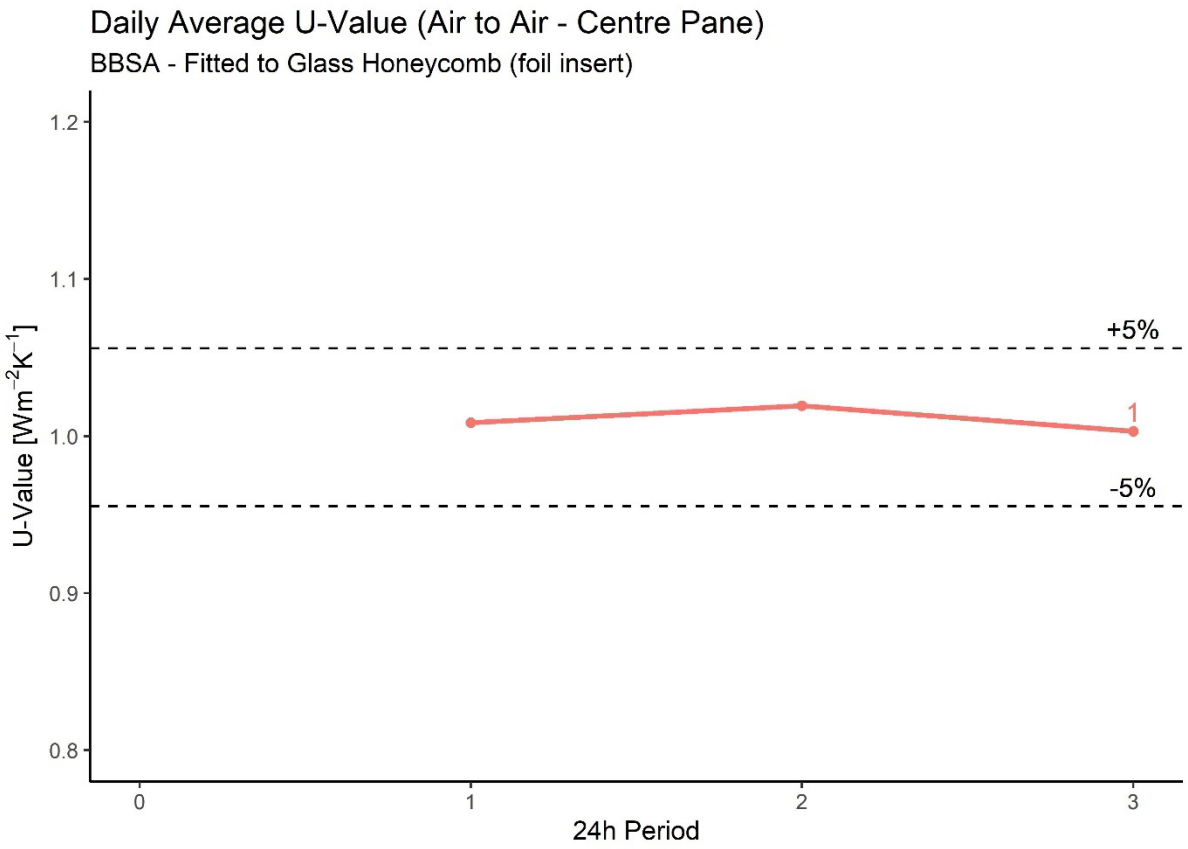


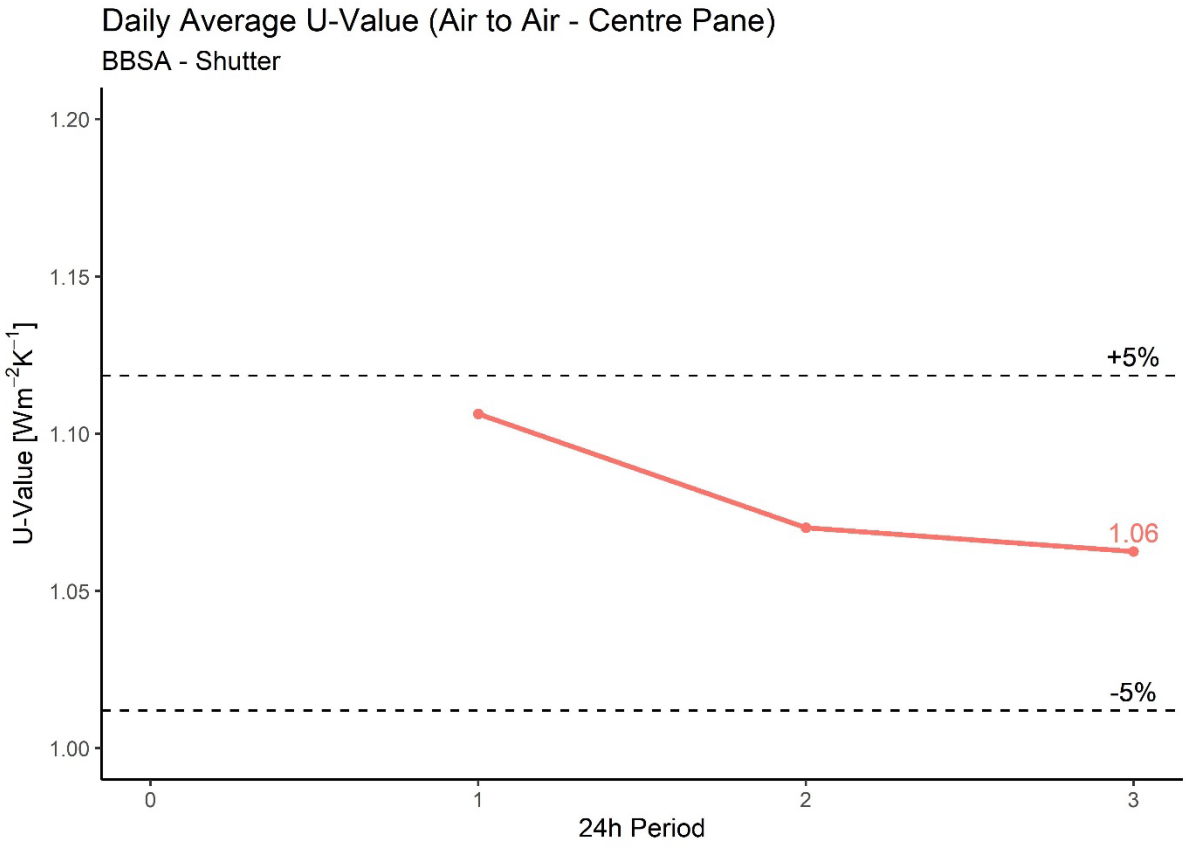

Daily Average U-Value (Air to Air - Centre Pane)
BBSA - Zip (Flocke)
U-Value [Wm^{-2}K^{-1}]
1.4
1.3
1.2
1.1
1.0
+5%
1.17
-5%
0
1
2
3
24h Period

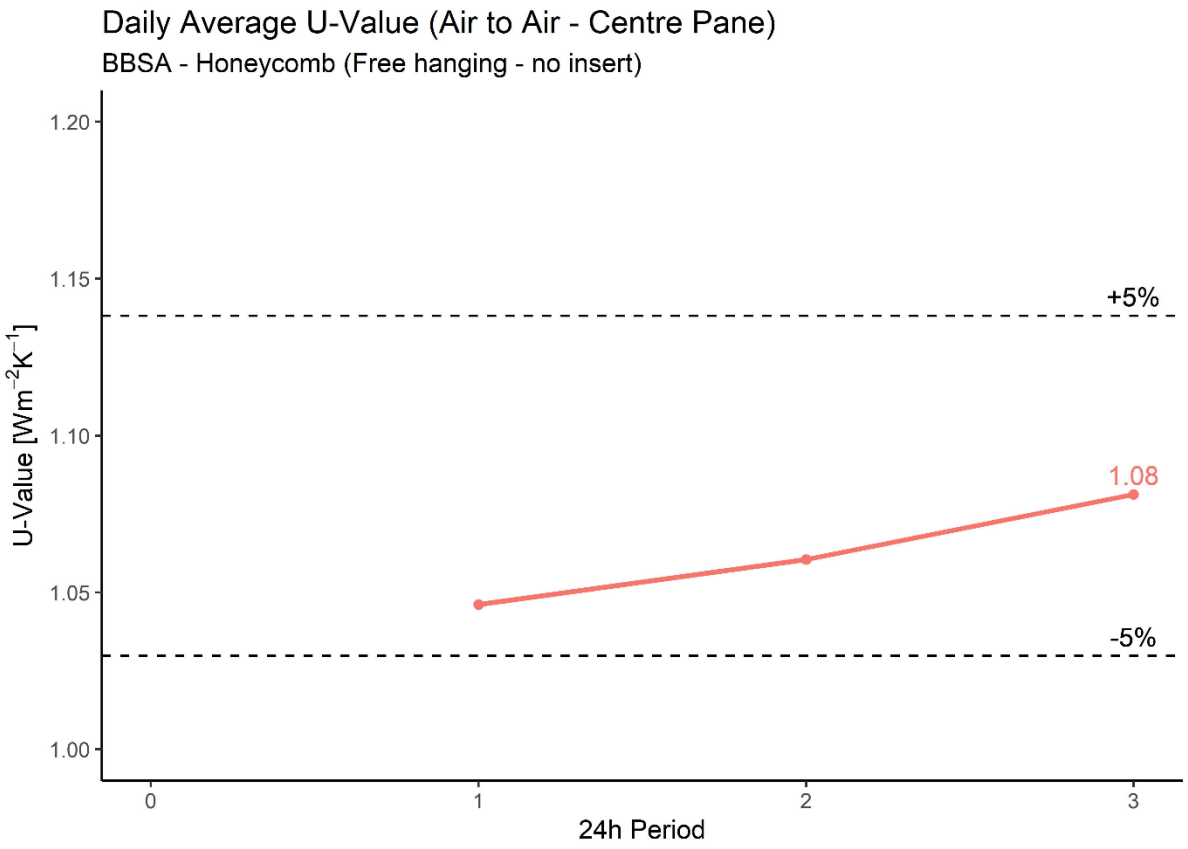

Daily Average U-Value (Air to Air - Centre Pane)
BBSA - Zip (Ultimetal)
U-Value [Wm^{-2}K^{-1}]
1.2
1.1
1.0
0.9
0.8
+5%
0.96
-5%
0
1
2
3
24h Period


Daily Average U-Value (Air to Air - Centre Pane)
BBSA - External Roller Blind (Flocke)
U-Value [Wm^{-2}K^{-1}]
1.4
1.3
1.2
1.1
1.0
+5%
-5%
1.2
0
1
2
3
24h Period


Daily Average U-Value (Air to Air - Centre Pane)
BBSA - Honeycomb (Free hanging - foil insert)
U-Value [Wm^{-2}K^{-1}]
1.20
1.15
1.10
1.05
1.00
+5%
-5%
1.09
0
1
2
3
24h Period

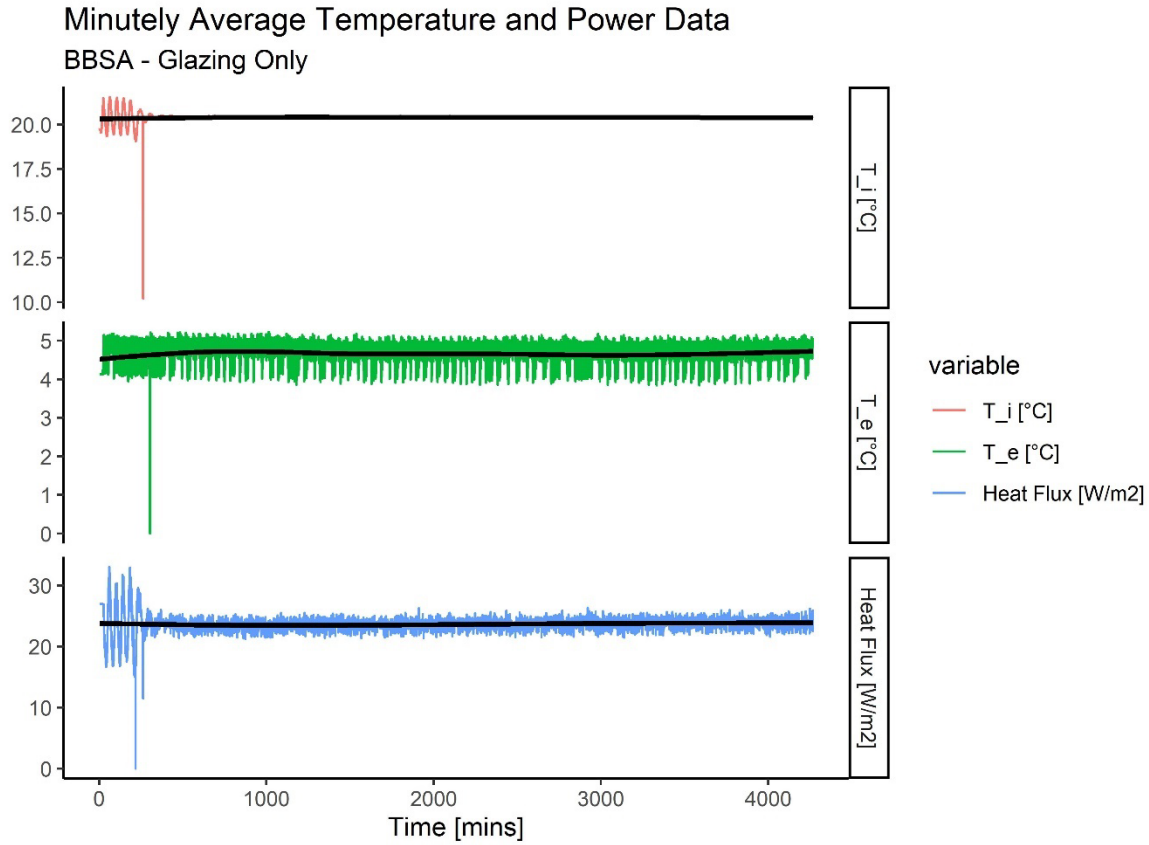

Daily Average U-Value (Air to Air - Centre Pane)
BBSA - Fitted to Glass Honeycomb (foil insert)
U-Value [Wm^{-2}K^{-1}]
1.2
1.1
1.0
0.9
0.8
+5%
1
-5%
0
1
2
3
24h Period

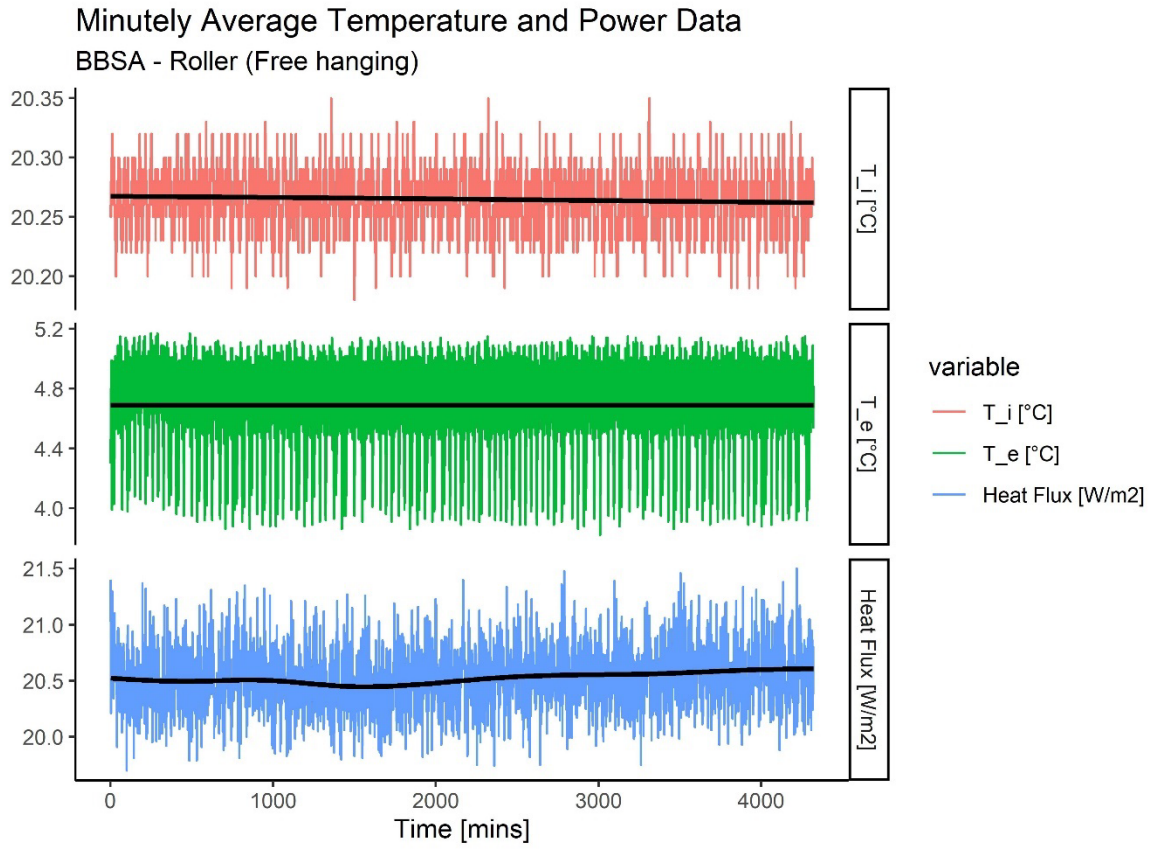

Daily Average U-Value (Air to Air - Centre Pane)
BBSA - Shutter
U-Value [Wm^{-2}K^{-1}]
1.20
1.15
1.10
1.05
1.00
+5%
1.06
-5%
0
1
2
3
24h Period

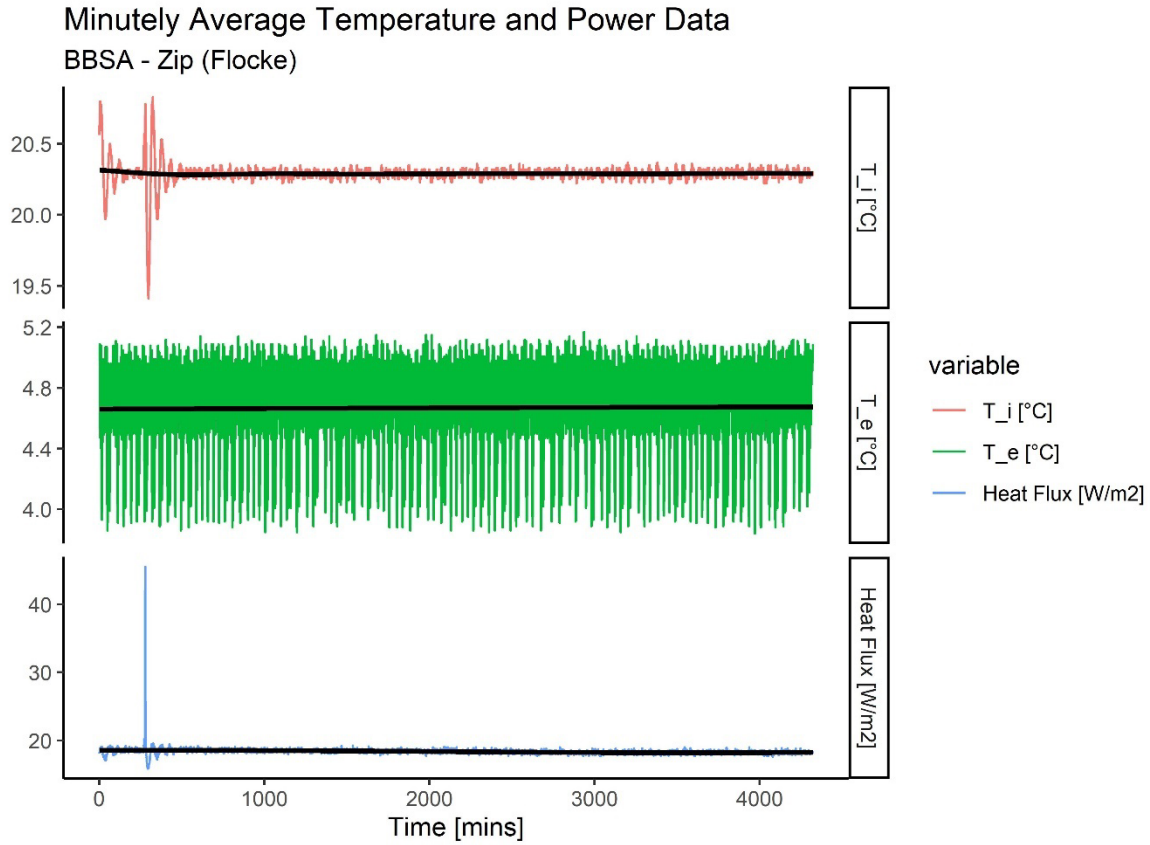

Daily Average U-Value (Air to Air - Centre Pane)
BBSA - Honeycomb (Free hanging - no insert)
1.20
1.15
1.10
1.05
1.00
U-Value [Wm^{-2}K^{-1}]
+5%
1.08
-5%
0
1
2
3
24h Period

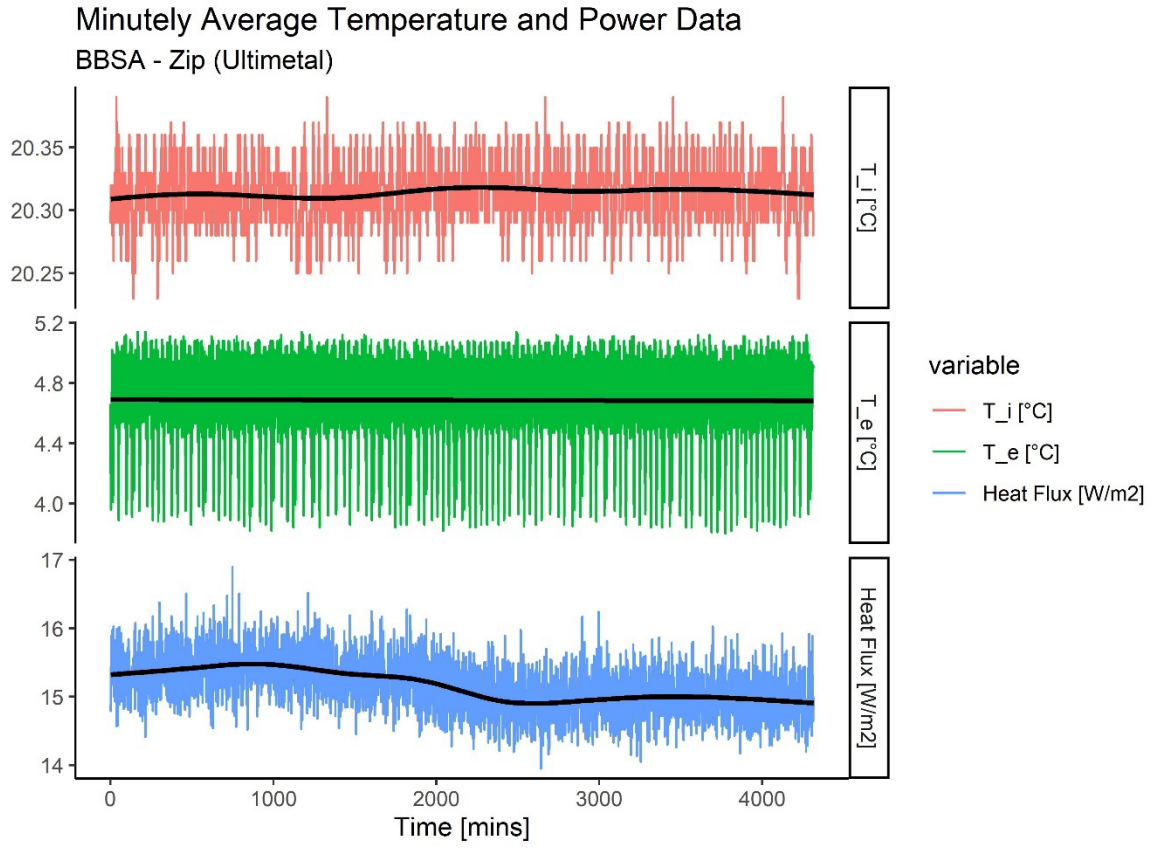
Appendix B - 72h Temperature and Heat Flux Plots

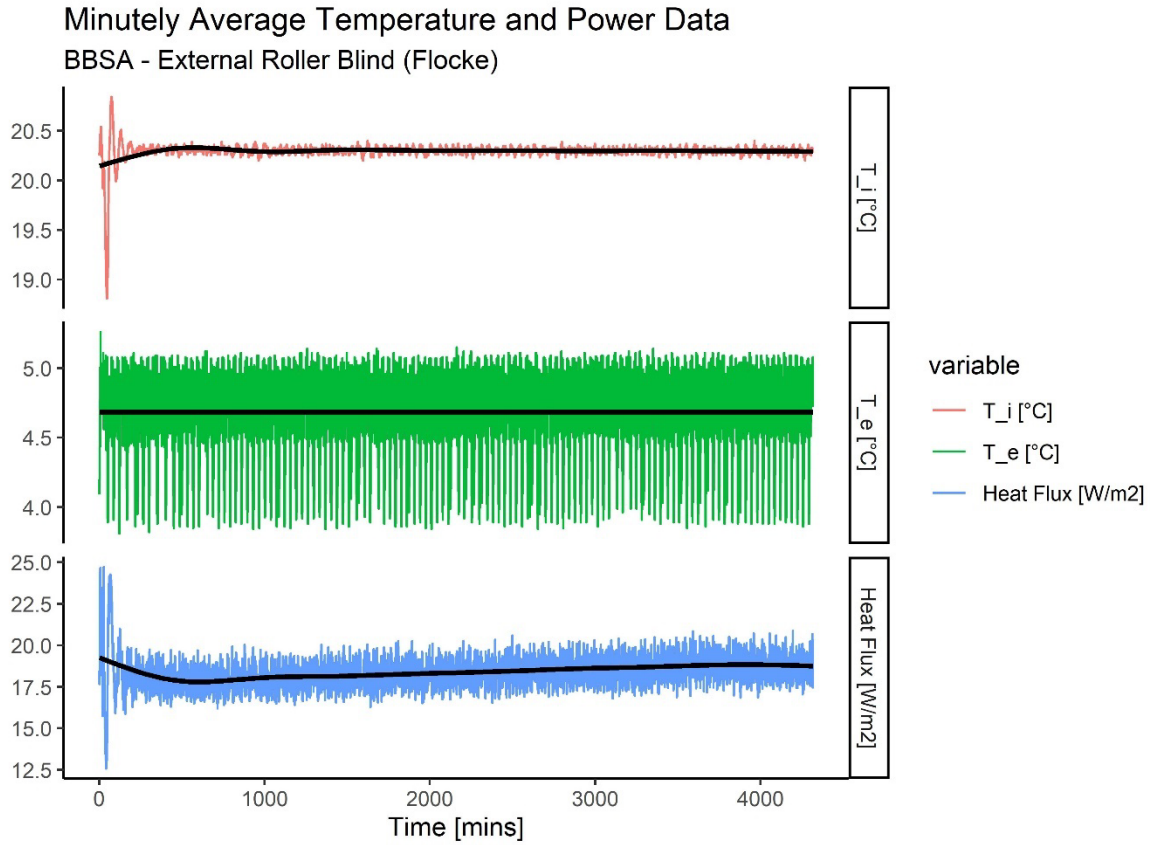
All heat flux measurements relate to centre pane only.

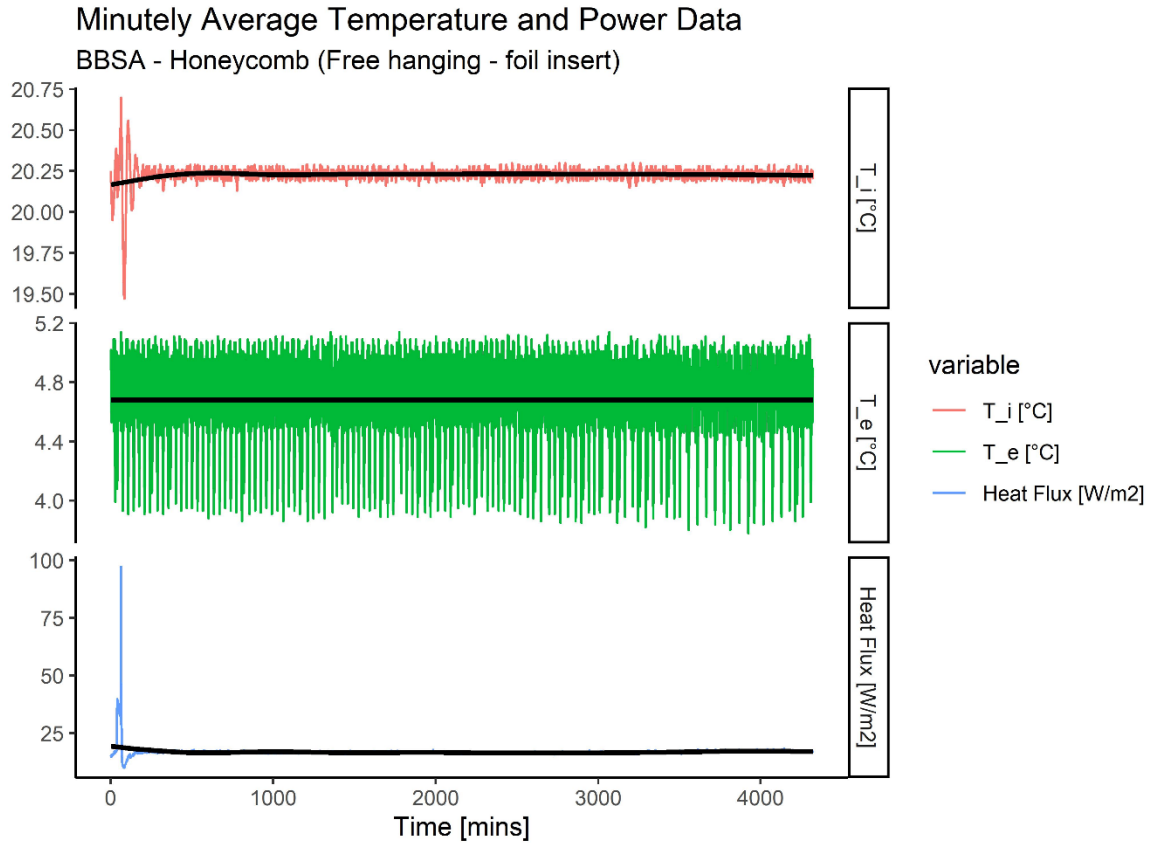


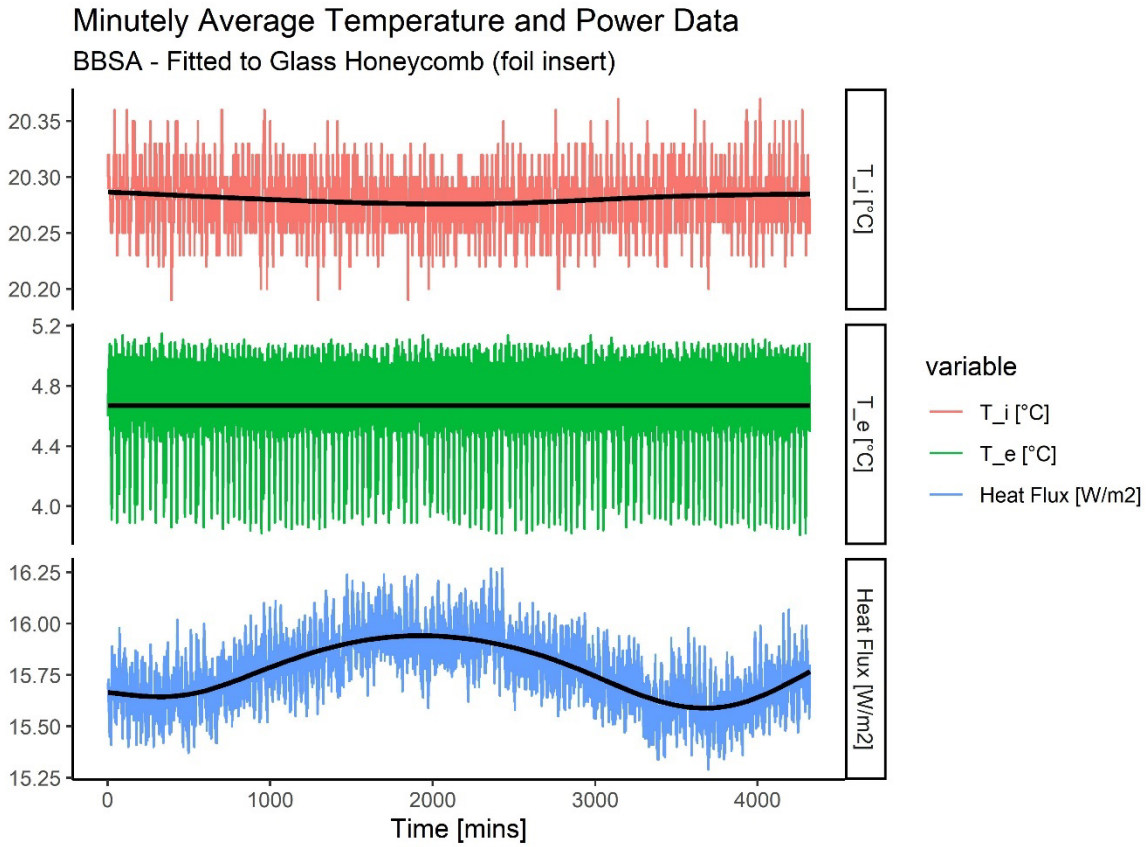


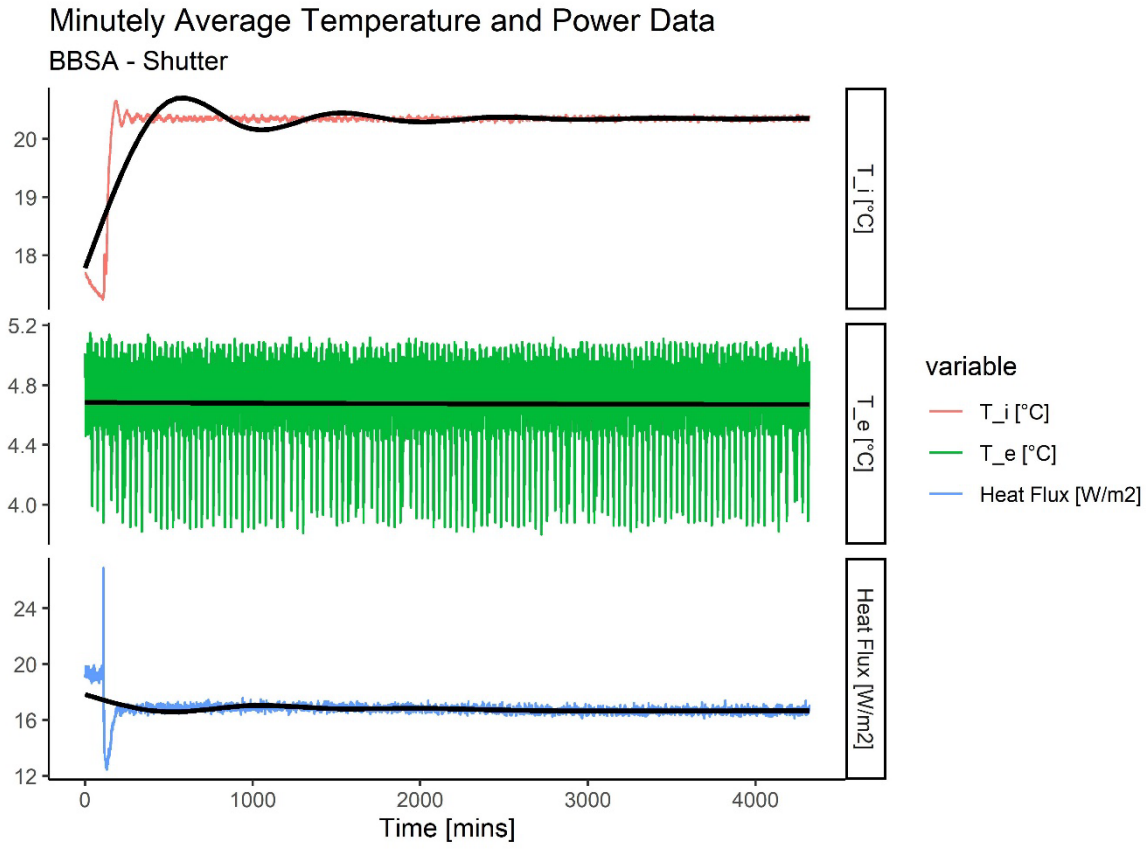

Minutely Average Temperature and Power Data
BBSA - Zip (Flocke)
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
Time [mins]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]

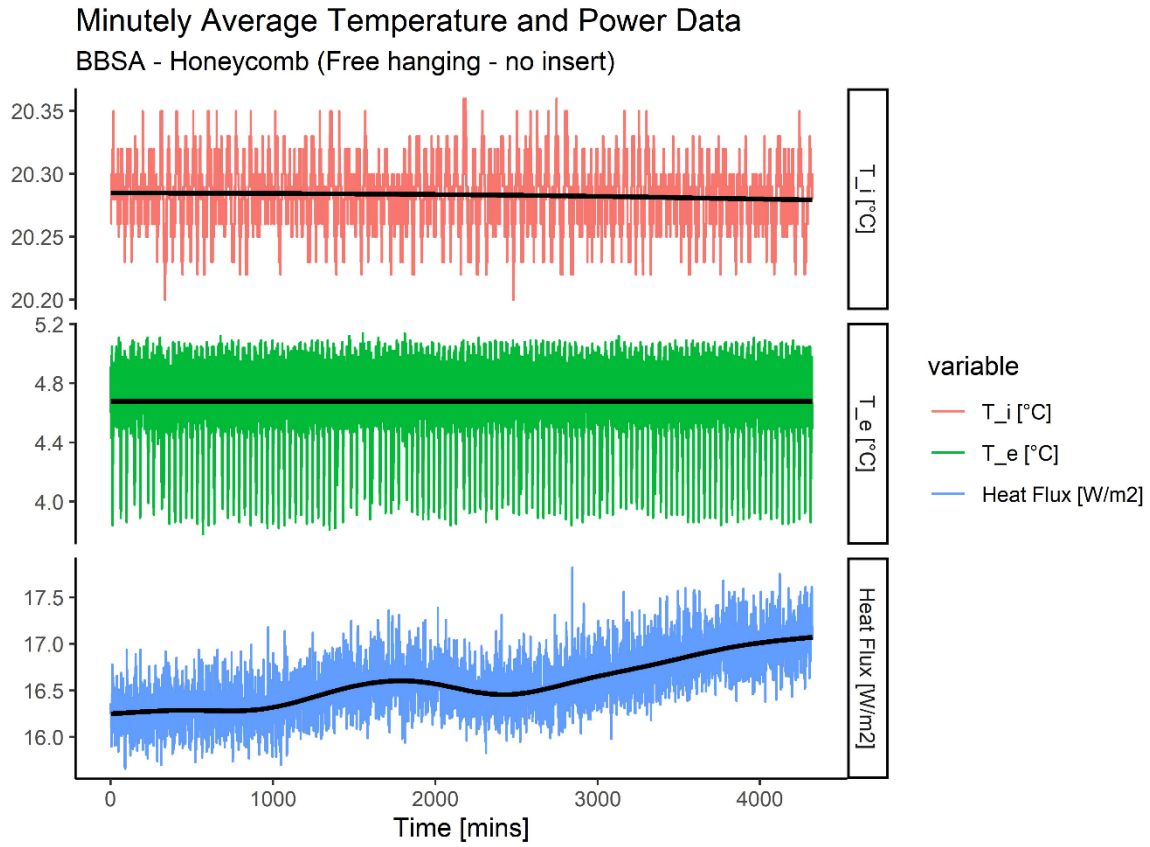

Minutely Average Temperature and Power Data
BBSA - Zip (Ultimetal)
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
Time [mins]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]


Minutely Average Temperature and Power Data
BBSA - External Roller Blind (Flocke)
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
Time [mins]


Minutely Average Temperature and Power Data
BBSA - Honeycomb (Free hanging - foil insert)
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
Time [mins]


Minutely Average Temperature and Power Data
BBSA - Fitted to Glass Honeycomb (foil insert)
20.35
20.30
20.25
20.20
T_i [°C]
5.2
4.8
4.4
4.0
T_e [°C]
16.25
16.00
15.75
15.50
15.25
Heat Flux [W/m2]
0
1000
2000
3000
4000
Time [mins]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]


Minutely Average Temperature and Power Data
BBSA - Shutter
20
19
18
T_i [°C]
5.2
4.8
4.4
4.0
T_e [°C]
24
20
16
12
Heat Flux [W/m2]
0
1000
2000
3000
4000
Time [mins]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]


Minutely Average Temperature and Power Data
BBSA - Honeycomb (Free hanging - no insert)
20.35
20.30
20.25
20.20
T_i [°C]
5.2
4.8
4.4
4.0
T_e [°C]
17.5
17.0
16.5
16.0
Heat Flux [W/m2]
0
1000
2000
3000
4000
Time [mins]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]

Appendix C - U-Value Correction Methodology

Glazing only resistances breakdown:

We measured the resistance of the glazing as:

$$R_{Gl} = \frac{T_{s_i} - T_{s_e}}{q} = 0.43\ m^2 \cdot K\ \cdot W^{-1}$$

We also measured the U-Value of the glazing panel as:

$$U_{Gl} = \frac{q}{T_i - T_e} = 1.52\ W \cdot m^{-2} \cdot K^{-1}$$

U-Value is defined as:

$$U \equiv \frac{1}{R_{Tot}} \equiv \frac{1}{R_{s_i} + R + R_{s_e}}$$

Therefore, for the glazing panel alone:

$$U_{Gl} = \frac{1}{R_{s_i} + R_{Gl} + R_{s_e}}$$

$$\therefore R_{s_i} + R_{s_e} = \frac{1}{U_{Gl}} - R_{Gl} = \frac{1}{1.52} - 0.43 = 0.23\ m^2 \cdot K\ \cdot W^{-1}$$

As we are in a chamber, assume:

$$R_{s_i} \approx R_{s_e}$$

$$\therefore R_{s_i} + R_{s_e} = 2R_s$$

$$\therefore R_s = \frac{R_{s_i} + R_{s_e}}{2} = \frac{0.23}{2} = 0.11\ m^2 \cdot K\ \cdot W^{-1}$$

Note – this is similar to the R_{s_i} value of 0.13 m²K/W in ISO 6946

Glazing only U-Value correction:

The glazing should have had a U-Value lower than the one measured. To correct this, we'll alter the glazing resistance component of the U-value calculation. We'll denote any corrected values as "prime" (*).

$$U^*_{Gl_0} = \frac{1}{2R_s + R^*_{Gl}} = 1.40\ W \cdot m^{-2} \cdot K^{-1}$$

$$\therefore R^*_{Gl_0} = \frac{1}{U^*_{Gl_0}} - 2R_s = \frac{1}{1.40} - 0.23 = 0.48\ m^2 \cdot K\ \cdot W^{-1}$$

We can now use this corrected resistance for the glazing in the U-Value calculation including blinds.

System U-Values (Blinds + Glazing) correction:

We will refer to the measured U-Value (those given in the initial results document) as the *system* U-values, defined as:

$$U_{System} \equiv U_{Sys} \equiv \frac{1}{R_{Tot}}$$

$$R_{Tot} = R_{s_i} + R + R_{s_e}$$

$$R = R_{Fabric} + R_{Gap} + R_{Gl}$$

$$\therefore R_{Tot} = R_{s_i} + R_{Fabric} + R_{Gap} + R_{Gl} + R_{s_e}$$

We assume $R_{Gl}$is constant throughout the testing, and is measured 0.43 m²K/W.

We will define $R_{Product}$ as the sum of the resistances that may change because of the blind/shutter:

$$R_{Product} \equiv R_{Prod} \equiv R_{s_i} + R_{Fabric} + R_{Gap} + R_{s_e}$$

$$\therefore R_{Tot} = R_{Prod} + R_{Gl}$$

$$\therefore U_{Sys} = \frac{1}{R_{Prod} + R_{Gl}}$$

Using the "Roller" blind result as an example, we get:

$$U_{Sys} = \frac{1}{R_{Prod} + R_{Gl}} = 1.32\ W \cdot m^{-2} \cdot K^{-1}$$

$$\therefore R_{Prod} = \frac{1}{U_{Sys}} - R_{Gl} = \frac{1}{1.32} - 0.43 = 0.33\ W \cdot m^{-2} \cdot K^{-1}$$

We can now define the corrected U-Value, U^*_{Sys}, as:

$$U^*_{Sys} = \frac{1}{R_{Prod} + R^*_{Gl}} = \frac{1}{\left(\frac{1}{U_{Sys}} - R_{Gl}\right) + R^*_{Gl_0}} = \frac{1}{\left(\frac{1}{1.32} - 0.43\right) + 0.48} = 1.24 W \cdot m^{-2} \cdot K^{-1}$$

Comparing the % change on baseline between the measured and the corrected (*) U-Values:

	U Glazing	U System	ΔU	% Change
Measured	1.52	1.32	-0.20	-13.2%
Corrected (*)	1.40	1.24	-0.16	-11.4%

Note, in the full "corrected" results table, the measured R_{Gl} is used from each test.

Product	Glazing to Shade (dglaz) [mm]	Top Gap (dtop) [mm]	Left Side Gap (dside_L) [mm]	Right Side Gap (dside_R) [mm]	Bottom Gap (dbot) [mm]	Comments
Roller (Free hanging)	77	10	21	28	8	AM measurement
Zip (Flocke)	81	N/A	3	3	1	PM install, dtop foam covered, L/R reveal to metal
Zip (Ultimetal)	81	N/A	3	3	1	
External Roller Blind / Flocke	82	3	3	3	7	dtop - Packed in, couldn't get a good angle
Honeycomb (Free hanging - foil insert)	108	2	6	7.8	15	dtop - Pretty much flush
Fitted to Glass Honeycomb (foil insert)	20	1	5	3	2	
Shutter	86	5	5	5	2	includes gaps between folds
Honeycomb (Free hanging - no insert)	84	3	7	3.3	1	