Blind Screen
Phase 4 DGU / SGU & Phase 5
Energy House Product Test

Test Report v1.0

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1. Introduction

This report provides U-value measurements from window blind testing at the University of Salford Energy House 1 test facility. The purpose of the testing was to measure, under controlled conditions, the impact that products manufactured by Blind Screen has on the heat loss through window glazing.

2. Methodology

2.1. Test facility

The Energy House 1 test facility contains the Energy House, a replica Victorian solid wall end-terrace house constructed within an environmental chamber. The Energy House was built using reclaimed materials and traditional construction methods and can be retrofitted to most fabric thermal performance standards. The chamber can replicate external air temperatures between -12 °C and +30 °C and simulate rainfall, wind, and solar radiation. The Energy House has a conventional hydronic central heating system with radiators in each room that is served by either a domestic gas condensing combination boiler or an air source heat pump. Its building automation control system enables simulation of occupant behaviour, such as window and door opening, lighting and appliance use, and domestic hot water (DHW) draw-offs. The Energy House shares a party wall with an adjoining building, referred to as Pemberton House. Environmental conditions in the chamber and Pemberton House can be controlled and repeated across multiple test periods. This makes it possible to measure the impact of changes building fabric, space heating provision, and occupancy behaviour with greater confidence and speed than houses in the field.

A double-glazed window housed in a uPVC frame in Pemberton House was used for the test. It has 24 mm double glazing panels (4 mm + 16 mm space + 4 mm) with low emissivity coating on the outer surface of the inner pane, the cavity is filled with 90 % argon.

2.2. Centre pane in situ U-value measurements

2.2.1. In situ U-value measurement method

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

2.2.2. Environmental conditions

The internal temperature was maintained 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 perform the test within steady state conditions, the chamber HVAC was set to achieve and maintain 5°C throughout the test period.

2.2.3. Measurement Equipment

Internal and external temperature measurements were made using Campbell Scientific Hygrovue 10 sensors (±0.1 °C). Heat flux measurements were made using a Hukseflux HFP01 (±3%) in the centre of the main glazing panel. The data was 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 the external temperature sensor highlighted in yellow.

3. Products Tested

3.1.1. Phase 4 – 02 Double Track - Sheer Intimacy Net

The tested Blind Screen product consisted of three slide screen panels within an enclosed frame system. When considering the screen positions, 'inner' refers to the screen closer to the glazing, and 'outer' refers to the room-side screen. Two different screens share the 'outer' screen runner. Figure 2 shows the experimental set-up for the inner Sheer Intimacy Net.

Figure 2 – Sheer Intimacy Net screen test.

3.1.2. Phase 4 – 02 Double Track – Double Sheer Intimacy Net

The tested Blind Screen product consisted of three slide screen panels within an enclosed frame system. Figure 3 shows the experimental set-up for both inner and outer Sheer Intimacy Net.

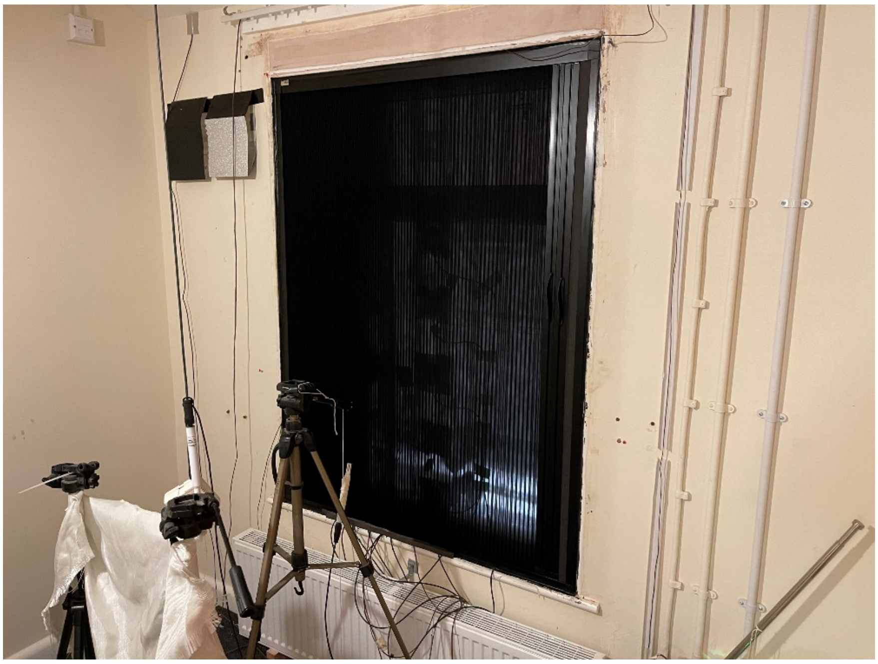


Figure 3 – Experimental set-up for the Double Sheer Intimacy Net.

3.1.3. Phase 4 – 02 Double Track – Sheer Intimacy Net & Light Seal

The tested Blind Screen product consisted of three slide screen panels within an enclosed frame system. Figure 4 shows the experimental set-up for inner Sheer Intimacy Net and outer Light Seal.

Figure 4 – Experiment set-up for the Sheer Intimacy and Light Seal.

3.1.4. Phase 4 – SGU – 02 Double Track – Duette

The tested Blind Screen product consisted of two slide screen panels within an enclosed frame system. Figure 5 shows the experimental set-up for Duette, the screen closest to the glazing.

Figure 5 – Single glazing test set-up for Duette, the inner screen closest to the glazing.

3.1.5. Phase 4 – SGU – 02 Double Track – Double Duette

The tested Blind Screen product consisted of two slide screen panels within an enclosed frame system. Figure 6 shows the experimental set-up for the Double Duette.

Figure 6 – Single glazing test set-up for Double Duette.

3.1.6. Phase 5 – 02 Single Light Seal

The tested Blind Screen product consisted of a single slide screen panel within an enclosed frame system. Figure 7 shows the experimental set-up for the 02 Single Light Seal.

Figure 7 – Test set-up for 02 Single Light Seal.

4. Results

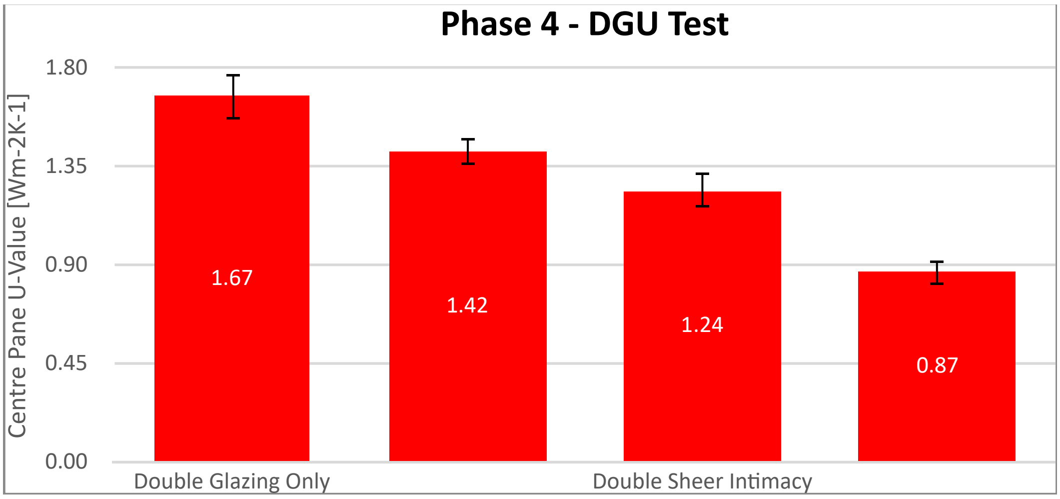
Table 1 provides a set of U-value results for Phase 4 and Phase 5. Regarding the Phase 4 double glazing test, the Blind Screen 02 Double Track – Sheer Intimacy Net resulted in an in-situ centre pane U-value of 1.42 (±0.09) W/m²K, representing a centre pane U-value reduction of 13% from the baseline measurement performed with no window covering, which was 1.67 (±0.11) W/m²K. Additionally, the Double Sheer Intimacy, resulted in an in-situ centre pane U-value of 1.24 (±0.08) W/m²K, which represents a U-value reduction of 24% from the baseline measurement. Finally, the Sheer Intimacy and Light Seal resulted in an in-situ centre pane U-value of 0.87 (±0.06) W/m²K, a reduction on the double-glazing baseline of 47%. Phase 4 also comprised of single-glazed testing. The single-glazed baseline test was measured at 4.88 W/m²K. The provided 02 Double Track – Duette resulted in an in-situ centre pane U-value of 1.4 W/m²K, a 71% reduction on the baseline measurement and the Double Duette resulted in an in-situ centre pane U-value of 0.91, a reduction of 81% on the baseline single-glazed measurement.

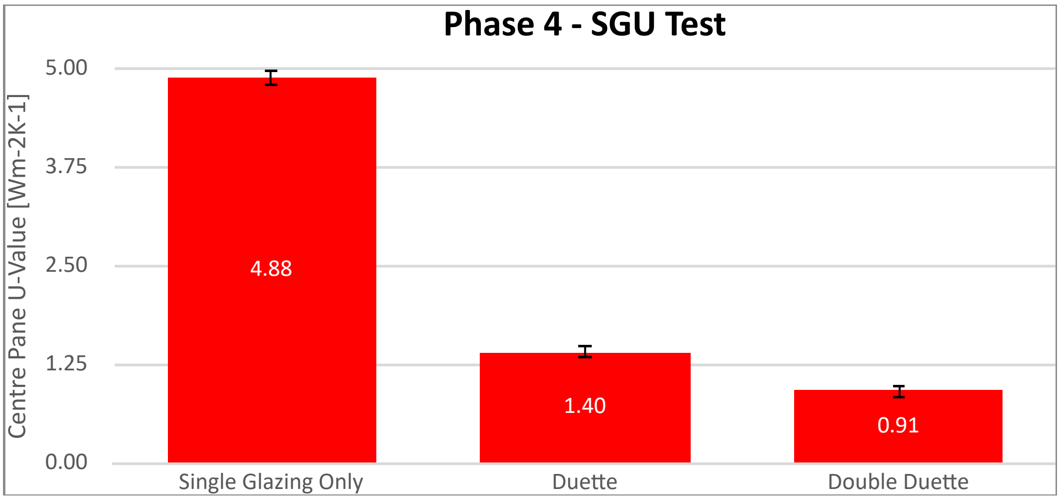
Regarding the Phase 5 double-glazed unit test, Blind Screen 02 Single Light Seal had an in-situ centre pane measured U-value of 0.99 (±0.07) W/m²K. This was a reduction of 41% on the baseline double-glazed U-value measurement of 1.67 (±0.11) W/m²K.

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

Phase	Product	U-Value [$Wm^{-2}K^{-1}$]	ΔU on baseline [$Wm^{-2}K^{-1}$]	U % Change on Baseline[1]
Phase 4	**Double Glazed (Baseline)**	1.67 (±0.11)	-	-
	Sheer Intimacy	1.42 (±0.09)	-0.22 (±0.14)	-13% (±8%)
	Double Sheer Intimacy	1.24 (±0.08)	-0.4 (±0.13)	-24% (±8%)
	Sheer Intimacy & Light Seal	0.87 (±0.06)	-0.77 (±0.12)	-47% (±7%)
	Single Glazed (Baseline)	4.88	-	-
	Duette	1.4	-3.61	-71%
	Double Duette	0.91	-4.1	-81%
Phase 5	**Double Glazed (Baseline)**	1.67 (±0.11)	-	-
	02 Single Light Seal	0.99 (±0.07)	-0.68 (±0.13)	-41% (±8%)

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





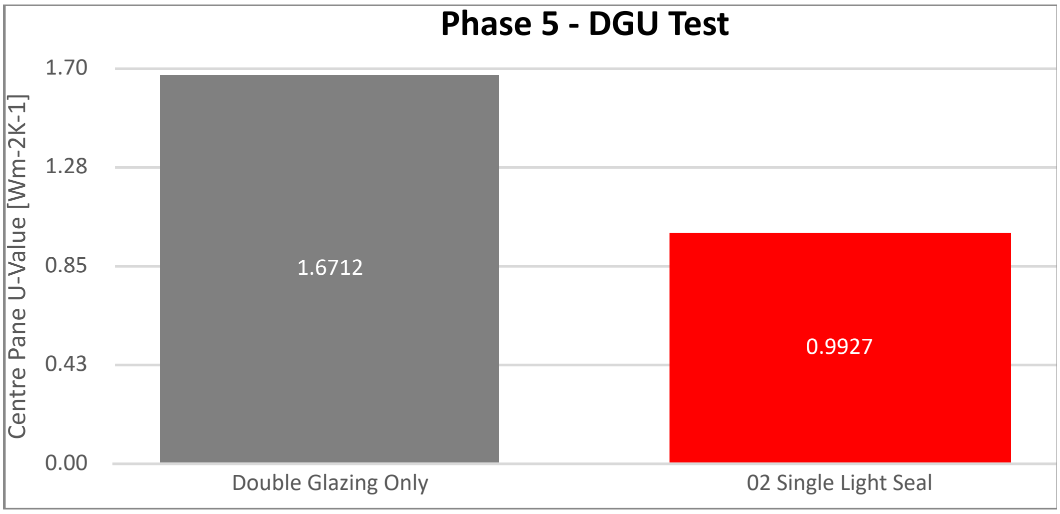


Figure 8 - Centre pane U-value measurements for Phase 4 (DGU & SGU) and Phase 5.

Results presented comply with ISO 9869 measurements and are based on the final 24-hour 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 has been stated for each measurement. The methodology followed for the uncertainty calculations can be found in Appendix C.

4.1.1. Data Comparison

For completeness, Table 2 contains all the results of the previous Blind Screen tests.

Test	Product	U-Value [$Wm^{-2}K^{-1}$]	ΔU on baseline [$Wm^{-2}K^{-1}$]	U % Change on Baseline	R-value [m^2K/W]	ΔR on baseline [$Wm^{-2}K^{-1}$]	R % Change on Baseline[1]
Future Homes Phase 1	**Double Glazed (Baseline)**	1.33	-	-	0.75	-	-
	ZeddFit 01	0.69	-0.65	-49%	1.45	+0.70	+93%
	Double Track 02	0.68	-0.65	-49%	1.47	+0.72	+96%
Future Homes Phase 2	**Double Glazed (Baseline)**	1.37	-	-	0.73	-	-
	Blind Screen 02 Dual	0.82	-0.54	-40%	1.22	+0.49	+67%
Phase 3	**Double Glazed (Baseline)**	1.59	-	-	0.63	-	-
	ZeddFit 25mm Double Duette	0.67	-0.92	-58%	1.49	+0.86	+137%
	ZeddFit 20mm	0.79	-0.8	-50%	1.27	+0.64	+102%
Phase 4	**Double Glazed (Baseline)**	1.67	-	-	0.6	-	-
	Sheer Intimacy	1.41	-0.26	-16%	0.71	+0.11	+19%
	Double Sheer Intimacy	1.23	-0.44	-26%	0.81	+0.21	+36%
	Sheer Intimacy & Light Seal	0.86	-0.81	-48%	1.16	+0.56	+93%
	Single Glazed (Baseline)	4.88	-	-	0.21	-	-
	Duette	1.4	-3.48	-71%	0.71	+0.50	+245%
	Double Duette	0.91	-4.0	-81%	1.09	+0.88	+430%
Phase 5	**Double Glazed (Baseline)**	1.67	-	-	0.6	-	-
	02 Single Light Seal	0.99	-0.68	-41%	1.01	+0.41	+41%

Table 2 – Result data providing comparison of the previous Phases of Blind Screen tests and current Phase of testing.

5. Summary

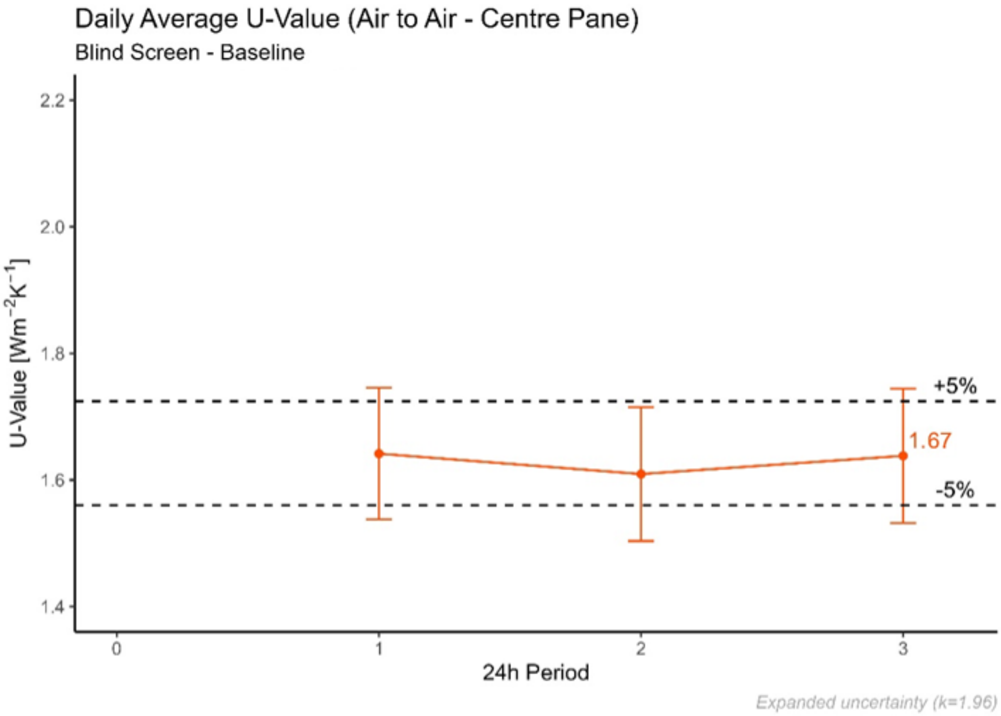
Regarding the Phase 4 – DGU test, in-situ centre pane U-value measurements under controlled conditions found that when compared to the glazing only baseline, the Sheer Intimacy, Double Sheer Intimacy, Sheer Intimacy & Light Seal resulted in a reduction in centre panel U-value of 13% (±8%), 24% (±8%) and 47% (±7%) respectively. In the Phase 4 – SGU test, when compared to glazing only, Duette and Double Duette resulted in a centre pane U-value reduction of 71% and 81% respectively.

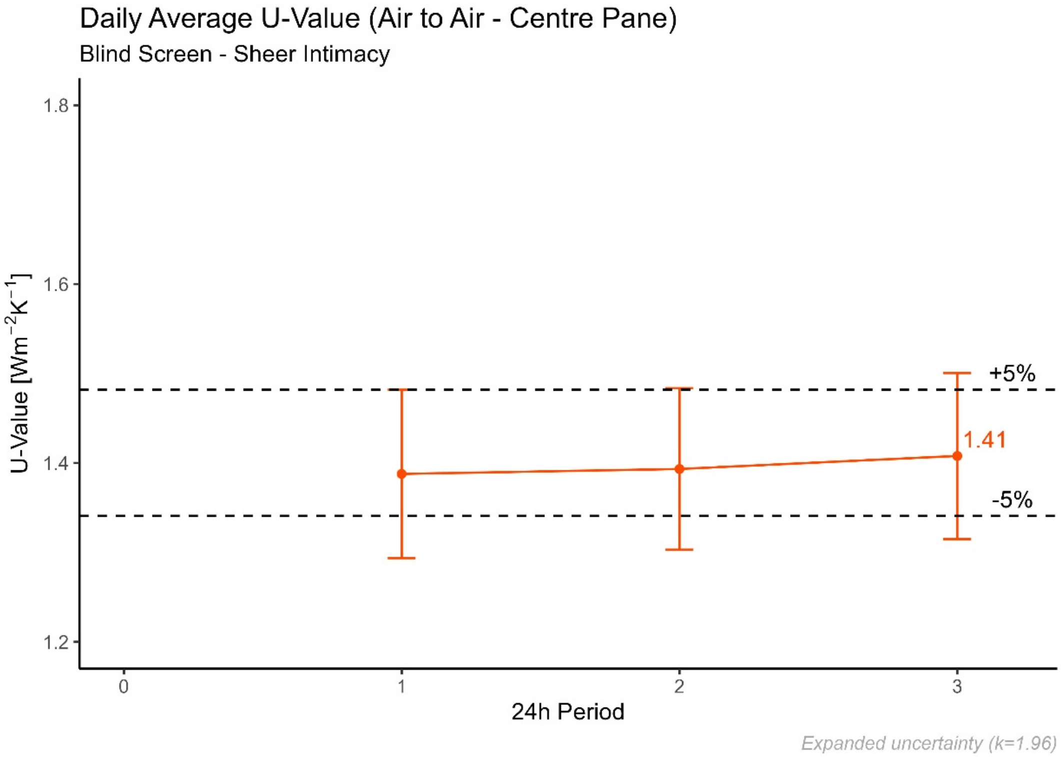
When compared to the double-glazed unit, the Phase 5 test of the 02 Single Light Seal blind saw a centre pane U-value reduction of 41% (±8%).

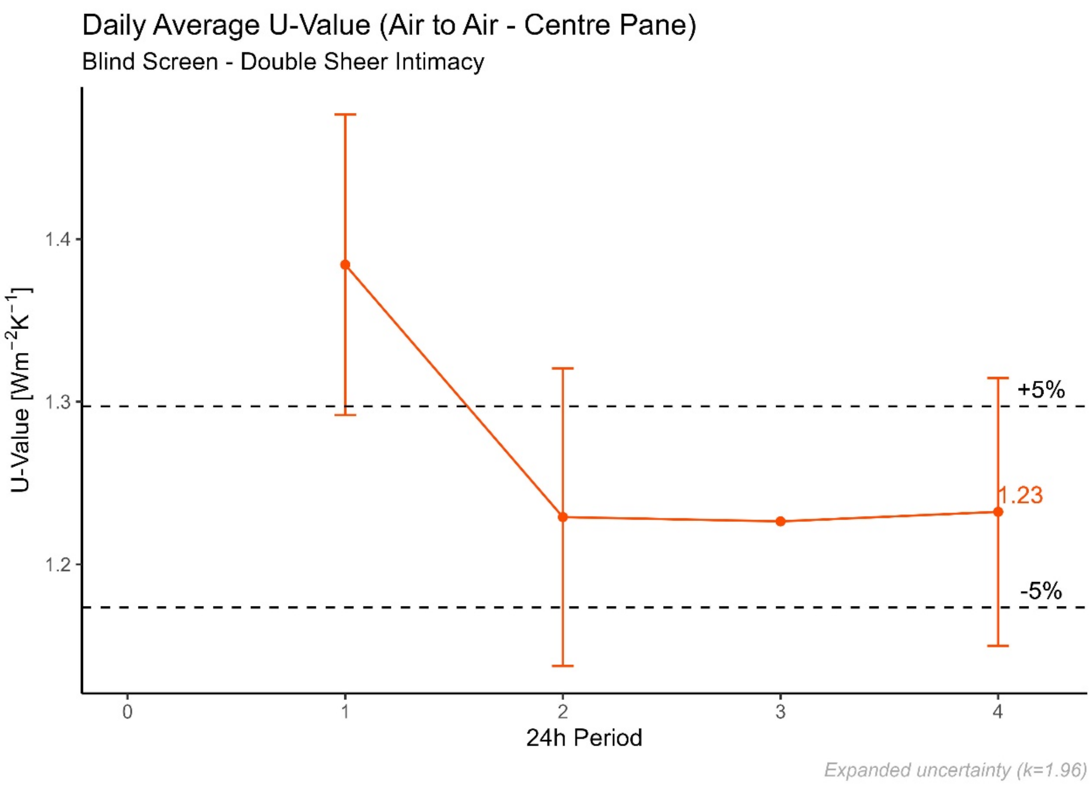
Appendix A - 24-hour Average Centre Pane U-Value

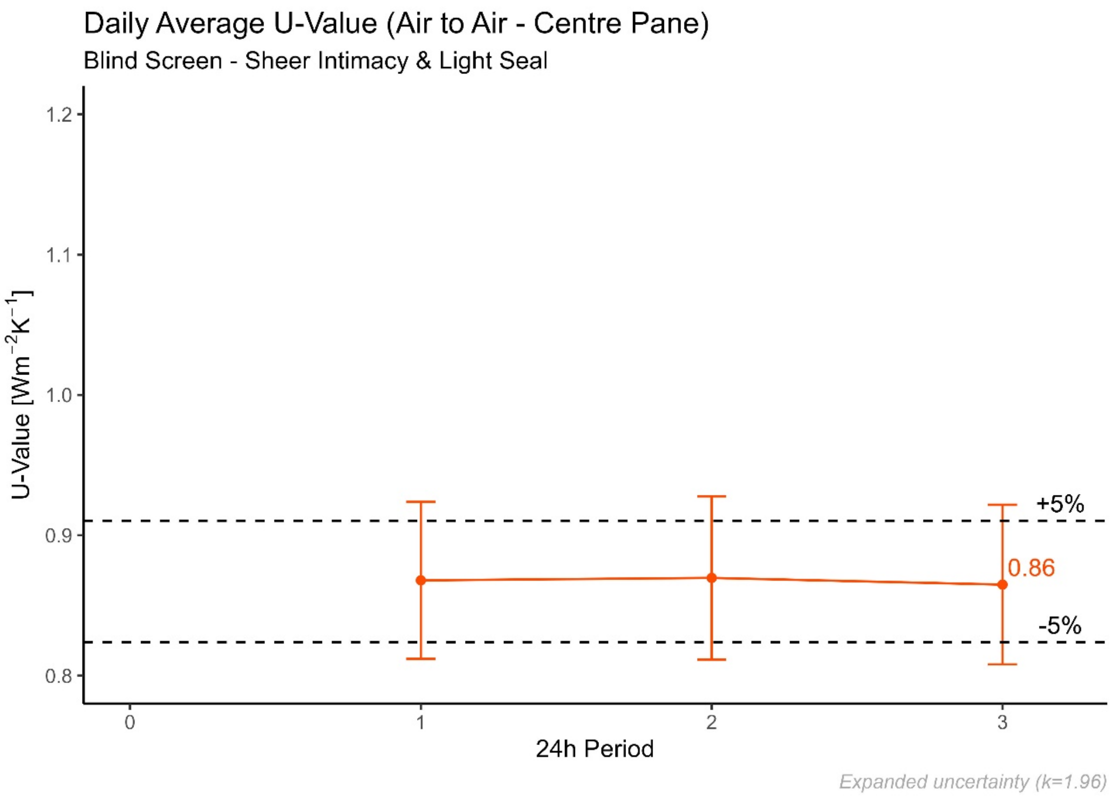
±5% lines are to show conformity to part of the criteria stated in ISO9869:1.

Phase 4 - DGU





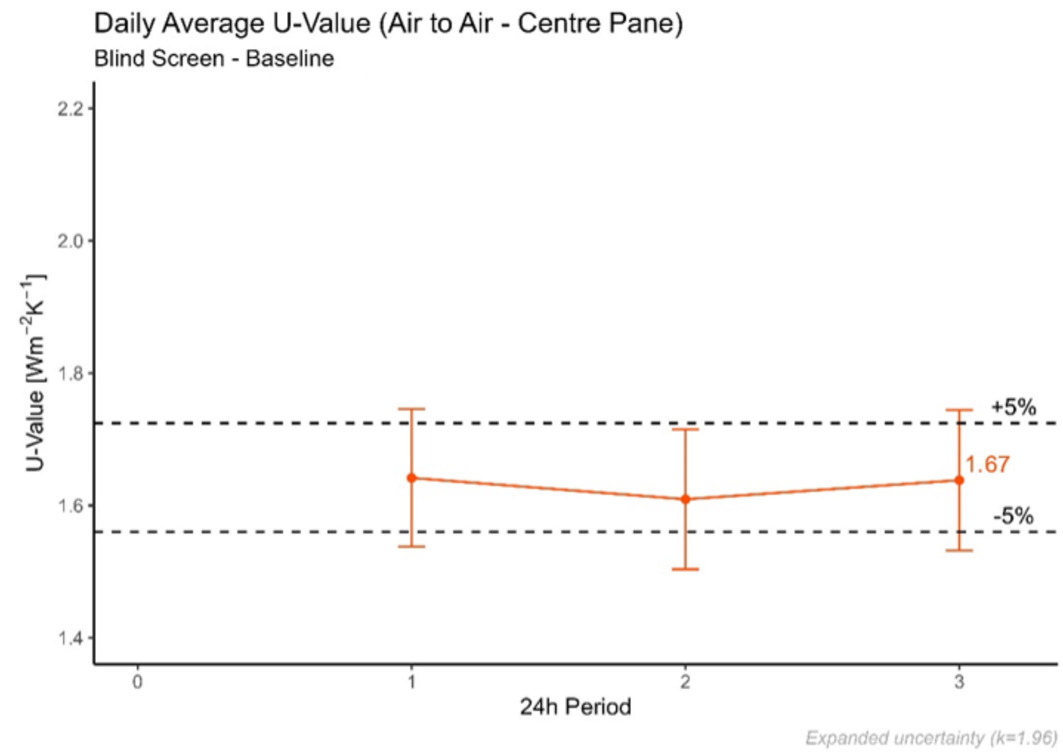

Daily Average U-Value (Air to Air - Centre Pane)
Blind Screen - Double Sheer Intimacy
U-Value [Wm^{-2}K^{-1}]
1.4
1.3
1.2
+5%
1.23
-5%
0
1
2
3
4
24h Period
Expanded uncertainty (k=1.96)

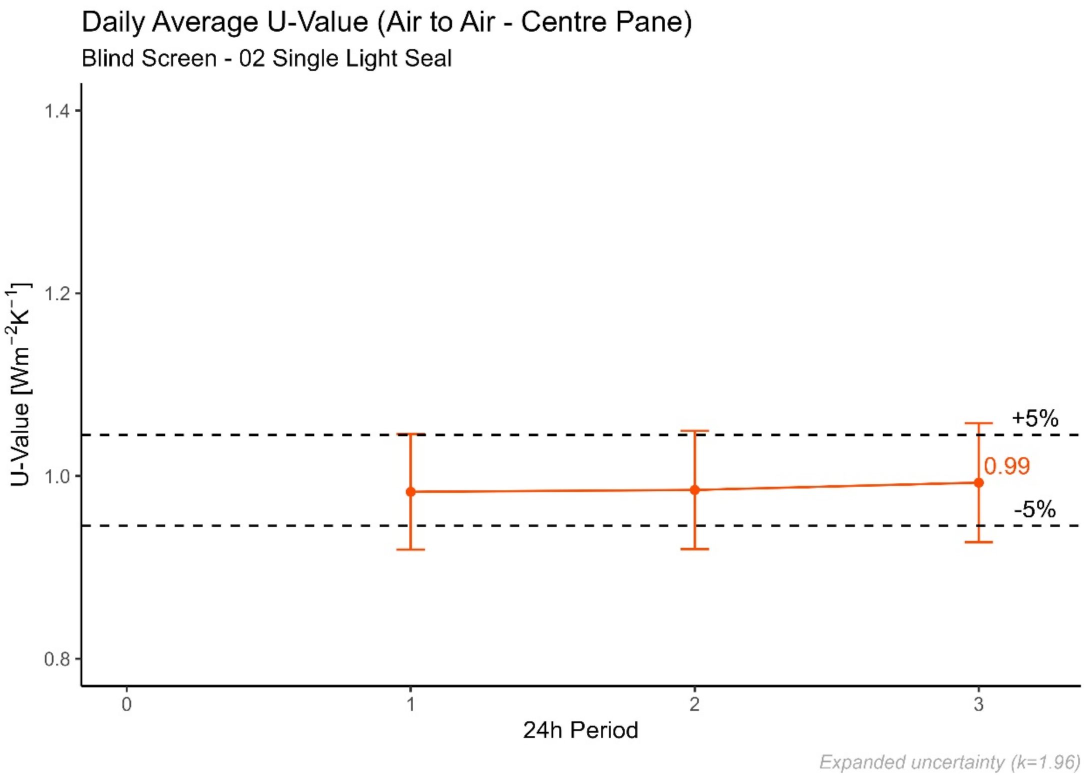

Daily Average U-Value (Air to Air - Centre Pane)
Blind Screen - Sheer Intimacy & Light Seal
U-Value [Wm^{-2}K^{-1}]
1.2
1.1
1.0
0.9
0.8
+5%
0.86
-5%
0
1
2
3
24h Period
Expanded uncertainty (k=1.96)

Phase 4 - SGU

Single glazed U-value visual data has not yet been applied to the required script.

Phase 5

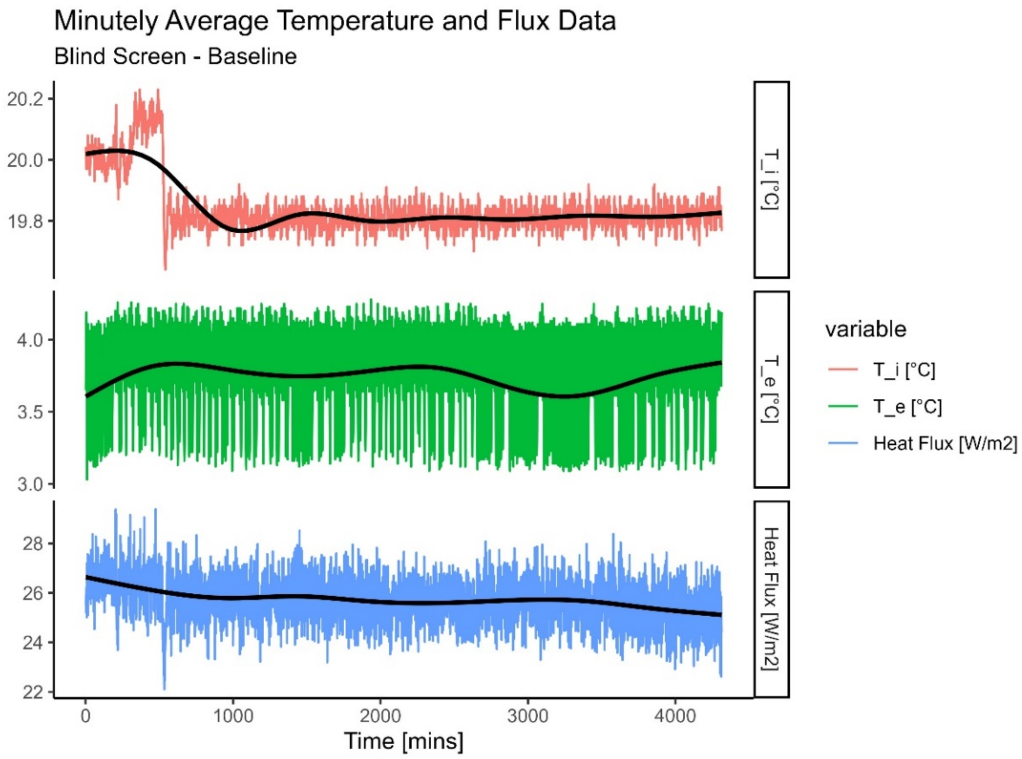


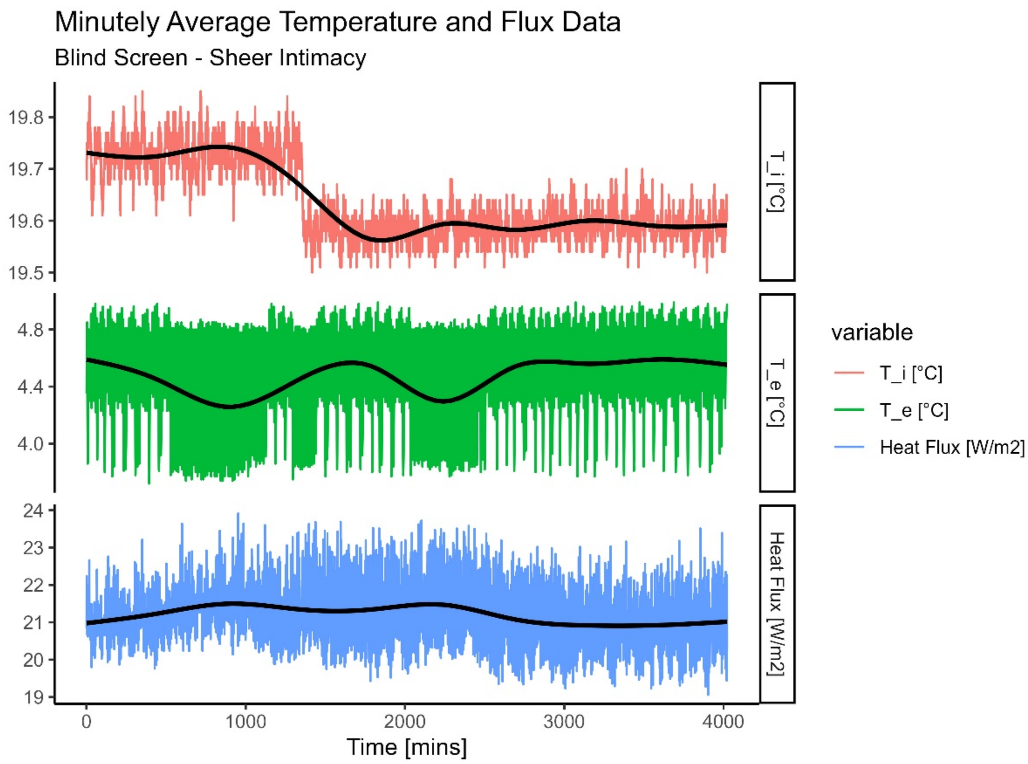


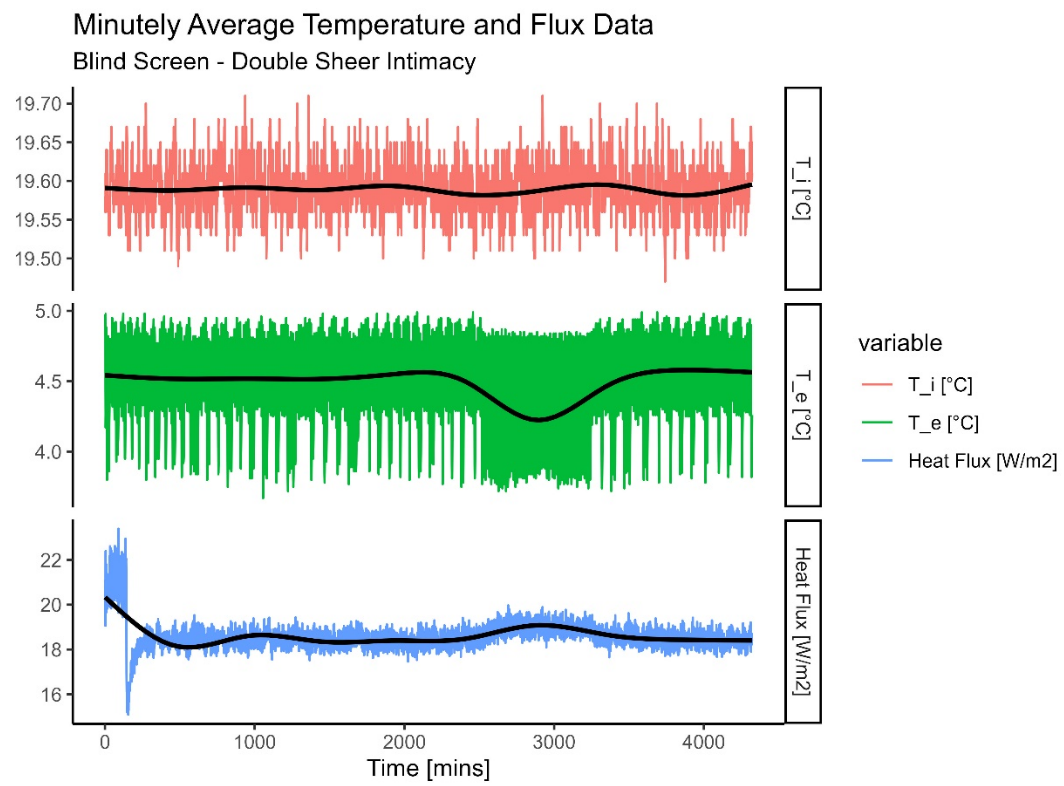
Appendix B - 72h Temperature and Heat Flux Plots

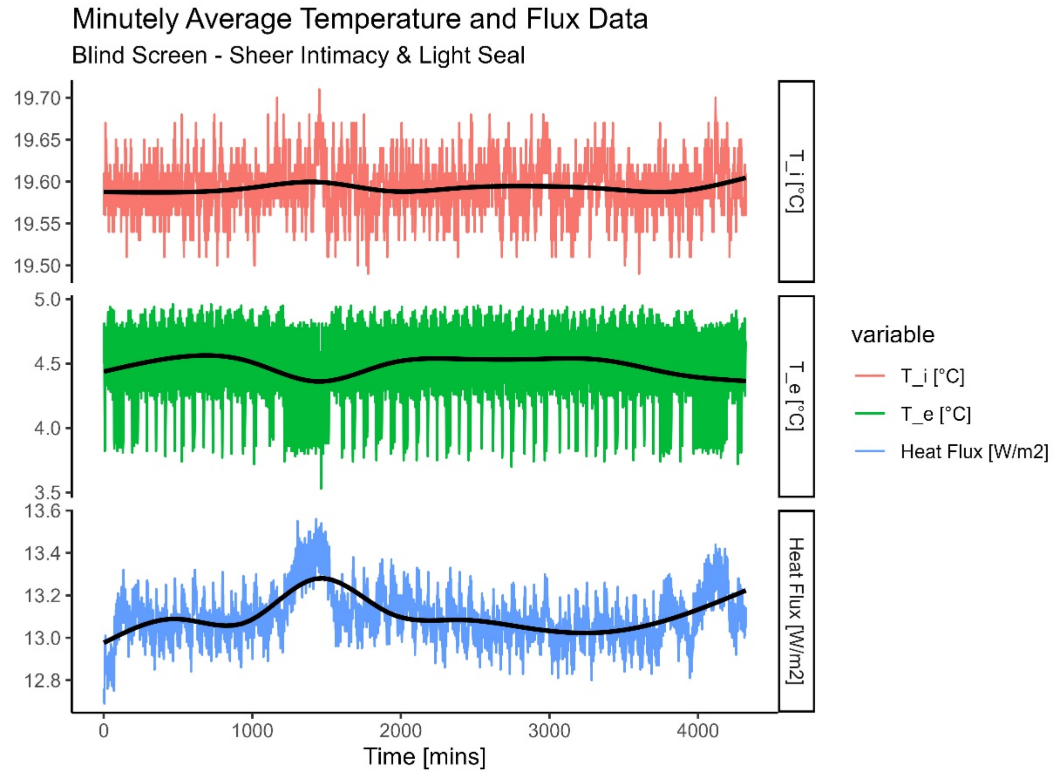
All heat flux measurements relate to centre pane only.

<u>Phase 4 - DGU</u>


Minutely Average Temperature and Flux Data
Blind Screen - Baseline
20.2
20.0
19.8
T_i [°C]
4.0
3.5
3.0
T_e [°C]
28
26
24
22
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 Flux Data
Blind Screen - Sheer Intimacy
19.8
19.7
19.6
19.5
T_i [°C]
4.8
4.4
4.0
T_e [°C]
24
23
22
21
20
19
Heat Flux [W/m2]
0
1000
2000
3000
4000
Time [mins]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]

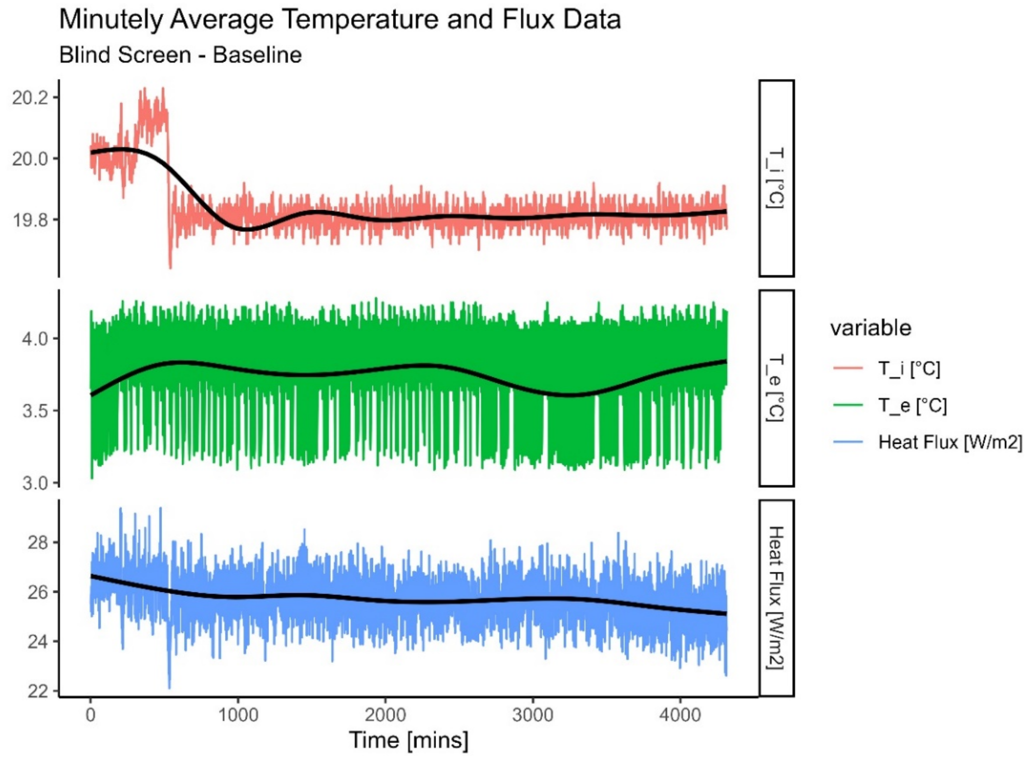

Minutely Average Temperature and Flux Data
Blind Screen - Double Sheer Intimacy
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
variable
Time [mins]

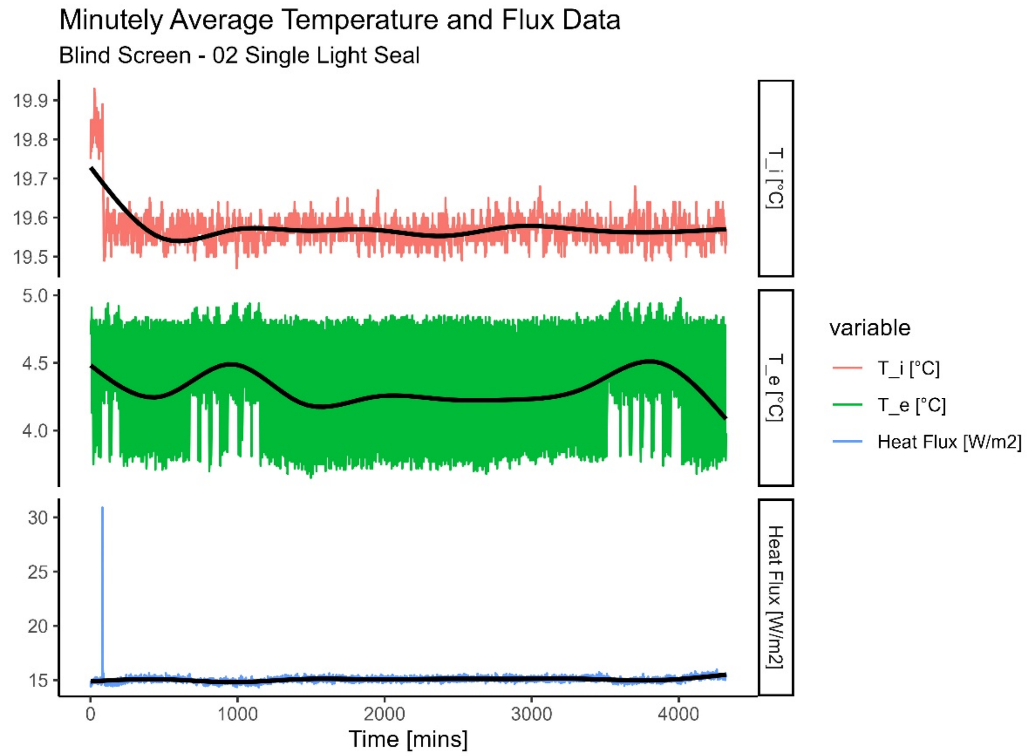

Minutely Average Temperature and Flux Data
Blind Screen - Sheer Intimacy & Light Seal
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
variable
Time [mins]

Phase 4 – SGU

Single glazed Heat Flux visual data has not yet been applied to the required script.

Phase 5





Appendix C – In-situ U-value measurement method

In-situ U-value measurements of each thermal element were undertaken in accordance with ISO 9869-1. The thermal transmittance of a building element (U-value) is defined in ISO 7345[1] as the

[1] ISO (1987) ISO 7345: Thermal insulation –Physical quantities and definitions. Geneva, Switzerland, International Organization for Standardisation.

"Heat flow rate in the steady state divided by area and by the temperature difference between the surroundings on each side of a system". To account for thermal storage and release, ISO 9869-1 uses a cumulative moving average of the heat flow rate and ΔT to calculate in-situ U-values. However, steady state conditions at the Energy House allows in-situ U-values to be calculated as defined by ISO 7345 using the following equation.

$$U = \frac{q}{\Delta T}$$

Where:

U = in-situ U-value (W/m^2K)

q = 24-hour mean heat flow rate (W/m^2)

ΔT = 24-hour mean internal to external air temperature difference (K)

The heat flow rate was measured using Hukseflux HFP-01 heat flux plates (HFPs). The HFPs were affixed to centre of glazing panels using adhesive tape and thermal contact paste. Care was taken to ensure that HFPs were not unduly influenced by excessive air movement by positioning air circulation fans in such a way that air was not blown directly on to the HFPs.

The ΔT for each in-situ U-value measurement was calculated using the internal and external air temperature differential measured in the vicinity of each HFP.

In-situ U-value uncertainty

ISO 9869 applies an uncertainty value of 14-28% to in-situ U-value measurements. However, this uncertainty is based on measurements undertaken in the field without control of external conditions. The ISO 9869 uncertainty calculation was modified for the controlled environment and to include type A and type B uncertainties.

Type A uncertainty

Type A uncertainties consider the statistical variation in the recorded data.

Heat Flux (q)

To reduce noise caused by the operation of electric resistance heaters and fans. the "sma()" function from the "smooth" R programming language package is used to create a simple moving average of the heat flux data. This package optimises moving average by varying the averaging period.

The standard deviation of the smoothed data is calculated and taken as the type A heat flux uncertainty.

T_i and T_e

All U-Value measurements considered a single local internal temperature sensor and a single local external temperature sensor. The standard deviation over a 24-hour period for each sensor was calculated and taken as the type A uncertainty.

Type B uncertainty

Type B uncertainties are based on the sources of uncertainty listed in ISO 9869. Table F1 lists the measurement uncertainties provided by ISO 9869 and modifications that were made for DEEP based on the apparatus and test environment. It must be noted that many of the assumptions regarding sources of uncertainty contained within ISO 9869 are not accompanied with background information as to how they have been derived.

Table F1: Measurement uncertainties provided by ISO 9869 and modifications made for DEEP

ISO 9869 consideration	Notes	% error	Absolute error
Apparatus - Logger	Based on logger accuracy and offset value and DEEP steady state ΔT and heat flux for a U-value of 0.09 W/m²K	0.3	
Apparatus - HFP	Hukesflux HFP01 datasheet	2	
Apparatus - I. C. temperature sensor	Based on steady state ΔT of 15.3 °C	0.9	0.1
HFP contact	ISO 9869 - unadjusted	0	
Isotherm modification	ISO 9869 - unadjusted	2	
Variation in temp & heat flow	ISO 9869 ~10%. Removed as steady state measurement reported. **Captured in type A uncertainty**	0	
Variation in air (T_i) & radiant (T_r) temperature differences	ISO 9869 suggests 5%. Value halved as air circulation fans increase homogeneity & typical 1-2 °C between T_r and T_a at most locations	2.5	
type B uncertainty	**Quadrature sum**	**3.9**	

Combined Uncertainty

The Type A and Type B uncertainty attributed to each measurement are combined through the RSS method prior to error propagation in the HTC calculation.

$$u_{combined} = \sqrt{u_A^2 + u_B^2}$$

Expanded Uncertainty

All prior uncertainties have been given as k=1. When stating the uncertainty on plots, the expanded uncertainty (k=1.96) is stated, such that:

$$U = k \cdot u$$

Such a coverage factor should result in a 95% confidence interval.