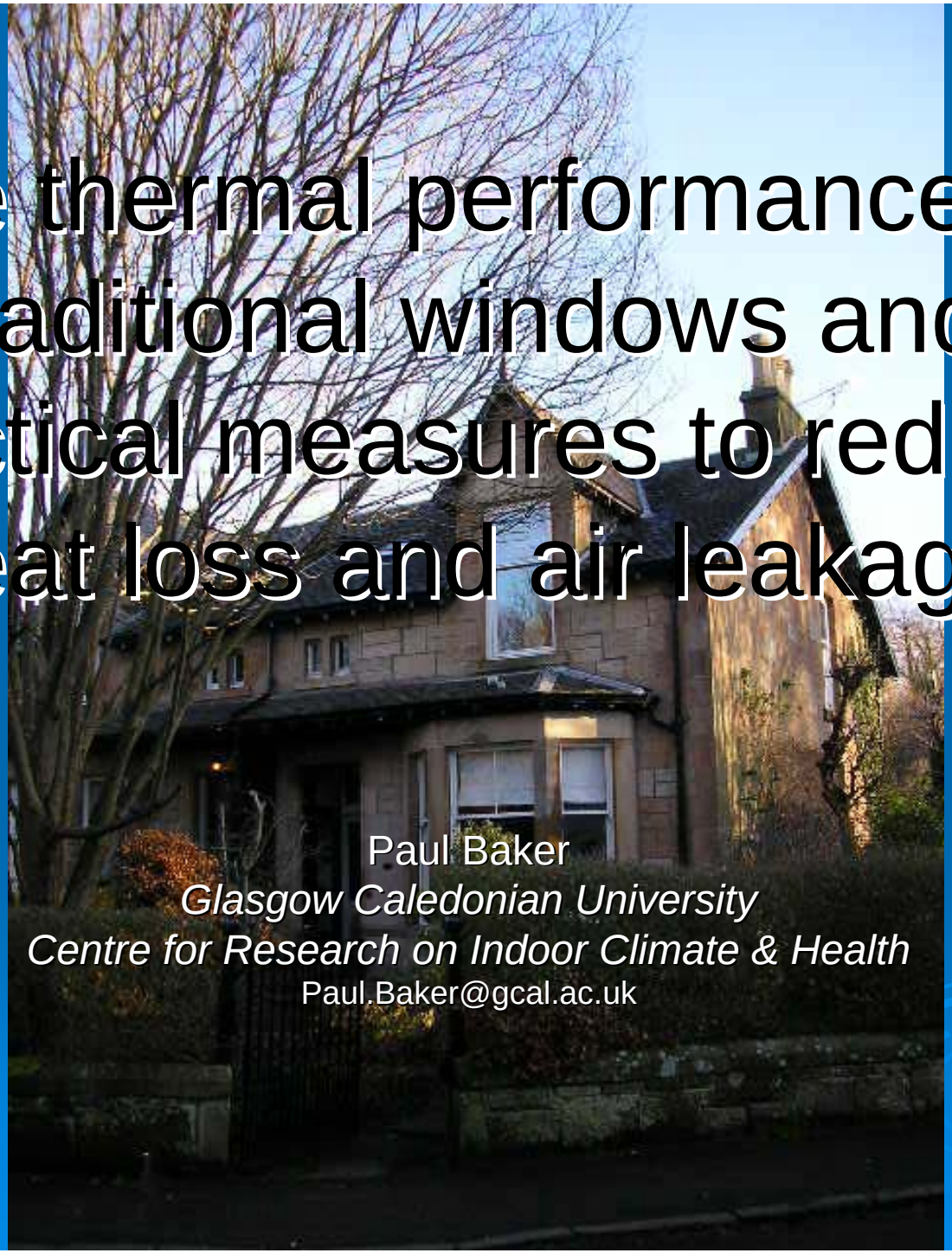
The thermal performance of traditional windows and practical measures to reduce heat loss and air leakage



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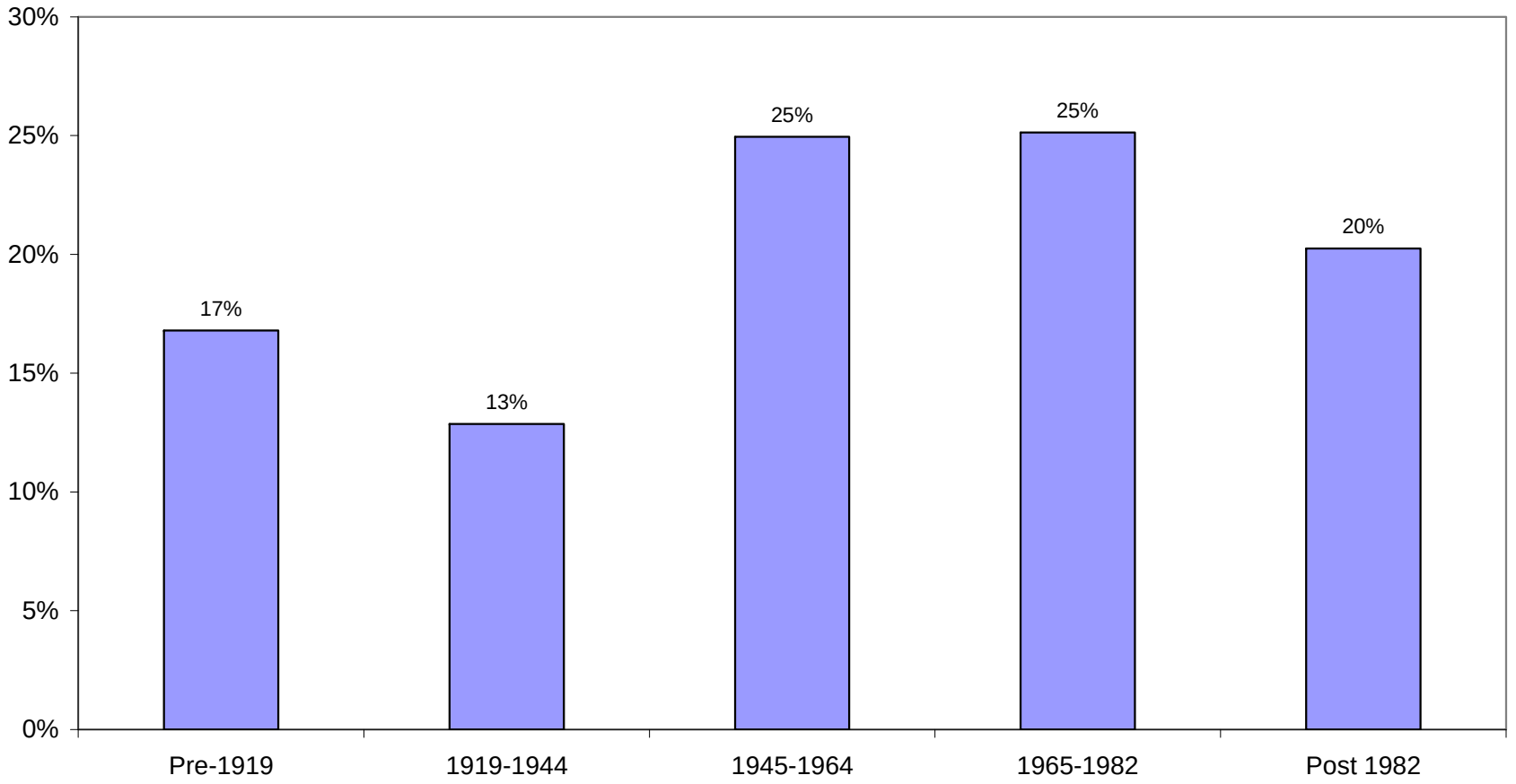
Introduction

- 27% of the UK's carbon dioxide emissions can be attributed to the energy used in people's homes.
- A third of the CO_2 emissions from the average home could be saved by adopting simple energy saving measures.
- Achieving further reductions in carbon emissions from UK households to meet the UK Government's 60% target is a major challenge

Scottish distribution of dwellings

Figure 1: Age of Dwelling (Scottish House Condition Survey Key Findings for 2005/6)



National Home Energy Ratings of Scottish housing stock

by age as a percentage of the total housing stock (SHCS 2005/06)

	Poor %	Moderate %	Good%
Pre-1919	2.4%	10.6%	3.9%
1919-1944	0.5%	7.5%	4.9%
1945-1964	0.7%	13.0%	11.2%
1965-1982	0.5%	12.6%	12.1%
Post 1982	0.0%	5.1%	15.2%
TOTAL	4.1%	48.6%	47.2%

- 53% of dwellings in Scotland may be considered to have only moderate or poor energy efficiency
- Pre-1919 are the largest proportion with poor rating

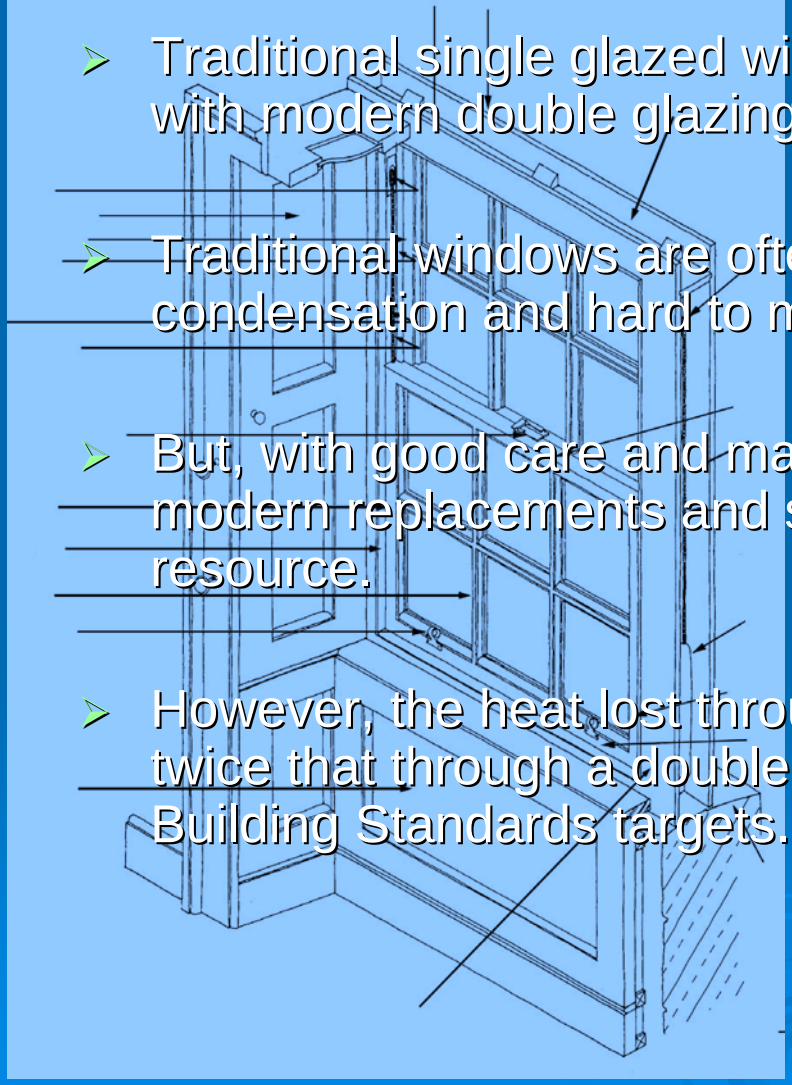
Traditional Buildings: Refurbish or Replace?

- Traditional buildings are viewed as energy inefficient.
- The *operational* carbon emissions of new buildings are lower than traditional buildings.
- However, traditional buildings already embody carbon.
- Energy is required for demolition and disposal of waste, and to produce and transport new building materials.
- Existing building also have cultural and societal value.

The challenges

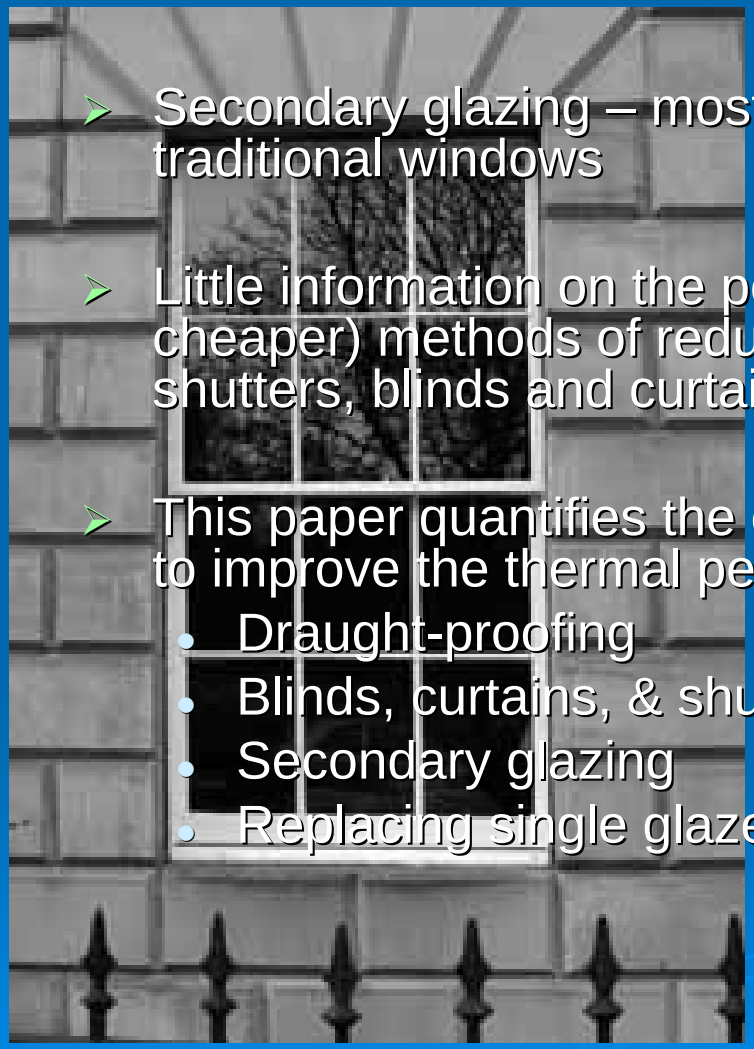
- Improve the housing stock in response to climate change and reduce CO_2 emissions
- Improve comfort and lower energy bills for occupants
- Maintain our architectural heritage
- The options for upgrading the thermal performance are particularly limited for pre-1919 dwellings with solid wall constructions.

Traditional Windows



- Traditional single glazed windows - easiest option for replacement with modern double glazing?
- Traditional windows are often considered to be draughty, prone to condensation and hard to maintain.
- But, with good care and maintenance traditional windows will outlast modern replacements and should be considered as a sustainable resource.
- However, the heat lost through a single glazed window is about twice that through a double glazed window meeting the current Building Standards targets.

Options



- Secondary glazing – most effective option to preserve existing traditional windows
- Little information on the performance of more traditional (and cheaper) methods of reducing heat loss, such as, draught proofing, shutters, blinds and curtains.
- This paper quantifies the effectiveness of relatively simple measures to improve the thermal performance of traditional windows by
  - Draught-proofing
  - Blinds, curtains, & shutters
  - Secondary glazing
  - Replacing single glazed panes with double glazing

Laboratory Studies - Objectives

- Determine the benefits of various options on reduction of heat loss through glazing of a sash & case windows provided by Historic Scotland (HS).

- Measure the benefits of draught-proofing.

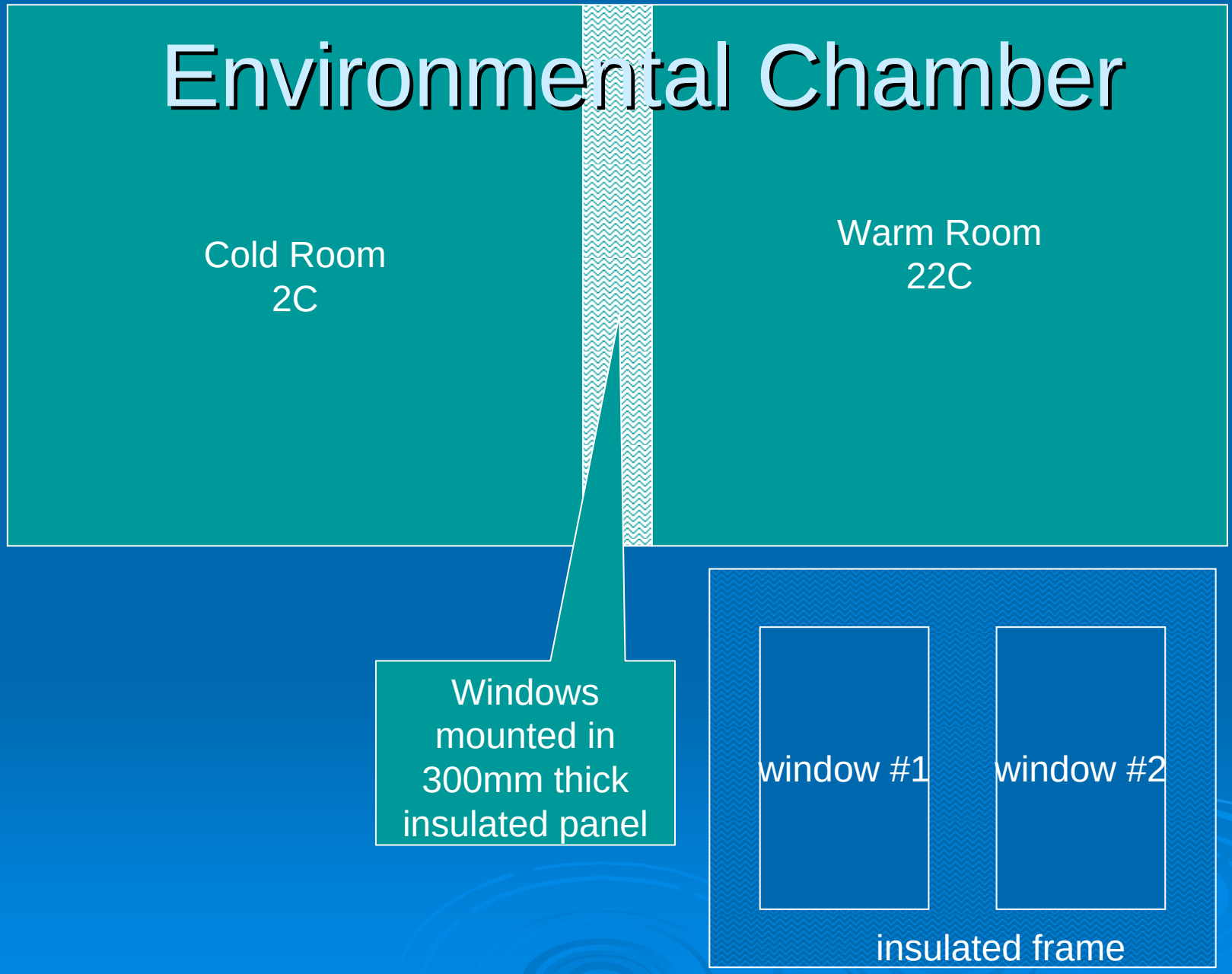
Historic Scotland Window 1.89m (h) x 1.06m (w)

Laboratory Studies – Thermal Performance

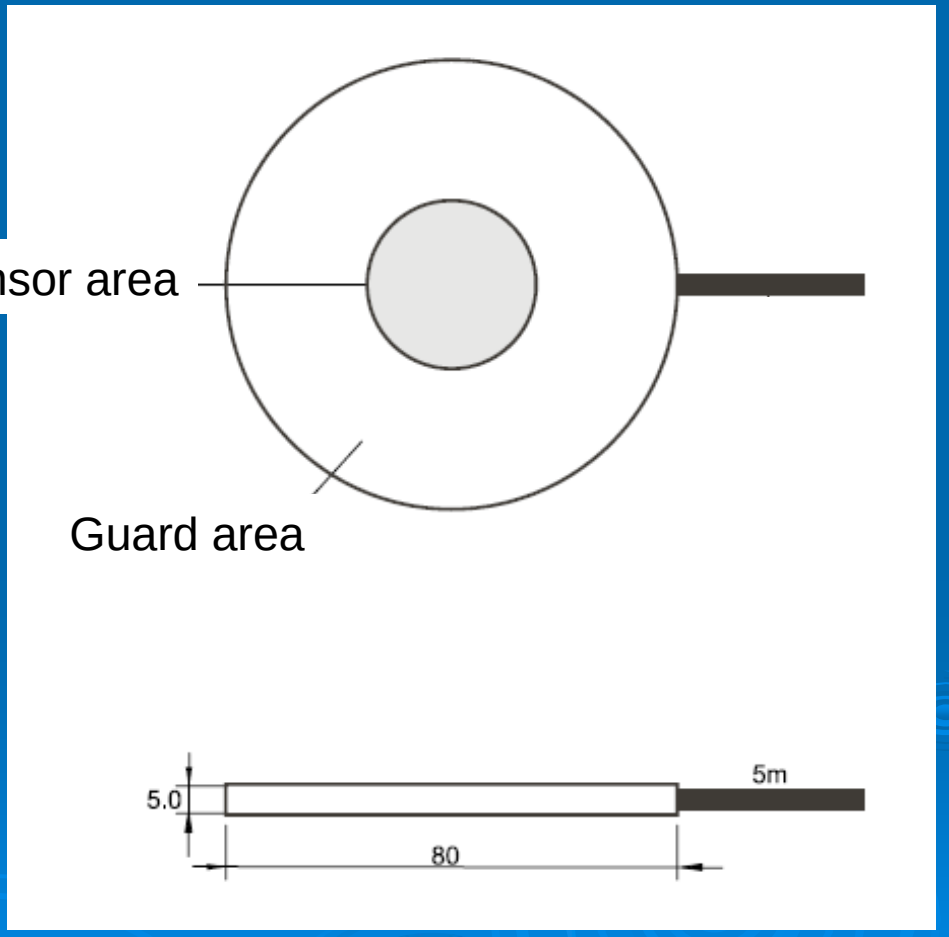
- Tests performed in environmental chamber using *in situ* heat flux measurements on glazing.
- Approach justified since NPL guarded hot box measurements on HS window indicate that 72% heat lost through glazing.
- The reduction in heat using the various option compared with ‘base’ measurement on single glazing only.
- Surface temperature measurements also made to determine U-values and assess impact on thermal comfort.

GCU Environmental Chamber

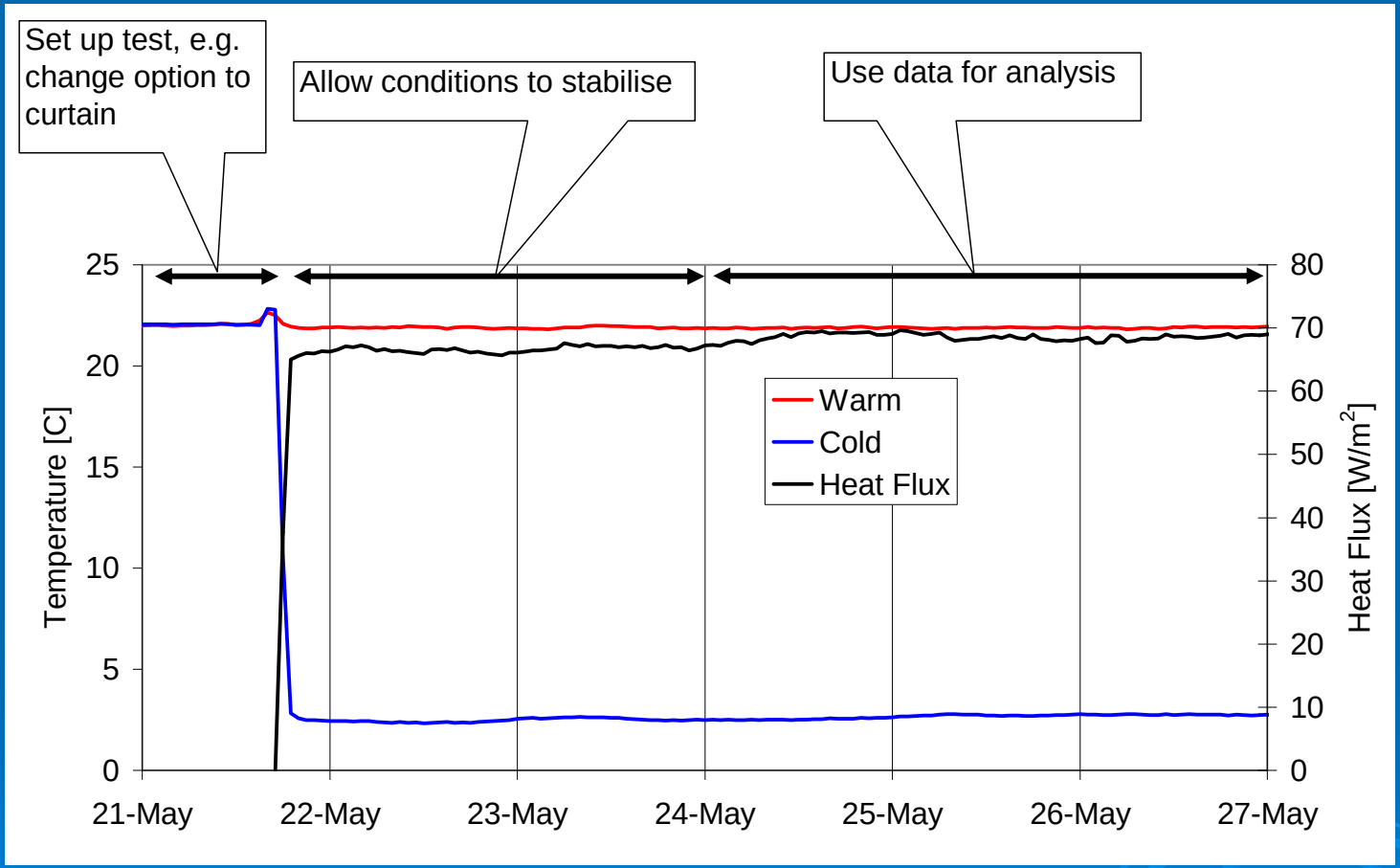
Environmental Chamber



Heat Flux Meters



Test Sequence



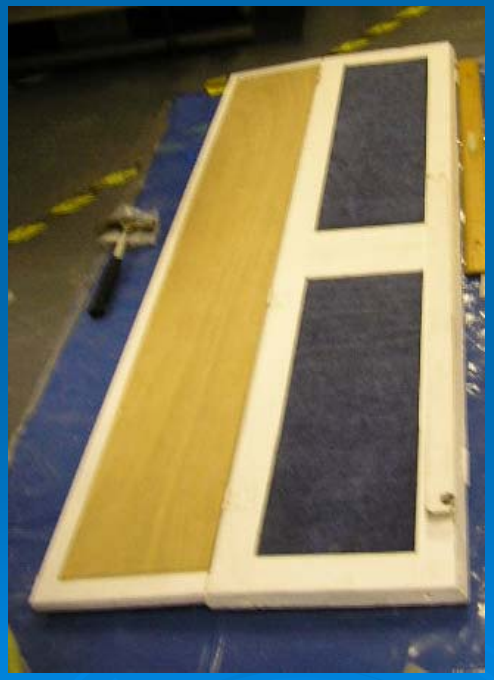
Options tested

- Heavy curtains.
- Timber shutters (salvaged traditional panelled shutters)
- Modified traditional shutters, with insulation inserted into panels and covered with 6mm plywood. The insulated area of the shutters is 55%.
- Modern roller blind.
- Modern roller blind, covered with a low emissivity film.
- Victorian blind fitted to the top of the recess formed by the window case pulley stiles at the side of the upper sash.
- A “thermal” Duette honeycomb blind manufactured by Hunter Douglas Europe b.v.
- Secondary glazing system with low-e glazing.
- Window re-glazed with Slimlite low-e double glazed panes, manufactured and installed by Fountainbridge Windows Ltd., Edinburgh.

Heavy Curtains

Traditional Shutters

Insulated Shutters with Spacetherm



Modern Roller Blind

Blind with low-e foil applied

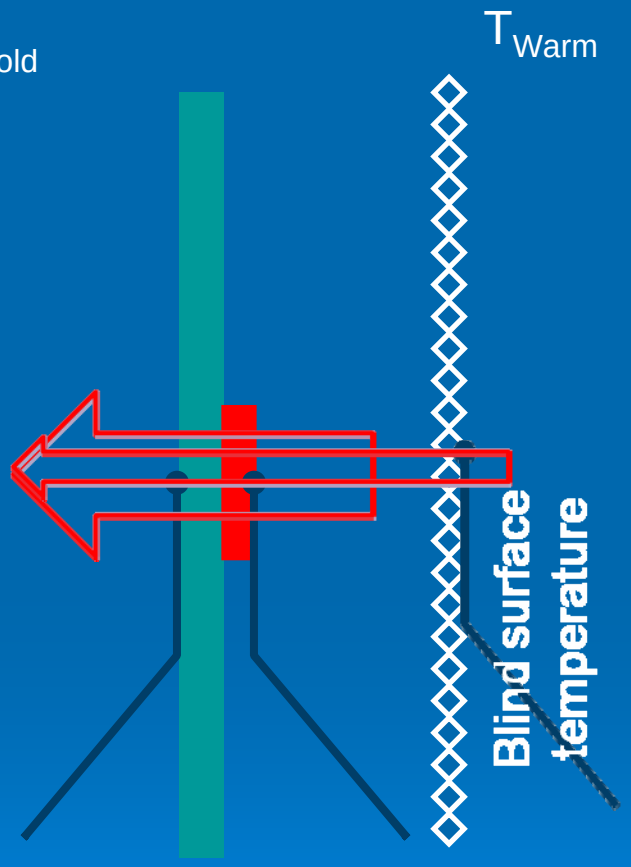
Victorian Blind

Honeycomb Blind

Low-e Secondary Glazing

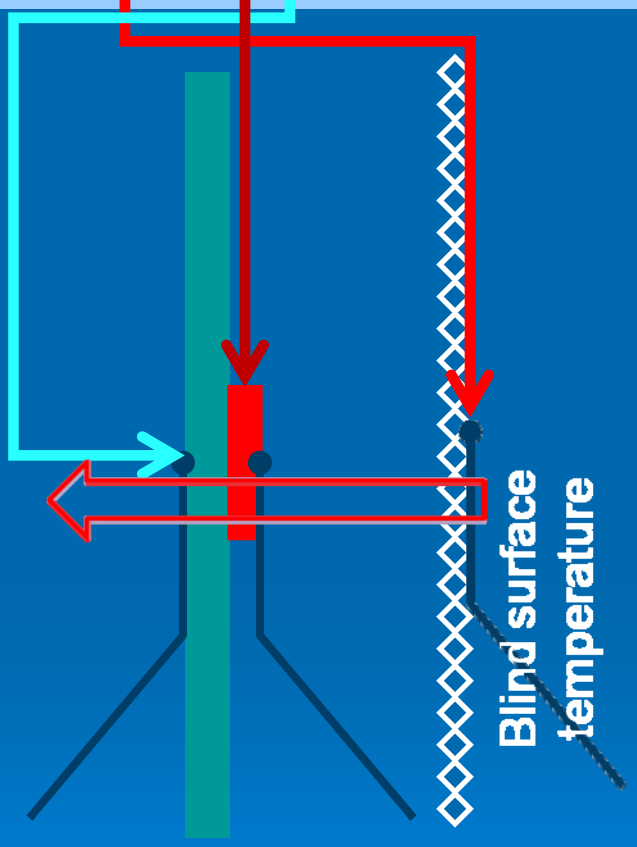
Results

- The effect of the various options on the heat loss through the glazing was estimated as follows:
- **The reduction in heat loss** compared directly with the test on glazing only.
- **A centre of pane U-value**, calculated from the average heat flux meter reading and surface temperature difference between the outer glazing surface and the inside (room-facing) surface of the curtain, shutter or blind with a correction for the standardised internal and external surface resistances.
- A correction was also applied for the thermal resistance of heat flux meter.
- Uncertainty of U-values is 0.3 W/m^2K.



Surface glazing temperatures

$$U = \frac{1}{\left(\frac{T_{si} - T_{se}}{Q}\right) + 0.17 - 6.25 \times 10^{-3}}$$

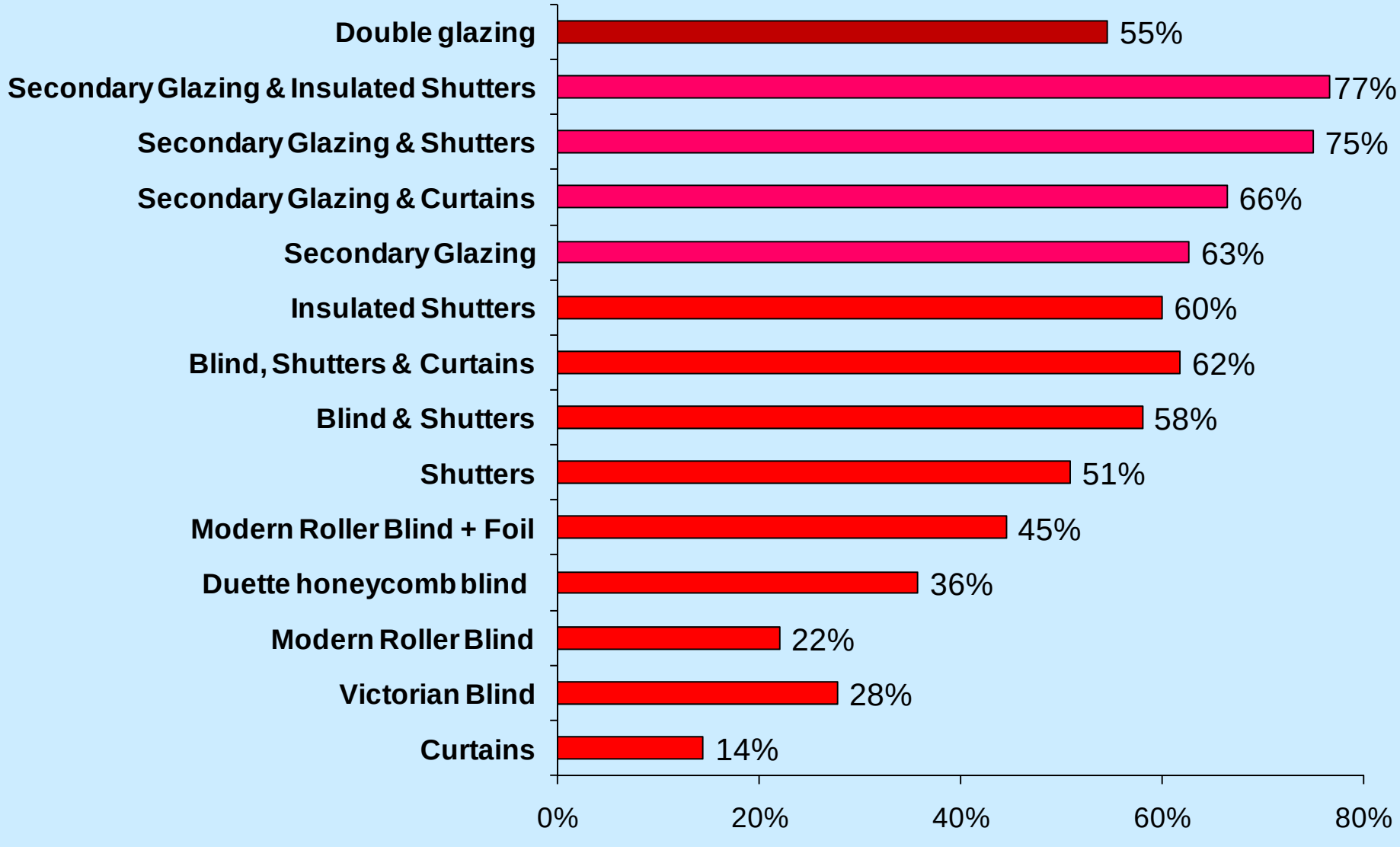


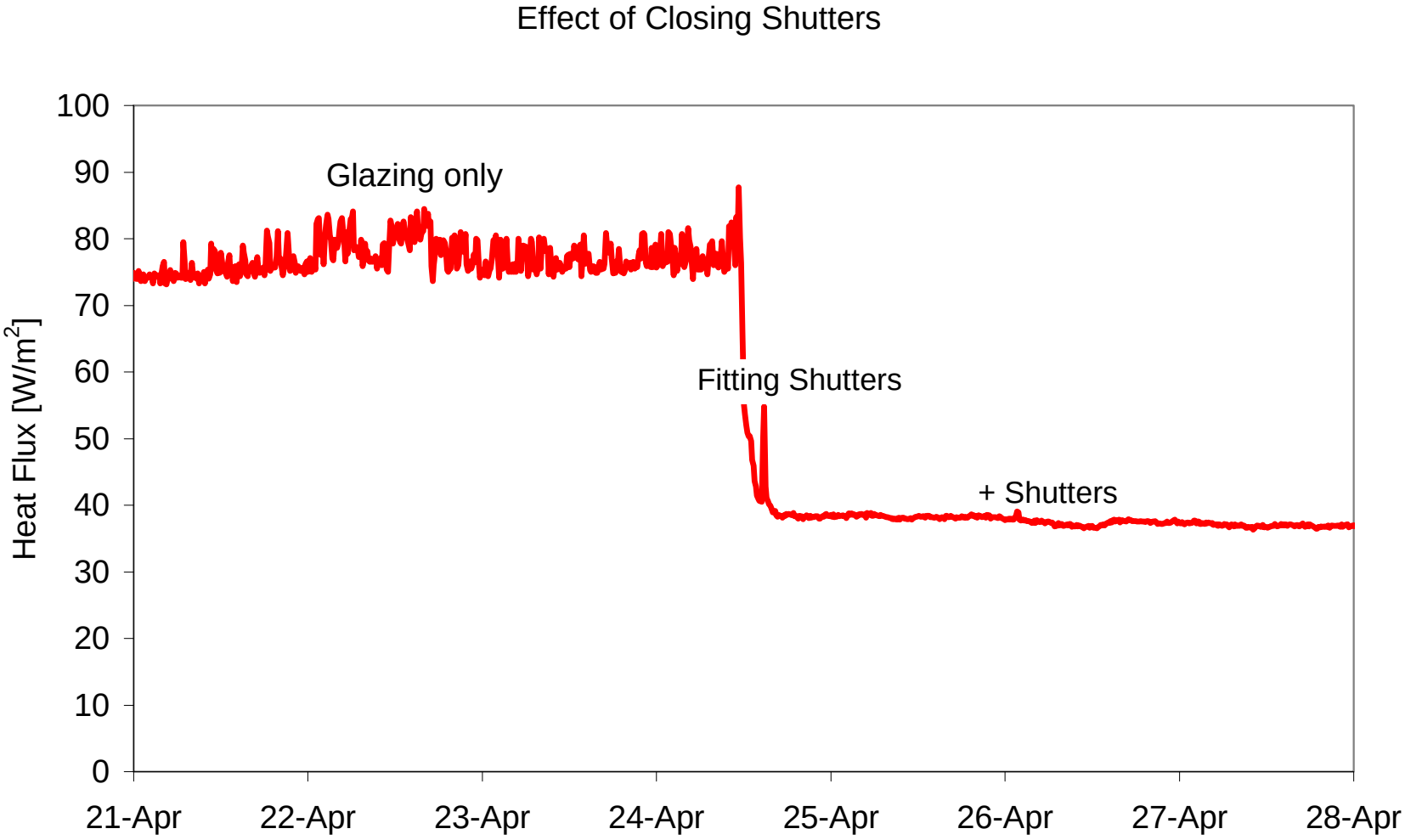
T_{Cold}

T_{Warm}

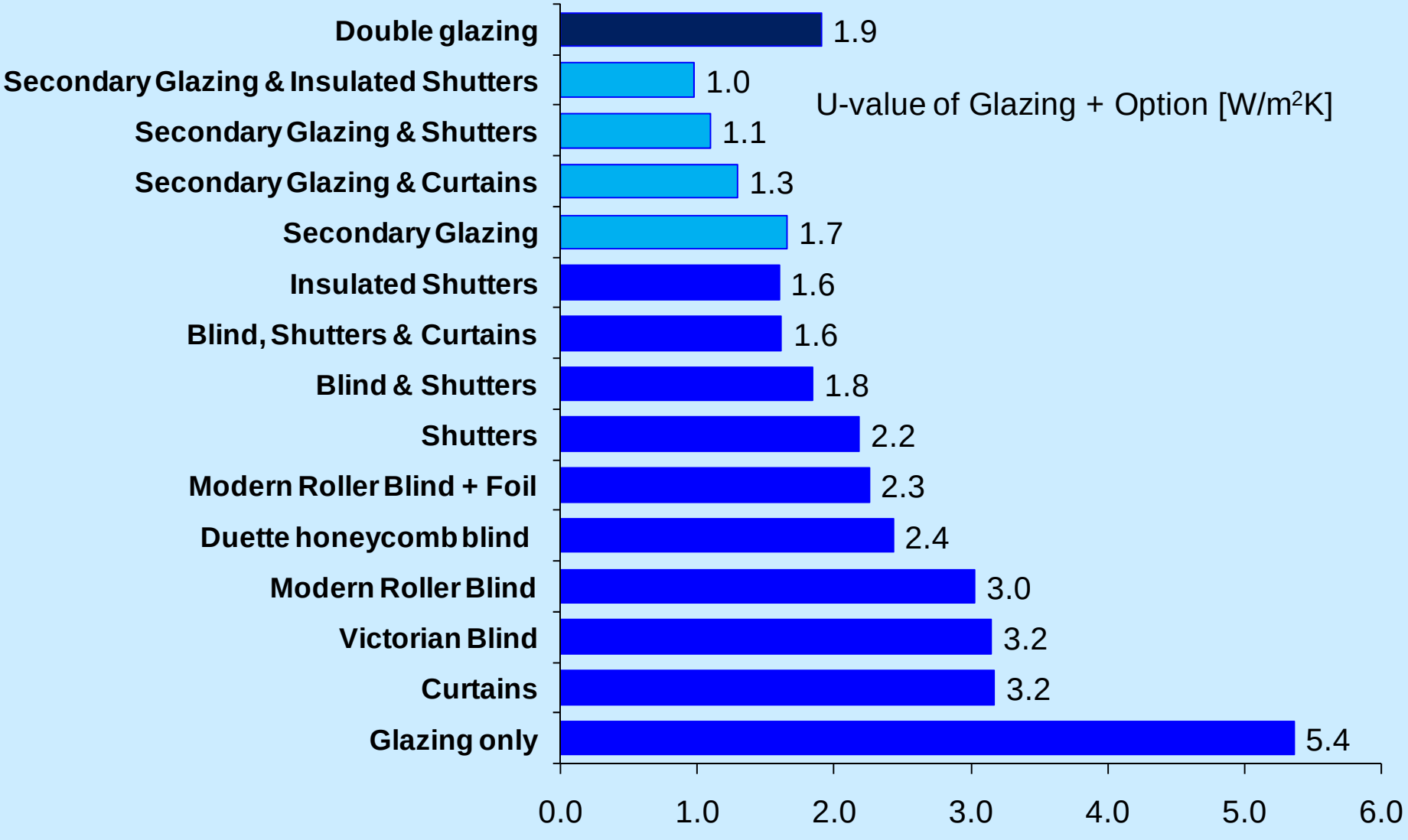
Surface glazing temperatures

Reduction in heat loss




Effect of Closing Shutters
Heat Flux [W/m2]
100
90
80
70
60
50
40
30
20
10
0
Glazing only
Fitting Shutters
+ Shutters
21-Apr
22-Apr
23-Apr
24-Apr
25-Apr
26-Apr
27-Apr
28-Apr

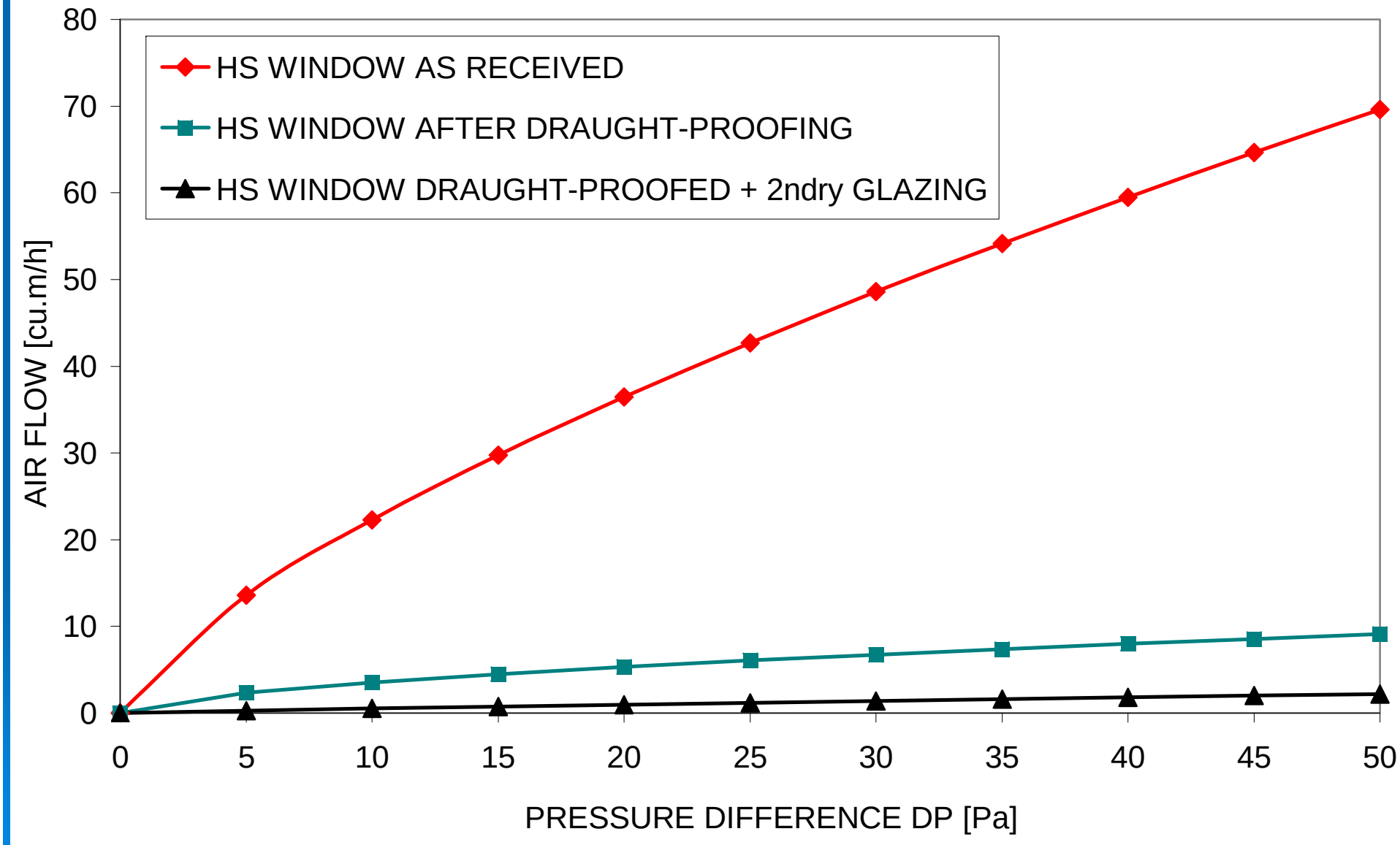
U-Values


U-value of Glazing + Option [W/m²K]
Double glazing
1.9
Secondary Glazing & Insulated Shutters
1.0
Secondary Glazing & Shutters
1.1
Secondary Glazing & Curtains
1.3
Secondary Glazing
1.7
Insulated Shutters
1.6
Blind, Shutters & Curtains
1.6
Blind & Shutters
1.8
Shutters
2.2
Modern Roller Blind + Foil
2.3
Duette honeycomb blind
2.4
Modern Roller Blind
3.0
Victorian Blind
3.2
Curtains
3.2
Glazing only
5.4
0.0
1.0
2.0
3.0
4.0
5.0
6.0

Airtightness Measurements

- The air-tightness of the window was measured by depressurisation with both test rooms at 22^{o}C.

- Measurements were made:
  - Before and after draught-proofing by Ventrolla
  - After installation of secondary glazing.


HS WINDOW AS RECEIVED
HS WINDOW AFTER DRAUGHT-PROOFING
HS WINDOW DRAUGHT-PROOFED + 2ndry GLAZING
AIR FLOW [cu.m/h]
PRESSURE DIFFERENCE DP [Pa]
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40
45
50

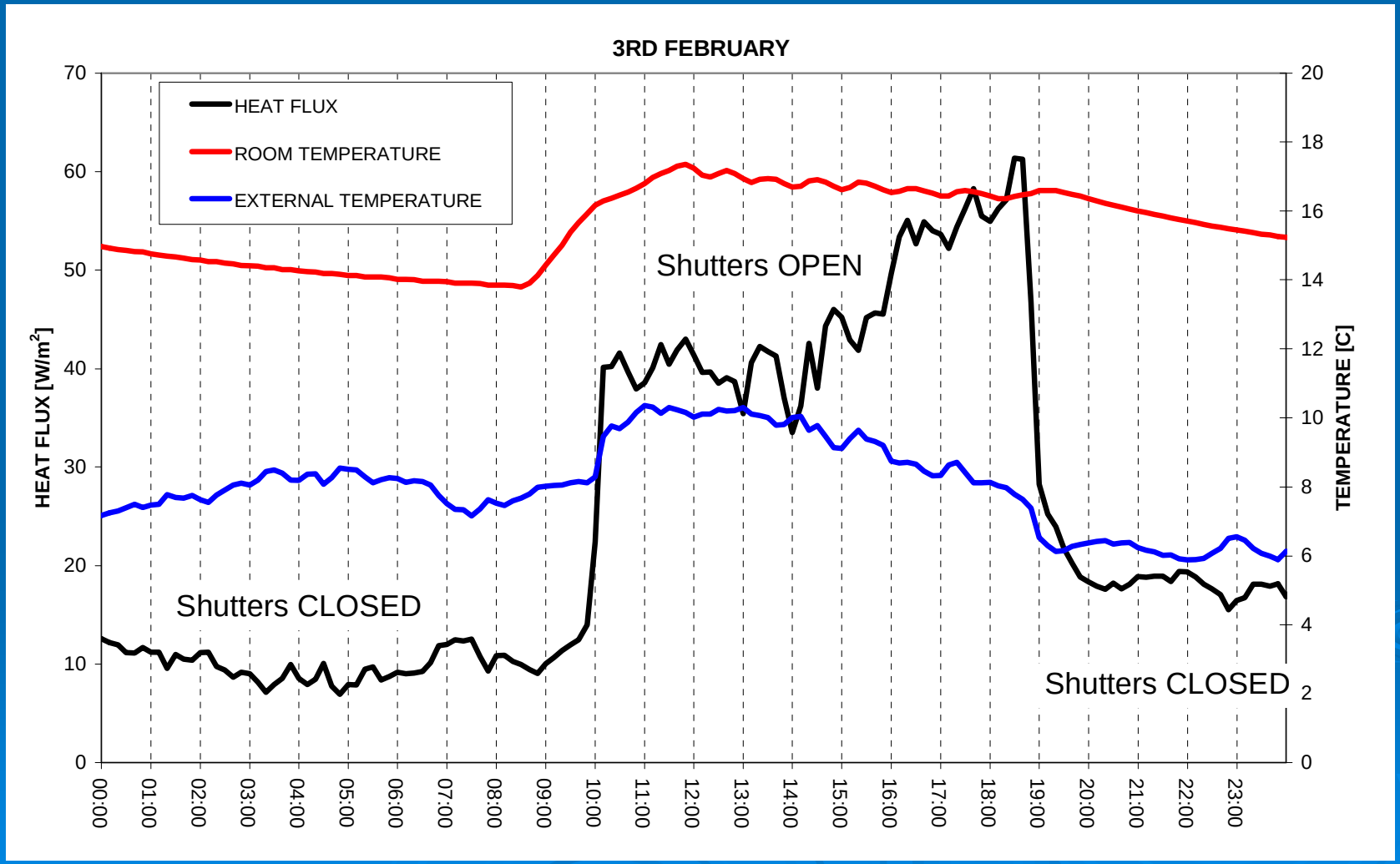
Results

- Professional draught proofing reduces air leakage by 86% compared with the as-received condition
- The addition of the secondary glazing system provides a further reduction in air leakage
- A trickle vent with an area of 4000mm^2 (Section 3.14 SBS 2007) has an air leakage about 5 x that of the draught proofed window.
- Whole window U-value measurements by NPL show no significant difference before & after draught proofing

In situ measurements at Lauriston Place, Edinburgh

- Shutters & Secondary Glazing Tested
  - Shutters similar performance to laboratory tests
  - Secondary glazing result (2.3W/m^{2}K) higher than the environmental chamber result.

Effect of closing shutters



Conclusions

- All measures have significant benefits.
- Shutters are most effective of traditional methods particularly with addition of insulation.
- Improved blind designs also have potential to reduce heat loss - roller blind with low-e foil facing glazing very effective (but not attractive?)
- High performance secondary glazing and replacement double glazed panes offer improved thermal performance throughout the day.
- Careful installation of the secondary glazing also results in improved air-tightness.
- All measures offer improved thermal comfort due to higher surface temperatures compared to single glazing alone.