A Future for Historic Windows

Royal Agricultural University Cirencester 27-28 June 2024

Old windows and the science of heat, air and moisture transfer

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www.usablebuildings.co.uk

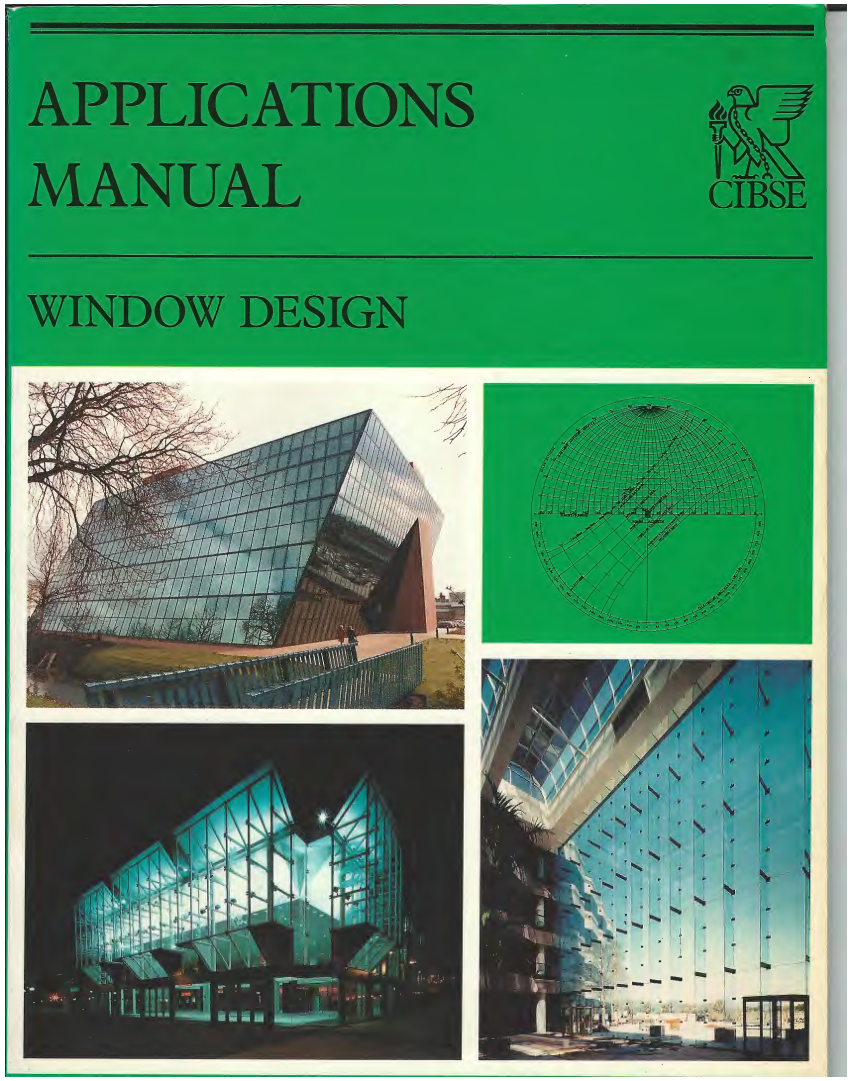
Windows are complex systems

items in blue are the focus of this talk

- They provide light *(and sometimes glare)*
- Provide view and outside awareness *(not always privacy)*
- Let the sun in *(sometimes too much and too glary)*
- Let solar heat in *(sometimes too much)*
- Let heat in and out *(radiation, convection, conduction)*
- Let air and out *(sometimes too little, too much, or draughty)*
- Can let moisture out *(sometimes not enough)*
- Let in noise, insects etc *(can be adapted to control them)*
- May or may not be secure *(can inhibit other functions)*
- Can afford many means of control *(but often inadequate)*
- **AND** give character to a building *(or debase it)*

One can add many controls *(manual & auto):*

can be very sophisticated, but too often poor in the UK today



FREUDIAN SLIP?

All three buildings on the cover of the original CIBSE Window Design manual (1987) had:

" ALL GLASS AND NO WINDOWS "

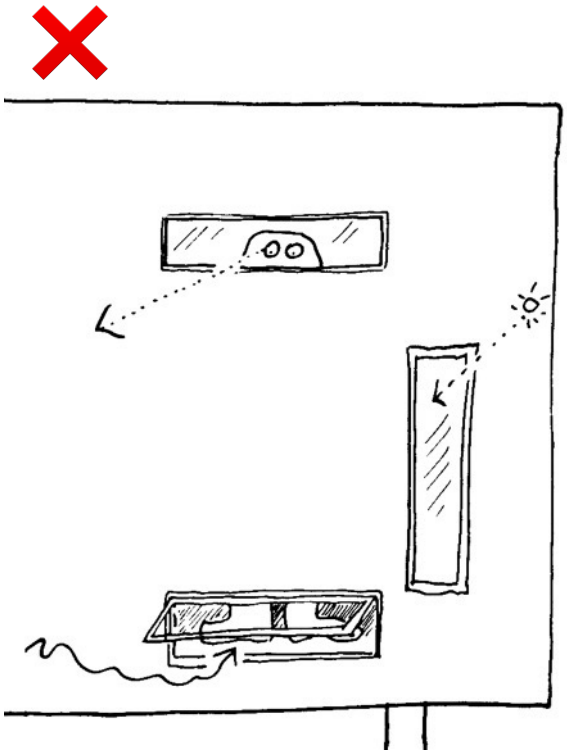
and no controls either !

Is there a link to the epidemic of overheating and glare in many recent UK buildings?

"All glass and no windows" quote attributable to Amory Lovins, e.g. Weizsacker, Lovins & Lovins, *Factor Four* (Earthscan, 1997).

Separation of functions may not be clever:
It's whole system performance that counts

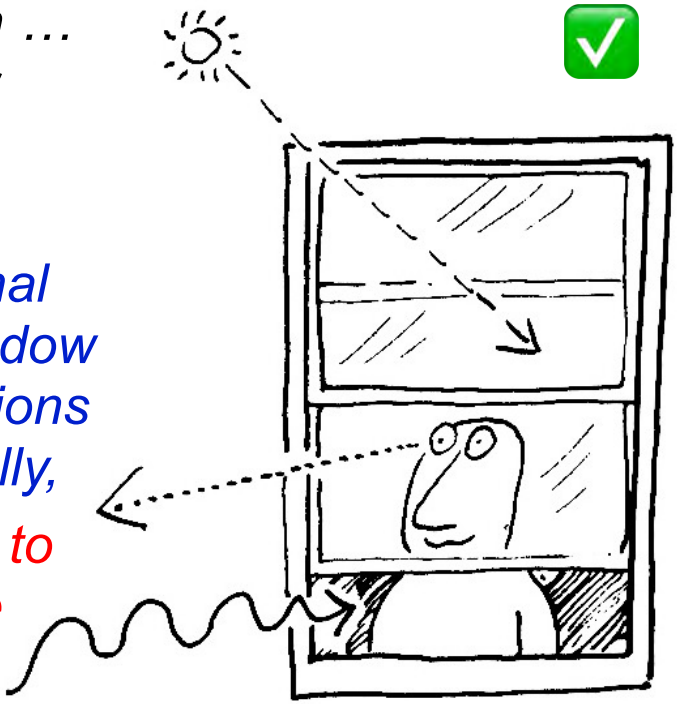
" Le Corbusier's desire for rationalism (breaking down into constituent parts) ranged from … town planning … to elements of the building. "For example, a window is: a) to let light in; b) to see out of; c) to let air in.



"He might then design … separate elements for each function [in] an abstract pattern.

"Whereas the traditional sash or casement window integrates these functions safely and economically,

"[he] taught architects to over-complicate in the name of innovation … to create more problems than were solved."



SOURCE: L Hellman, *Architecture for Beginners,* London: Writers & Readers, (1988), page 141.

But to start with, I'll keep things separate !

1. Keeping the heat in
2. Keeping the heat out
3. Managing air and moisture
4. Putting it all together

1.

KEEPING THE HEAT IN

Heat transfer through windows

Windows are usually characterised by their **U-values:**
their thermal transmittance, *in Watts/sq m per degree (W/m^2K).*

This is typically built up from **conductive, convective and radiative components**, via three main routes:

- The **glazing** itself *(centre-pane U-value)*
- All the components of the **frames** and sashes *(complex heat flow in 3 dimensions)*
- **Interactions** between glazing and frames, including effects of perimeter and intermediate spacers in multiple glazing.

In hot weather, heat may also be gained by these mechanisms.

Heat is also lost or gained when air passes into or out of the building through windows and their frames, as either:

- *Ventilation, as designed and as chosen by occupiers;*
- *Infiltration, adventitiously, through cracks and gaps.*

Typical centre-pane U-values (W/m^2K)

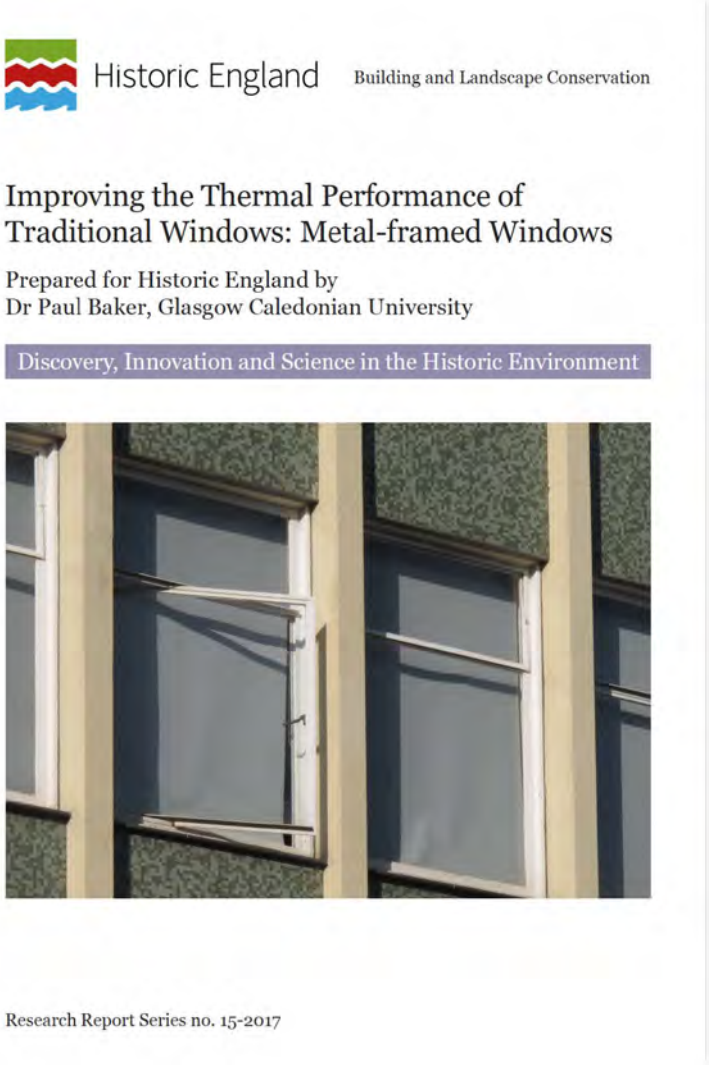
(heat loss rate, vertical glazing, normal external exposure)

Clear single glazing	5.8
Sealed double glazing, Slimline, 6 mm air gap	3.3
Sealed double glazing, 16 mm air gap	2.7
Sealed triple glazing, 2 x 16 mm air gaps	1.8
Low-emissivity (0.1) double glazing, 16 mm air gap	1.5
Low-emissivity (0.05) double, 16 mm gap, Argon fill	1.2
Low-emissivity (0.05) double, Slimline 6 mm Argon fill	2.0
Vacuum glazing, 1st generation, 0.2 mm vacuum gap	1.3
Vacuum glazing, best today, coated, 0.3 mm gap	*< 0.5*

***Typical frames** with no thermal break: Timber 2, Metal 6.*

SOURCE: CIBSE Guide A , *Environmental Design,*(2021), Table 3.23 and vacuum glazing manufacturer literature.

Laboratory and modelling work at GCU:
Glasgow Caledonian University



SOURCE: C Wood, W Bordass & P Baker, *Research into the thermal performance of traditional windows,* English Heritage (2009)

Laboratory and modelling work at GCU:

Timber Window U-values including frame ($W/m^2K \pm 0.3$)

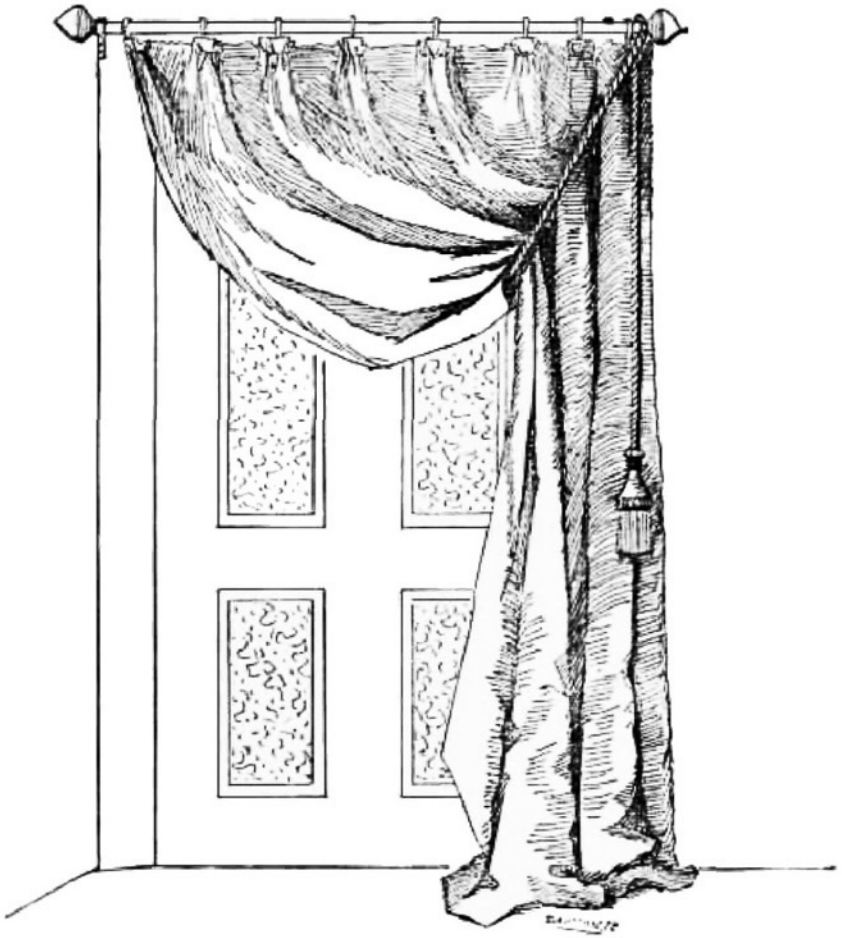
4.3	As found from site
4.3	Joinery repaired
4.3	Draughtproofing added
2.5	Heavy Curtains
1.7	Well fitting shutters
2.7	Plain roller blind
1.8	Reflective roller blind
2.1	Honeycomb insulating blind
1.8	Aluminium Low-E Sec Glazing
1.6	Aluminium Low-E Sec+Shutters
1.0	*Vacuum Sec. Glazing (est)*

Radiators under windows can reduce some benefits

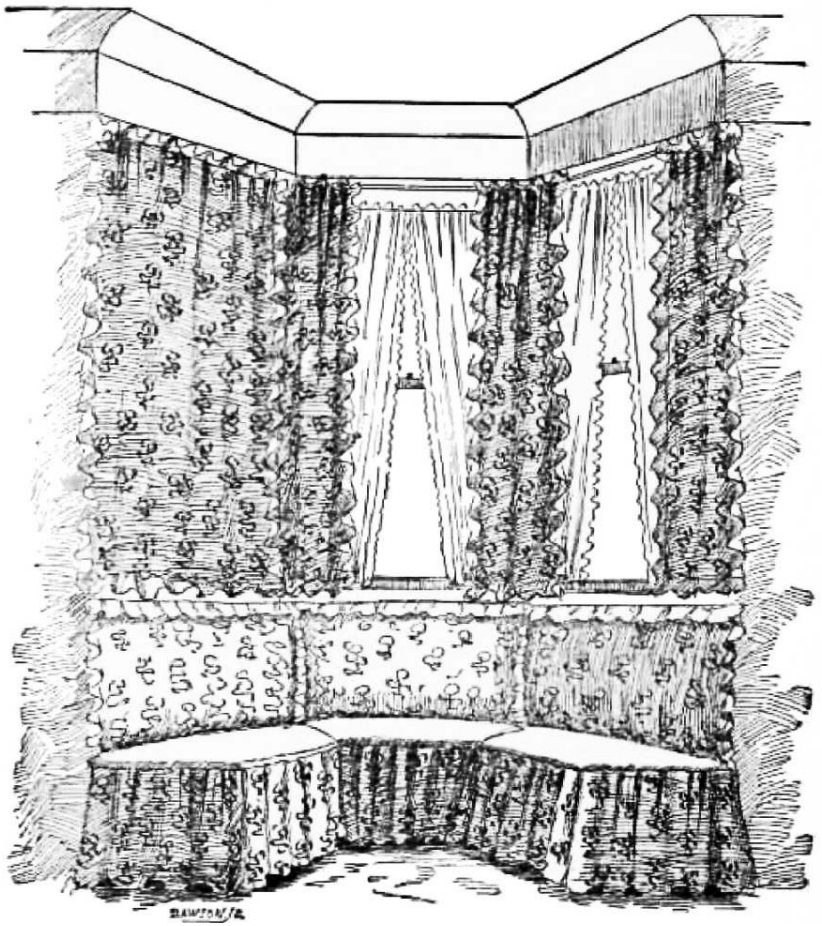
SOURCE: C Wood, W Bordass & P Baker, *Research into the thermal performance of traditional windows,* English Heritage (2009)

Reducing draughts and "cold" radiation:

Victorian soft furnishings were partly for thermal reasons



"This [cord] allows the curtain being dropped in one moment should more warmth be desired."



"[the male architect]… too many windows … and almost ruins us in blinds and curtains"

SOURCE: J E Panton, *From kitchen to garrett: Hints for young householders,* Ward & Downey (7th Edition 1890).

Downdraughts and “cold” radiation:

Internal surface temps (°C) @ 22°C int, 2°C ext.

12	As found
12	Joinery repaired *
12	Draughtproofing added
21	Heavy Curtains
17	Well fitting shutters
18	Plain roller blind
19	Reflective roller blind
20	Honeycomb insulating blind
19	Aluminium Low-E Sec Glazing
20	Aluminium Low-E Sec+Shutters

Since people are very sensitive to radiation and draughts, warmer internal surfaces have multiple comfort benefits.

SOURCE: C Wood, W Bordass & P Baker, *Research into the thermal performance of traditional windows,* English Heritage (2009)

2.

KEEPING THE HEAT OUT

Overheating: a growing problem

UK Parliament POST

POSTnote 723

By Sara Mehrhof, Sarah Bunn
23 May 2024

Public health impacts of heat

Overview

- The frequency, duration and intensity of extreme heat and heatwaves in the UK has been increasing. Five periods of extreme heat were recorded in England in 2022. Temperatures exceeded 40°C for the first time.
- Heat impacts the body and can lead to illness and death. The summer 2022 heat periods were associated with 2,985 deaths in England.
- The number of heat-related deaths is projected to increase with climate change, and as the population grows and ages.
- The impact of heat on health varies across the population. Vulnerability factors include: advanced age; physical and mental health conditions; pregnancy; environmental factors such as living in urban areas; housing conditions; occupational setting; homelessness; poverty; low educational attainment and being an immigrant.
- The Adverse Weather and Health Plan, published by the UK Health Security Agency, constitutes the overarching policy framework responding to heat-health risks. The plan includes an impact-focused heat-health alert system.
- Stakeholders from the academic, healthcare and charity sectors stress the importance of a joint policy response, including building regulations, urban planning, healthcare, public communication and research.

Direct solar radiation often predominates:

though rising air temperatures + humidities don't help

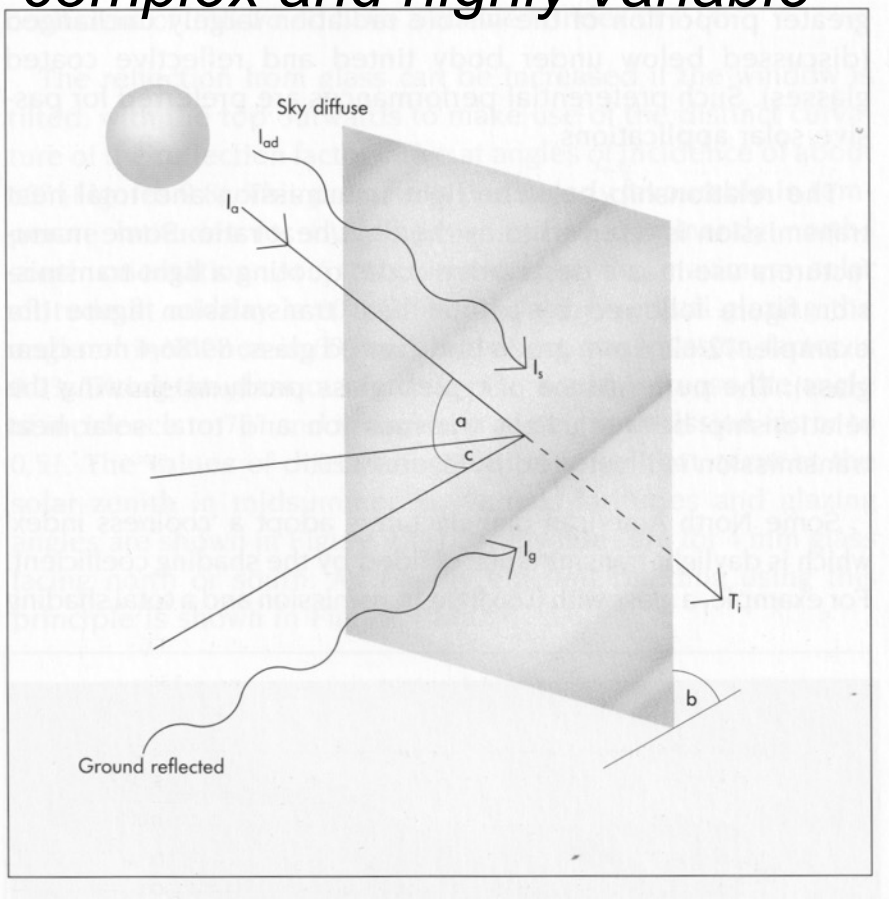
The exact situation is complex and highly variable

Solar radiation

25 June 2024

Hours ^ Total: **6780** wh/m²

06:00	**58** w/m²
07:00	**192** w/m²
08:00	**346** w/m²
09:00	**496** w/m²
10:00	**628** w/m²
11:00	**732** w/m²
12:00	**771** w/m²
13:00	**781** w/m²
14:00	**671** w/m²
15:00	**659** w/m²
16:00	**557** w/m²
17:00	**408** w/m²
18:00	**265** w/m²
19:00	**149** w/m²
20:00	**66** w/m²
21:00	**1** w/m²



Typical solar control device effectiveness:
approximate solar heat transmission (% @ 90°)

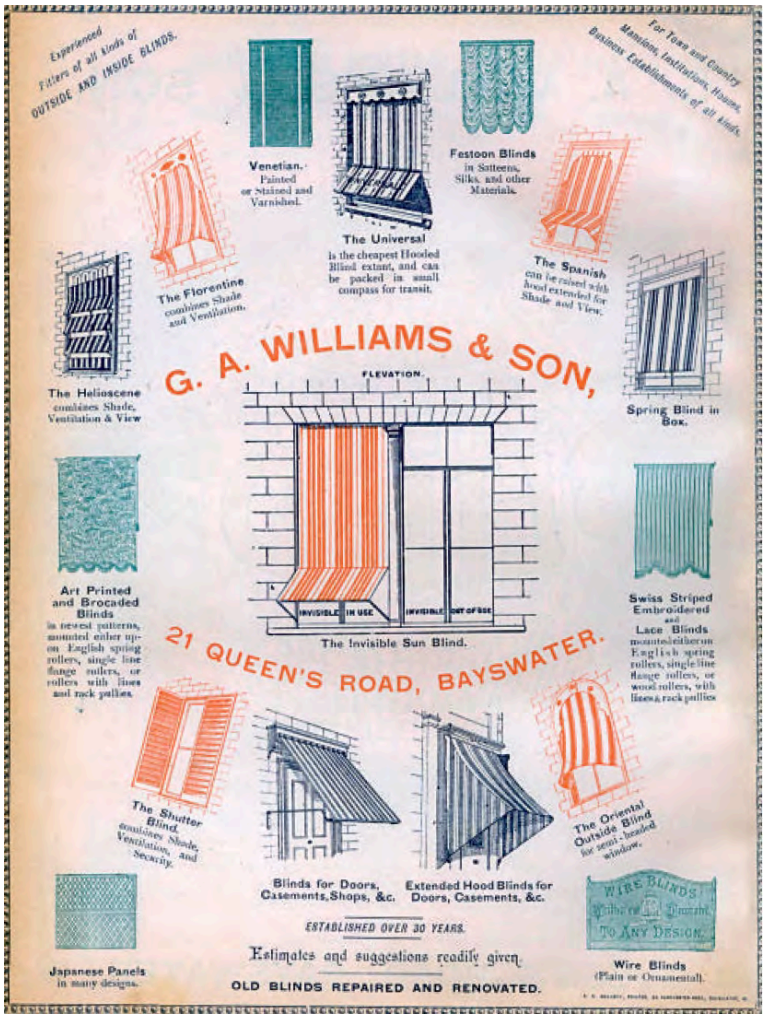
75%	Single clear glass
60%	Interior venetian blind (horizontal and 45°)
40%	Interior venetian or roller blind (closed)
20%	Interior blind (reflective, closed)
15%	Exterior blind, light colour
60%	Double clear glass
35%	Double clear glass with clear selective coat
30%	Double clear glass, with mid-pane blind (45°)
22%	Double clear glass, with mid-pane blind (closed)

Blinds between primary and secondary glazing can keep yet more heat out, when they are ventilated to the outside.

SOURCES: J Carmody et. al., *Window systems for high-performance buildings,* Norton (2004) and other sources

Historically, we seemed to know what to do:

Vestiges of head boxes in a Listed terrace in North London

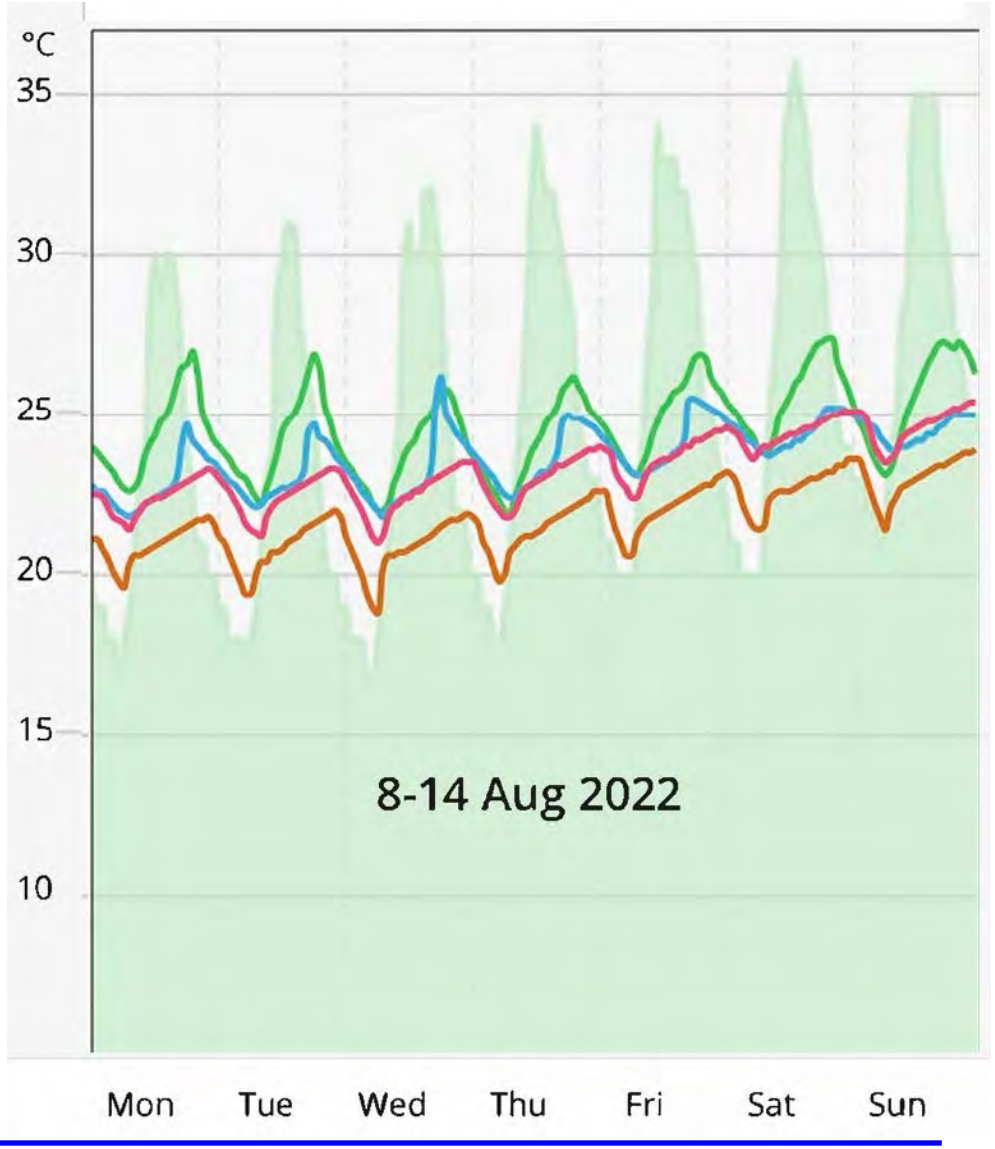


Recently added external blinds

in West London

Or on the cheap in the 2022 London heatwave:

Old linen sheets and night cross-ventilation



3.

MANAGING AIR AND MOISTURE

Requirements for ventilation
as part of an integrated whole-building approach

Provide outside air for people *(usually the least onerous task),*

WHILST REMOVING:

- Pollutants generated by people and their activities
- Pollutants from building materials and contents
- Excess heat from any internal or external source
- Moisture generated by people and their activities
- AND Control moisture balance between fabric and air

SOME SIMPLE PRINCIPLES:

- Background ventilation to keep things sweet *(natural or mechanical)*
- Extract moist air from concentrated sources *(kitchens and bathrooms)*
- Include facilities to ventilate rapidly when necessary *(e.g. to remove excess heat, cooking smells, or at times of high occupancy)*
- Allow removal of accumulated heat *(e.g. by secure night ventilation)*

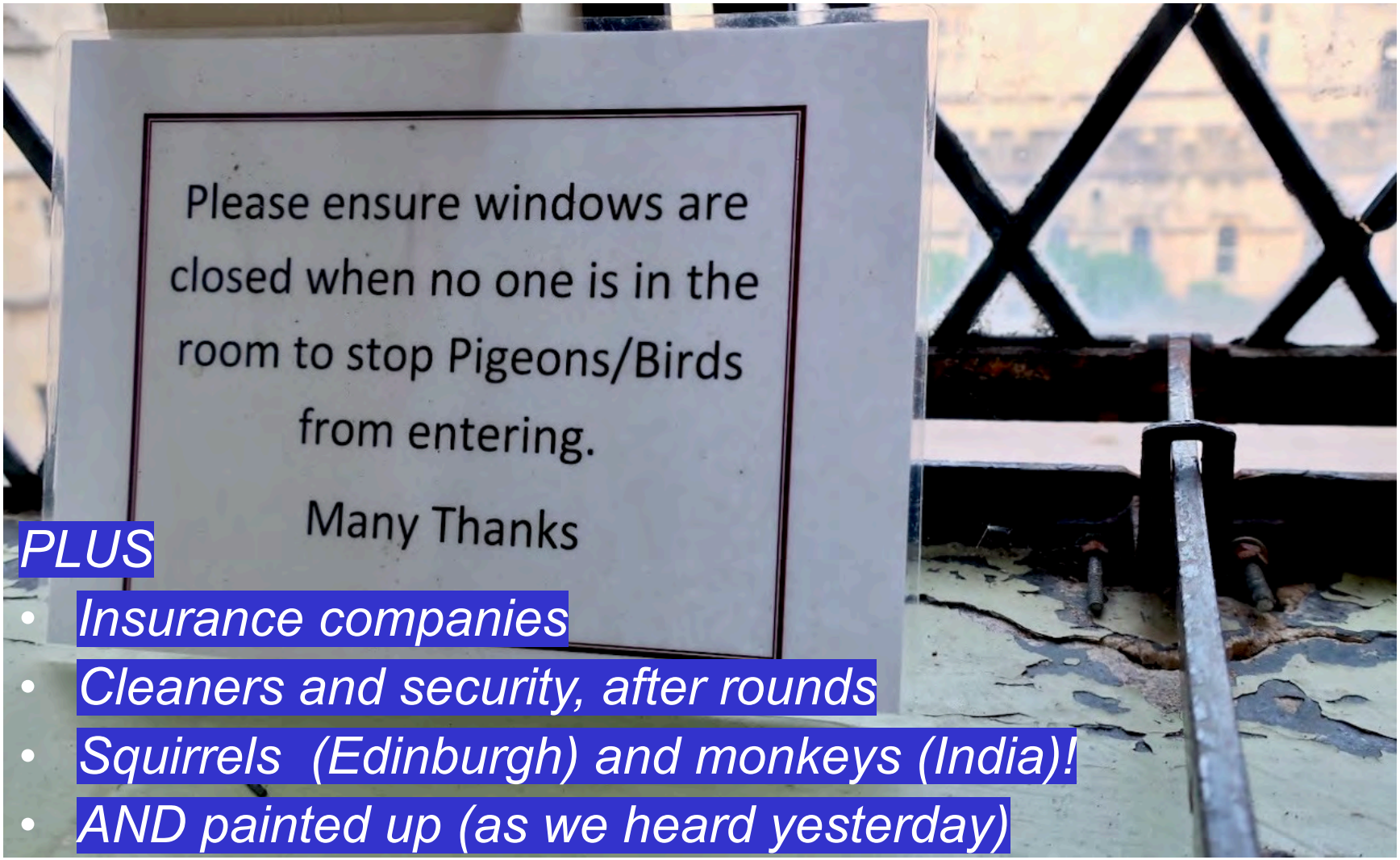
REPLACEMENT WINDOWS TOO OFTEN FAIL TO DO ALL THIS!

Forget the clumsy appearance:

100 mm safety restrictors exacerbate overheating

There may be other inhibiting factors

As indeed in our rooms, here at the RAU !



PLUS

- *Insurance companies*
- *Cleaners and security, after rounds*
- *Squirrels (Edinburgh) and monkeys (India)!*
- *AND painted up (as we heard yesterday)*

Air infiltration rates through the GCU window

as percentages of the as-found window below

100% As found
66% Joinery repaired *
14% Draughtproofing added

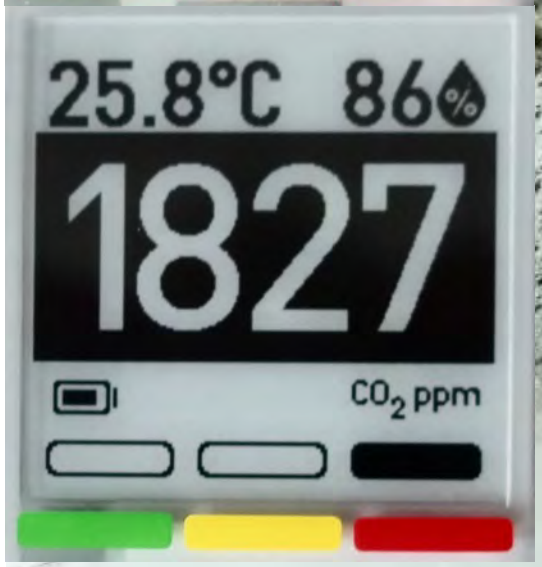
<14% Heavy Curtains
<14% Well fitting shutters
<14% Plain roller blind
<14% Reflective roller blind
<14% Honeycomb insulating blind

4% Aluminium Low-E Sec Glazing
4% Aluminium Low-E Sec+Shutters

Infiltration as-found: 63% of total heat loss through window *and also enough to ventilate the room.* ***Insufficient after draughtproofing.***

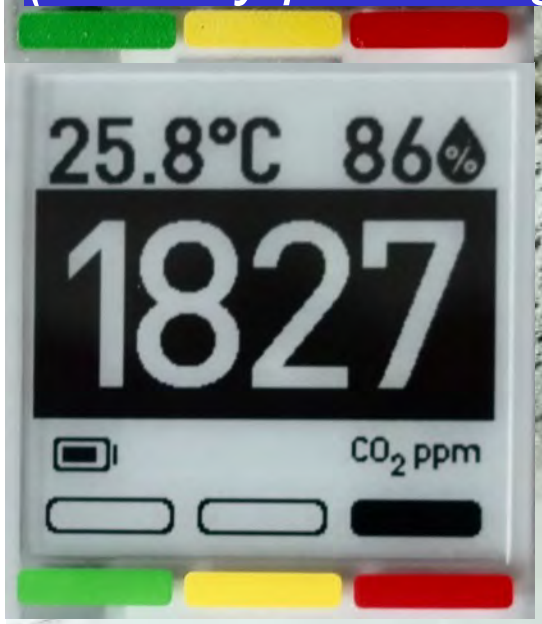
SOURCE: C Wood, W Bordass & P Baker, *Research into the thermal performance of traditional windows,* English Heritage (2009)

If ventilation becomes inadequate, *things may go badly wrong with air quality, the building and occupant health*



If ventilation becomes inadequate, *things may go badly wrong with air quality, the building and occupant health*

Low cost monitoring with alarms can help manage risks before they become acute. *Of particular interest to owner-occupiers and to landlords (security permitting).*



4.

PUTTING IT TOGETHER

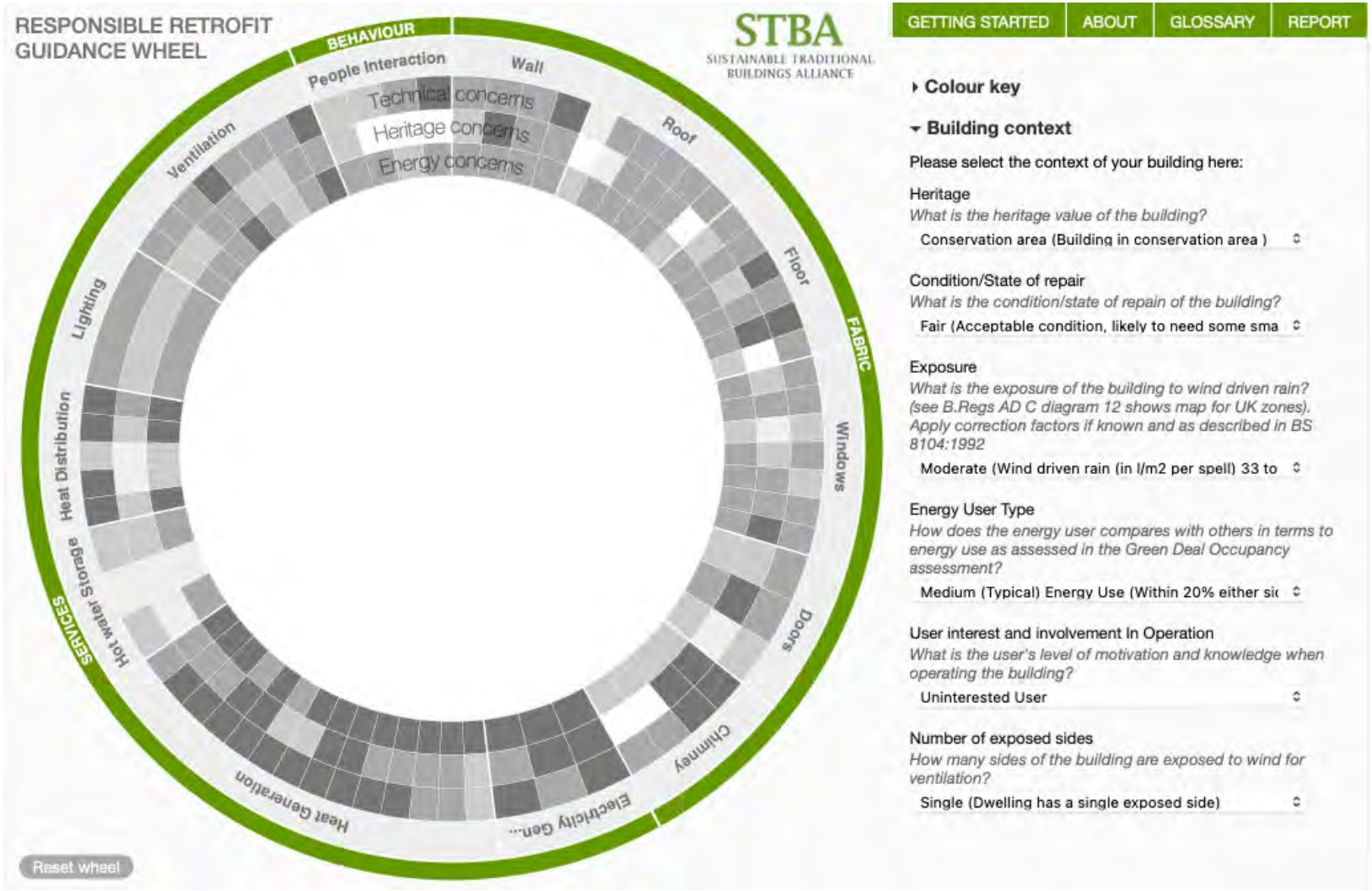
In an integrated, proportionate, sensitive, people first, whole building and system approach …

Windows should let things in when they are beneficial and keep them out when they are not, including:

- Heat
- Light
- Sun
- Air
- Sounds
- Smells
- Outsiders, *both human and from the natural world*

"Get the diodes right" **–** JOHN DOGGART

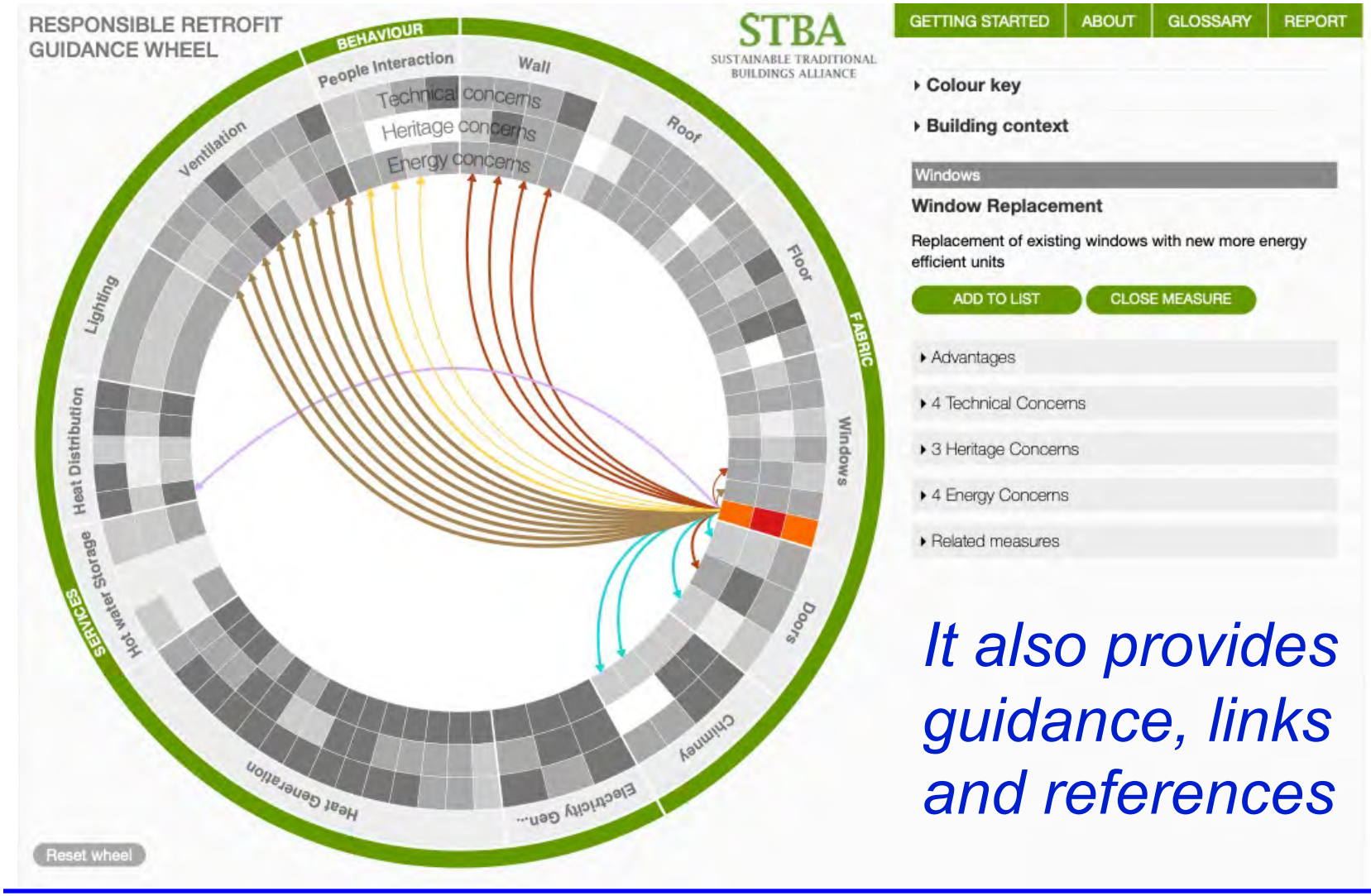
The STBA Green Wheel (2013):
Helping to manage energy retrofit-related risks



A development from the English Heritage Triage prototype. Available at: www.responsible-retrofit.org/wheel

The STBA Green Wheel (2013):

Everything has knock-on effects, including windows



It also provides guidance, links and references

AVAILABLE AT: www.responsible-retrofit.org/wheel

"FABRIC FIRST" envelope performance:

has been a mantra for low energy & carbon buildings

JUST AS IT SHOULD BE FOR NEW BUILDINGS:

get rid of demand by passive measures before adding kit.

FOR EXISTING BUILDINGS, it may be better to work out from people to the fabric than vice-versa:

A "People First" approach can be quicker, more effective and economical, with work much less costly and carbon-intensive.

Rapid decarbonisation of UK electricity also changes the balance between fabric improvement, engineering systems and energy supply measures.
N Banks of Octopus argues "Fabric Fifth": I think this is a bit extreme.*

*The Global North has already maxed out its carbon budget, so we must seriously consider **SUFFICIENCY:** how to consume less and instead invest in better use of our existing resources and improving quality of life.*

---

* Nigel Banks's argument is here: https://www.linkedin.com/pulse/fabric-fifth-nigel-banks-riofe/

Old windows have proved their sustainability: *they have lasted !*

Why replace them with what could turn out to be a consumable?

"Maintenance-free = Impossible to maintain" – BERNARD FEILDEN

Sufficiency, Energy and Comfort:

Helping people to avoid discomfort and stay healthy

MAIN METHODS:

1. Review appropriate standards *and promote adaptive comfort*
2. Control draughts, air movement and radiant heat gains and losses
3. Wear the right clothing and have suitable furniture etc.
4. Consider local and personal heating and cooling systems
5. Have *or reinstate* accessible, user-friendly controls
6. Improve thermoregulatory fitness where practicable
7. ADD thermal refuges, *both hot and cold, local and communal.*
8. *Plan to avoid health and moisture-related unintended consequences.*

"He gets so dramatic when I lower the thermostat."

P C Vey cartoon from the New Yorker (1 April 2019).

They also save energy and carbon much more quickly and cheaply than heavy capital investment.

FOR MORE SEE:https://www.usablebuildings.co.uk/UsableBuildings/Unprotected/EnergyRetrofitsAndTraditionalBuildings.pdf

Improving window performance:
A people-first proportionate approach

A. Fabric First - again !!! *Now not rushing to upgrade it, but seeking to understand how it works, how it used to work; and its state, condition, and maintenance requirements.*

B. Engage occupiers: *What they like, what they find difficult or annoying, and what they think might need doing.*

C. Work with occupiers to understand and make use of the building's potential: ***"How to sail it"*** *– R PENDER.*

POSSIBLE UPGRADES *in order of increasing disruption:*

1. Simple measures, *largely portable & tweaks*
2. Low-cost alterations, *e.g. draughtproofing, screens*
3. Reversible alterations, *e.g. secondary glazing.*
4. Glass replacement.
5. Window replacement.


Spot the secondary glazing


Magnetically attached acrylic sheet, *U~2*
Taken down and stored in summer
Rooms need alternative ventilation for air quality to stay OK: it has here

Vacuum secondary glazing prototype 2009

U~1, not far off a Passivhaus window

Note the upper sash is on the INSIDE, to improve operability

Complements original windows

Major heat loss saving:
U-Value < 1.0 W/m² K.

Improved winter comfort
(less infiltration, little or no downdraught, less radiation loss, as in includes low-E glass).

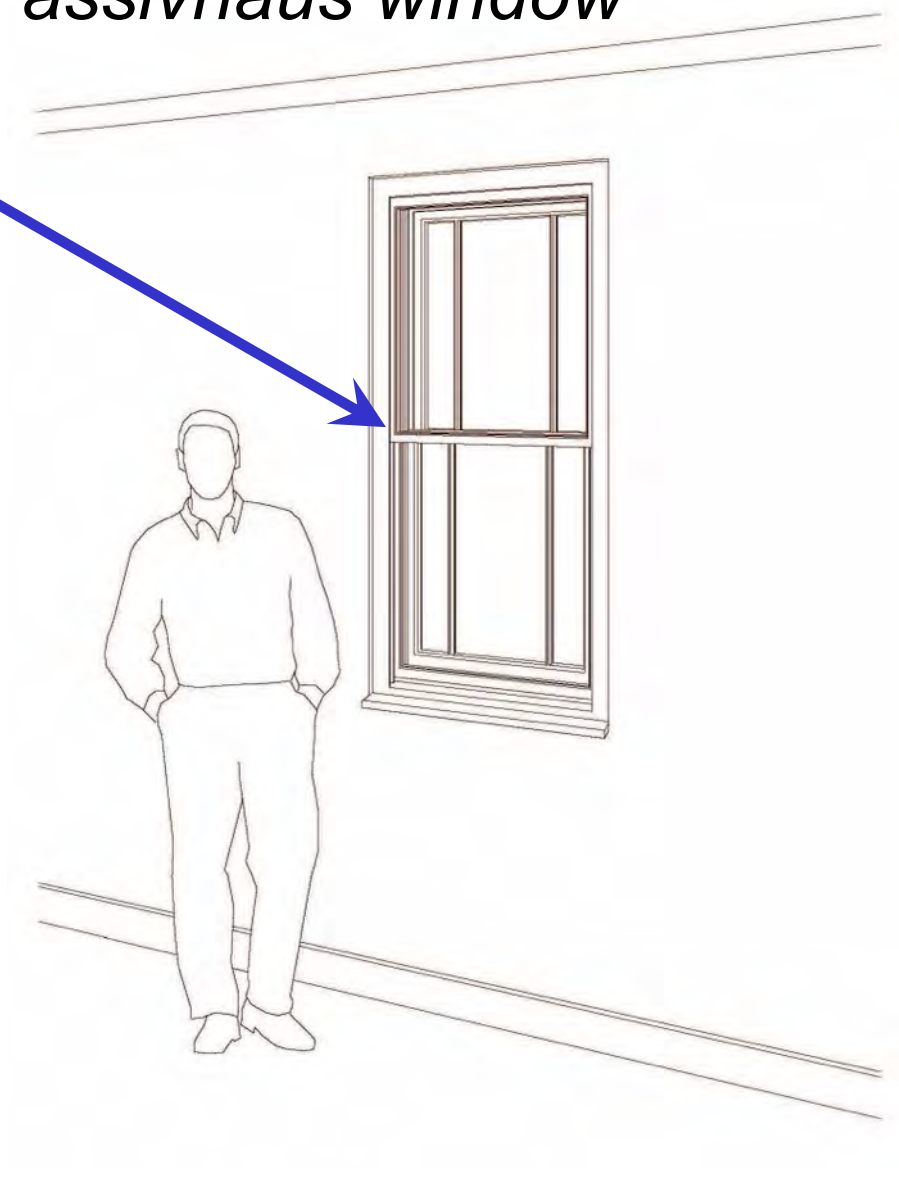
Trickle vents can be included. *Option for heat recovery from interspace.*

Improved summer comfort *with blinds between primary & secondary sashes.*

Minimal disruption + installation cost.

Particularly useful for front elevations in conservation areas.

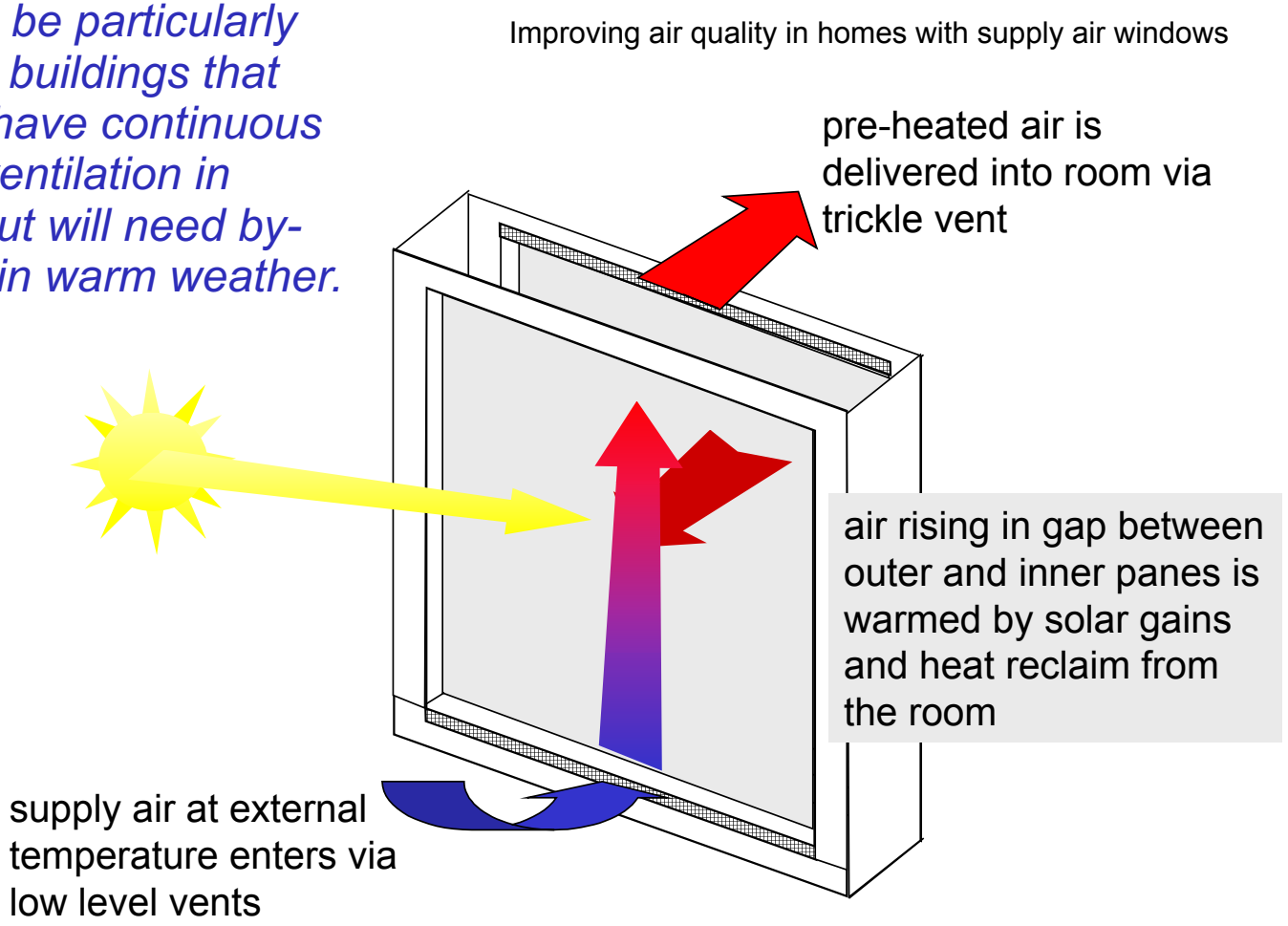
Fits well with internal wall insulation, making continuous inner envelope.



Developed with Bob Prewett of Prewett Bizley Associates and Jeremy Murphy's joinery company

You can potentially use secondary single glazing to recover outgoing heat too *(U~1.0)*

This can be particularly useful in buildings that already have continuous extract ventilation in winter, but will need by-passing in warm weather.



Classic double and secondary glazing:

Railway works Swindon

Doppelfenster Leipzig

Vacuum re-glazing of primary windows

U~1.5 in retrofit of BRE's former Stables Block (2010)

Vacuum primary windows at BRE Stables

More elegant than sealed units in the same building

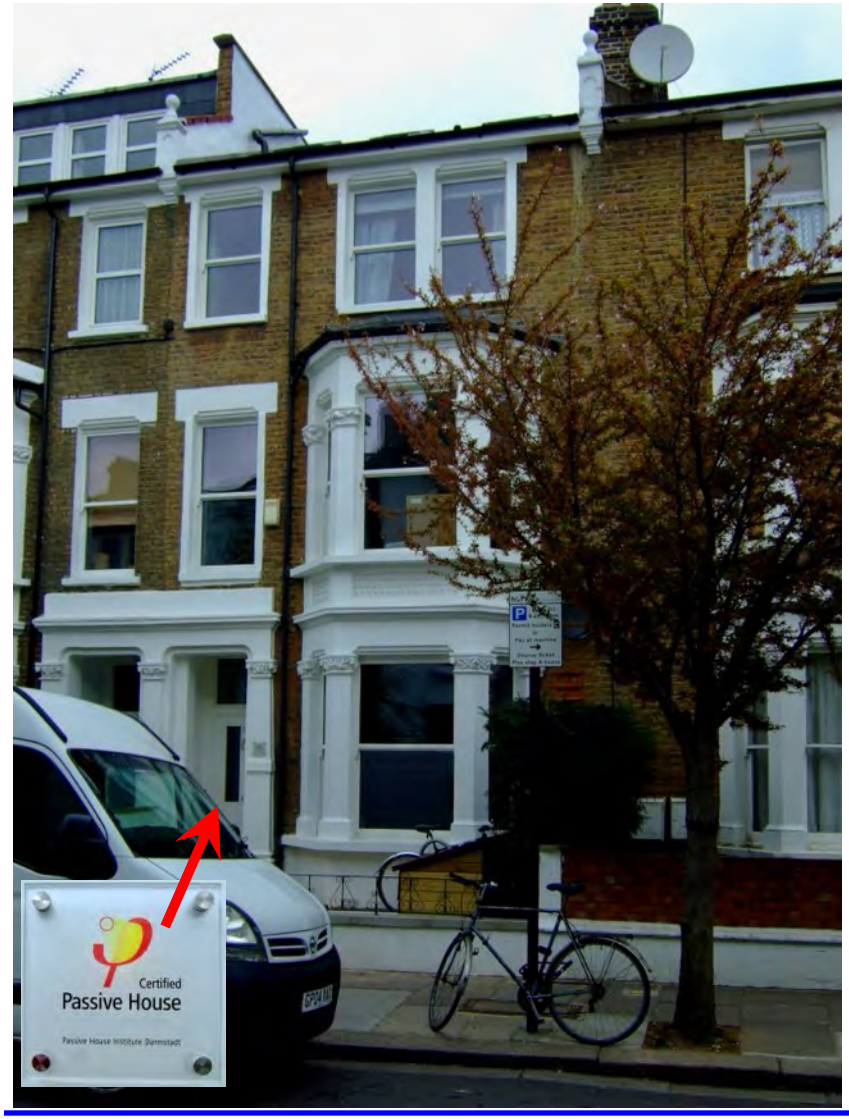
<< *Conventional sealed double units look clumsy in comparison*

Vacuum glazing with planted bars virtually indistinguishable from single glazing, except under very close examination

Bold triple-glazed replacement:
Industrial to office in Wels, Austria

Discreet triple-glazed replacement:

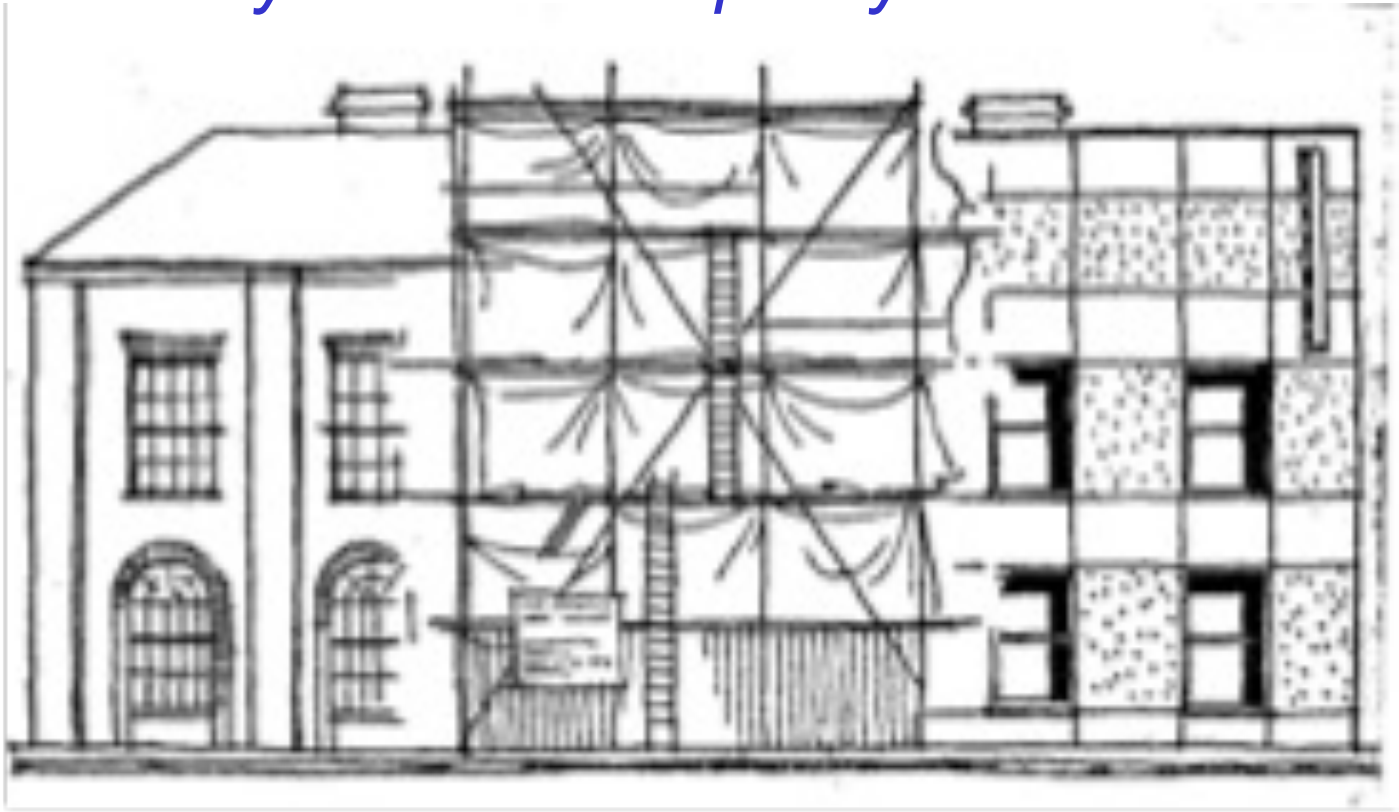
U=0.8 in Passivhaus deep retrofit in West London



Not really a workalike:

Only the bottom centre opens (in)
Less functionality than a sash,
***but** the house has mechanical ventilation & heat recovery MVHR*

"… prioritise heritage buildings within the energy efficiency and climate policy." - *POLICYMAKER*



Or might policy have as much to learn from heritage as heritage from policy?

That's it – THANK YOU

www.usablebuildings.co.uk

Illustration from: R Boyd, *The Australian Ugliness,* (Penguin, Melbourne, 1968)