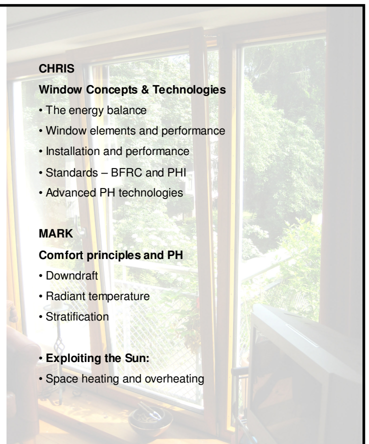
Which windows?

Understanding and specifying windows for low energy construction

Chris Herring,
Green Building Store

Mark Siddall,
DEWJ'OC Architects



"As well as letting in daylight and sunlight and allowing for natural ventilation, the window is also usually required to provide a view while retaining privacy. As an interruption in the external wall the window poses problems of structural stability, heat loss and noise transmission, and is arguably one of the most complex of building elements.

....It is the very interconnectedness of all these factors which is the essence of design problems, rather than the isolated factors themselves."

Lawson, 1997

"A window is an opening in a wall of a building that allows light, air and burglars to enter a room and people to see out"

Wikipedia

Window performance

This section examines:

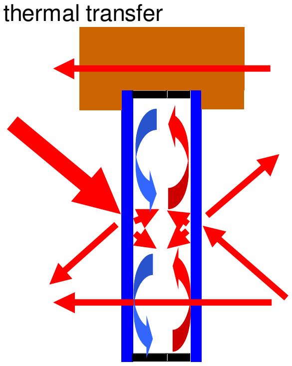
- Thermal transfer
- The energy balance
- U and Ψ values

Elements of thermal transfer

Radiation

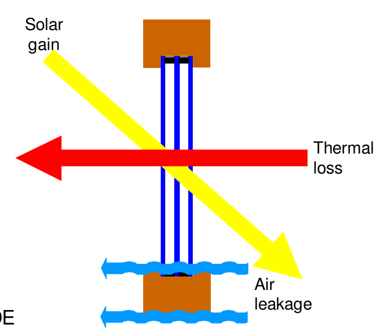
Conduction

Convection

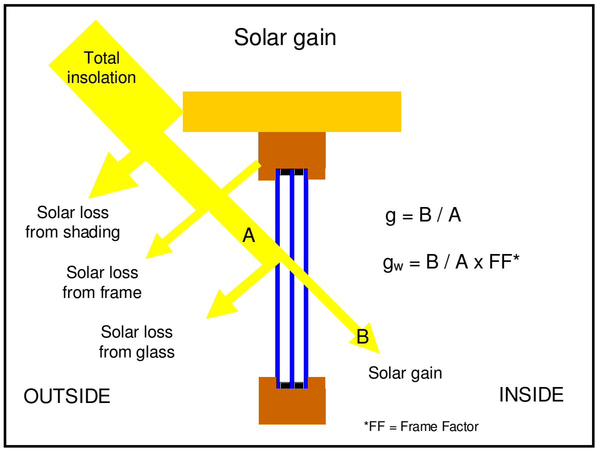


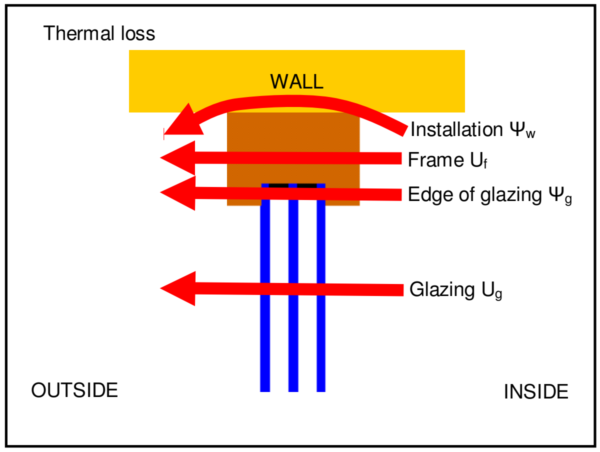
OUTSIDE INSIDE

The energy balance



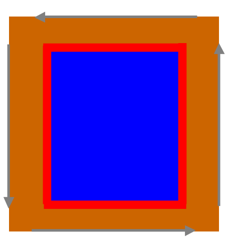
OUTSIDE INSIDE





What is the glazing psi value Ψg?

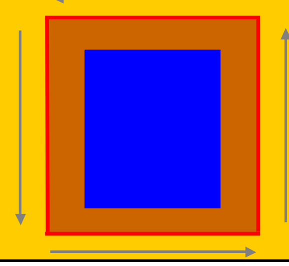
Uw x Aw - Uf x Af - Ug x Ag = Ψg x lg



What is the window installation psi value Ψw?

Heat loss calculated through window/wall combination

- Uwall x Awall - Uw x Aw = Ψw x lf



Window U values

$$Uw = \frac{Ug \times Ag + Uf \times Af + \Psi g \times lg}{A}$$

Unlike SAP, in Passive House methodology the Ψw is included in an overall U value, Uw inst

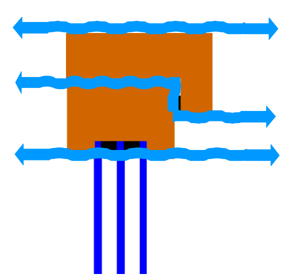
$$Uw\ inst = \frac{Uw \times A + \Psi w \times lf}{A}$$

Air leakage

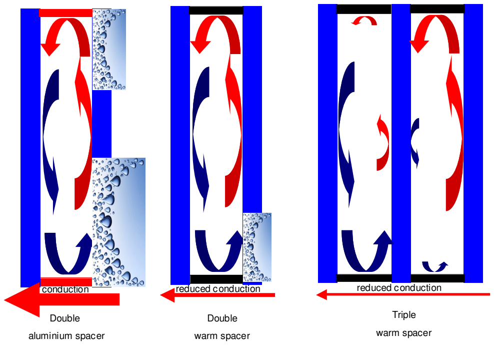
Leakage through frames via seals

Leakage between glazing and frame

Leakage resulting from installation, between frame and building fabric



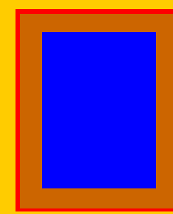
Effect of spacer and cavity on condensation



Window elements

This section examines:

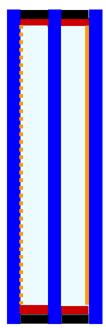
- Glazing
- Frame
- Installation



Glazing

High performance glazing units comprise:

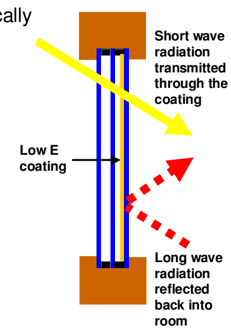
- 2 or 3 sheets of glass (obviously!)
- Low emissivity coating(s)
- Warm edge spacer bar
- Edge seal, typically polysulphide
- Inert gas fill

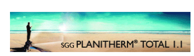


Low emissivity coating

Thin metallic layer, which dramatically reduces heat loss by radiation.

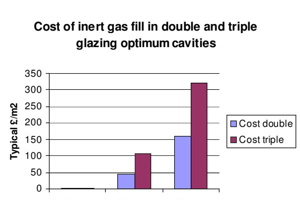
- Hard coat
  eg Pilkington K glass
  ✓Easy to handle for fabricators
  ✓Long shelf life for fabricators
  ✓Can have higher levels of solar transmission
- Soft coat
  eg St Gobain Planitherm Total
  ✓Lower emissivity values = lower heat loss
  ✓Solar transmission improving

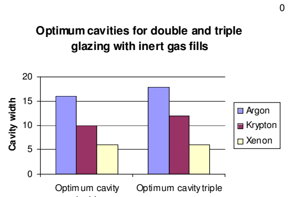




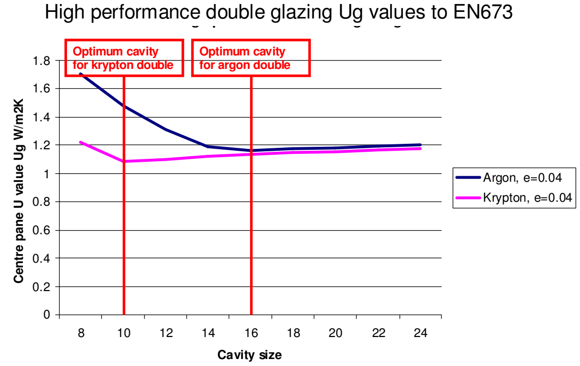
Gas fill

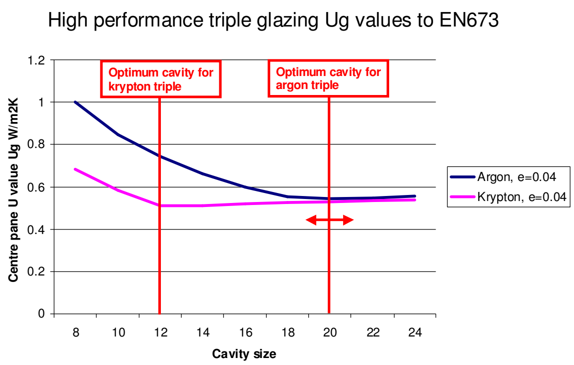
Heat loss through conduction and convection can be significantly reduced through filling unit cavity with inert gas – argon, krypton, xenon





High performance double glazing Ug values to EN673





Spacer bar functions

- Physical location of sheets of glass
- Fill gas retention
- Vapour diffusion barrier
- Dessicant retention

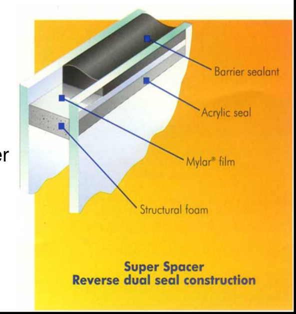
Spacer bars - types

- Standard – bad thermal bridging
  - Aluminium
- Reduced thermal bridging
  - Stainless steel
  - Stainless steel U channel eg Intercept
  - Aluminium with thermal break eg Azon
- True 'warm edge'
  - Polymer - stainless steel reinforced eg Thermix
  - Glass fibre eg Swisspacer
  - Structural foam eg Edgetech Superspacer

Spacer bars – example of a warm edge technology

Superspacer – example of 'warm edge' spacer

- Structural foam incorporating dessicant
- Mylar film is vapour barrier and gas diffusion barrier
- Barrier seal – usually polysulphide



Frames

- PVC
- Aluminium
- Steel
- Fibreglass
- Timber
- Composites
- Insulated composites

Typical composites:

- Aluminium clad timber
- Aluminium clad PVC
- PVC clad timber
- Aluminium – timber hybrid

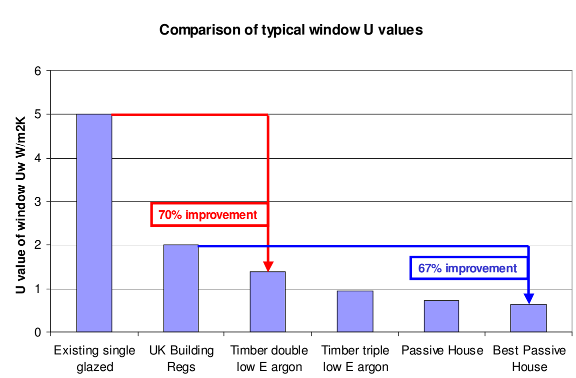
Insulated composites:

- Timber with PU
- Timber with cork
- Al/timber with PU
- PVC with PU
- Insulated fibreglass timber hybrid

Greenpeace
The production and disposal of PVC windows leads to the release of highly poisonous chemicals which threaten the environment and human health.
Look out: your choice of window frames could seriously affect the health of the planet December 1998

WWF
While the plastics industry claims that 'PVC is as good as any material', findings presented in this report justify the long-held position by WWF and other major environmental organizations that PVC is unsustainable and hazardous.
Report 'Window of opportunity' July 2005

Centre for Alternative Technology
…….timber frames have a much lower environmental impact than uPVC or aluminium.
Factsheet 2006

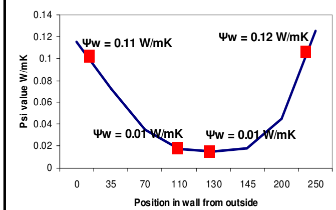


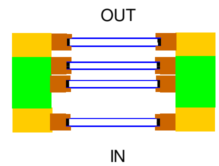
Installation

This section examines critical aspects of installation:

- Effect of position of window in wall on Ψ_w
- Effect of position of window in wall on solar shading
- Effect of wrapping insulation around the frame on Ψ_w
- Measures to ensure high levels of airtightness

The effect of installing window in different positions in the wall

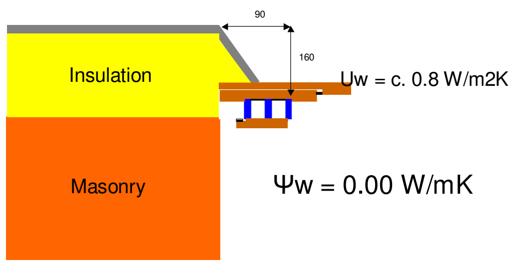




Schematic for illustration purposes based on installation positions for a high performance double glazed window into advanced specification cavity wall construction

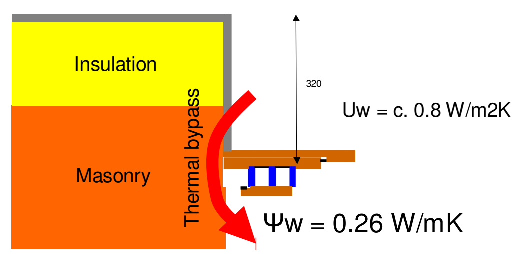
From "Stamford Brook – making sustainability work" Lowe et al

The effect of wrapping insulation around the face of the frame



Schematic drawing based on an example from proceedings of the Passive House Conference 2006 for renovation of typical German construction using PH standard window. Freundorfer, Kaufmann and Krause

The effect of wrapping insulation around the face of the frame



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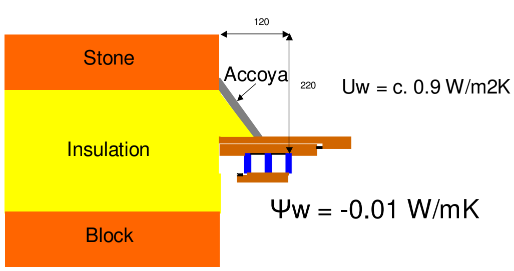


Schematic drawing based on cavity wall design for the Denby Dale House, courtesy Green Building Company

What difference does Ψw make?

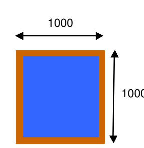
Example 1

Uw = 1.5 W/m2K; Ψw = 0.12 W/mK

Thermal transmission = Uw x A + Ψw x lf

= 1.98 W/K

A 32% increase in effective U value



Example 2

Uw = 1.5 W/m2K; Ψw = 0.05 W/mK

Thermal transmission = Uw x A + Ψw x lf

= 1.7 W/K

A 13 % increase in effective U value

What difference does Ψw make?

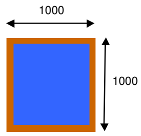
Example 3

Uw = 0.8 W/m2K; Ψw = 0.04 W/mK

Thermal transmission = Uw x A + Ψw x lf

= 0.96W/K

A 20 % increase in effective U value



Example 4

Uw = 0.8 W/m2K; Ψw = 0.01 W/mK

Thermal transmission = Uw x A + Ψw x lf

= 0.84 W/K

A 5% increase in effective U value

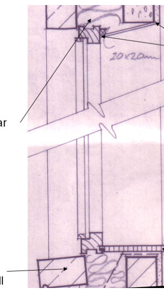
Window detailing - the Longwood Low Energy House 1992

(the year after completion of the first Passivhaus in Darmstadt)

Uw = c. 2.0 W/m2K

Ψw = 0.02 W/mK

(estimated)



Typical Passive House certified window installation detail

Uw = 0.85 W/m2K

(not certified to PH standard)

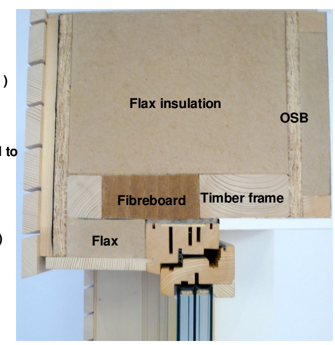
Uw inst = 0.85 W/m2K

(installed window is certified to PH standard)

Uw = 0.75 W/m2K

(actual with Ug 0.56 W/m2K))

Ψw = - 0.001 W/mK



Sigg window installation detailing. See www.passivhausfenster.at

Passivhaus window certified installation

F R A M E   T Y P E   A C C O R D I N G   T O   C E R T I F I C A T I O N

for glazings, go to row: 2

	Type	U_f-Value	Frame Dimensions				Thermal Bridge	Thermal Bridge
Assembly No.	Frame	Frame	Width - Left	Width - Right	Width - Below	Width - Above	Ψ_{Spacer}	$\Psi_{Installation}$
85								
86								
87								
88	Sigg - installation lightweight wood construct	0.93	0.100	0.100	0.117	0.100	0.036	-0.001
89	Sigg - installation ETICS (Passivhaus Venster)	0.93	0.100	0.100	0.117	0.100	0.036	-0.001
90	Wenger - installation wood construction (EIGER	1.05	0.090	0.090	0.125	0.090	0.[illegible]41	-0.017

Passive House Planning Package

Window detailing for airtightness

It is essential when installing windows to Passive House standard or other low energy approaches that full consideration is given to ensuring continuity of the air barrier.

One of the most effective ways of doing this around windows is the use of proprietary tape systems.

Standards

This section examines key standards relating to windows:

- EN 14351
- EN 10077-1 & 2 and EN 12567-1
- BFRC
- PHI

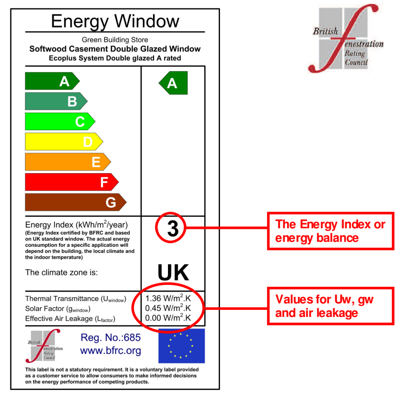
BFRC

What is it?

- Rates windows on the basis of a nominal energy balance
- Rating A - G
- Ensures publication of standardised values for U_f, g_w and effective air leakage
- Has value as a comparative tool
- C+ rated windows can use the Energy Efficiency Label

BFRC

Typical window energy rating label



BFRC

- Energy balance =

$$218.6 \times g_w - 68.5 \times (U_w + \text{effective } L_{50})$$

Solar gain coefficient for window

Window U value to BFRC standard

Effective heat loss resulting from air leakage

- 'A' rating has 'positive' energy balance

BFRC

BFRC Rating Scale	BFRC Rating (kWh/m²/year)
A	0 or greater
B	-10 to < 0
C	-20 to < -10
D	-30 to < -20
E	-50 to < -30
F	-70 to < -50
G	Less than -70

Best BFRC Rating is currently

5 kWh/m2/a

Typical PassivHaus window ratings might be in the range:

13 - 32 kWh/m2/a

BFRC

Advantages

- Publication of Uw values, and reduced confusion with Ug
- Allows comparison of windows
- Improved window performance
- Increased market for better performing windows

Disadvantages

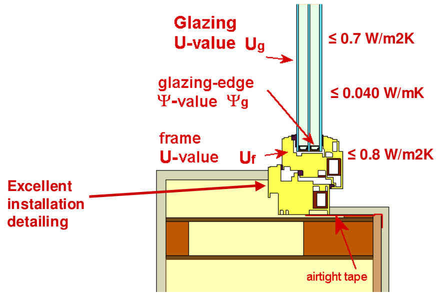
- Solar too significant, favouring hard coat low E.
- 2 methodologies for Uw in the UK
- Confusing: takes no account of designing a window into the building
- Does not adequately reflect the performance of advanced window systems
- 'A' grade too low

Passive House Institute

Key window certification criteria

- U_w not more than 0.8 W/m2K, when window is assessed with glazing U_g = 0.7 W/m2K
- $U_{w\ inst}$ not more than 0.85 W/m2K
- $U_g - 1.6$ W/m2K x g ≤ 0 (which generally means that g value is greater than 50%)

Typical PH window



The PH window and comfort

The key feature of Passive Houses is lack of perimeter heating.

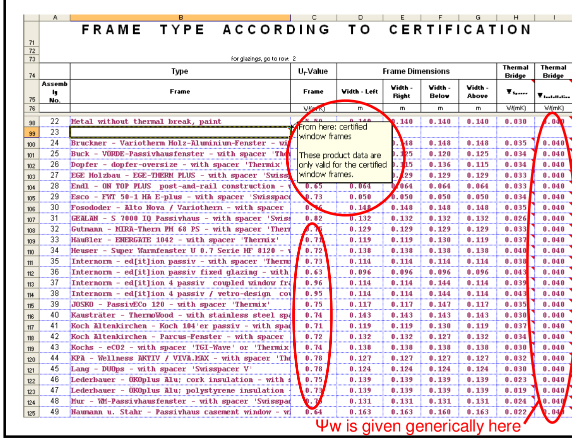
Internal surface temperature of the window must be sufficient to keep internal surface ≥ 17 ^{0}C

This defines the key window criteria

Passive House Institute

Two types of certification:

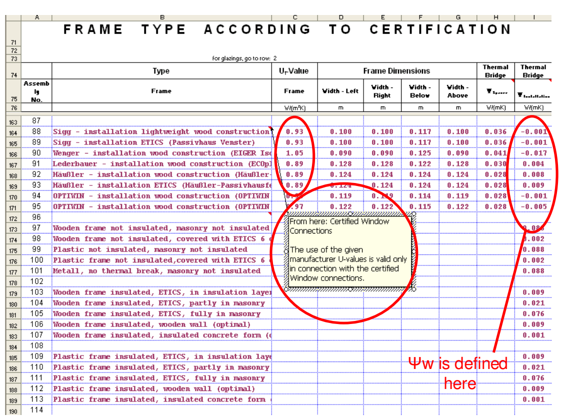
- Certified window, where $U_w \leq 0.8$ W/m2K, when window is assessed with glazing $U_g = 0.7$ W/m2K. Ψ_w is generally generic in PHPP for these windows.
- Window only certified with approved installation detail, where installed value of $U_{w\ inst} \leq 0.85$ W/m2K. Ψ_w is always given in PHPP for these windows.
- Both categories can be seen in PHPP, separately listed.



FRAME TYPE ACCORDING TO CERTIFICATION

for glazings, go to row: 2

Row	Assembly No.	Type: Frame	U_f-Value: Frame W/(m²K)	Frame Dimensions: Width - Left m	Width - Right m	Width - Below m	Width - Above m	Thermal Bridge Ψ_{spacer} W/(mK)	Thermal Bridge $\Psi_{installation}$ W/(mK)
98	22	Metal without thermal break, paint	[illegible]	[illegible]	0.140	0.140	0.140	0.030	[illegible]
99	23								
100	24	Bruckner - Variotherm Holz-Aluminium-Fenster - wi	[illegible]	[illegible]	[illegible]	0.148	0.148	0.035	0.040
101	25	Buck - VÖRDE-Passivhausfenster - with spacer 'The	[illegible]	[illegible]	[illegible]	0.120	0.125	0.034	0.040
102	26	Dopfer - dopfer-oversize - with spacer 'Thermix'	[illegible]	[illegible]	[illegible]	0.136	0.115	0.034	0.040
103	27	EGE Holzbau - EGE-THERM PLUS - with spacer 'Swiss	[illegible]	[illegible]	[illegible]	0.129	0.129	0.033	0.040
104	28	Endl - ON TOP PLUS post-and-rail construction - v	0.65	0.064	[illegible]	0.064	0.064	0.033	0.040
105	29	Esco - FWT 50-1 HA E-plus - with spacer 'Swisspace	[illegible]	0.050	[illegible]	0.050	0.050	0.034	0.040
106	30	Fosododer - Alto Nova / Variotherm - with spacer	[illegible]	[illegible]	0.148	0.148	0.148	0.035	0.040
107	31	GEALAN - S 7000 IQ Passivhaus - with spacer 'Swiss	0.82	0.132	0.132	0.132	0.132	0.026	0.040
108	32	Gutmann - MIRA-Therm PH 68 PS - with spacer 'Therr	[illegible]	0.129	0.129	0.129	0.129	0.033	0.040
109	33	Häußler - ENERGATE 1042 - with spacer 'Thermix'	0.71	0.119	0.119	0.130	0.119	0.037	0.040
110	34	Heuser - Super Warmfenster U 0.7 Serie HF 8120 - v	0.72	0.138	0.138	0.138	0.138	0.040	0.040
111	35	Internorm - ed[it]ion passiv - with spacer 'Thermi	0.73	0.114	0.114	0.114	0.114	0.038	0.040
112	36	Internorm - ed[it]ion passiv fixed glazing - with	0.63	0.096	0.096	0.096	0.096	0.043	0.040
113	37	Internorm - ed[it]ion 4 passiv coupled window fra	0.96	0.114	0.114	0.144	0.114	0.039	0.040
114	38	Internorm - ed[it]ion 4 passiv / vetro-design co	0.95	0.114	0.114	0.144	0.114	0.043	0.040
115	39	JOSKO - PassivECo 120 - with spacer 'Thermix'	0.75	0.117	0.117	0.147	0.117	0.035	0.040
116	40	Kausträter - ThermoWood - with stainless steel spa	0.74	0.143	0.143	0.143	0.143	0.030	0.040
117	41	Koch Altenkirchen - Koch 104'er passiv - with spac	0.71	0.119	0.119	0.130	0.119	0.037	0.040
118	42	Koch Altenkirchen - Parcus-Fenster - with spacer	0.72	0.132	0.132	0.127	0.132	0.034	0.040
119	43	Kochs - eCO2 - with spacer 'TGI-Wave' or 'Thermix	0.74	0.138	0.138	0.138	0.138	0.030	0.040
120	44	KPA - Wellness AKTIV / VIVA.MAX - with spacer 'The	0.78	0.127	0.127	0.127	0.127	0.032	0.040
121	45	Lang - DUOps - with spacer 'Swisspacer V'	0.78	0.124	0.124	0.124	0.124	0.030	0.040
122	46	Lederbauer - ÖKOplus Alu; cork insulation - with s	0.75	0.139	0.139	0.139	0.139	0.023	0.040
123	47	Lederbauer - ÖKOplus Alu; polystyrene insulation -	0.73	0.139	0.139	0.139	0.139	0.019	0.040
124	48	Mur - WM-Passivhausfenster - with spacer 'Swisspac	[illegible]	0.131	0.131	0.131	0.131	0.024	0.040
125	49	Naumann u. Stahr - Passivhaus casement window - wi	0.64	0.163	0.163	0.160	0.163	0.022	[illegible]



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for glazings, go to row: 2

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163	87								
164	88	Sigg - installation lightweight wood construction	0.93	0.100	0.100	0.117	0.100	0.036	-0.001
165	89	Sigg - installation ETICS (Passivhaus Venster)	0.93	0.100	0.100	0.117	0.100	0.036	-0.001
166	90	Wenger - installation wood construction (EIGER Isc	1.05	0.090	0.090	0.125	0.090	0.041	-0.017
167	91	Lederbauer - installation wood construction (ECOpl	0.89	0.128	0.128	0.122	0.128	0.030	0.004
168	92	Häußler - installation wood construction (Häußler-	0.89	0.124	0.124	0.124	0.124	0.028	0.008
169	93	Häußler - installation ETICS (Häußler-Passivhausfe	0.89	[illegible]	0.124	0.124	0.124	0.028	0.009
170	94	OPTIWIN - installation wood construction (OPTIWIN	[illegible]	0.119	[illegible]	0.114	0.119	0.028	-0.001
171	95	OPTIWIN - installation wood construction (OPTIWIN	[illegible]	0.122	0.122	0.115	0.122	0.028	-0.005
172	96								
173	97	Wooden frame not insulated, masonry not insulated							[illegible]
174	98	Wooden frame not insulated, covered with ETICS 6							[illegible]
175	99	Plastic not insulated, masonry not insulated							0.088
176	100	Plastic frame not insulated,covered with ETICS 6							0.002
177	101	Metall, no thermal break, masonry not insulated							0.088
178	102								
179	103	Wooden frame insulated, ETICS, in insulation layer							0.009
180	104	Wooden frame insulated, ETICS, partly in masonry							0.021
181	105	Wooden frame insulated, ETICS, fully in masonry							0.076
182	106	Wooden frame insulated, wooden wall (optimal)							0.009
183	107	Wooden frame insulated, insulated concrete form (c							0.001
184	108								
185	109	Plastic frame insulated, ETICS, in insulation laye							0.009
186	110	Plastic frame insulated, ETICS, partly in masonry							0.021
187	111	Plastic frame insulated, ETICS, fully in masonry							0.076
188	112	Plastic frame insulated, wooden wall (optimal)							0.009
189	113	Plastic frame insulated, insulated concrete form (							0.001
190	114								

Methodologies

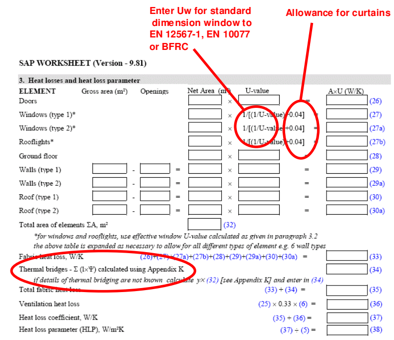
This section examines the two key methodological differences between German Passive House and the UK

- Calculation of U value to EN 10077 standard *or* BFRC standard is accepted in the UK (we have already noted this)
- Modelling of windows in SAP and PHPP (Passive House Planning Package)

SAP

- Window U value is calculated by using standard Uw: U value = Uw x A
- There is a small allowance for curtains
- Ψ_w can be calculated and added in separately using: $H_{TB} = \Sigma(L \times \Psi)$
- Or y value of 0.15 (unknown details) or 0.08 for Accredited Construction Details using $H_{TB} = y\ \Sigma\ A_{exp}$*

* A_{exp} is total area of exposed elements



SAP WORKSHEET (Version - 9.81)

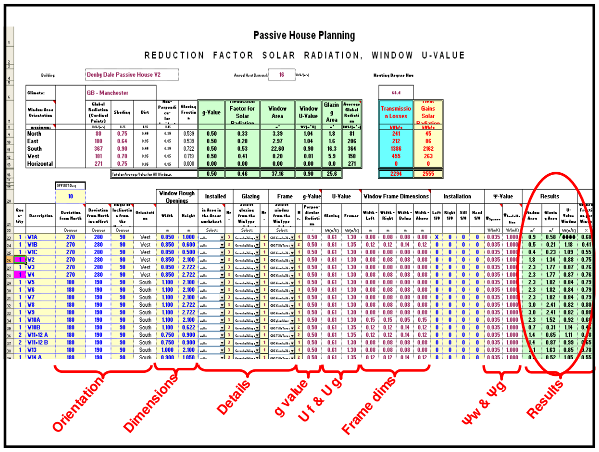
3. Heat losses and heat loss parameter

ELEMENT	Gross area (m²)		Openings		Net Area (m²)		U-value		A×U (W/K)	
Doors						×		=		(26)
Windows (type 1)*						×	1/[(1/U-value)+0.04]	=		(27)
Windows (type 2)*						×	1/[(1/U-value)+0.04]	=		(27a)
Rooflights*						×	1/[(1/U-value)+0.04]	=		(27b)
Ground floor						×		=		(28)
Walls (type 1)		-		=		×		=		(29)
Walls (type 2)		-		=		×		=		(29a)
Roof (type 1)		-		=		×		=		(30)
Roof (type 2)		-		=		×		=		(30a)

Total area of elements ΣA, m² (32)

*for windows and rooflights, use effective window U-value calculated as given in paragraph 3.2
the above table is expanded as necessary to allow for all different types of element e.g. 6 wall types

Fabric heat loss, W/K (26)+(27)+(27a)+(27b)+(28)+(29)+(29a)+(30)+(30a) = (33)
Thermal bridges - Σ (l×Ψ) calculated using Appendix K (34)
if details of thermal bridging are not known calculate y× (32) [see Appendix K] and enter in (34)
Total fabric heat loss (33) + (34) = (35)
Ventilation heat loss (25) × 0.33 × (6) = (36)
Heat loss coefficient, W/K (35) + (36) = (37)
Heat loss parameter (HLP), W/m²K (37) ÷ (5) = (38)



Results			
Window Area	Glazing Area	U-Value Window	Glazed Fraction per Window
m^2	m^2	$W/(m^2K)$	%
0.9	0.58	0.95	0.68
0.5	0.21	1.18	0.41
0.4	0.23	1.09	0.55
1.8	1.34	0.88	0.75
2.3	1.77	0.87	0.76
2.3	1.77	0.87	0.76
2.3	1.82	0.84	0.79
2.3	1.82	0.84	0.79
2.3	1.82	0.84	0.79
3.0	2.41	0.82	0.80
3.0	2.41	0.82	0.80
2.3	1.52	0.92	0.66
0.7	0.31	1.14	0.46
1.4	0.65	1.11	0.48
1.4	0.87	0.99	0.65
2.1	1.63	0.85	0.78
0.9	0.52	1.05	0.55
0.9	0.52	1.05	0.55
0.7	0.34	1.13	0.47
0.4	0.12	1.23	0.[illegible]4
[illegible]9	1.14	0.97	[illegible].60

This section examines:

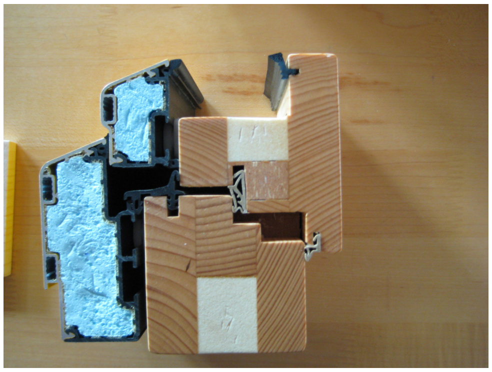
Insulated frames to meet Passive House Standard

To meet PH certified window standard, conventional timber or other frames do not have a low enough Uf. They need additional insulation if they are not to be extraordinarily deep. A number of approaches have been used.

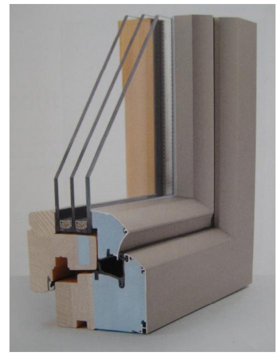
However, there is a question of whether insulated frames are actually needed (at additional cost), particularly in S England, if suitable installation details are used. Can comfort conditions be met without?

Here are some examples of insulated frames and prospects for future development……

Classic PU insulated timber. Variotec profile. PH certified window



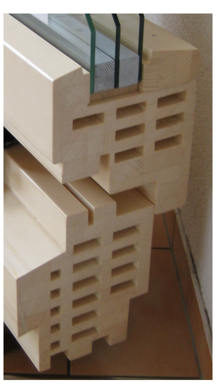
Gutmann Mira Therm window detail. PH certified window



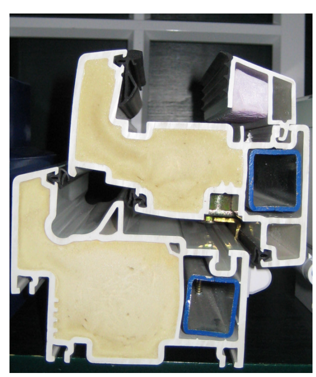
Internorm. PH certified window

Optiwin Three Timber system. PH certified window

Innovative composite approach. Energsign window. PH Certified



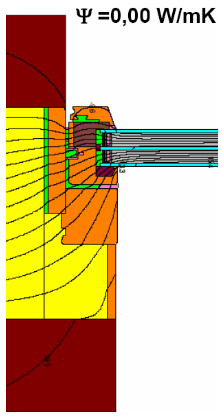
Holz-Schiller Airotherm System. Awaiting PH certification



Insulated PVC profile. PH certified window

And as for outward opening PH window…

Yes, it is possible, but will the building detailing be more difficult?



Optiwin/Vipo proposed outward PH standard window

This section examines

- the conditions (whole-window and frame U-values) under which perimeter (base-of-window) heating units can be eliminated while maintaining thermal comfort

Elimination of perimeter heating units

The criterion for elimination of perimeter heating units is that the innermost glazing temperature must be sufficiently warm, in the absence of perimeter heating, that

- thermal asymmetry is avoided,
- uncomfortable downdrafts are avoided, and
- condensation is avoided

Comfort Criteria

We interpret these criteria as implying, for a room air temperature of 20℃
Maintaining suitable comfort under ISO 7730.

Considerations include: -

- Downdraft
- Radiant temperature
- Stratification

PassivHaus Design Conditions

- Central European winter design day -10℃
- Ambient internal temperature 20C

PassivHaus Window

- Whole window U-value 0.85 W/(m²K)

So why is this the PassivHaus Standard U-value?

Down Draft:
PHI: Hochwärmedämmende Fenstersysteme: Untersuchung und Optimierung im eingebauten Zustand

Air speed/Draft:

DIN 1946 and ISO 7730 demand maximum air speeds of approx. 0.15 m/s depending upon turbulence degrees of air (PD = 20%).

Air speeds under this are valid in each case as sufficiently comfortable.

Down Draft:

PHI: Hochwärmedämmende Fenstersysteme: Untersuchung und Optimierung im eingebauten Zustand

PHI Fluid dynamic analysis :

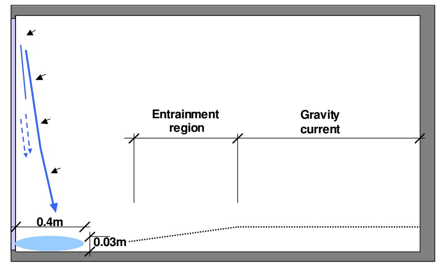
- Down draft velocity of 0.11 m/s.
- ISO 7730 states that 0.08 m/s, less than 6% of people will feel a draft.
- ASHRAE Comfort Class "A" achieved

- Ambient internal temperature 22C
- Down draft velocity of 0.07 m/s.

Draught Risk From Cold Vertical Surfaces

Per Heiselberg, Building and Environment, Vol. 29, No. 3, pp. 297-301, 1994, Elsevier Science Ltd

Notional room dimensions (length × width x height:) = (7 m x 6 m × 3 m)

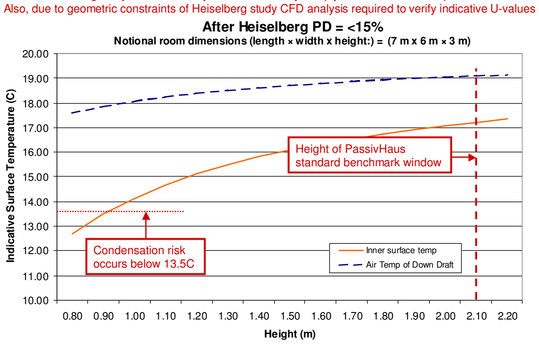


Principle of flow development along the floor

NOTE: Heiselberg study for interest only. Does not directly comply with PassivHaus requirements

Avoiding Draught Risk From Cold Vertical Surfaces

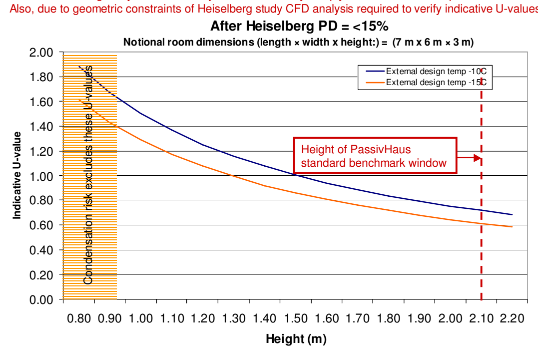
NOTE: Heiselberg study for interest only. Does not directly comply with PassivHaus requirements
Also, due to geometric constraints of Heiselberg study CFD analysis required to verify indicative U-values



Umax down draft velocity of <0.14 m/s, < 0.4m from vertical surface, <0.03m from floor, PD = <15%

Avoiding Draught Risk From Cold Vertical Surfaces

NOTE: Heiselberg study for interest only. Does not directly comply with PassivHaus requirements
Also, due to geometric constraints of Heiselberg study CFD analysis required to verify indicative U-values

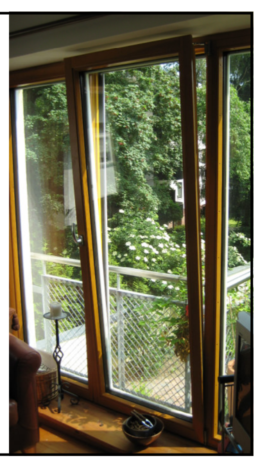


Umax down draft velocity of <0.14 m/s, < 0.4m from vertical surface, <0.03m from floor, PD = <15%

Radiant Temperature:

- PassivHaus standard benchmark window
- Inner pane temperature 17C
- A maximum 3C temperature differential

- At an internal air temperature of 21ºC and an external temperature of -14 °C with no solar radiation the resultant radiant temperature asymmetry, for a window with a U-value of 0.85W/m²K at a height of 1.1 m above the floor, is: -
- approximately 4.5ºC at 0.25m from window
- approximately 3.8ºC at 0.5m from window
- approximately 3ºC at 1m from window



Stratified Air Temperature:

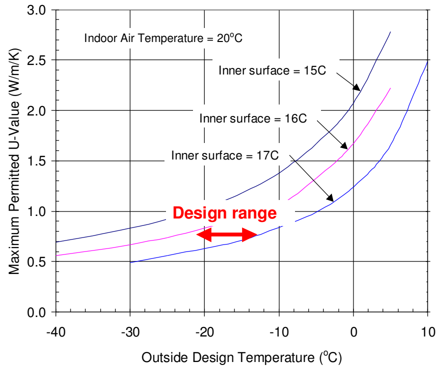
- Glazing with a 0.85 U-value
- External temp of -14C
- Ambient internal temperature 20C

At a distance of 0.5m from glazing

- there is a temperature of 20C @1.1m
- there is a temperature of 18.4 @ 0.1M.
- Temperature differential 1.6C
- Room air temperature stratification is less than 2 °C
- Thus satisfies ISO 7730
- Internal pane temperature under this condition is ~16°C

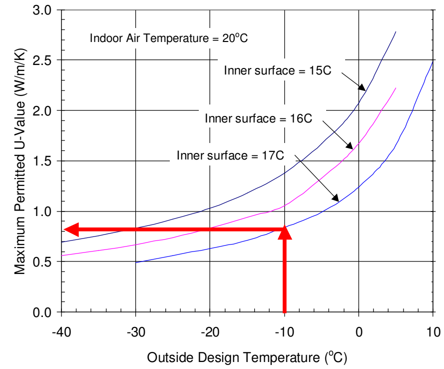
Glazing and Internal Surface Temperature

NOTE: Design temperature to be determined on a site by site basis



Glazing and Internal Surface Temperature

NOTE: Design temperature to be determined on a site by site basis



Conclusions:

Comfort

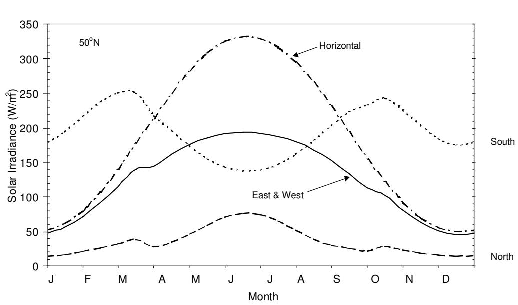
- Downdraft
- Radiant temperature
- Stratification

- Perimeter heating can be designed out
- Saving capital cost without compromising comfort
- When < 2.1 m, can have significantly higher Uw inst.
- It may be that these frames do not need to be insulated
- Some parts of the UK climate are less extreme than Central Europe therefore, into meet the comfort criteria, the Uw may not be required to be 0.85W/(m²K). NOTE: Site by site analysis is required to assess this matter.

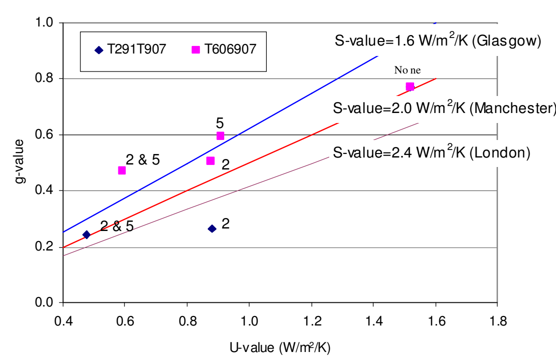
This section examines

- Exploiting Passive Solar
  - Seasonal concerns about solar gain
  - g-values
  - Space heating contribution

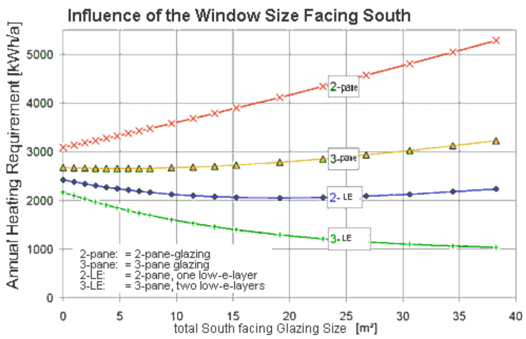
Windows: Solar Gains



Windows: Solar Gain / Heat losses

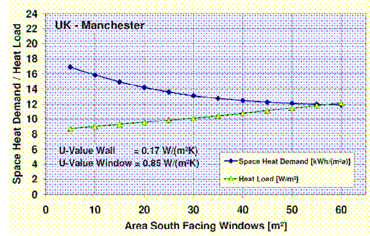


Windows: Solar Gain / Heat losses



Impact of Passive Solar

From "Climate Data for the Determination of Passive House Heat Loads in North West Europe" by Jurgen Schnieders



- Base Case:
- Relatively good ratio of exterior area to enclosed volume (0.59 m-1),
- Facing due south and has large south facing windows
- 30.4 m² gross window area, 19.9 m² glazed area in an overall 74 m² façade

- The UK climate: strongly influenced by the gulf stream and the thermal buffer effect of the sea
- Solar radiation levels in winter are comparable to Germany
- A lot less insulation than in Germany is required
- Under favorable boundary conditions, south facing windows may achieve high net solar gains

Conclusions:

Exploiting the Sun:

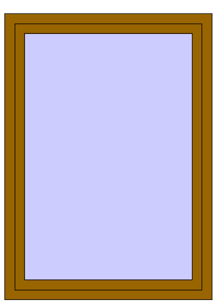
- Space heating and over heating

- Take care with east and west facing windows (to avoid over heating)
- Min g-values should be climatically considered

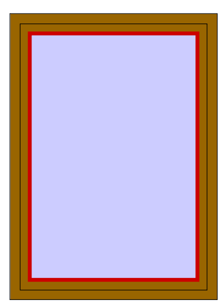
This section examines

- Whole window design: including the implications of the
  - Window frame design
  - Thermal bridging cause by the spacer bar
  - Thermal bridging from installation details
  - Solar gain vs. Thermal bridging

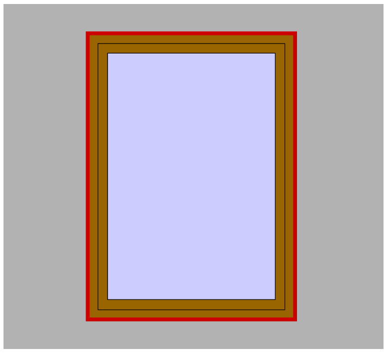
Windows: Frame Design



Windows: Spacer Bar



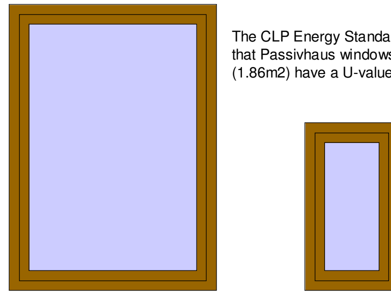
Windows: Installation



Not required under BS EN 10077-1, but required consideration in Passivhaus and AECB Standards

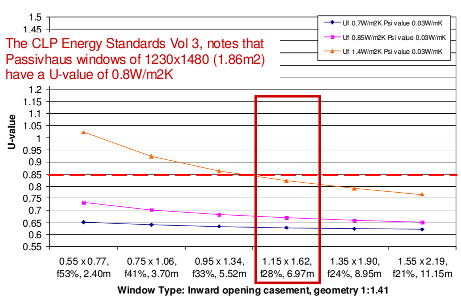
Windows: Frame Proportion (Opening light, 100mm notional frame)

Height (m)	Length (m)	Total Area (m2)	Glazed Area (m2)	% Glazed Area	% Frame Area
0.400	0.800	0.320	0.120	38%	63%
1.300	1.300	1.690	1.210	72%	28%
1.230	1.480	1.820	1.318	72%	28%
2.750	2.500	6.875	5.865	85%	15%

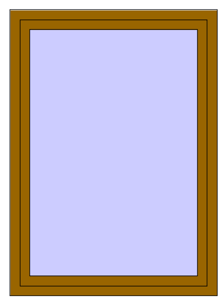


The CLP Energy Standards Vol 3, notes that Passivhaus windows of 1230x1480 (1.86m2) have a U-value of 0.8W/m2K

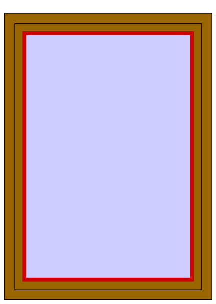
Windows: Frame Proportion (Opening light, 100mm notional frame all further examples)



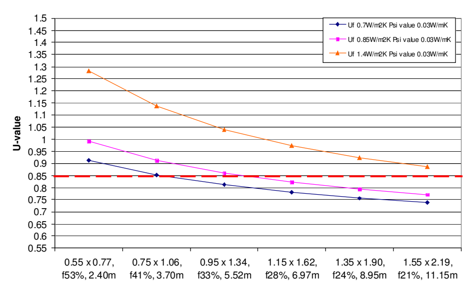
Windows: Ψg



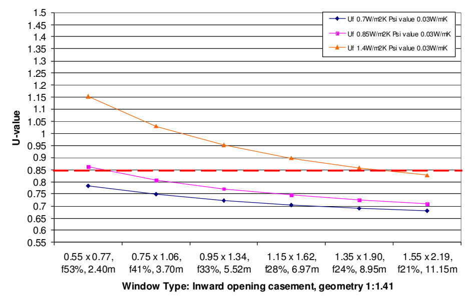
Windows: Ψg



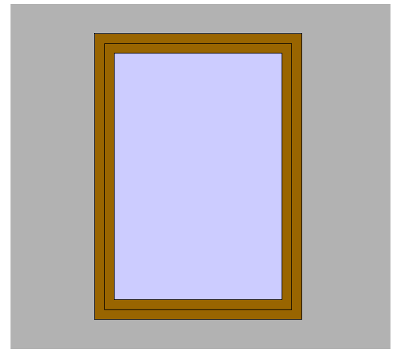
Windows: Frame Proportion and Ψg (Aluminium spacer = 0.06W/mK)



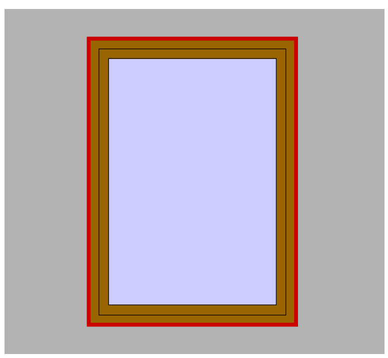
Windows: Frame Proportion and Ψg (High performance spacer = 0.03W/mK)



Windows: Ψinst.



Windows: Ψinst.



Not required under BS EN 10077-1, but required consideration in Passivhaus and AECB Standards

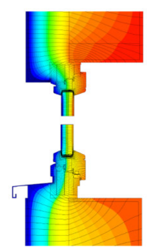
Thermal-Bridge-Free Construction

It is namely possible to determine without computation whether a detail represents a severe thermal bridge, solely through painstaking geometrical analysis.

- Continuity Rule: Where possible, do not interrupt the thermal envelope.
- Penetration rule: Where an interrupted insulating layer is unavoidable, thermal resistance in the insulation plane should be as high as possible; this indicates use of e.g. aerated concrete or, better still, timber instead of normal concrete or sand-lime bricks.
- Junction rule: At building element junctions, insulating layers should meet without any gaps. Insulating layers should join without interruption or misalignment.
- Geometry rule: Design edges to have as obtuse angles as possible.

The thermal envelope can then be termed 'thermal-bridge-free'. This is because the slightly elevated heat losses at some points will be compensated for by the reduction in heat flows attributable to geometrical thermal bridges.

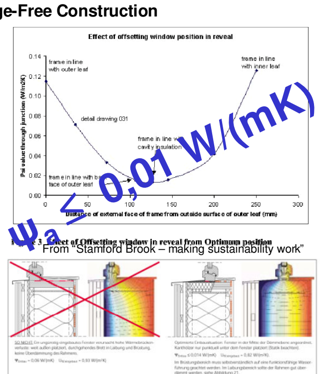
Avoiding thermal bridges helps to reduce condensation risks



from Hochwärmedämmende Fenstersysteme
R. Pfluger J. Schnieders

Thermal-Bridges typically = 25% of heat losses
Thermal-Bridges in a PassivHaus are <4%

Thermal-Bridge-Free Construction



from Holzbau Handbuch, Dr. Berthold Kaufmann

Thermal-Bridge-Free Construction

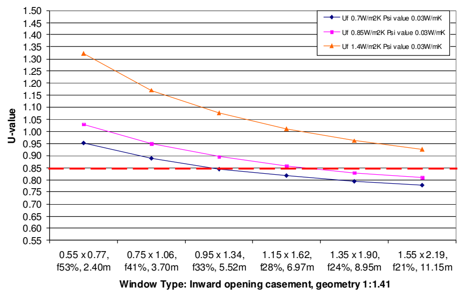
Level	Level 1: B.Regs Default	Level 2: Robust Details 2002	Level 2: Robust Details 2006	Level 3: AECB Silver	Level 3: PassivHaus/AECB Gold
Description	Details not conform and not shown to be equivalent with Accredited Construction Details	Conform with Accredited Construction Details	Conform with Accredited Construction Details	Detailed calculation	Detailed calculation
Consideration in SAP calculation	HTB = 0.15·ΣAexp	HTB = 0.148·ΣAexp	HTB = 0.084·ΣAexp	HTB = Σ(l·ψ) + Σχ HTB = 0.027·ΣAexp	HTB = Σ(l·ψ) + Σχ HTB = 0.003-0.006·ΣAexp
Absolute improvement in thermal bridge performance value	0%	1.2%	43.7%	82.1% (if thermal bridges are well insulated)	92.3-96.1% (ψ ext) (if thermal bridges are well insulated)
Reduction of the mean U-value (relative to 0.3 W/m²K)	43%	42.3%	24,1%	7.7% (if thermal bridges are well insulated	1.7-0.7% (if thermal bridges are well insulated
Reduction of the mean U-value (relative to 0.25 W/m²K)	60%	59.3%	33,8%	10.8% (if thermal bridges are well insulated	2.4% (if thermal bridges are well insulated
Reduction of the mean U-value (relative to 0.15 W/m²K)	100%	98.8%	53.6%	17.9% (if thermal bridges are well insulated	3.9% (if thermal bridges are well insulated
Reduction of the mean U-value (relative to 0.1 W/m²K)	150%	148.1%	84.4%	26.8% (if thermal bridges are well insulated	5.9% (if thermal bridges are well insulated

Additional quantity insulation to compensate for thermal bridges

ψ values are an often missed Value Engineering opportunity (i.e. avoided labour, insulation, founds, wall/roof structure)

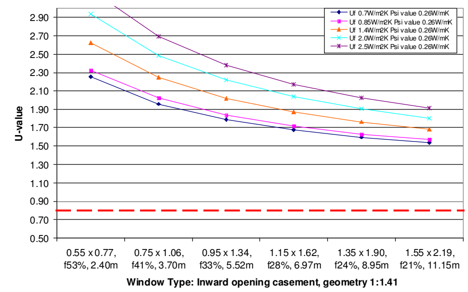
Windows: Frame Proportion, Ψg and Ψinst. (0.03W/mK)

Whole Window U-value Due to Frame and Ψg and Inst. Ψ
(Ug 0.6W/m2K, Ψg 0.03W/mK, Ψinst 0.03W/mK)



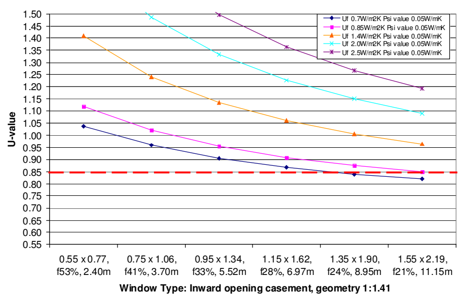
Windows: Frame Proportion, Ψg and Ψinst. (0.26W/mK)

Whole Window U-value Due to Frame and Ψg and Inst. Ψ
(Ug 0.6W/m2K, Ψg 0.03W/mK, Ψinst 0.26W/mK)



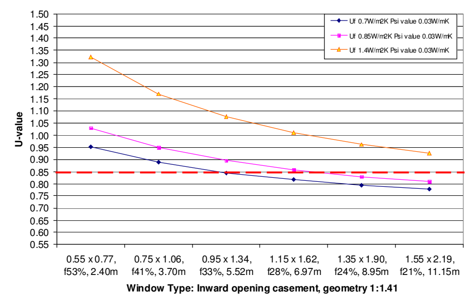
Windows: Frame Proportion, Ψg and Ψinst. (0.05W/mK as BRE IP106)

Whole Window U-value Due to Frame and Ψg and Inst. Ψ
(Ug 0.6W/m2K, Ψg 0.03W/mK, Ψinst 0.05W/mK)



Windows: Frame Proportion, Ψg and Ψinst. (0.03W/mK)

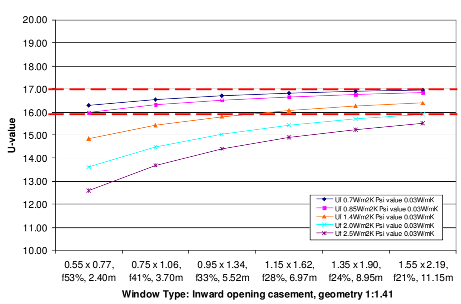
Whole Window U-value Due to Frame and Ψg and Inst. Ψ
(Ug 0.6W/m2K, Ψg 0.03W/mK, Ψinst 0.03W/mK)



Windows: Resultant average temp of degraded glazing system

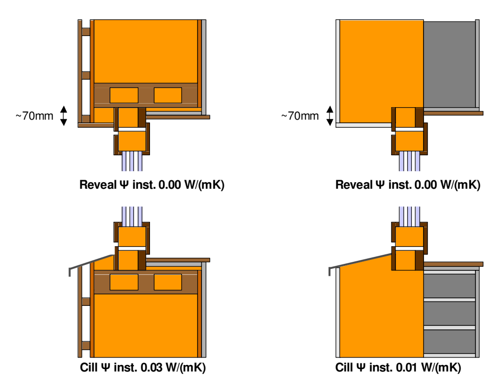
Int. Temp 20C, Ext. Temp –10C

Whole Window U-value Due to Frame and Ψg and Inst. Ψ
(Ug 0.6W/m2K, Ψg 0.03W/mK, Ψinst 0.03W/mK)

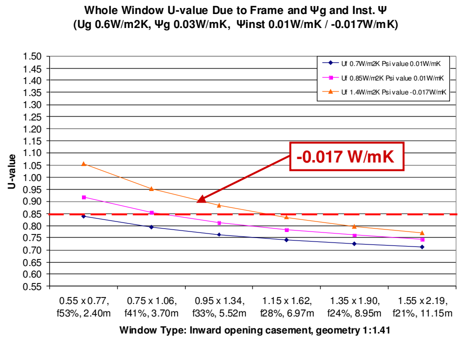


Installation Ψ

From PHPP 2004

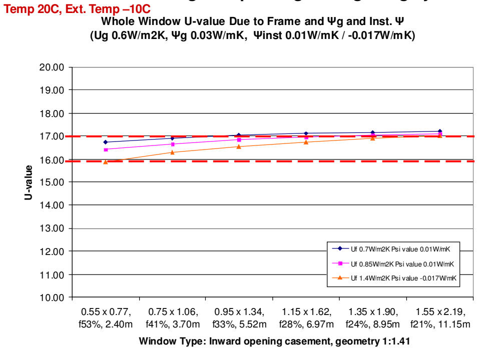


Windows: Frame Proportion Ψg and Ψinst. (0.01 W/mK vs. -0.017 W/mK)



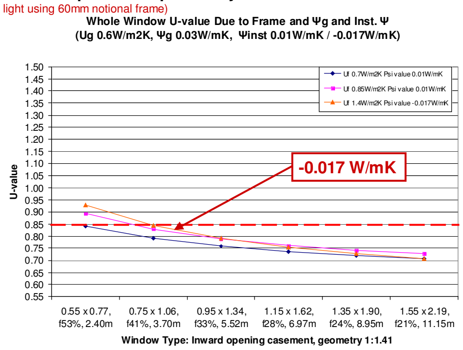
Windows: Resultant average temp of degraded glazing system

Int. Temp 20C, Ext. Temp –10C



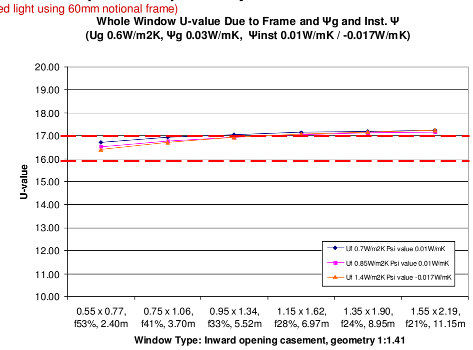
Windows: Required compensatory CP U-value (0.01W/mK / –0.017W/mK)

(Fixed light using 60mm notional frame)



Windows: Required compensatory CP U-value (0.01W/mK / –0.017W/mK)

(Fixed light using 60mm notional frame)



Conclusions:

Whole systems window design:

- Frames
- Spacer
- Installation

} • Subtle decisions can have a major impact, especially installation details

Thanks for listening.