HIGH-PERFORMANCE GLAZING

Uncoated single-glazed windows are considered to be the weakest thermal component in the building envelope, transmitting large amounts of heat into and out of a building. Most windows in Australia are of this type, with double/triple glazing comprising only a niche market. Types of glazing that can be applied to help insulate windows include double or triple glazing also known as "insulated glazing units" or IGUs, and low-emissivity (low-e) glazing. Frames that have good thermal properties aid the insulating properties of the glazing unit. As the Buildings Plan's focus is on retrofitting, it considers those options which are easily retrofitted – this is particularly an issue for non-residential buildings where full replacement may be costly and disruptive. It should be noted that in hot sunny weather, these options still benefit from additional external shading.

Tinted, reflective and toned glass treatments. These can control either or both (as required) of the visible light and infrared solar gain entering a building, and are usually blue, green, grey or bronze. Selective coatings and films, which allow visible but restrict infrared radiation, provide a very discrete and low-cost way of controlling unwanted solar gain.

Low-emissivity coatings. Emissivity is the degree to which a surface radiates energy based on its temperature.

For an opaque surface the sum of reflected radiation and emitted radiation should equal the incident radiation. Solar radiation is comprised primarily of visible and near-infrared (short-wave) light. When solar radiation is absorbed by glass it is either convected away by moving air or re-radiated by the glass. This emitted energy is in the form of far-infrared (long-wave) radiation [23, 24]. Low-e coatings and films work by selectively reducing the emissivity of different parts of the light spectrum. This corresponds to the different profiles in Figure 3.8 below. Window coatings have the added benefit of stopping most ultraviolet radiation.

For heating-dominant climates/applications a low-e outer surface will lessen the amount of long-wave infrared radiation (from internal heat loads) being re-radiated by the window, without necessarily effecting the ability to receive solar radiation. For cooling-dominant climates/applications a low-e inner surface will lessen re-radiation into the cooled building.

Double glazing. A double-glazed window has two panes of glass with a sealed air gap between them. The spacing of the glass panels is usually between 6-20mm; generally the window is more effective at 12-20mm gap. The panes are spaced with plastic or metal (sometimes sandwiched between thin rubber or similar layers, to prevent thermal conduction), and with a dessicant to prevent condensation between the panes. The gap may also be filled with a gas of lower thermal conductivity, usually argon, rather than air.

The glazing can be plain glass, or a combination of the coatings above, which further improves its thermal performance. In comparison with single glazing, double glazing reduces heat conduction by about 50% [25]. Triple glazing, which is becoming common in some European countries, further reduces heat conduction by about 30% (relative to double glazing). Contrary to common belief, the main contributor to improved thermal performance is not the trapped layer of air, but the number of air/glass boundaries.

Benefits

There are many benefits to choosing high-performance glazing that is appropriate to the climate and the building use. These benefits include:

- Reduction of energy consumption from artificial heating and cooling
- Provision of an additional measure of insulation to the building facade
- Provision of access to passive solar heating in heating-dominant climates/buildings, by maximising solar gain (in winter) while minimising conductive heat transfer
- Aid in minimising solar gain in cooling-dominant climates/buildings, in conjunction with proper shading
- Improved comfort in all climates, as thermal resistance acts to preserve internal temperatures

- Maximisation of natural light (when required) and consequent reduction of need for electric lighting
- Reduction of ultraviolet radiation that contributes to skin cell damage, and fading of furniture and carpet
- Worthwhile reduction in noise transmission
- Reduction of condensation that occurs when warm humid air it meets a relatively cold single pane of glass. This condensation is a common cause of deterioration of timber-framed windows.

Demand-Reduction Potential

The performance of windows or glazed doors is defined by the heat transfer coefficient – U value, solar heat gain coefficient – SHGC, and the visible light transmittance – VT [26].

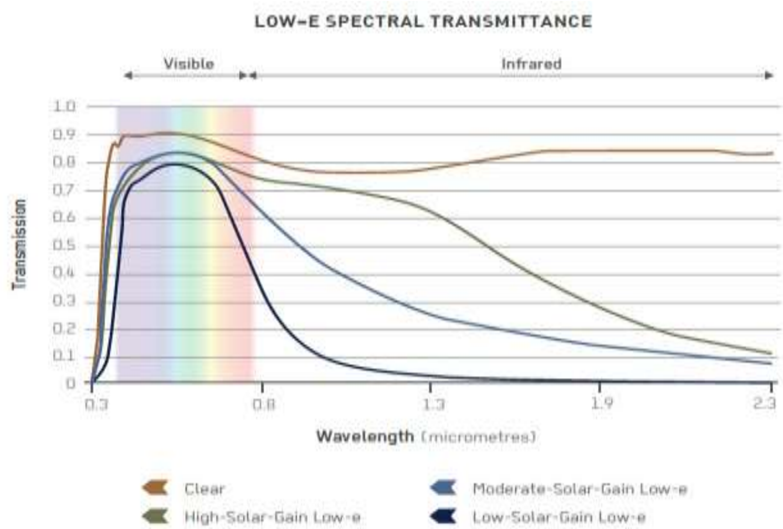

FIGURE 3.8

How light passes through various window types

U value, as discussed under the Insulation Section, is a measure of heat transfer by conductance and is given in W/m^2K. As an example the U value of a timber-framed window with 3mm clear glass is around 5.9, and with an aluminium frame can be as high as 6.9 [27]. To calculate the conductive heat transfer though a window, multiply the U value by the area of the glazing unit and the temperature differential between inside and outside. For example, for a house with $70m^2$ of aluminium framed windows with clear glass (with a U value of 6.2), if it is 15°C colder outside, the conductive heat loss through the windows would be about 6.2*15*70 = 6,510 W [27].

SHGC is the proportion of solar energy that passes through the window, both directly and indirectly. For example 3mm clear glass has a SHGC of 0.86. The lower the coefficient, the less solar heat it transmits. Low-emissivity glass that reduces emission of short-wave infrared radiation significantly reduces the proportion of solar heat transmitted through the glass, such that SHGC for a clear single glazed element can get to roughly 0.4 - 0.5 [28] and down to 0.27 for double glazed windows [24].

VT measures how much light comes through the window, expressed between 0 and 1. The VT of clear glass is around 0.8. Tinted and reflective coatings can reduce this significantly.

Measurement and ratings. There is a large variation in performance for double and triple glazing from different manufacturers. Table 3.5 shows the results for two manufacturers' products which are toward the higher quality end of the market. In Australia, the Window Energy

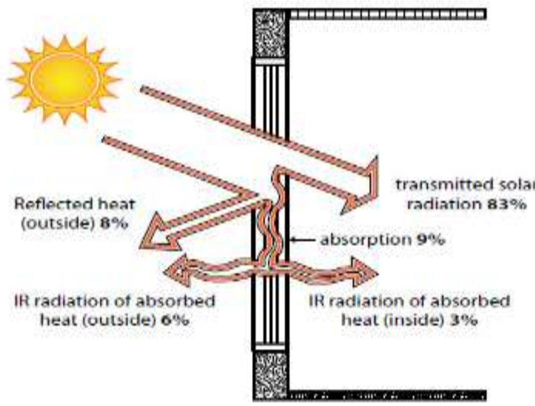

FIGURE 3.9
When solar radiation meets a typical window [Your Home]

Rating Scheme (WERS) – see www.wers.net – publishes performance data on manufacturers' windows which have been tested by accredited testers. They include U value, SHGC, VT, air infiltration and condensation, and give a star rating for products.

Note that an effective U value is typically calculated to incorporate the effect of reflective or low-emissivity properties of material, even though these act on reducing heat transfer by radiation not conduction. The effect of reflectance or emissivity of a material is to reduce temperature difference across a surface, which would in turn influence the rate of heat transfer by conduction – even though the material constant is not altered! In practice this can be somewhat misleading, but is common practice. The low-e options presented above are of type 1, which reflect long wave infrared and transmit short wave, hence the high SHGC values.

Frames. The frame material contributes to the thermal properties of the window. Aluminium is a good conductor of heat, and particularly for double or triple glazing, aluminium frames can reduce the window performance, compared with wood or uPVC, which are much better insulators. Some manufacturers of double-glazed windows offer 'thermally broken' aluminium frames. These have a plastic spacer and/ or air gap between the inner and outer aluminium frame, and their performance is intermediate between aluminium and wooden frames. Table 3.6 gives typical U values. A middle ground between standard and thermally-broken is commonly called 'thermally improved'.

Films. Low-e films are the best option among films. Tinted films are available but there are problems associated with tints. They absorb heat which is then transferred into the building adding to the building's cooling load which, in the case of an Australian non-residential building, is the dominant load. Also, they act to reduce the visible light that enters the building and distort the occupant's view out the window [29]. Low-e films come in thin rolls with a sticky back [30] and can be installed to the inside of the window. They last for between 5 and 15 years [31]. A 2012 study commissioned by the International Window Film Association reviewed a number of film products for residential and commercial applications. It found that low-e films gave SHGC of 0.2 -0.35 for VT of 0.18 - 0.3 [32]. Whilst this shows impressive reductions in solar heat gain the low transmittance of light may be a problem for buildings with poor daylight access. Window Energy Solutions, an Australian company, sells a low-e film, marketed for commercial buildings, with high VT. Its SHGC is 0.42 (for 6 mm glass) with a VT of 0.5 [33].

Case Studies

There have been a number of modelling studies in several countries which have looked at the potential energy savings of various building envelope improvements, including glazing. For domestic dwellings, modelled energy savings from advanced glazing, usually double glazing, range from 9% to up to 24%. For instance, the Moreland Energy Foundation study [34] of 15 typical Melbourne houses, found double glazing gave an average of 8.7% energy saving over single glazing with heavy drapes with pelmets, but because of the high cost of retrofitting, was the least cost-effective improvement of those examined. They pointed out that had they modelled the glazing without the addition of drapes the energy saving would have been higher. The cost of removing the existing windows and replacing with double glazing was around \$580 /m^2, while the average cost saving in electricity was \$27 /annum.

Two studies in warm climates (Cyprus and Greece) [35],[36] gave higher figures.

The Cyprus paper modelled up to 24% saving in annual cooling load with low-e double glazing, with a payback time of 3.8 years, while the Greek paper estimated 14-20% savings with double glazing. Poel et al [37] included modelling from Austria, Denmarkand the Netherlands for high performance glazing which showed energy savings of 75 to 80 kWh/m^2/annum and payback times ranging from 8 to 12 years.

A paper [38] on very well insulated terrace houses in Sweden modelled the effect of different triple glazing options on the peak load and space heating demands compared to double glazing and to no windows (opaque). It showed a halving of the space heating requirements when upgrading from clear double glazing to triple glazing with one low-e film.

Implementation Recommendations

The proposed ranges for U value and solar heat gain coefficients of glazing in various climate zones are presented in Table 3.6. Visual transmission should generally be greater than 0.6 unless glare is a problem (although this can be moderated with internal blinds).

Replacement windows. The window performance can be achieved using new IGUs or secondary glazing as appropriate depending on the type and condition of frame.

In order to achieve these performance levels the frames would need to have a low conductivity, such as uPVC, thermally broken aluminium, or timber. uPVC or thermally broken aluminium is recommended here as they require less maintenance and are readily recyclable. If the existing frame is highly conductive, or in poor condition, then secondary glazing should not be considered.

TABLE 3.5
Typical U values for framed windows

Frame type	**U value**		
	Timber	**Aluminium**	**Thermally Broken Aluminium**
Double glazing - plain glass	3.0 - 3.3	4.9 - 5.4	3.1 - 3.6
Double glazing - low-E glass	1.7 - 2.0	2.5 - 5.0	2.1 - 2.6
Double glazing - low-E glass, argon	1.4 - 1.8	2.2 - 2.7	1.8 - 2.6
Triple glazing - two low-E panes, argon	1.2 - 1.7		2.2

TABLE 3.6 Recommended glazing

Climate Zone Description	**U Value**	**SHGC**	**Strategy**
Cooling-dominant/ low-demand (Darwin, Townsville,	medium (←5)	lowest (~0.3)	If existing frames in good-condition, then fit solar film. Otherwise. a) (if replacement is practical) replace windows with new low-e single glazing, or

Brisbane)			b) (if replacement is not practical), fit solar film.
Balanced moderate-demand (Sydney, Perth)	low (~3)	midrange (~0.5)	If existing frames good-condition and low-conductive, then fit secondary glazing. Otherwise, a) if replacement is practical then replace windows with new double glazing or b) (if replacement not practical) use low-e film.
Heating-dominant (Canberra, Hobart, Melbourne)		highest (→0.7)	

Note: Climate Zone descriptions are at Appendix 2. This Table necessarily reflects a simplified view and other factors may influence the final appropriate glazing for any given building.

Films. In cases where it is considered impractical to remove existing glazing, particularly retail and offices, an applied film is proposed. Specifically, low-emissivity films with high visible transmittance and low solar heat gain coefficients are recommended for use in curtain wall offices, and retail buildings with highly glazed external surfaces.

Costs

Within the current housing stock in Australia the number of dwellings which have double glazing account for less than 5% [39].

This low market share for PVC-U and aluminium framed double glazed units limits the ability of manufactures to be able to provide prices that are attractive to customers. At present the majority of pre-fabricated double glazed units are entering Australia from Europe or China. The poor economies of scale result in higher prices. There are only a limited number of PVC-U window fabricators in Australia and no profile fabricators as the demand does not warrant change within the sector at present.

FIGURE 3.10
A blind with insulating air-filled cells. [R. Keech]

European double glazing accounts for market shares above 70% (UK, France, Switzerland, Germany). In these countries the the market has grown significantly in sync with new thermal regulation building codes [40]. These rises in market share combined with policy have allowed for the reduction in cost of double-glazed units as economies of scale have improved.

Within the double glazing market here in Australia, there is potential for manufacturers to meet increased demand, although the market is considered niche. In a report carried out on behalf of the ABCB by the AWA they found that 76% of manufacturers would be in position to produce mainly double glazed windows and doors within one year [41]. The authors of the current report believe that with substantial growth in the Australian market the cost of double glazing in Australia will meet parity with that of Europe. At present the cost of PVC-U residential double glazed windows in Australia is $800-$900 per square metre. Costs in the UK for double glazing per m^2 range between 220-320GBP equating to AUD 337-AUD 490 (2012 dollars). In the UK the cost of double glazing is equivalent to and possibly cheaper than single glazing [42]. In Australia the cost of single glazed windows is around $500 per m^2.

Other service upgrades

Secondary glazing. Secondary glazing systems involve affixing a second, removable glazing element (typically perspex) on top of the existing internal window frame. They give a substantial improvement over single glazing, and the performance approaches that of factory-built double glazing. Secondary glazing can be combined, if needed, with add-on window treatments to provide low-e or reduction in SHGC. Products such as EcoGlaze and Magnetite are effective solutions and would provide U values in the range of 3, sufficient for heating-dominant and balanced moderate climates. They are also significantly cheaper than full replacement of entire existing window and frame.

Source: http://decarboni.se/publications/zero-carbon-australia-buildings-plan/2-improving-thermal-performance-building-envelope