Glazing

Windows are complex and interesting elements in the fabric of a home. They let in light and fresh air and offer views that connect interior living spaces with the outdoors. However, windows can be a major source of unwanted heat gain in summer and significant heat loss in winter.

Energy efficient windows make your home more comfortable, dramatically reduce your energy costs and help to create a brighter, cleaner and healthier environment.

Windows can severely impact on the heating and cooling loads of a building. Up to 40% of a home's heating energy can be lost and up to 87% of its heat gained through windows. Improving windows' thermal performance reduces energy costs and greenhouse gas emissions.

Glazing and thermal performance

The impact of glazing on the thermal performance of a building is complex. Consider:

- climatic conditions in your location — temperature, humidity, sunshine and wind
- building design — the orientation, form and layout of the building
- building materials — the amount of mass and insulation
- the size and location of windows and shading
- thermal properties of glazing systems.

The impact of glazing is the result of the interaction of all of these aspects.

Passive solar design

Incorporating passive solar principles at the design stage is the most cost effective way of achieving good thermal performance. (see *Design for climate*; *Orientation*; *Shading*; *Passive solar heating*; *Passive cooling*; *Insulation*; *Thermal mass*)

At the design stage, some simple principles can be followed to optimise the thermal performance of your home.

- Locate and size windows and shading to let sunshine in when the temperature is cold and exclude it when it's hot.
- Use thermal mass to store the sun's heat and provide night-time warmth in cold conditions.
- Locate window and door openings to allow natural cooling by cross-ventilation.
- Provide seals to openings to minimise unwanted draughts.

The implementation of passive solar design principles can be more challenging on some sites. For example, winter sun might be blocked by neighbouring buildings, or views may be to the south or west, often leading to the inclusion of windows with poor orientation. In these instances, select glazed elements with improved thermal performance to compensate for aspects of the building design that are detrimental to its thermal performance.

Photo: DLG Aluminium

Thermal comfort

Careful choice of glazing greatly improves thermal comfort for people close to windows, especially large windows. Our sense of comfort is not just determined by air temperature: the temperature of surrounding surfaces has a great impact. The objective should be to achieve an inside glass surface temperature as close as possible to the desired room air temperature. This means glass that is neither cold in winter nor hot in summer.

Orientation

Orientation of glazing is critical (see *Orientation*].

It is common practice to use windows with the same U-value (see below) and solar heat gain coefficient (SHGC) on all elevations but the optimisation of windows by orientation is likely to yield at least half a star more than the 'one type fits all' approach often used.

Choosing the right window

Windows can add to the energy performance of your home through two distinct heat transfer mechanisms — conduction and solar heat gain.

Conduction: U-value

U-value (expressed as Uw in windows) measures how readily a window system conducts heat. It is a measure of the rate of non-solar heat loss or gain through it. The rate of heat is indicated in the terms of the U-value of a window assembly which includes the effect of the frame, glass, seals and any spacers. The lower the U-value, the greater a window's resistance to heat flow and the better its insulating value.

A simple formula can help quantify the impact of improved U-value:

- the amount of heat conducted through a glazed unit (in watts) equals the U-value (Uw)
- multiplied by the number of degrees difference in air temperature on each side (T)
- multiplied by the area of the glazing unit (A)

Uw x T x A = watts (W)

If your home has 70m^2 of windows and glazed doors with aluminium frames and clear glass (i.e. U-value of 6.2), on a winter's night when it's 15°C colder outside, the heat loss would be about:

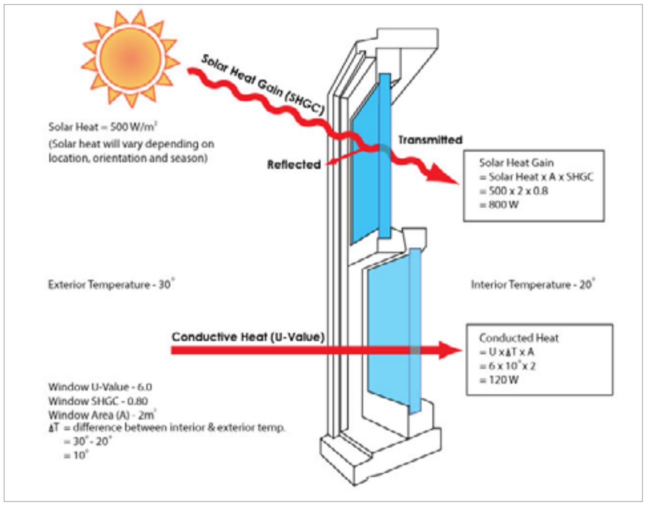
6.2 x 15 x 70 = 6,510W

That's equivalent to the total heat output of a large gas heater or a 2hp air conditioner running at full capacity.

If you roughly halve the U-value of the window by selecting double glazing, you can halve the heat loss — in this example avoiding about 3,000W of heat loss, equivalent to the energy use of fifty 60W incandescent light bulbs.

Solar heat gain coefficient

The SHGC for windows (expressed as SHGCw) measures how readily heat from direct sunlight flows through a window system. The SHGC is the fraction of incident solar radiation admitted through a window, directly transmitted as well as absorbed and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's SHGC, the less solar heat it transmits.

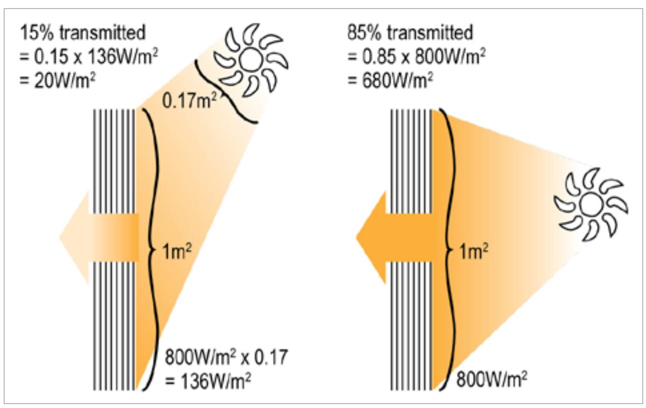


Source: The Australian Window Association

Heat transfer mechanisms.

Angle of incidence

The angle that solar radiation strikes glass has a major impact on the amount of heat transmitted. When the sun is perpendicular to the glass it has an angle of incidence of 0°. For standard clear glass 85% of solar heat is transmitted. As the angle increases, more solar radiation is reflected, and less is transmitted. It falls sharply once the angle exceeds 55°. Also, as the angle increases, the effective area of exposure to solar radiation reduces.



Solar gain varies according to the sun's angle of incidence.

Thus the same window can have a hugely different solar gain, depending on the angle of incidence, which is influenced by the position of the sun according to location, season and time of day, and the orientation of the glazing.

A north-facing window in summer, when the sun is high in the sky, may have an angle of incidence of 8° (depending on location). In winter, the angle of incidence at midday is about 35° and the glass is exposed to a greater effective area of solar radiation. That window can transmit more solar heat in winter than in summer.

A west-facing window on a summer's afternoon has an angle of incidence from near 0° up to 30° with a large effective area of solar radiation. A north-facing window, in summer, has a high angle of incidence and a low effective area of solar radiation, so can transmit less heat than a west-facing one.

The SHGC declared by glazing manufacturers is always calculated as having a 0° angle of incidence, i.e. the maximum solar heat gain.

In temperate and cool temperate climates such as Sydney, Perth, Melbourne, Adelaide and Hobart, northerly glazing should have a high SHGC. This is standard passive solar practice for temperate climates. Northerly windows are the home's solar collectors. However, these windows should also have fixed shading designed to shade as little of the glass in winter as possible while shading as much as possible in summer. (see *Shading*)

East and west-facing windows should have a low SHGC, particularly if they are large, because they present energy efficiency problems. It is better to use adjustable external shading if it is possible. The next best thing is a low SHGC window which dulls the overheating problem in summer at the expense of passive solar gain in winter. This is a trade-off where the summer benefit normally outweighs the winter issues.

It is always the case that the lower the U-value the better, because it is the U-value that measures the ability to retain heat in winter and cold in summer, regardless of orientation. In hot climates such as Darwin and Brisbane, there is little compromise: a low SHGC is best. In those climates, if passive solar gains are desired in the coolest months, they should be obtained from northerly windows only. These can have a slightly higher SHGC if they are protected by climate-appropriate overhangs or other shading measures.

For all orientations a low U-value outperforms a high U-value, especially for north-facing windows.

South-facing windows can have any SHGC because there is little solar heat gain from that direction in winter or summer. However, for all orientations a low U-value outperforms a high U-value, especially for north-facing windows.

It is a common misconception that north-facing windows should be clear and single glazed to obtain the best house energy rating. Maximising passive solar gain doesn't necessarily lead to the lowest annual heating energy. Low-emissivity (low-e) double glazing (*see 'Types of glazing' below*) with high solar transmission provides a better annual result because the small drop in solar gain is more than outweighed by the lower U-value of the insulating glass. In net terms, the low-e double glazing is considerably better and returns a lower annual heating energy requirement while providing superior thermal comfort.

An indoor swimming pool benefits from a glazed northern wall.

In cool (heating dominated) climates such as Melbourne, Hobart and Canberra, the driver of annual energy consumption is overwhelmingly U-value; however, high passive solar heat gains from north-facing windows can significantly reduce annual heating energy. Passive solar gains significantly reduce, but do not eliminate, the need for artificial heating. The physical reason for the dominance of U-value is that heating energy is mostly determined by heat loss from the inside to outside — which is very sensitive to window U-value.

In warm (cooling dominated) climates such as Brisbane, SHGC is more influential than U-value except in the hottest zones such as Darwin where U-value again becomes nearly as influential as SHGC. Cooling loads everywhere are due mostly to unwanted solar heat gain. However, a significant additional load from conduction heat gains occurs in hotter climates: this is sensitive to U-value and driven by heat gain from outside to inside.

Compliance

Under the Building Code of Australia (BCA), window manufacturers are required to supply windows and glazed doors that meet mandatory minimum specifications for structural sufficiency and water penetration resistance under Australian Standard (AS) 2047, Windows in buildings, selection and installation. Energy efficiency provisions state that windows performance data must be determined in accordance with the guidelines of the Australian Fenestration Rating Council (AFRC).

The Australian Building Codes Board (ABCB) recently introduced a requirement that all windows in new homes and apartments that are more than 2m off the ground must be fitted with window locks that stop the window being opened more than 125mm or have reinforced screens to prevent children from falling from a height.

Thermal properties of glazing

There are literally thousands of types of glass and frames to choose from. Selecting the right ones is critical to improving the energy efficiency of your home. Specific products have been designed to keep heat in or out and have varying impacts on daytime lighting, noise control, maintenance and security.

Visible light

Reducing the amount of solar radiation transmitted through glazing can reduce the amount of daylight entering your home. The amount of light transmitted by glazing is specified by the visible light transmittance, which is recorded as either TVw (visible transmittance of the window) or VLT (visible light transmittance). Both mean exactly the same.

A simple way to consider this is:

Low TVw = too dark inside = lights on = higher energy costs.

Air movement

Heat is transferred through windows and glazed doors as air moves through gaps around operable sashes, from outside to inside or vice versa. This transfer can be minimised by installing good seals between moving sashes and their surrounding frames. In general, awning windows and casement windows, which seal by compression, control air leakage much better than do sliding windows and doors, whose seals tend to lose their shape and wear out gradually from constant friction.

Types of glazing

Glass

A wide variety of glass products is available. The thickness of glass has negligible impact on its U-value and SHGC. However, it does have a significant effect on noise transmission and the strength and safety of the glazing.

Glass products can be divided into several categories.

Toned glass has colouring additives included during manufacture. It is available in various colours, usually bronze, grey, blue and green. The different colours provide different SHGC and some variation in TVw. Body tinting does not change the U-value of the glass because glass conductivity is unaffected by the presence of a pigment in the glass. Other toned glass options include 'supertoned', which has heavier pigmentation that preferentially transmits visible wavelengths while filtering out solar near-infrared wavelengths. This provides lower SHGC while preserving adequate TVw.

Low emissivity glass (commonly known as low-e glass) has either a vacuum-deposited thin film metal coating or a pyrolytic coating. As vacuum-deposited coatings are soft, for protection and longevity they must only be deployed inside an insulating glass cavity. Pyrolytic coatings are baked onto the surface in the factory while the glass is still hot to make it hard and durable. Soft and hard coatings are available in products for use in both high and low transmission applications.

- High transmission/low-e glass has a coating that allows daylight from the sun to pass into the house but reduces the amount of the long wavelength infrared heat that can escape through the window.
- Low transmission/low-e glass has a coating that reduces the amount of solar heat gain while still maintaining good levels of visible light transmission.


Photo: DLG Aluminium

Low-e coatings make glass a practical wall material for contemporary living spaces.

Low-e coatings can effect a very dramatic improvement in both U-value and SHGC but they must be employed correctly or they will either deteriorate or fail to perform to specification. Low-e coatings can be used in combination with clear, toned or reflective glass.

Laminated glass has a plastic glazing layer, called an interlayer, to improve impact resistance. This interlayer is placed between two sheets of glass in order to reduce the danger of the glass breaking and forming long dangerous shards. Typical applications include areas in the home most prone to injury from human impact such as bathrooms, doors, around staircases and in areas close to the floor. Careful selection of different interlayer types has the added advantage of addressing specific noise and energy efficiency requirements.

Insulated glass units (IGUs) are the combination of two or more glazing layers sealed with a gap between the layers. Multiple layers of glass can be assembled with sealed cavities between each sheet. The performance of IGUs depends on the properties of each layer of glass and the width of the cavity, seal type and content of the cavities between the glass layers.

> *It is often wrongly assumed that insulated glazing is only for cold climates when in fact it achieves the best performance levels in both U-value and SHGC in all climates.*

It is often wrongly assumed that insulated glazing is only for cold climates. In fact, the best performance levels in both U-value and SHGC can only be achieved by using IGUs. This facilitates higher performance for all climates, especially in heated and air conditioned homes.

The performance of the cavity in IGUs impacts on the U-value and serviceability of the glazing. Cavities must be sealed to minimise convective heat transfer. If the cavity is not properly sealed or contains inadequate desiccant (drying agent) it may contain moisture which, under cold conditions, condenses on the colder glass surface. The spacer (metal or polymer strip) that separates the two glass layers contains a desiccant to absorb any moisture. IGU cavities may also be filled with an inert, low conductivity gas such as argon. Cavity thickness is usually in the range of 6–18mm. Wider cavities provide lower (better) U-values, with 12mm normally accepted as the preferred gap.

Using combinations of standard and low-e glass allows the IGU to be tailored to have extremely low U-values. Using clear, toned or low-e glass can deliver a wide range of SHGC and TVw values for performance options.

Secondary glazing allows single-glazed windows to be retrofitted with a transparent acrylic or glass sheet attached to the inside of the frame or operable sash via a secondary frame or magnetic strips. This creates an air space between the glass and the acrylic layer which reduces the U-value and air infiltration. It does not deliver quite as good performance as a manufactured IGU but does provide good noise control.

Films

Window films can be a cost effective way to reduce solar heat gain through existing windows. They consist of a thin polymer film containing an absorbing dye or reflective metal layer, with an adhesive backing.

Applied to existing glass, some window films can halve the overall SHGC of the window by means of absorption and/or reflection of solar radiation. This can be particularly beneficial in hotter climates where cooling is the main concern or on east and west elevations directly exposed to long spells of sunshine. They may also cause an equal reduction in visible light transmittance, which must be considered when choosing a film.

Glass panes with applied films exposed to direct sun become hotter than untreated glass and industry guidelines must be followed to avoid thermally induced cracking. For this reason it is generally best to use an accredited installer of window film. The U-value and SHGC values of films fixed to specific types of glass indicates the performance achieved.

Frames

After glazing, frames have the greatest impact on the thermal performance of windows.

Aluminium window frames are light, strong and durable, with a variety of powdercoated and anodised finishes, but aluminium is also a good conductor of heat and can decrease the insulating value of a glazing unit. Aluminium frames, especially dark coloured ones in full sun, absorb a lot of solar heat and conduct it inside.


Photo: DLG Aluminium

Aluminium window and door frames can decrease the insulation value of the glazing unit.

A thermal break is often used to reduce the heat conducted through aluminium frames. It separates the exterior and interior pieces of the frame using a low conductivity component (typically urethane or other low conductivity polymer).

A large amount of energy is used to make aluminium but it can be recycled at the end of its use, time and time again.

Timber frames are a good natural insulator. They do require larger tolerances in openings which can result in gaps that allow air infiltration unless good draught sealing (weather stripping) is installed. Timber absorbs carbon dioxide as it grows and retains that carbon until the wood is burnt or decays. Timber species must have naturally high durability or be treated to prevent decay and deformation. Check that the timber is sourced from a sustainably managed forest.

Composite frames use thin aluminium profiles on the outer sections with either a timber or uPVC (unplasticised polyvinyl chloride) inner section. These combine the low maintenance and durability of aluminium with improved thermal performance.

uPVC frames are relatively new in Australia but common in Europe and North America. Their insulating properties are similar to timber and they can be moulded into complex profiles that provide excellent air seals. The colour range is more limited than powdercoated aluminium.

Materials such as fibreglass — offering strength, durability and good insulation — are available overseas and are currently making their way to Australia.

Energy performance of common window types

Indicative window types	Total window system values		
	Uw	SHGCw	TVw
Aluminium window — single glazed with 3mm clear glass	6.9	0.77	0.80
Timber or uPVC window — single glazed with 3mm clear glass	5.5	0.69	0.72
Aluminium window — double glazed with 3mm clear glass/6mm air gap/3mm clear glass	4.2	0.69	0.72
Timber or uPVC window — double glazed with 3mm clear glass/6mm air gap/3mm clear glass	3.0	0.61	0.65

NOTE: These values are indicative only and cannot be used for compliance purposes.
Source: Window Energy Rating Scheme; Copyright owner: The Australian Window Association

Frame styles

Windows and doors come in a wide range of styles or configurations that impact on energy performance in several ways.

Different styles provide different opening areas, which determine how much cross-ventilation can be gained. Louvres and hinged or pivoting units that open at least 90° achieve maximum opening areas; awning, hopper or casement windows, opened by short winders, provide the least opening area.

Example opening areas for a two pane window or sliding door, i.e. one fixed and one operable pane (excluding louvre) below 2m, are:

- casement — 45%
- sliding — 45%
- awning — 30%
- double hung — 40%
- two panel sliding door — 45%
- louvre — 80%.

Source: DCCEE

Window furnishing

If you want to leave your windows without coverings, perhaps to make the most of a view or natural light, the most effective way to control heat flow is by selecting systems with appropriate U and SHGC values. Alternatively, window furnishings, blinds and curtains can enhance performance and can be an effective way to overcome problems with existing windows.

Blinds can reduce solar heat gain by reflecting incoming heat back out through the window. This is not as effective as preventing the solar heat from entering the window in the first place because only a portion of the heat is reflected back to the outside. To reflect solar heat, the external surface of blinds should be white or near-white. Some offer a metallic, reflective film on the external surface, with a decorative fabric facing in. The space between the blind and window traps a lot of heat, which a ventilation opening in the window can allow to escape.


Photo: Scar top Joinery

These louvred windows are undressed, making the most of natural light.

Reduce convective heat transfer through windows with snugly fitted blinds and curtains with pelmets that trap a layer of still air next to the window. Eliminate air gaps around all perimeters of the curtain and pelmet to improve performance.

Heavy fabrics and multiple layers of fabric help increase the insulation provided by curtains by reducing the amount of heat conducted between the air in the room and the air adjacent to the window. This benefit is reduced if there is air movement around the curtain.

Specifying and documentation

Because windows have a major impact on the thermal performance of buildings, and because there are thousands of different types, it is essential that they be clearly specified and documented. Inadequate specification and documentation can lead to products being used that do not meet the intended performance standard and may fail to satisfy regulatory requirements — leading to potentially expensive errors.

The thickness of glass is often included in thermal specifications but be aware that the requirements of Australian Standards for safety and wind loading must take precedence.

The type of glass and frame is not as critical as the system U-value and SHGC. It may matter for aesthetic or maintenance reasons but the thermal performance depends solely on the system U-value and SHGC values. For example, you may require a window with a system U-value of 4 and SHGC of 0.7. That could be achieved by a standard aluminium frame with clear double glazing or a timber, uPVC or composite frame with low-e single glazing.

All glazed window and door systems in Australia are rated according to guidelines recognised by the AFRC. The testing conditions and documentation procedures recognised by the AFRC are based on the procedures of the US National Fenestration Rating Council (NFRC).

You may encounter AFRC, NFRC, CEN and ANAC ratings for any given product. All these acronyms might be confusing, but the differences are significant! Be absolutely sure, when selecting and specifying products, that the declared U-value and SHGC values are according to the AFRC requirements or you could end up with products that don't meet performance expectations and may not comply with regulatory requirements. Look for evidence that the ratings are AFRC approved and if you are not sure, question the supplier.

Window Energy Rating Scheme

The Window Energy Rating Scheme (WERS; www.wers.net) rates the energy and energy-related performance of windows, skylights and glazed doors in accordance with AFRC procedures.

Window Energy Rating Scheme logo.

WERS provides the system U-value and SHGC values as well as air infiltration and visible light transmittance. It also provides a star rating of glazing units according to their heating and cooling performance. It includes thousands of specific products from most manufacturers, listed according to the types of frame and glazing.

Design considerations

Thermal mass

Thermal mass does not create heat — it just stores it. For thermal mass to provide beneficial evening heat in cool climates it is essential that glazing is used to admit solar radiation during the day to warm the mass. (see *Passive solar heating; Passive cooling; Thermal mass*)

If thermal mass is used in warm and hot climates to absorb heat from the air, minimise solar gain through glazing and do not locate the mass where it is exposed to solar heat gain.

Noise control

Sealing cracks and gaps around windows, and elsewhere in the building, is probably the most effective initial way to control noise, although appropriate windows and glass can assist with noise control.

Sealed double glazing reduces transmission of medium to high frequency noises such as the human voice.
To reduce low frequency noise such as traffic and aircraft, choose thicker glass, preferably double glazed with

a large air gap between the panes (100mm or more): such large gaps allow convection to occur between the panes and reduce insulating properties.

Thick laminated glass is also effective in reducing noise transmission but offers little in the way of thermal performance. (see the appendix *Noise control*)

Fading

Exposure to sunlight causes many modern interior furnishings to fade. The wavelengths most responsible for fading are the ultraviolet, violet and blue wavelengths. Appropriate glazing blocks some of these wavelengths and reduces fading, but does not prevent it completely.

Condensation

Condensation occurs when moist air is cooled or when it meets cooler objects. The interior and exterior surfaces of energy efficient glazing are closer to the adjacent air temperature, reducing condensation and the build-up of unsightly and unhealthy mould and fungus. Less efficient windows create greater differences between room temperature and glass surface temperature, facilitating the formation of condensation.

Life cycle costing

Glazing is a significant investment in the quality of your home.

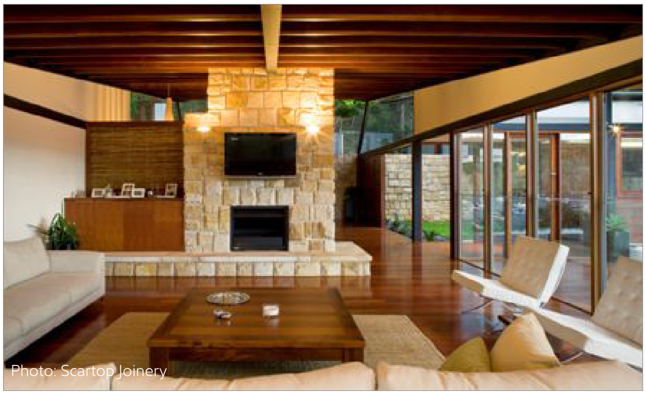


Photo: Scartop Joinery

Walls of glazing create light-filled living areas.

The cost of windows and the cost of heating and cooling your home are closely related. An initial investment in energy efficient windows can greatly reduce your annual heating and cooling bill. Energy efficient windows also reduce the peak heating and cooling load, which can reduce the size of an air conditioning system by 30%, leading to further cost savings.

The Australian Window Association has developed a tool (see www.efficientglazing.net) that calculates the savings that may be achieved by energy efficient glazing. This tool compares window selections to a base aluminium window with 3mm clear glass.

References and additional reading

Contact your state, territory or local government for further information on passive design considerations for your climate. www.gov.au

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