

Glazing

Glazing has a major impact on the energy efficiency of the building envelope. Poorly designed windows, skylights and glazed surfaces can make your home too hot or too cold. If designed correctly, they'll help maintain year-round comfort, reducing or eliminating the need for artificial heating and cooling.

Windows in a typical insulated home can account for more heat gain or loss than any other element in the building fabric. In summer, heat gain through an unshaded window can be 100 times greater than through the same area of insulated wall. One square metre of ordinary glass can let in as much heat as would be produced by a single bar radiator. In winter, heat lost through a window can be ten times more than through the same area of insulated wall.

Glazing is a key element of your home's design providing, light, ventilation, noise control and security.

It can enhance the appearance and amenity of your home, providing views and connection with outdoor spaces. You can enjoy these benefits and have high thermal performance by selecting the right type of glass and frames and choosing the right size, location and shading of windows.

GLAZING AND THERMAL PERFORMANCE

The impact of glazing on the thermal performance of a building is complex!

There are several aspects to consider:

- > Climatic conditions in your location.
- > Building design – the 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 units.

The impact of glazing is the result of the interaction of each of these aspects. For example, hot and cold climates benefit from different types of glazing. High mass buildings can benefit from larger areas of glazing than would be optimum for a lightweight building. Double glazing is beneficial for almost all orientations. High performance toned, double or low-e glazing will be more beneficial in specific orientations of the building.

Because of the complex interaction of many variables, the best way to accurately assess the impact of glazing on your home's thermal performance is to model it with one of the sophisticated computer programs now available. AccuRate, BERS Pro and FirstRate calculate a home's heat gains and losses, hour by hour, and the resulting levels of thermal comfort achieved. They consider all aspects of the building's design and construction as well local climatic conditions such as temperature, humidity, sunshine and wind. These programs allow options for each window to be compared to ensure that the best performance is achieved without unnecessary expense.

Software assessment of building thermal performance is governed by the Nationwide House Energy Rating Scheme. See 1.5 Rating Tools for more information.

PASSIVE SOLAR DESIGN

There are simple principles that can be followed, at design stage, to optimise the thermal performance of your home. These include:

- > Locate and size windows and shading to let sunshine in when the temperature is cold and exclude it when it is its 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.

Incorporating passive solar principles at design stage is the most cost-effective way to achieve good thermal performance. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Including energy efficient windows in a well designed home can further improve its thermal comfort.

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

THERMAL COMFORT

Careful choice of glazing system provides major improvements in 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 or hot in summer.

THERMAL PROPERTIES OF WINDOWS & GLAZED SURFACES

There are literally thousands of types of glass and frames to choose from – selecting the right ones is critical to improving energy efficiency of the building.

Specific products have been designed to keep heat in or out and have varying impacts on daylighting, noise control, maintenance & security.

Heat flow

Heat flow through glazed elements such as a windows, glass doors or fixed glass panels is determined by the combined effect of the glass, frame and seals.

Heat flows through glazed systems in several ways:

- > Conduction.
- > Convection.
- > Radiation.

Conduction

Conduction is the movement of heat energy through the glass and frame materials from the air on the warmest side to the air on the colder side. The greater the difference in temperatures – the more heat flow. Different frame and glass materials have varying ability to conduct heat, specified by the U-value. The lower the U-value – the less heat is transmitted.

U-values may be for just the frame, just the glass, or the combined glass and frame unit – referred to as the system U-value. The system U-value will depend on the U-values of the frame and glass and the proportions of the area of the glazing unit occupied by each, which are referred to as the frame fraction and vision fraction respectively. The system U-value also accounts for the complex heat flows at the edge region of the glass near where it meets the frame.

The following table shows the difference between element and system U-values.

Indicative value of conducted heat performance.

COMPONENTS	U-VALUE
Aluminium frame	10.0
Timber frame	2.8
3mm clear glass	5.9
Double glazing (uncoated) – 2 x 3mm glass with 6mm air gap	3.1
SYSTEMS	
Aluminium frame with 3mm clear glass	6.9
Aluminium frame with double 3mm clear glass and 6mm gap	3.8
Timber frame with 3mm clear glass	5.5
Timber frame with double 3mm clear glass and 6mm gap	3.0

Note: Values for specific products may be significantly different.

The ability to conduct heat can also be expressed as its opposite – the ability to resist conducted heat flow – represented by R-values. R-values are used to describe insulating properties in many other building materials. The higher the R-value, the less heat is conducted. U-values and R-values can be easily converted:

R-value = 1 / U-value.
 U-value = 1 / R-value.

For example, a window with a U-value of 5 will have an R-value of 1/5 i.e. 0.2

Windows in Australia are certified for their energy performance by rating organisations who conform to Australian Fenestration Rating

Council (AFRC) standards. In the AFRC system, performance is always certified for the whole system – glazing and frame combined – never the glass or the frame alone.

There is a simple formula that can help you quantify the impact of improved U-value:

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

$U \times T \times A = \text{watts}$

If your home has 70m² of windows and glazed doors with aluminium frames with clear glass, on a winter's night when it's 15 degrees colder outside, the heat loss would be about:

$6.2 \times 15 \times 70 = 6,510 \text{ watts.}$

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 saving about 3000 watts of heat loss – equivalent to the energy use of fifty 60 watt incandescent light bulbs.

The U-value is important in both hot and cold climates. Conducted heat flow is relative to the difference between indoor and outdoor temperature. In hot climates it may regularly be 10 or 15 degrees hotter outside than inside, so halving the U-value will halve the conducted heat gain.

Single glazing offers little resistance to conducted heat flow. The small amount of insulation that single glazing does provide is due to thin films of still air adjacent to the surfaces of glass. Increasing the thickness of the glass has negligible impact on its U-value.

Insulating glass units or IGUs (usually in the form of double glazing) provide additional thermal resistance in the sealed space between the panes and a gap which conducts much less heat. Increasingly, argon gas is used to fill the space between the panes instead of air, because it has a lower conductivity than air and is plentiful and cheap.

Conducted heat transfer through the frames can be reduced by choosing materials with a low U-value, such as timber. The heat transfer through conductive frame materials, such as aluminium, can be reduced by minimising the area of frame through which heat is conducted or by incorporating a thermal break in the frame section.

Convection

Convection is the movement of heat energy by air that passes over the surface of the glazing unit, taking heat away from the glass and frame. Higher air speed causes greater convected heat transfer.

Minimising convective heat transfer can be achieved by reducing air movement adjacent to the surfaces of glazing units through shielding the exterior by walls, screens and plantings and by shielding the interior with curtains and pelmets. It can also be achieved through double glazing which creates a still gas layer between the panes.

Radiation

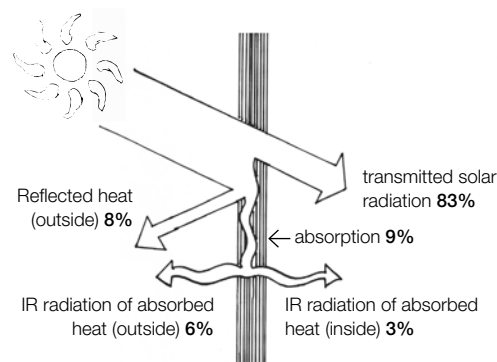
Radiation is heat that is transmitted as electromagnetic waves. They can pass through space, in the same way as visible light moves through space, until reflected or absorbed by materials.

Solar radiation

The sun transmits solar radiation which is comprised of ultraviolet (2% of the total solar energy), visible (47%) and solar near-infrared (IR) (51%). Warm objects like people and buildings, radiate the longer wavelengths of infrared heat.

When sunlight strikes a sheet of glass, some of the solar radiation is transmitted straight through, some is reflected and some is absorbed by the glass. The heat energy absorbed by the glass is then radiated to both the inside and outside as infrared radiation.

The sum of reflected, absorbed and transmitted heat always equals 100%.



For example, 3mm clear glass: 83% of solar radiation is transmitted, 8% reflected and 9% is absorbed. 3% is then radiated inside and 6% outside.

The total amount of solar heat that passes through the glass is the sum of the heat transmitted plus that part of the heat absorbed in the glass which is subsequently re-radiated and convected inside. For the above example this equals 86%. This proportion of solar energy that passes through the window, both directly and indirectly, is called the Solar Heat Gain Coefficient (SHGC). Therefore, 3mm clear glass has a SHGC of 0.86.

The amount of infrared heat energy radiated from the surface of glass depends on its emissivity (also known as emittance). A 'perfect radiator' has an emissivity of 1.0. Untreated (uncoated) glass, whether clear or tinted, has an emissivity of 0.84. It is almost a perfect radiator.

Low emissivity (low-e) glass has a coating on its surface which minimises the amount of heat, absorbed by the glass, being subsequently radiated into the building. It can also be designed to block some of the solar radiation transmitted through glass. Low-e glass is available with an emissivity as low as 0.03 ('soft' coat) or 0.15 ('hard' coat).

Reducing solar heat gain through glass can be achieved by using toned (body tinted) glass which absorbs a greater proportion of solar heat than clear glass. The absorbed heat is then radiated to inside and outside. Including a low emissivity coating on the inside-facing surface reduces the proportion of absorbed heat that is radiated into the building which dramatically increases the effectiveness of the toned glass.

The solar heat gain can also be reduced by reflective glass which increases the proportion of incident solar heat that is reflected away from the glass.

Spectrally selective glazing has a low-e coating which 'filters' solar radiation, allowing maximum visible light transmission while reflecting unwanted UV and solar near-infrared wavelengths. Spectrally selective coatings have very low emissivities – as low as 0.03.

Double glazing is an effective way to reduce U-value, but its impact on solar heat gain depends on the type of glass. One layer of clear glass has a SHGC of 0.86. Two layers have a combined SHGC of about 0.76. This may be reduced much further by using tinted, low-e or spectrally selective low-e coatings. Because low-e coatings also reduce radiative heat transfer compared to uncoated glass, the glazing system U-value may be halved again, especially if the air between the panes is replaced by argon gas.

The SHGC of timber and uPVC frames is negligible. Aluminium frames can account for more than 5% of the total solar heat gain of a complete aluminium-framed window.

Metal frames with high conductivity, such as aluminium and steel, absorb solar heat, some of which is conducted through the frame and radiated/convected to the inside. It is common for dark-coloured frames to become too hot to touch on their inside-facing surfaces.

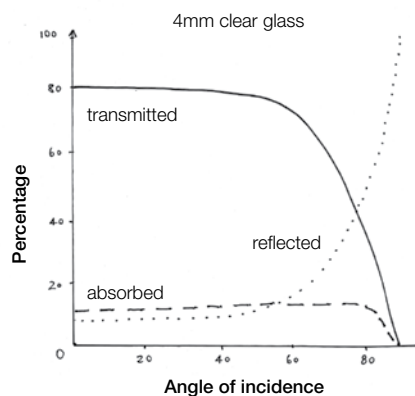
Such heat gain through aluminium frames can be reduced by choosing frames with a light colour, which reflects most of the solar heat. Frames with a thermal break have a low-conductivity polymer separating the inside and outside parts of the frame. Alternatively, some frames use a 'composite' construction with aluminium to the outside and timber to the inside.

Different glazing products offer a wide range of SHGC, enabling you to choose how much solar heat comes into your home.

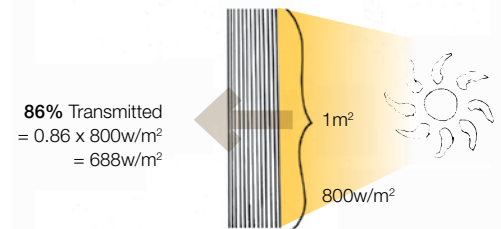
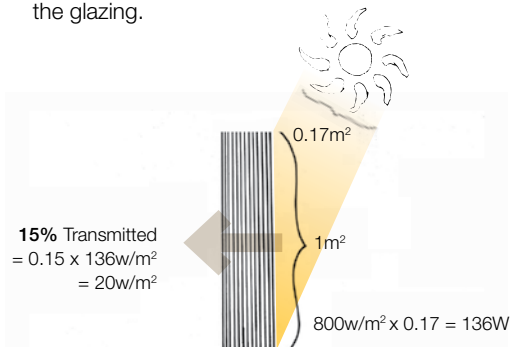
Angle of incidence

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 86% of solar heat is transmitted. As the angle increases, more solar radiation is reflected, 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.



So, the same window can have hugely different solar gain, depending on the angle of incidence. The angle of incidence 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 would be about 35° and the glass will be exposed to a greater effective area of solar radiation. That window can transmit more solar heat in winter than in summer.

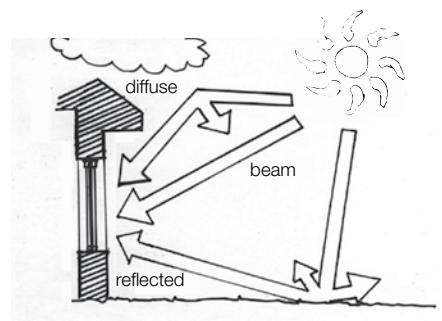
A west-facing window on a summer's afternoon will have an angle of incidence from near-zero up to 30° with a large effective area of solar radiation. A north-facing window, in summer, has a high angle of incidence and low effective area of solar radiation. So, in summer, north facing windows can transmit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

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

Indirect solar heat

We normally think of solar radiation as coming in a direct beam from the sun. However, as radiation from the sun hits our atmosphere some is scattered in all directions. Some of this radiation is scattered towards the earth and is called diffuse solar radiation.

The total solar radiation (direct plus diffuse) is called global radiation. Beam radiation may be up to 80Wm^2 . Diffuse radiation varies according to sky conditions and location but may be around 300Wm^2 .



Some solar radiation strikes the earth is reflected by surrounding surfaces. This is called reflected radiation. Light coloured surfaces reflect more than dark ones.

Shading by eaves is generally designed to protect glazing from beam radiation but may leave it exposed to diffuse and reflected radiation. Using glass with a lower SHGC provides protection from all three kinds of solar radiation: beam, diffuse and reflected.

Warm radiant heat

Glazing units transfer heat radiated by the sun. They also transfer radiant heat, in the form of long wave infrared radiation, from warm objects around the glazing. All warm objects radiate infrared heat. In cold climates warm objects and people inside the building radiate heat to outside. In hot climates the warm surfaces surrounding the building radiate heat to inside.

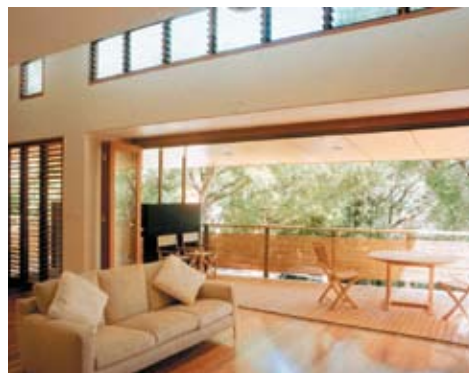
Standard clear glass absorbs about 84% of this long wave infrared radiation then radiates that heat both inside and outside – the amount depends on the temperatures of surrounding objects. The glass effectively blocks a third to a half of the long wave infrared heat transfer.

So, clear glass transmits 86% of solar radiation but only transmits about half of the infrared radiation. This difference in solar versus infrared radiant heat transfer gives us the ‘greenhouse’ effect: a large amount of solar heat enters through the windows, warms the materials within the building which then radiate lower intensity infrared heat, most of which is trapped inside the building.

The infrared radiant heat transfer can be further reduced by using glass with low emissivity coatings and by double glazing.

Visible light

Reducing the amount of solar radiation transmitted through glazing can reduce the amount of light entering your home. The amount of light transmitted by glazing is specified by the Visible Light Transmittance value or Visible Transmittance (VLT or VT). The ratio of light to heat transmittance varies according to the type of glass and is sometimes called the Light to Solar Gain (LSG) ratio. The bigger the LSG, the more useful light the window admits relative to the overall solar heat gain.



Infiltration and exfiltration

Heat transfer through glazed units is also caused by air that infiltrates and exfiltrates through gaps around operable sashes. This moves warm air from inside to outside or vice versa. Minimising infiltration, or draughts, can be achieved through good seals between moving sashes and their surrounding frames. In general, awning windows, casement windows and French 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

There is a wide variety of glass products currently available. They can be divided into several categories.

Toned glass has colouring additives included during the melting process of forming glass. It is available in various colours, usually bronze, grey, blue and green. The different colours provide different SHGC and some variation in VT. Body tinting does not change the U-value of the glass because glass conductivity and emissivity are unaffected by the presence of a pigment in the glass. Green and blue tones tend to have a higher ratio of visible light to solar heat transmittance.

Supertoned glass has heavier pigmentation which is tuned to preferentially transmit visible wavelengths while filtering out more invisible solar near-infrared wavelengths. This provides lower SHGC while preserving adequate VT.

Reflective glass has either a vacuum-deposited thin-film metal coating or a pyrolytic coating. Vacuum-deposited coatings are soft and for protection and longevity they must be deployed inside an insulating glass cavity. Pyrolytic coatings are baked onto the surface in the factory while the glass is still hot; they are hard and durable and are normally glazed with the reflective surface to the exterior. To function to specification they must be kept clean and free of condensation. Reflective glazing causes glare which may annoy neighbours. In such instances, reflectivity must be kept below 15 to 20 percent.

High transmission Low emissivity (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 which reduces the amount of solar heat gain while still maintaining good levels of visible light transmission. Low-e coatings

can be ‘hard’ or ‘soft’ and can enable 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. The Australian glass industry manufactures a wide range of high-performance, low-e coated glass products, in addition to imported products.

Spectrally selective glass (such as supertoned and low transmission low-e glass) has a surface coating which allows maximum visible light transmission while reflecting unwanted UV and infrared wavelengths. Spectrally selective coatings generally have the lowest emissivities of any type of coated glass – as low as 0.03.

Low-e and spectrally selective coatings can be used in combination with clear, toned or reflective glass. All coating should be protected from abrasion and damage by paints, solvents and harsh cleaning chemicals.

Polymers are used instead of glass in some applications, such as translucent glazing and skylights. A plastic glazing layer, called an interlayer, is used in laminated glass to improve impact resistance or within double glazing to improve insulation.

The thickness of glass has negligible impact on its U-value and SHGC. It does though, have a significant impact on noise transmission and the strength and safety of the glazing.

Glazing may be provided as single sheets, or two sheets with a polymer laminate bonded between the glass. The performance of laminated glazing is determined by the type of glass in each layer. The plastic laminate does provide a slight reduction in U-value.

It is often wrongly assumed that double glazing is only for cold climates. In fact, the best performance levels in both U-value and SHGC can only be achieved by double-glazing.

This facilitates higher performance for all climates, especially in heated and air-conditioned homes. Multiple layers of glass can be assembled with sealed cavities between each sheet. This is commonly called double or triple glazing but is now increasingly referred to as an Insulating Glazing Unit (IGU).

Insulating Glazing Unit: The performance of IGUs depends on the properties of each layer of glass and the thickness, sealing and content of the cavities between the glass layers.

Using combinations of standard and low-e glass allows IGU to be tailored to have extremely low U-values ranging from 3.5 to as low as 1. Using clear, toned, reflective or low-e glass can deliver a wide range of SHGC values from 0.2 to 0.7. However in housing, good daylighting is invariably required; in this situation only a double-glazed configuration will simultaneously achieve very low SHGC values coupled with high VT.

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 it may contain moisture which, under cold conditions, will condense 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 6 to 18mm. Wider cavities provide lower (better) U-values with 12mm normally accepted as the preferred gap.

Vacuum glazing is just now being commercialised. The cavity is evacuated and the panes are kept mechanically separated by a fraction of a millimetre. The prototype systems were developed in Australia. Because there is no air or other gas to conduct heat across the gap, the separation between the panes need only be sufficient to prevent the two glass layers from 'shorting' on each other. Usually, vacuum glazing units employ a low-e coating on both glass surfaces facing into the cavity. With such a combination of technologies, U-values as low as 1.0 are routinely achieved. If toned glass or spectrally selective low-e coatings are used, vacuum glazing units can also have very low SHGC. Windows with such high-performance glazings are sometimes called 'superwindows'.

Single-glazed windows can also be retrofitted with a thin, flexible, transparent polyethylene membrane attached to the inside of the frame or operable sash using an adhesive tape or magnetic strip. This creates an air space between the glass and the film which reduces the U-value and air infiltration and can be useful for retrofitting to existing windows but does not deliver quite as good performance as a manufactured IGU.

Films

Window films can be an cost effective option for significantly reducing 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. They may also cause an equal reduction in visible light transmittance which must be considered when choosing a film.

Window films do not generally have significant impact on the glazing U-value because they do not add thermal resistance nor reduce the emissivity of the glass.

Glass panes 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- and SHGC values of films fixed to specific types of glass will indicate the performance achieved.

Frames

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

Aluminium window frames are light, strong, durable and easily extruded into complex shapes, but aluminium is a good conductor of heat and can decrease the insulating value of a glazing unit by 20 to 30 percent. Aluminium frames, especially dark coloured ones in full sun, absorb a lot of solar heat and conduct it inside.

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. Some manufacturers may be able to provide aluminium frames made from recycled material which uses far less energy to produce. Powder-coated aluminium never needs painting, which significantly reduces its resource impact.



Timber frames are a good insulator but requires more maintenance than aluminium. Timber frames may require larger tolerances in openings, which can result in gaps that allow air infiltration, unless good draught sealing (weatherstripping) is provided.

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. It is important to check that the timber is sourced from a sustainably managed forest. There are currently Australian hardwood window frame manufacturers that use timber certified by the Forestry Stewardship Council (FSC). Plantation-grown hoop or radiata pine can be treated with LOSP (light organic solvent preservative) and painted which provides another option apart from FSC-certified durable hardwood.

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

uPVC frames are petroleum derived products which 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 powder coated aluminium.

Fibre-reinforced polyester (FRP) frames are used overseas and are generally the most thermally efficient high-strength framing materials available.

Styles

Windows come in a range of styles or configurations: fixed, horizontal sliding or vertical sliding (double-hung), hinged, (awning, casement or hopper), louvres or as fixed glazing. Doors come in hinged or sliding configurations. The style of system impacts on its energy performance in several ways.

Different styles of glazing unit have different frame fractions which impacts on the system U-value.

Aluminium frames are more conductive than glass. Therefore, increasing the area of aluminium frame increases the overall (system) U-value. Timber, composite or plastic frames have lower conductivity than a single pane of glass so increasing the area of frame improves the system U-value of a single glazed window.

Small glazing units tend to have a higher frame fraction than larger units, simply because of the different ratios of perimeter to area.

Different styles of doors and windows provide different opening areas, which determines how much cross ventilation can be provided by the glazing unit. Maximum opening area can be achieved by louvres and hinged or pivoting units that open at least 90°. Awning, hopper or casement windows, opened by short winders, provide least opening area.

Window furnishing

The most effective way to control heat flow through windows is selection of systems with appropriate U- and SHGC values. Window furnishings, blinds and curtains, can enhance performance and can be an effective way to overcome problems with existing windows.

Reducing solar heat gain can be achieved by blinds that reflect solar heat that was transmitted through the window, 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 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 will trap a lot of heat – a ventilation opening in the window can allow that to escape.

Reducing convective heat transfer through windows can be achieved by snugly-fitted blinds and curtains with pelmets, that trap a layer of still air next to the window. Avoiding air gaps around all perimeters of the curtain and pelmet is key to improving 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 air-movement around the curtain is not prevented.

SPECIFYING AND DOCUMENTATION

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

Specification of glazing units must include:

- > Dimensions.
- > Style.
- > System U-value.
- > System SHGC value.

The use of system U and SHGC values is much better than using the component values i.e. the U-value of the frame plus the U-value and SHGC value of the glass. The system U- and SHGC values are not the sum of their parts – they are the result of the interaction of the parts. There is a significant difference between component and system values – so be sure to be explicit about the values you specify and require.

If you are using toned glass, it may be worthwhile to check the visible transmittance (VT) if you want to maximise natural daylighting. Be aware that only high-performance IGUs are able to simultaneously combine low U-value with low SHGC (when needed) and high VT (when needed).

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

The type of glass and frame is not as critical as 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 either a standard aluminium frame with clear double glazing or a timber or composite frame with low-e single glazing.

All glazing units for residential use have a rating of their system U-value and SHGC values. These include generic and custom ratings.

- > Generic (default) ratings use simple descriptors of the type of frame and glazing and apply a system U and SHGC value. The range of descriptors is limited eg. timber, aluminium or uPVC frame and clear, toned, low-e, double or double glazing with low-e.
- > Custom (proprietary) ratings have been calculated for products with specific brands, style, glass and frame type so are more detailed and precise.

All glazing units in Australia are rated according to guidelines recognised by the Australian Fenestration Rating Council (AFRC). The testing conditions and documentation procedures recognised by the AFRC are based on the U.S. NFRC (National Fenestration Rating Council) procedures. This is an international scheme applicable to residential and non-residential buildings. NFRC standards were introduced in Australia in 2007 replacing the previous ANAC standard.

All these acronyms might be confusing, but the differences are significant. For a given product, NFRC and ANAC ratings are different! Be absolutely sure, when selecting and specifying

products that the declared U- 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)

rates the energy and energy-related performance of residential windows, skylights and glazed doors in accordance with AFRC procedures.

WERS provides the system U- and SHGC values as well as air infiltration, condensation performance rating, fading protection (which quantifies damaging transmission of ultraviolet and short-wave visible wavelengths) and visible 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.

WERS-rated windows, skylights and glazed doors carry a sticker and a certificate specifying their performance. It provides manufacturers, designers, consumers and regulatory authorities with certainty that the glazing products meet the required performance specifications.

DESIGN

Passive design considerations

Selection of the right glazing units is a key element of passive design. The range of window performance gives you great flexibility when designing a home.

The starting point is to understand your climate. When do you want inside to be warmer than outside or cooler than outside? How humid is it? What is the position of the sun? What is the frequency and direction of winds?

You can then define the periods of the year and the times of day and night that you want glazing to encourage or avoid heat gain and when you want to encourage or limit air movement.

If you understand the heat flow through glazing you can assess each glazed element and select an appropriate SHGC value to determine how much solar heat comes in.

Its emissivity will determine how much infrared heat (from warm objects) comes in or out.

Its U-value will determine how much conducted heat (resulting from a temperature difference between inside and out) is gained or lost.

The style will determine the opening area and ability to allow cross ventilation.

Your selection of glazing units will also depend on their location in the building and orientation. Without appropriate shading a north facing window will admit winter solar heat gain but allow excessive summer solar heat gain. Without appropriate shading a west facing window will admit some afternoon solar heat in winter, but will admit even more in summer.

Reducing heat loss

Conducted heat loss can be reduced by glazing units with a low U-value. Low emissivity will also reduce heat loss from infrared radiation from warm objects..

Internal coverings such as closely fitting heavy curtains with pelmets can reduce conducted and convective heat loss.

External screens can minimise wind speed across the surface of glazing, reducing convective heat loss.

Increasing heat loss

In hot climates there may be times when you need to purge heat from the building. Ventilation through openings in the building replaces indoor air with outdoor air, but the incoming air must be cool in order to be beneficial.

Reducing heat gain

The major part of heat gain is solar radiation. Well designed eaves and overhangs can shade glazing from beam solar radiation and some diffuse solar radiation at specific times of day or months of the year. Blinds and vertical screens can protect glazing from beam and diffuse solar radiation. [See: 4.4 Shading]

Increasing heat gain

In cold climates you generally want to encourage solar gain. Use glazing with a high SHGC.

Orientation of glazing is critical. It will receive most Winter solar heat on the north elevation. It receives less on the east and west though morning sun can be very pleasant. The south sides receives only diffuse and reflected solar radiation in cold climates in winter.

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: 4.5 Passive Solar Heating; 4.6 Passive Cooling; 4.9 Thermal Mass]

If thermal mass is used in warm and hot climates to absorb heat from the air, solar gain through glazing should be minimised and the mass should not be located where it is exposed to solar heat gain.

Low mass buildings cannot store any heat to make night time warm so choose glazing with a low U-values to minimise heat loss at night and on cloudy days. Low mass buildings can not absorb solar heat during the day, so solar heat gain through windows may cause air temperatures to get too hot during the daytime – even in winter.

Light transmittance

Good window design and location maximises natural lighting. Bright, naturally lit homes promote health and well-being and reduce the need for electric lighting. Natural light provides good colour rendition and skin tones and is preferred by most indoor plants.

Choose glazing with high visible light transmittance to maximise day lighting.

Diffuse lighting (as opposed to direct sunlight) is generally the best for providing good uniform illumination over a room and avoiding glare.

Skylights are an excellent way to provide natural day lighting for a room, particularly in cooling climates where shading and other passive design elements can reduce light transmittance through windows. Conventional skylights can let in too much heat and light, but new designs (such as angular-selective skylights) can be a very efficient way to light a room.

A Skylight Energy Rating Scheme (SERS) has been developed in Australia, similar to WERS and is being used by some manufacturers.

Ventilation

Providing ventilation is an important function of windows. The ventilation depends on physical characteristics such as the placement of the windows, the opening size and the frame type.

Cross ventilation is about five times as effective at encouraging air movement through the house as ventilation from a single opening.

It is important to balance the need for ventilation in summer against air leakage and winter heat loss.

Noise control

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

Sealed double glazing reduces transmission of medium to high frequencies such as the human voice. To reduce low frequency noise such as traffic and aircraft, thicker glass, preferably double-glazed with a large air gap in between the panes (100mm or more) is most effective. Note that 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: 2.7 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 will block some of these wavelengths and reduce fading although it will not prevent it completely.

Fabric Fading Transmittance is a measure of the extent to which a window transmits those wavelengths of light that cause fading. It can be found at the bottom of the WERS rating label. The lower this number, the lower the potential for fading.

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 on windows.

Less efficient windows create greater differences between room temperature and glass surface temperature, facilitating the formation of condensation.

Properly constructed double glazed units are sealed, filled with inert gas, evacuated or have a desiccant in the cavity to eliminate condensation. IGMA is the National body representing qualified IGU manufacturers and can be contacted for further information on these products.

Lifecycle costing

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

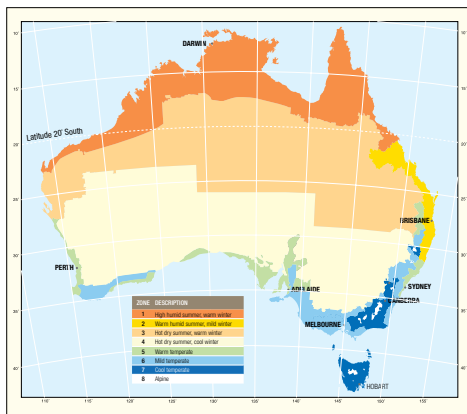
The cost of windows and the cost of heating and cooling your home are closely related. An initial investment in energy-efficient windows can greatly reduce your annual heating and cooling bill. Energy-efficient windows also reduce the peak heating and cooling load, which can reduce the size of an air-conditioning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

The cost of high performance glazing is coming down significantly as demand and production increases. Money spent on improved glazing is need not be seen as a cost but an investment in the value of your property which should be recouped upon resale.

Improved glazing delivers greater comfort and a healthier home that is kinder to our environment.

CLIMATE CONSIDERATIONS

Australia can be divided into cooling, mixed and heating climates to assist in window selection and design. These guidelines are intended as a simple summary of strategies for glazing. They should be combined with good design of other building elements.



Cooling climates

ZONE 1 High humid summer, warm winter

ZONE 2 Warm humid summer, mild winter

ZONE 3 Hot dry summer, warm winter

ZONE 4 Hot dry summer, cool winter

Cooling climates are warmer climates where most energy is used to cool the home. Geographically, most of Australia has a cooling climate. In these climates windows should be designed to keep the heat outside. These are climates where houses use more than 70 percent of their total space-conditioning energy for cooling.

Climates that are too hot most of the year can present fairly simple design solutions:

- > Provide maximum shading of glazing – beam, diffuse and reflective.
- > Use light coloured frames.
- > Select glass with a low SHGC.
- > Consider low U-value to minimise conducted heat gain.
- > Choose window styles that provide maximum openable area, located on opposite sides of the building to promote cross ventilation.

Mixed climates

ZONE 5 Warm temperate

ZONE 6 Mild temperate

Mixed climates are warm and mild temperate climates where more than 30 percent of the total space-conditioning energy is used for heating in winter and more than 30 percent is used for cooling in summer. A typical house in Sydney (a mixed climate) may use 57 percent of its total heating and cooling energy for heating and 43 percent for cooling.

Mixed climates present more design challenges. Heat gain is required in winter and it needs to be avoided in summer.

A low U-value will improve both summer and winter performance.

The passive design of the building will mean North facing windows will receive more solar radiation in winter than in summer. These windows may perform best, year round, with a high SHGC.

West and east windows will receive more solar radiation in summer than in winter – the opposite to what is desirable. They may perform best with a low SHGC. The best solution is operable shading that can be drawn in summer and opened in winter or shading screens that block summer sun which sets WSW, but admits winter sun which sets WNW.

Mixed climates can require some compromises between summer and winter performance. Thermal modelling software is useful for determining the exact performance.

Heating climates

ZONE 7 Cool Temperate

ZONE 8 Alpine

Heating climates are those in which a typical house uses more than 70 percent of its total space-conditioning energy for heating in

winter and less than 30 percent for cooling in summer. The objective is to maximise solar heat gain most of the year and minimise heat loss. Consider the following:

- > Locate most glazing facing north where it receives maximum solar exposure (especially in living areas).
- > Avoid shading windows or use adjustable shading for periods when it is too hot or eaves and screens that provide shading only in mid-summer.
- > Choose glazing units with low U-values.
- > Choose glazing units with high SHGC to maximise solar gain except if specific windows allow unwanted, summer afternoon heat gains.

About 70 percent of Australia's population lives in heating or mixed climates. In such climates, more advanced windows return a net energy benefit over a whole year, regardless of which direction they face. It is possible for an advanced window's energy gains to exceed its losses, even if it faces south.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on passive design considerations for your climate.
www.gov.au

Australian Bureau of Meteorology
www.bom.gov.au/climate/enviro/design/design.shtml

Australian Windows Association
www.awa.org.au

BEDP *Environment Design Guide*
PRO 32 Glazing, Windows, Skylights and Atria
– Properties and Rating Systems.

Commonwealth of Australia, *Australian Model Code for Residential Development* (AMCORD) (1995), AGPS Canberra.

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www.renew.org.au

Wrigley, Derek (2004), *Making Your Home Sustainable: A Guide to Retrofitting*, Scribe, Carlton North, Victoria.

Windows Energy Rating Scheme
www.wers.net

Window Film Association of Australia and New Zealand
www.wfaanz.org.au

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