climate control

This brochure shows how glass is used to control the climate in which we live.

this includes:

- climate control factors
- climate types
- measuring glass performance:
  SHGC
  U-Value
- basic principles of heat transfer through glass
- heat gain reduction
- heat loss [winter]
- glare reduction
- condensation
- UV and fading protection

climate control using glass

Single glazed clear glass is a poor insulator against summer heat gain and winter heat loss. On warm days a large proportion of the sun's direct heat energy will make rooms or houses unbearably hot and will increase cooling costs. On cold days, the warmth that may be generated in a room quickly transfers to the colder environment outside, increasing heating costs. Not only do we have less comfortable homes but also energy inefficient ones.

To improve comfort levels and energy efficiency, the glass industry has developed solar control glass (tinted, low-E, and reflective glass) and thermal control glass (low-E and IGU's). Australian governments have now focused upon the objective of reducing greenhouse gas emissions through the efficient use of energy in housese. This has been achieved through various codes and legislation at local, state and federal government levels. Energy efficient housing measures through government legislation have been in place for many years in North America and Europe.

This brochure shows how glass is used to control the climate in which we live in. It will however in most cases limit the discussion to glass only. Performance values shown are for glass only. Energy efficient window compliance to the various building codes should in most cases make reference to the total glazing system, meaning glass and window frame. Window fabricators should have accredited testing to prove the performance of their window or glazing system to meet compliance requirements. Any information used from this publication should be cross-referenced against tested product and building codes that are in existence.

It should also be noted that external shading, air infiltration, curtains, insulation, building construction type and orientation are equally important in building design and effectiveness in controlling climatic conditions.

climate control factors

- **Heat Gain** (warm climates/summer);
- **Heat loss** (cooler climates/winter);
- **Glare** (whilst maintaining adequate levels of natural daylight);
- **Condensation**;
- **UV** and **fading**.

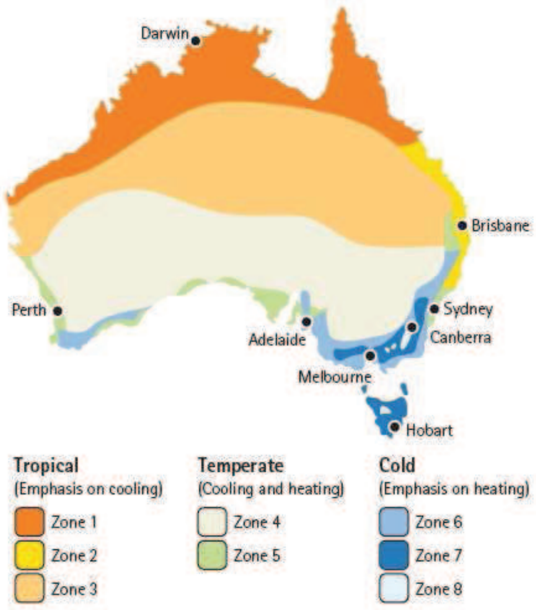
climate types

The type of climate has major influence on window performance. Essentially, Australia can be divided into three broad climatic zones *(see Diagram 15.1)*:

For actual area/locality details on climate zones, refer to BCA.

- **Cooling climate** (tropical, subtropical and hot arid areas) - warmer climates where most of the energy used year round is to cool the building;
- **Mixed climate** (temperate) - in these areas heating and cooling represent approximately a 50/50 split of energy use;
- **Heating climate** (alpine and cool temperate) - colder climates where most of the energy used year round is in heating the building.

diagram 15.1: climate zones



measuring performance

There are two important terms to know when measuring glazing performance:

1 SHGC - shading heat gain co-efficient

Refers to the total amount of **solar energy transmittance** entering a building throught the glazing as **heat gain**. This measure equates to the Sun's direct transmittance energy (**T**) plus the part of this energy absorbed by the glass and re-radiated inside (**E**). The lower the number the better. It's most commonly used in regards to the cooling of the buiding. SHGC can also be calculated as 86% of the Shading Co-efficient. 3mm clear float has a SHGC of 0.86.

The SHGC can also be stated in the following ways:

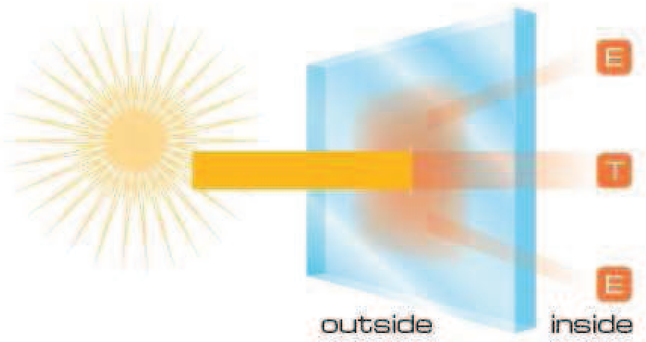
- 3mm clear lets in 86% of the Sun's total direct heat;
- 3mm clear keeps out only 14% of the Sun's total direct heat.

Another way to describe how the SHGC is used is in terms of energy consumption in watts/m².

For example the sun's direct energy typically radiates on a hot day 785 watts per m² and 6mm Sunergy® Green has a SHGC of 0.42. If you multiply 785 watts x 0.42 (SHGC) you get 329 watts per m² radiated into the building. In this example the Sunergy® glass is reducing the sun's direct energy through the glass into the building by 58%.

diagram 15.2: SHGC formula

SHGC = Sun's direct transmission energy (T)
+ Re-radiated heat (E)
= SHGC



measuring performance

2 U-value

See Diagram 15.3.

Measures heat transfer by method of **re-radiation**, **conduction** and **convection**. The Sun's direct energy transmission through the glass is not the only way in which heat is transferred through the glazing. Heat also flows naturally from warm air/bodies to cold air/bodies. This heat flow is in the form of long wave (infrared) energy. Lets explain this further. On warm days the Sun's direct heat on an object (called short wave infrared - what we feel as sunlight heat on our bodies) causes it to absorb and re-radiate this heat in the form of a low-energy heat (long wave infrared radiation). U-value is used to measure this type of non solar heat transfer. On cold winter days/night time, U-value is measuring the amount of heat loss from inside the home generated, for example, from a heater. It is not to be confused with measuring the Sun's direct energy transmission on the glass as measured by SHGC. U-value and SHGC are both important when considering energy costs and comfort. However, each measure may have more weight in different climates.

U-value is measured in watts per square meter per degree Celsius (Wm²K) difference. The amount of heat energy transferred as measured by the U-value can be calculated by taking for example 4mm clear float with a U-value of 5.9w/m²°C and multiplying the difference between outdoor and indoor temperature (32°C outside and 24°C inside = 8°C) > 5.9 x 8°C= 47watts per m² heat transferred between the thermal insulation properties of the glazing system. The U-value is progressively reduced by adding; more than one pane of glass (IGU's) which reduces the effect of conduction and convection and; a low-E coating which redues the effect of re-radiation.

Table 15a shows insulation comparisons between glass and other building materials. The lower the number the better the insulation.

The U-value is the reciprocal of the "R" value and either can be calculated from the other e.g. U = 1/R or R = 1/U.

U and R values are variable and dependent upon climatic conditions. That means that the transmittance of heat through a glazing system changes. Therefore glass transmits heat at varying rates depending upon the prevailing climatic condition. When comparing glazing systems based upon U-value, it is important that the climatic conditions used to model all the systems are the same.

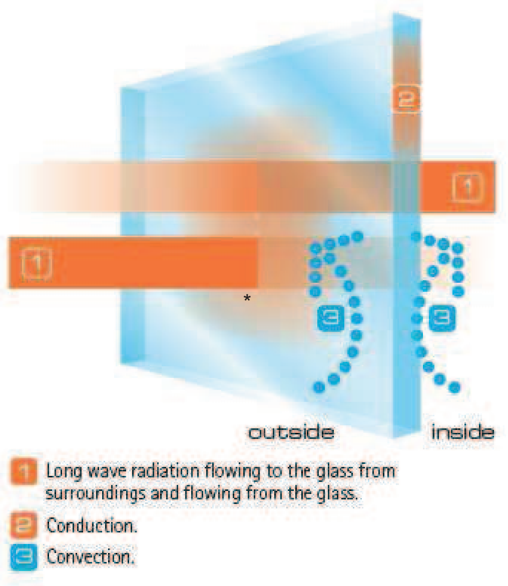
table 15a: insulation comparisons U-value w/m²k

Single glazing	5.60-6.20
Single low-E coating	3.80-4.20
Standard IGU	2.40-2.70
Low-E IGU	1.60-2.10
Low-E/argon gas IGU	1.50-2.00
Low-E/triple/argon gas IGU	0.80
Wall insulated*	0.50-1.00
Ceiling/roof insulated*	0.25-0.33

**Average recommended insulation levels (converted from R-value) for Australian homes.*

diagram 15.3: U-value

- **U-value** (summer and winter conditions);
- Measures thermal or non-solar heat flow occurring through conduction, convection and re-radiation.



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which measurement is more relevant?

Conduction, convection and re-radiation are measured by the **U-value** whilst direct transmittance energy from the Sun is measured by the **SHGC**. Why use both measures? Are one of these measures more relevant than the other in different climates?

In general terms where homes are artificially cooled or heated in any climate, glass with a lower U-value will reduce energy costs. However, for warm climates when we combine the SHGC and U-value into one total heat gain number (relative heat gain - RHG), it is the control of the Sun's direct intensity on unshaded glazing as measured by the SHGC which becomes more relevant. The Sun's direct heat (measured by SHGC) controls a much larger percentage of the total heat gain when compared to other heat flows (as measured by U-value). For warm climated unshaded windows, control of teh Sun's direct energy with a glass that has a lower SHGC is the first important step in design. As previously mentioned, a lower U-value will further assist in heat gain reduction and lower energy costs. The following example highlights the dominance of the Sun's direct intensity over other heat flows through glazing.

relative heat gain RHG

Relative heat gain combines the shading co-efficient with U-value to measure the total heat gain for summer time conditions. This is particularly useful for building designers to determine air-conditioning loads.

formula for determining RHG

SC (Shading co-efficient) X **785 W/m²** (Direct solar intensity)

plus

U-Value W/m (Summer U-value) X **8°C** (Difference between outdoor and indoor temperature).

Using the above formula for warm climate conditions, the importance of firstly controlling the Sun's direct transmittance on glazing is explained with the following example:

5mm eurogrey: example only

SC 0.73/U-value 6.2

0.73 x 785 W/m² = 573.05 W/m²
6.2 x 8°C = 49.60 W/m²

RHG = 573.05 W/m² + 49.60 W/m² = 622.65 W/m²

This formulation compares the Sun's direct intensity gain (reduced by the Shading coefficient of the glass) adding the gain through other heat flows as measured by U-value. The values show 573.05 W/m² directly transmitted and 49.60 W/m² transmitted throother heat flows. It is obvious from this calculation example that the Sun's direct transmission will have the biggest impact upon cooling energy.

role of lower U-values in climate control

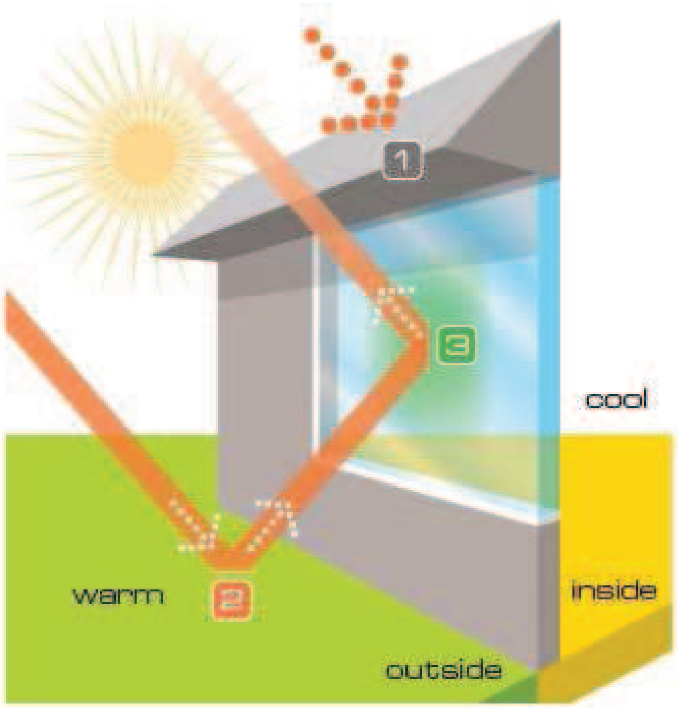
warm climates

We have established with the relative heat gain example that unshaded windows will benefit foremostly from selecting glass with lower SHGC. Improving the U-value will further improve and lower the total heat gain impact on the building. Using glass with a lower U-value provides best benefit to daytime shaded windows and during warm nightime conditions.

See Diagrams 15.4 and 15.5.

It is often the surroundings of the building including objects, the ground, other buildings etc which absorb heat and re-radiate it (as long wave radiation) towards the window. These objects may continue to release this energy throughtout the day and into the night. On warm summer nights it may usually be the case that fans are used or air-conditioning is left on. Energy use can thus be reduced through selection of glass with lower U-values. Preferred glazing solutions for warm climates are low SHGC glass with an integral low-E coating or low SHGC low-E coated glass combined in IGU's.

diagram 15.4:
summer day time



1 Shaded windows offer a greater time lag to the sun's direct intensity.

2 However we still have the impact of long wave (low energy) infrared heat reflecting from surroundings outside of the window.

3 The impact of this can be reduced by adding a Low-E coating which assists in rejecting this long wave radiation back outside.

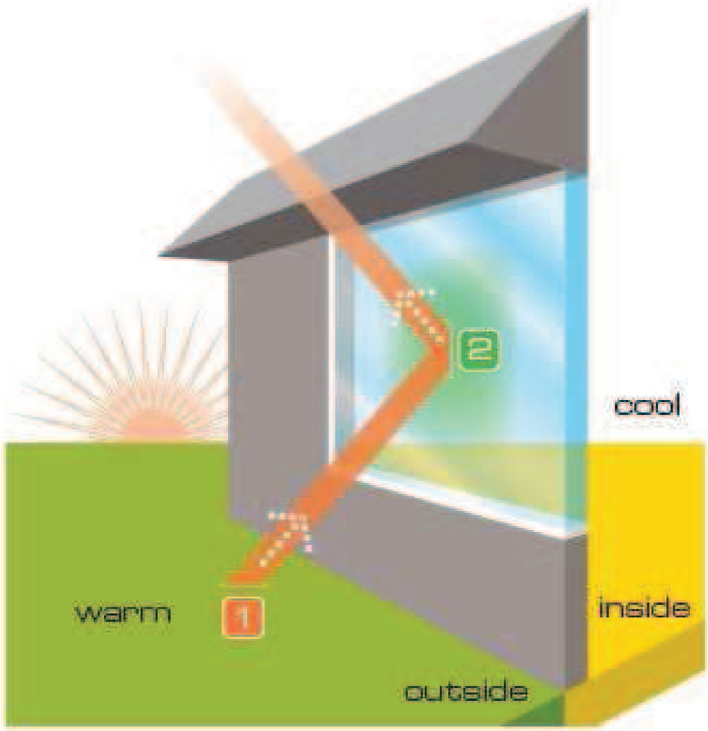
lets not forget cooler climates

We have previously established that the U-value is also important in warm climates on unshaded and shaded windows in both day and night conditions. U-values have most oftenbeen associated with heat loss measurement in cooler climates. This is still very true. The climatic conditions have now changed where we are wishing to retain any stored heat for as long as possible inside the building and there fore lessening our heating energy needs and increasing occupant comfort.

Table 15a compares the U-values of glass and building elements. The still air and additional glass pane of an IGU improves insulation by approximately 50% over single glazed, non-coated glass. Adding a low-E coating to an IGU makes for an improvement of approximately 70%.

In addition, where most of the energy used is to heat year round, a glass with a higher SHGC may be more beneficial. This allows for more of the Sun's direct energy to naturally heat the building, which can lower heating costs. Adding low-E coatings combined with IGU's will provide the optimal glazing solutions for control of heat loss.

diagram 15.5:
warm summer nights



1 Though the sun has set, the outside environment is still releasing long wave (low energy) radiation.

2 The impact of this can be reduced by adding a Low-E coating which assists in rejecting this heat back outside.

basic principles of heat transfer through glass

The basic principle of **heat transfer** is that heat will always move through the glazing to the colder side. Summer heat will migrate towards the colder interior and winter warmth will migrate to the colder outside environment. In both situations to various degrees and dependent on circumstances, to maintain comfortable living conditions we artificially heat or cool the building or home. The amount of energy we put into cooling and heating is greatly affected by our glass selection. Poor selection leads to greater energy costs.

Heat is transferred through the glazing by three methods:

Conduction;

Convection;

Radiation - Direct transmission and re-radiation

diagram 15.6: conduction

Conduction is the process where heat travels through a solid material or like a frying pan heating up.

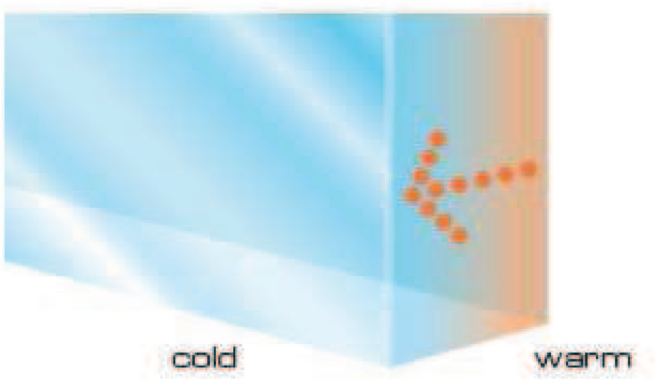
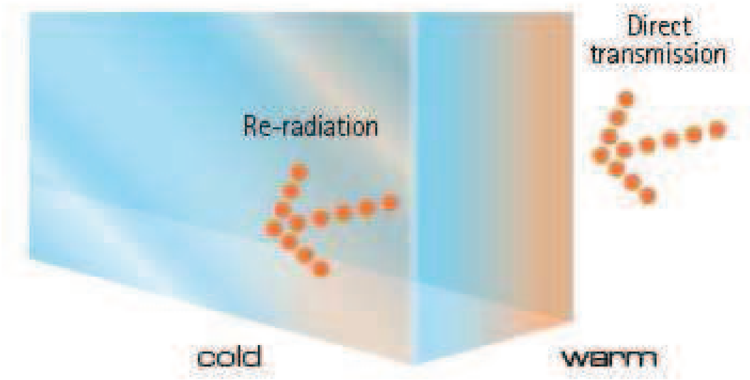


diagram 15.7: convection

Convection is the transfer of heat by the movement of air across a surface or similar to hot air from a hair dryer.

diagram 15.8: radiation

Radiation heat transfer makes reference to both direct transmission and re-radiation. Direct transmission is the heat we feel on our bodies when we are next to a sunny window, the Sun shining directly through the window (short wave radiation). Re-radiation (long wave radiation) occurs when the glass absorbs this short wave radiation and re-radiates it to the interior or exterior. Other objects outside the window such as the window sill, cars, the ground will also absorb and re-radiate the Sun's direct heat towards the glass. Objects inside the room such as carpets, furniture etc. will do likewise.



heat gain reduction glass selection

single clear glass

With its high transparency, single clear glass provides no protection against windows directly exposed to unwanted direct solar energy. This translates to hot rooms or buildings, glare and higher cooling costs. The major performance measure to consider when trying to control direct solar energy is the SHGC (shading heat gain co-efficient). The lower the number the better in terms of heat gain reduction.

- >3mm clear SHGC = 0.86;
- >5mm clear SHGC = 0.83.

single body tinted glass/ tinted PVB's laminates

With its lower levels of transparency, tinted glass restricts the entry of direct solar radiation. The principle of convection also applies to tinted glass. When the external surface of the glass is heated up, the heat generated is re-radiated outwards and convection through the aid of air movement or wind helps reduce the transfer of this heat to the interior. Essentially, tinted glass provides a greater time lag to the direct effects of the sun's direct energy over single clear glass. This translates to more comfortable homes, less glare and lower cooling costs.

- >6.38mm Grey PVB Lam SHGC = 0.62;
- >5mm EuroGrey = 0.63;
- >5mm Green Panasap = 0.58;
- >6mm Dark Blue Panasap = 0.58;
- >6mm Optigray = 0.42.

single reflective glass

Where reduction of heat gain is of primary concern, reflective glass absorbs and reflects a major proportion of the sun's direct energy more effectively than most tinted glass.

- >6mm Stopsol® Grey SHGC = 0.47.

single low-E coated clear glass

Single glazed hard coat low-E products such as **Comfort E2**™ which have high levels of transparency do offer marginal improvements in reduction of heat gain over single clear glass (around 10% - 12%). Though low-E clear glass may have a better "U" value, the primary concern here is the reduction of the direct effects of solar energy on a window. It may be more economical in some instances to use a body-tinted glass or low-E coated tinted product such as Sunergy® with a better SHGC. The main factor to consider is the SHGC (shading heat gain co-efficient). The lower the number, the better in terms of heat gain reduction.

- >4mm Comfort E2™ Low-E SHGC = 0.72.

single low-E coated tinted glass

To overcome the shortfalls in SHGC with standard low-E clear glass, new generation products such as Sunergy combine the benefits of tinted glass with the addtion of a low-E coating providing lower SHGC and U-values. These products are a cost effective alternative to IGU's for specific climatic conditions.

- >4mm Sunergy Clear SHGC = 0.61;
- >6.38mm Sunergy Grey PVB SHGC = 0.44;
- >6mm Sunergy Green SHGC = 0.42.

IGU's

Insulated glass units (IGU's) are a significantly more energy efficient glazing system than single glazed windows. The still air and additional glass pane in the IGU reduce the effects of heat transfer through conduction, convectin an radiation. However a degree of solar control is still required and in many circumstances in Australia where windows are exposed to direct solar energy, a tinted, reflective and/or low-E glass should be used in combination to reduce this heat gain.

- >6mm Sunergy Green/12mm air/6mm clear float SHGC = 0.33.

shading devices

Eaves and external shading devices can also be used in reducing the advers effects of direct heat gain particularly on east and west facing facades. External devices should be adjustable to allowe for different climate conditions. Internal blinds or curtains are less effective as the heat has already penetrated the room. A thermal assessment should be carried out o the glazing to deteermine the risk of thermal breakage when using these devices.

ventilation

The use of windows in a room that create abreezeway oir air draft can reduce the effects of heat gain. This is of particular use where the room or building is not air-conditioned.

louvre windows

More useful in cooling climates where air-conditioning is not used, provides adequate ventilation and reduces heat gain in a building.

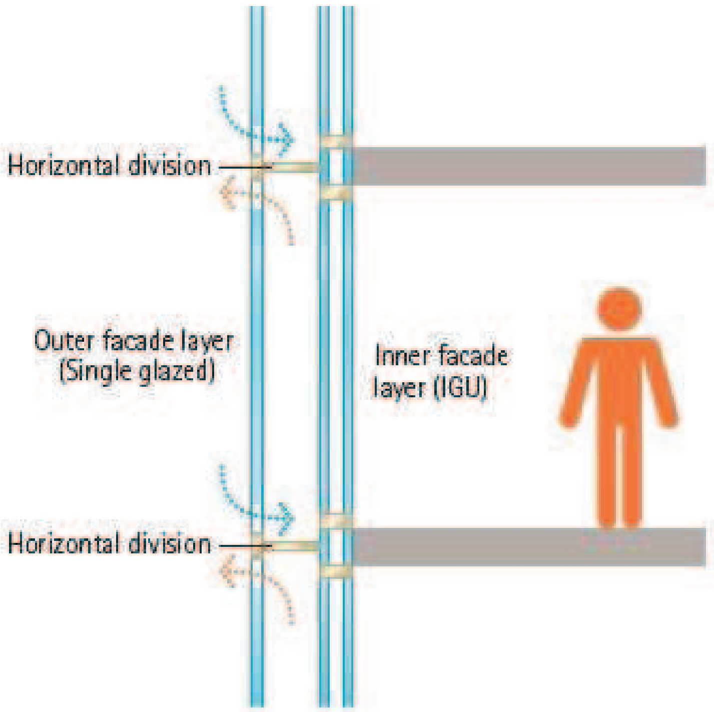
air-conditioning vents

Air from these vents should be directed away from the window. Air blowing on or close to the glass surface will create a greater convection of hot air into the room.

double facades

Similar to the functional features of an IGU, the double facade *(see diagram 15.9)* consists of an external facade, an itermediate space and the iner facade. The external facade provides protection from weather and acoustic benefits and with appropriate glass selection provides the first barrier to heat gain penetration. Vents in the external facade at intervals allow for the flow of air between the two facades, hot air rising and flowing through the vents, air or wind flowing in convecting heat away. The internal facade is the second barrier to heat gain.

diagram 15.9:
typical double facade



winter heat loss reduction glass selection

For heating and mixed climates, window location and insulation povide the optimal benefit. The measure most used to evaluate the insulation properties of glazing systems is the U-value. The lower the U-value, the better the glass is at insulating agains heat loss.

single clear glass

Though single clear glass may provide benefits on northern elevations, allowing heat gain to passively or naturally heat the interior, the poor insulation of single glazing allows the heat to escape when compared to other building materials. The main idea is to trap the heat in the room. This can only be done effectively through modifying the surface of the glass by adding a low-E coating or even better through the use of IGU's (insulated glass units).

single body tinted and reflective glass

Standard body tinted and reflective glass have almost the same U-values as single clear glass. Best effectiveness in residential homes is on western elevations for summer time conditions combined with low-E coatings and/or IGU's.

- >5mm EuroGrey U-value = 6.2 W/m²K;
- >6mm Grey Stopsol U-value = 5.8 W/m²K.

single low-E coated clear/ tinted glass

Single glazed low-E coated products shuch as Sunergy® can improve U-value by an average of 25% over some single glazed non-coated glass.

4mm Sunergy® Clear U-value = 4.2 W/m²k;

- 6mm Sunergy® Green U-value = 4.1 W/m²k.

IGU's

The ideal performer; Insulated glass units or double glazing perform the same way in winter and summer conditions. The still air and additional glass pane in the IGU reduce the effects of heat transfer through conduction, convection and radiation. U-values can be improved for 50% to 70% depending on unit make-up.

- >6mm Sunergy® Green/12mm air/6mm clear float U-value = 2.1 W/m²k.

window location/ building orientation

For heating and mixed climates, windows positioned on northern elevations allow for the sun's direct energy to passively or naturally heat the interior. In combination with low-E coated and/or IGU's, the heat generated can be trapped or re-radiated back into the room which in turn reduces heating costs.

internal curtains/drapes

These can also be of benefit during night time conditions (where daylight is not required). Tight fitting heavy drapes and pelmets around the window can assist in keeping the warmth in.

double facades

Equally effective for heat loss reduction. Ventialtion openings can be closed off to contain heat within space.

glare reduction

Reducing annyoying **glare** can be achieved through controlling the amount of daylight that passes through the glass. Thoug it should also be noted that glare is subject to individual perception. Some situations may require other methods to control glare such as external barriers, blinds, ceramic fritted patterns or matrixes on the glass itself or removing the cause of the glare.

To assist in reducing glare, the glazing industry looks at the Visible Light Transmittance (VLT) measurement. The higher this number the brighter the interior will be and possibly the greater level of glare. Typically 3mm clear has a high VLT of 90% which means that it lets through 90% of daylight. A body tinted glass such as 5mm Panasap Green (VLT 73%) will cut down VLT by close to 20% whilst 5mm Grey (VLT 50%) will cut down VLT by close to 45% when both are compare to 3mmm clear glass.

An adverse effect of restricting the level of interior light in a room is increased artificial lighting. This results in increased costs and less of the benefits of natural daylighting. As a general guide, glass with products with a VLT of around 70% or lower will aid in the reduction of glare.

condensation

Water from **condensation** build up and resultant water run-off can damage window frame/sills and seep into walls and adjoining areas. Condensation will form when the moisture in the air condenses out on surfaces that are cooler than the 'dew' point. Insulated walls, ceilings and floors provide better thermal barriers than windows. Window surfaces being colder than other surfaces in a room are more prone to condensation build up. Condensation can also occur on the outside of windows in hot humid climates where the inside room temperature (through air-conditioning) is lower than the outside temperature.

If this area is subject to condensation, IGU's are the best method to help reduce the likelihood of it occuring. IGU's provide a thermal barrier between the inside and the outside. The lower the U-value of the unit the better.

UV and fading protection.

There is no guaranteed that furnishings or objects can be completely protected from fading. Though **ultraviolet light** is a significant contributor to fading, it a can also be **visible light** and **infrared radiation** (heat) that cause fading and damage. Choosing glass products restricting UV transmission, visible light and infrared radiation will assist in the reduction of fading. For example, the poly butyral (PVB) interlayer in laminated glass can screen out up to 99% of all UV light. Adding either a tinted interlayer, a body tinted or reflective glass will further resist damage from visible and infrared components.