Understanding Energy Efficient Glass

Windows are a complex and interesting element in residential and commercial design. New window products and technologies have changed the performance of windows in a radical way. Issues such as climate, orientation, shading, and window area all effect the energy performance, but human factor issues such as access to fresh air, daylight, and natural views impact the comfort of a structure.

http://www.efficientwindows.org/understanding.php

In accordance with SANS 10400-XA:2011 the correct Energy usage in structures contributes to Environmental sustainability. High performance (energy efficient) windows and glass are critical to a whole structure's sustainable energy usage.

Unfortunately, ordinary windows do have a very high unwanted heat loss and gain. This causes strain on the structure's energy efficiency performance.

The answer here is to utilize high performance windows to boost the total structure's energy efficiency performance. There are specific contributing factors that will always play a role here.

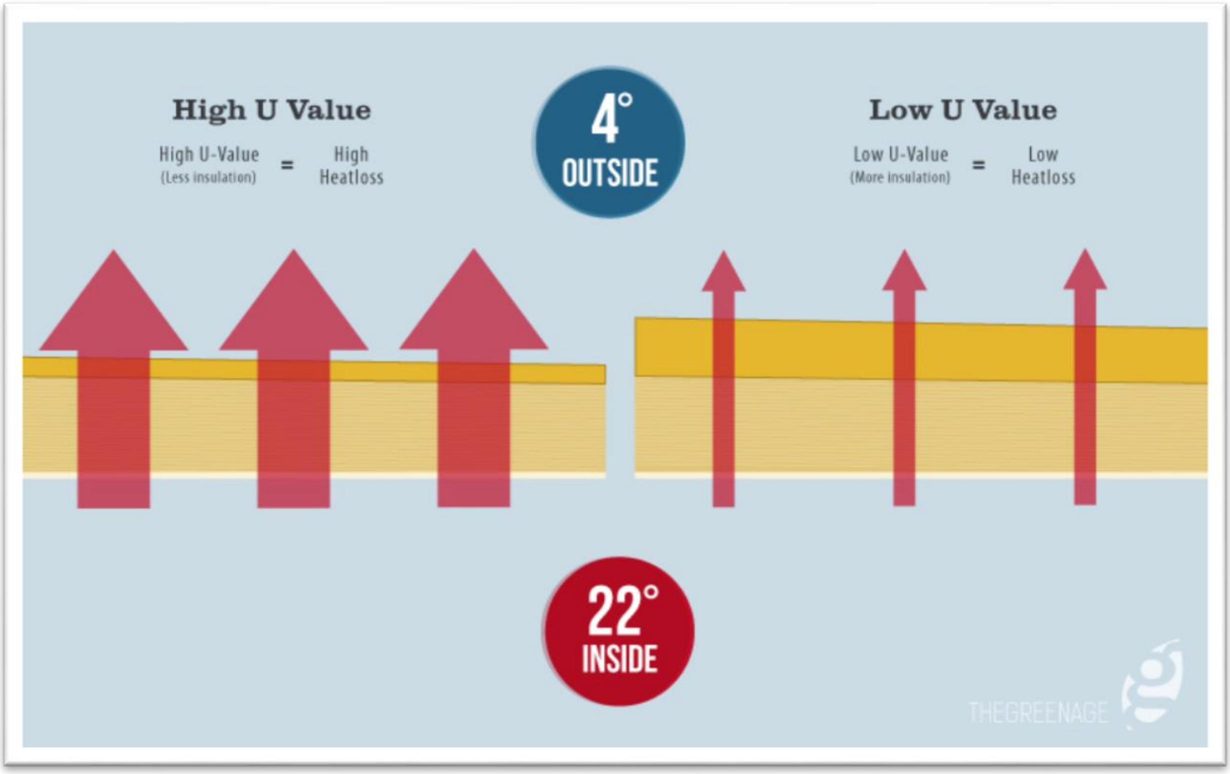
http://www.sagga.co.za/understandenergy.html

Measuring Performance

Heat flows through a window in three ways: **conduction, convection and radiation**. When these basic mechanisms of heat transfer are applied to the performance of windows, they interact in complex ways.

The main three energy performance characteristics of windows are used to portray how energy is transferred and is the basis for how energy performance is quantified.

- **Insulating value**. When there is a temperature difference between inside and outside, heat is lost or gained through the window frame and glazing by the combined effects of conduction, convection, and radiation. This is indicated by the U-value.
- **Heat gain from solar radiation**. Regardless of outside temperature, heat can be gained through windows by direct or indirect solar radiation. The ability to control this heat gain through windows is measured in terms of the Solar Heat Gain Coefficient (SHGC) of the window.
- **Infiltration**. Heat loss and gain also occur by Air Leakage (AL) through cracks in the window assembly. This effect is measured in terms of the amount of air (cubic meters per minute) that passes through a unit area of a window (square meter) under given pressure conditions. In reality, infiltration varies slightly with wind-driven and temperature-driven pressure changes.



U-Values

The R-value is a measure of resistance to heat flow through a given thickness of material. So the higher the R-value, the more thermal resistance the material has and therefore the better its insulating properties.

In real buildings a wall is made up of many different material layers. The total thermal resistance of the entire wall is calculated by adding the thermal resistance of each separate layer.

Unfortunately, heat moves in and out of a building in several different ways and R-values only take into account conduction. It does not include either convection or radiation.

Therefore, you may choose to use the U-value, a measure of how much heat is lost through a given thickness of a particular material.

The U-value takes into account all the different mechanisms of heat loss – conduction, convection and radiation. The environmental temperatures inside and outside a structure play an important role when calculating the U-value of an element. The lower the U-value is, the better the material is as a heat insulator.

Using U-Values, R-Values and Thermal conductivity

If you are confronted with thermal conductivity, R-values and U-values going forward, here are 3 simple things to remember, to make sure you get the best insulating product.

Higher numbers are good when comparing the Thermal Resistance and R-Values of products.

Low numbers are good when comparing U-Values.

The U-Value is the most accurate way to judge a material's insulating ability, taking into account all the different ways in which heat loss occurs, however it is more difficult to calculate.

http://www.thegreenage.co.uk/article/thermal-conductivity-r-values-and-u-values-simplified/

Solar Heat Gain Coefficient (Shading coefficient for buildings)

The second major energy-performance characteristic of windows is the ability to control Solar heat gain coefficient through the glazing. Solar heat gain coefficient through windows is a significant factor in determining the cooling load of many commercial buildings. The origin of Solar heat gain coefficient is the direct and diffuse radiation coming from the sun and the sky (or reflected from the ground and other surfaces). Some radiation is directly transmitted through the glazing to the building interior, and some may be absorbed in the glazing and indirectly admitted. Some radiation absorbed by the frame will also contribute to the overall window solar heat gain factor. Other thermal (non-solar) heat transfer effects are included in the U-factor of the window.

Solar heat gain coefficient is typically used to describe the solar heat transmittance properties of glass, but has also been used for other translucent and transparent materials. Solar transmittance is important for determining the Solar heat gain coefficient into an enclosed space during sunny conditions. Solar heat gain can be beneficial in the winter, as it reduces the need for heating, but in the summer it can cause overheating. The total solar heat transmittance is equal to the solar heat that is transmitted through the material directly, plus the solar heat that is absorbed by the material and then re-emitted into the enclosed space.

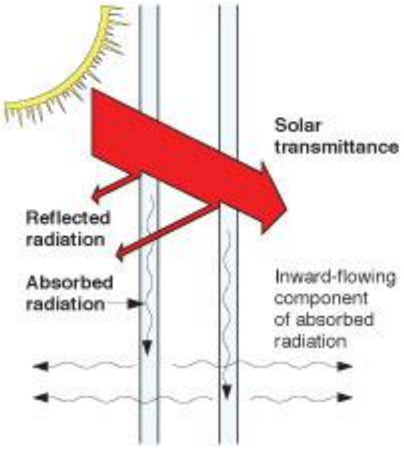


Figure 1: Simplified view of the components of solar heat gain. Heat gain includes the transmitted solar energy and the inward flowing component of absorbed radiation.

Solar heat gain coefficient is influenced by the glazing type, the number of panes, and any glass coatings. Solar heat gain coefficient of glazing ranges from above 80% for uncoated water-white clear glass to less than 20% for highly reflective coatings on tinted glass. A typical double-pane IGU has a SHGC of around 0.70. This value decreases somewhat by adding a Low-E coating and substantially when adding a tint. Since the area of a frame has a very low SHGC, the overall window SHGC is lower than the center-of-glass value. **Please also see section dealing with Visible Transmittance.*

The shading coefficient is expressed as a number without units between 0 and 1.

The lower a window's solar heat gain coefficient or shading coefficient, the less solar heat it transmits, and the greater is its shading ability.

The lower the shading coefficient number of the solar factor (total transmittance) of a glass configuration, the lower the amount of solar heat transmitted. Window standards are now moving away from a previous standard referred to as Shading coefficient (SC) to Solar Heat Gain Coefficient (SHGC), which is defined as that fraction of incident solar radiation that actually enters a building through the entire window assembly as heat gain.

Total shading coefficients (TSC) can be broken down into short-wave shading coefficients (SWSC) and long-wave shading coefficients (LWSC). The short wave shading coefficient is the direct transmittance (T) of the glass as a factor. The long wave-shading coefficient is the internally re-radiated energy that the glass has absorbed.

Why is a SHGC important?

Solar heat gain can provide free heat in the winter but can also lead to overheating in the summer. How to best balance solar heat gain with an appropriate SHGC depends upon the climate, orientation, shading conditions and other factors.

https://www.glassonweb.com/news/what-shading-coefficient

http://www.commercialwindows.org/shgc.php

Air Leakage (AL)

Air leakage control is an important but commonly misunderstood component of the energy efficient building. Tightening the structure with caulking and sealants has several positive impacts:

- Lower heating (electricity) bills due to reduced heat loss
- Improved ambient conditions
- Minimizing the chance of mould and rot by decreasing the amount of moisture likely to enter the structure and become trapped in cavities
- A better performing ventilation system
- Implementation of smaller heating, ventilation and air conditioning (HVAC) systems.

Air leakage is sometimes called infiltration, which is the unintentional or accidental introduction of outside air into a building, typically through cracks in the building envelope and through use of doors for passage. In the summer, infiltration can bring humid outdoor air into the structure.

Whenever there is infiltration, there is corresponding exfiltration elsewhere in the building. In the winter, this can result in warm, moist indoor air moving into cold envelope cavities. In either case, condensation can occur in the structure, resulting in mould or rot.

Infiltration is caused by wind, stack effect, and mechanical equipment in the building.

Wind creates a positive pressure on the windward face and negative pressure on the non-windward (leeward) facing walls, which pulls the air out of the building. Wind causes infiltration on one side of a building and exfiltration on the other. Wind effects can vary due to surrounding terrain, shrubs, and trees.

The **"stack effect"** is when warm air moves upward in a building. This happens in summer and winter, but is most pronounced in the winter because indoor-outdoor temperature differences are the greatest. Warm air rises because it's lighter than cold air. So when indoor air is warmer than the outdoor air, it escapes out of the upper levels of the building, through open windows, ventilation openings, or penetrations and cracks in the building envelope. The rising warm air reduces the pressure in the base of the building, forcing cold air to infiltrate through open doors, windows, or other openings. The stack effect basically causes air infiltration on the lower portion of a building and exfiltration on the upper part.

Mechanical equipment such as fans and blowers causes the movement of air within buildings and through enclosures, which can generate pressure differences. If more air is exhausted from a building than is supplied, a net-negative pressure is generated, which can induce unwanted airflow through the building envelope. Bathroom exhaust fans, clothes dryers, built-in vacuum cleaners, dust collection systems, and range hoods all exhaust air from a building. This creates a negative pressure inside the building. If the enclosure is airtight or the exhaust flow rate high, large negative pressures can be generated.

https://www.energycodes.gov/sites/default/files/documents/BECP_Buidling%20Energy%20Code%20Resource%20Guide%20Air%20Leakage%20Guide_Sept2011_v00_lores.pdf

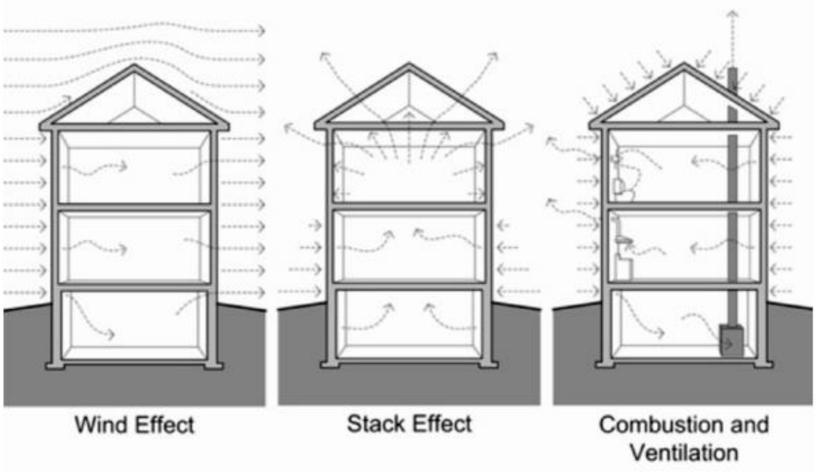


Figure 1: Examples of infiltration. Image courtesy: Building Science Corporation, www.buildingscience.com

Condensation Resistance (CR)

The ever stringent focus on the performance of fenestration products for thermal transmittance (U-value) and solar heat gain (SHGC) can sometimes overshadow the third thermal performance parameter of these systems; Condensation Resistance (CR). While U-value and SHGC are area weighted thermal performance averages of the fenestration system, condensation resistance is a localized condition that relies on performance characteristics of discrete locations in the fenestration system. Performance factors that may have a minimal impact on U-value and/or SHGC may be critical in the prevention of condensation formation that could, if not controlled, lead to health concerns and building component/system damage.

https://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/BEST/BEST2_059_WB14-2.pdf

- *Condensation Resistance (CR) measures how well a product resists the formation of condensation. CR is expressed as a number between 1 and 100. The higher the number, the better a product is able to resist condensation.*

http://www.sagga.co.za/understandenergy.html

Visible Transmittance (VT or Tvis)

Visible transmittance is the amount of light in the visible portion of the spectrum that passes through a glazing material.

A higher VT means there is more daylight in a space which, if designed properly, can offset electric lighting and its associated cooling loads. Visible transmittance is influenced by the glazing type, the number of panes, and any glass coatings.

Visible transmittance of glazing ranges from above 90% for uncoated water-white clear glass to less than 10% for highly reflective coatings on tinted glass. A typical double-pane IGU had a VT of around 78%. This value decreases somewhat by adding a Low-E coating and substantially when adding a tint. VT values for the whole window are always less than center-of-glass values since the VT of the frame is zero.

- ***Visible Transmittance**. The amount of light in the visible portion of the spectrum that passes through a glazing material. This property does not directly affect heating and cooling loads in a building, but it is an important factor in evaluating energy-efficient windows.*

Light-to-Solar-Gain Ratio

In the past, windows that reduced solar heat gain coefficient (with tints and coatings) also reduced visible transmittance. However, new high-performance tinted glass and low-solar-gain Low-E coatings have made it possible to reduce solar heat gain with little reduction in visible transmittance. Because the concept of separating solar gain control and light control is so important, measures have been developed to reflect this. The LSG ratio is defined as a ratio between visible transmittance (VT) and solar heat gain coefficient (SHGC).

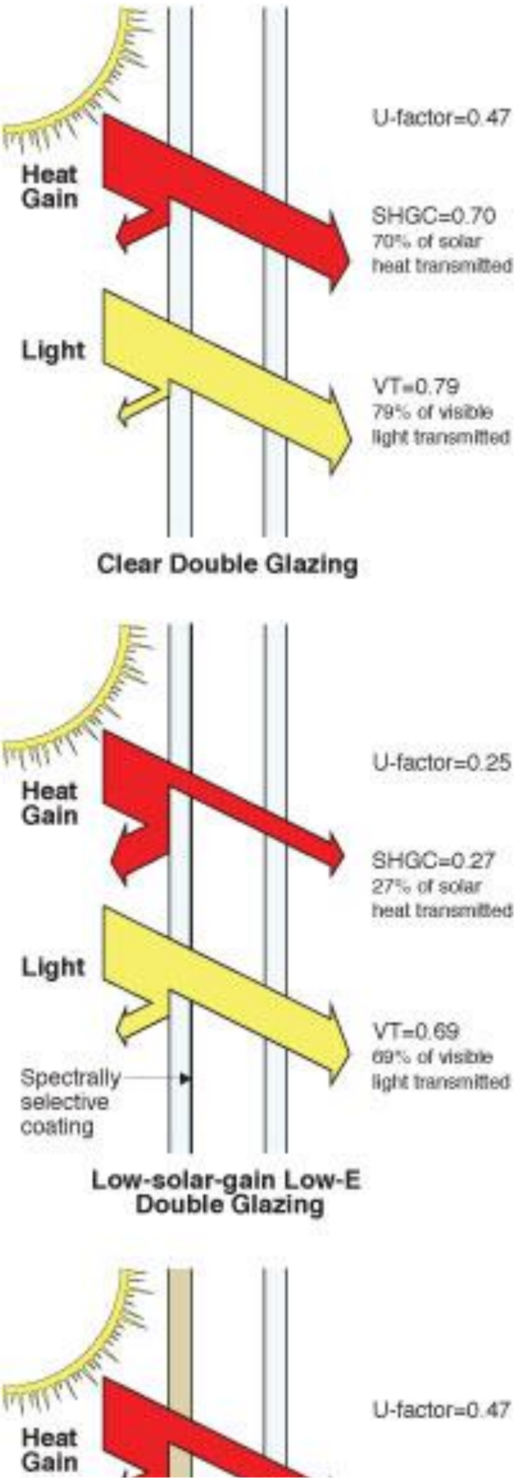


Figure 2: Center-of-glass values of double pane units with and without low-E coatings.

Low-E Coatings

When heat or light energy is absorbed by glass, it is either convected away by moving air or re-radiated by the glass surface. The ability of a material to radiate energy is called its emissivity. All materials, including windows, emit (or radiate) heat in the form of long-wave, far-infrared energy depending on their temperature. This emission of radiant heat is one of the important components of heat transfer for a window. Thus reducing the window's emittance can greatly improve its insulating properties.

Low-E glass coatings can have an emittance as low as 4% of the energy possible at its temperature, and thus reflect 96% of the incident long-wave, infrared radiation. Window manufacturers' product information may not list emittance ratings. Rather, the effect of the Low-E coating is incorporated into the U-value for the unit or glazing assembly.

The solar reflectance of Low-E coatings can be manipulated to include specific parts of the visible and infrared spectrum. This is the origin of the term *spectrally selective coatings*, which selects specific portions of the energy spectrum, so that desirable wavelengths of energy are transmitted and others specifically reflected. A glazing material can then be designed to optimize energy flows for solar heating, daylighting, and cooling.

The first generation Low-E coatings (intended mainly for residential applications), were designed to have a high solar heat gain coefficient and a high visible transmittance to allow the maximum amount of sunlight into the interior while reducing the U-value significantly.

The second-generation Low-E coatings still maintain a low U-value, but are designed to reflect the solar near-infrared radiation, thus reducing the total SHGC while providing high levels of daylight transmission.

Low-solar-gain coatings reduce the beneficial solar gain that could be used to offset heating loads, but in most commercial buildings this is significantly outweighed by the solar control benefits. Here it is common to apply Low-E coatings to both tinted and clear glass. While the tint lowers the visible transmittance somewhat, it contributes to solar heat gain reduction and glare control. Low-E coatings can be formulated to have a broad range of solar control characteristics while maintaining a low U-factor.

http://www.commercialwindows.org/lowe.php

Energy Savings for the residential and commercial sectors

To arrive at a realistic estimate of energy and carbon-emission savings that may be achieved as a result of the use of energy-efficient windows and ceiling insulation in South Africa's buildings, it is necessary to distinguish building energy consumption from other forms of consumption.

In 2000, the final end-user energy consumption was 2193 PJ. Of this, 17% (373 PJ) was in the residential sector, while 4% (88 PJ) was consumed in the commercial building sector. Gas has a relatively small share of the energy market: 2% of the total versus 26% for electricity.

Of all residential energy consumption in South Africa's households, it is assumed that two-thirds is from a combination of electricity and gas, versus one-third from fuelwood. After subtracting the relatively small fraction due to gas of various types it can now be estimated that approximately 17% of South Africa's electricity is used in homes for heating, cooling, lighting, cooking, appliances and water heating.

Better windows

In office buildings, the amount of energy that can be saved by means of better windows depends on many factors such as climate, building form, design, materials and patterns of occupancy. For example, a long, narrow building with unshaded, clear single glazing in a sunny climate, like Johannesburg, will tend to overheat long before a square-plan building in the same climate.

Extensive simulations indicate that, conservatively, a 25% reduction in annual energy use can be expected when standard windows are replaced with high-performance windows. By 'high performance' it is meant windows having at least a 60% reduction in overall U-value (thermal transmittance) and a 60% reduction in solar heat gain coefficient (SHGC), compared with 6mm clear single glazing in a thermally unbroken aluminium frame. This means a system U-value not exceeding 2.7 W/m2. K and a system SHGC not exceeding 0.30 (both determined at NFRC 100-2001 environmental conditions).

Such windows, while much better than most existing windows, still do not meet the Energy Star standard for many parts of the United States, which defines a maximum U-value of 2.0 W/m2. K Use of Energy Star standard windows would further increase efficiency savings.

file:///C:/Users/Design2/Downloads/Save%20a%20Power%20Station.pdf

Benefits of High Performance (Energy Efficient Windows)

- Energy & Cost Savings
- Improved Comfort
- Less Condensation
- Increased Light & View
- Reduced Fading
- Lower Heating, Ventilation and Air Conditioning Costs