AGNORA

ARCHITECTS QUICK FACTS

THERMAL INSULATION & SOLAR CONTROL OF ARCHITECTURAL GLASS

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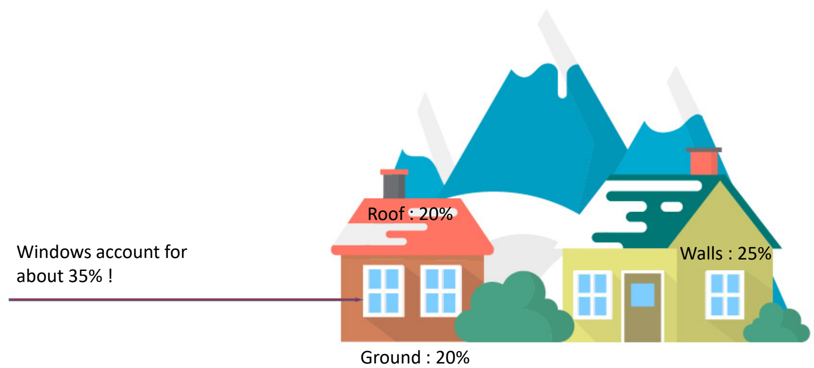
INTERACTION OF ENERGY & MATERIALS

A fundamental understanding of key concepts is required to realize the relationship and advantages of glazing and performance coatings of architectural glass. The following information provides a suitable framework.

SOURCES OF THERMAL LOSS

Within a given structure, roughly 35% of energy lost is a direct result of having windows. Reducing this number drastically reduces thermal loss, increasing efficiency and reducing the associated HVAC costs.

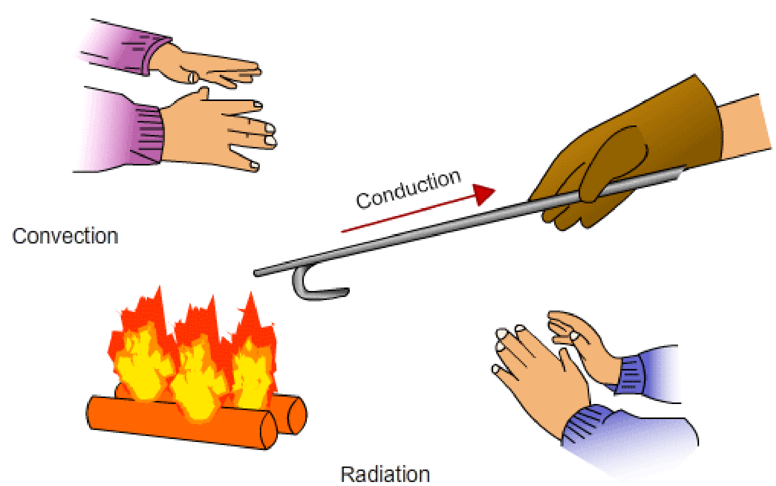


MODES OF ENERGY TRANSFER

Convection - Transfer of heat through a fluid (liquid or gas) caused by molecular motion

Conduction - Transfer of heat or electric current from one substance to the other by direct contact

Radiation - Energy that is radiated or transmitted in the form of rays or waves or particles



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THERMAL CONDUCTIVITY OF MATERIALS

The components of an Insulated Glass Unit (IGU) are included in the following table. It is important to note that air or argon are the two gases available within a cavity of an IGU. The argon is roughly 33% more effective than dry air at resisting thermal conductivity.

Material	W/ (m °C)	BTU/(ft h °F)
Argon	0.012	0.01
Air	0.018	0.01
Acetal (insulator)	0.2	0.1
Glass	1	0.5
Stainless Steel	15	9
Aluminum	205	118

EM SPECTRUM

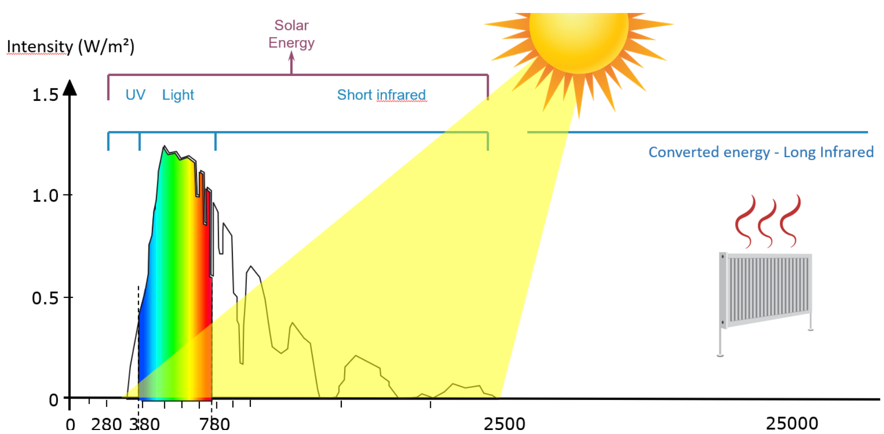
The EM spectrum as it relates to windows and thermal efficiency can be broken into four main categories, which will be used to describe temperature and light transmission.

Ultra Violet Radiation - 100-400 nm - Extremely short wavelengths that can cause skin irritation, burns and eye damage.

Visible Spectrum - 400-750 nm - The full range of visible light from violet (shortest wavelengths) to red (longest wavelengths).

Short Infrared - 750 - 2500 nm - Energy that is responsible for heating objects and the environment, as objects, such as furniture, are able to absorb short infrared wavelengths and re-emit as longer wavelengths.

Long Infrared - 2500-25000 nm - Energy that is re-emited from furniture hit by solar energy, or by heating devices such as radiators.



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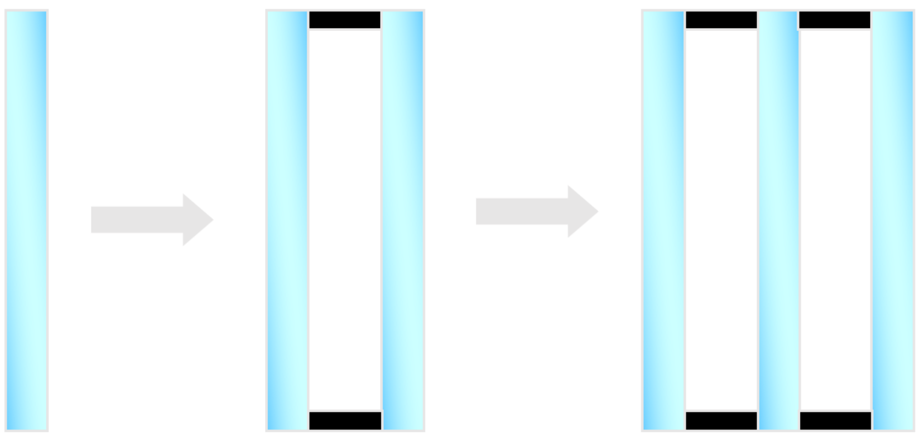
THERMAL CONTROL & GLAZING

If one was to use a single pane window, and require a U-Value of 1.4 - 1.8 W/ m^2C as is standard in many home and commercial applications, **700mm** of glass would be required meet these standards by limiting loss due to convection.

Thankfully, innovations such as double and triple glazing, in addition to performance coatings have resolved the need for this unlikely scenario.

SINGLE, DOUBLE & TRIPLE GLAZING U VALUES

To illustrate the difference between the U-values, 6mm examples will be examined. The units in this example are using dry air as the medium within the cavity:



$U = 5.8 \frac{W}{m^2 °C}$ $1.02 \frac{BTU}{Hft^2 °C}$

$U = 2.7 \frac{W}{m^2 °C}$ $0.48 \frac{BTU}{Hft^2 °C}$

$U = 1.8 \frac{W}{m^2 °C}$ $0.32 \frac{BTU}{Hft^2 °C}$

A 53% improvement from single to double glazed units, and a 69% improvement from single to triple units, in U-Value can be achieved simply by adding a sealed cavity between the panes, thereby dramatically reducing conduction.

The only appreciable energy transfer occurs due to convection through the dry air, which is has much less capacity to transfer energy as opposed to the dense material of glass, as evidenced in Fig.3. Some conduction does occur on the metal spacer, joining the two/three pieces of glass around the perimeter.

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THE EFFECTS OF PERFORMANCE COATINGS

The value of creating a double or triple glazed, Insulated Glass Units (IGU) are irrefutable. A cavity of dry, non conductive material greatly improves the overall insulation properties of the window.

Performance coatings add an even further degree of control to the IGU.

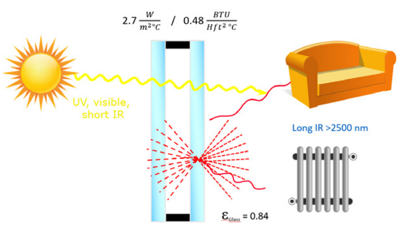
EMISSIVITY

Emissivity of the surface of a material is its effectiveness in emitting energy as thermal radiation. This is an important definition surrounding performance coatings.

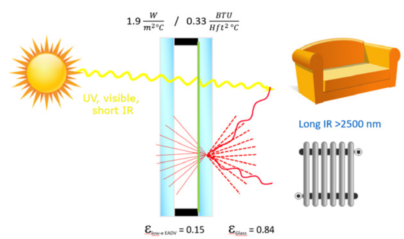
EFFECTS OF COATINGS ON U-VALUE

The following example demonstrates the impact of coatings, coating type and placement.

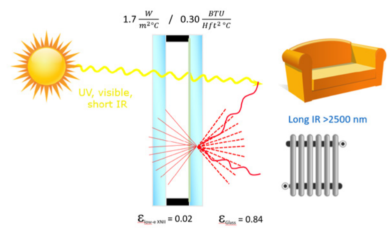
No Coating



Pyrolithic Coating



Low-E Coating

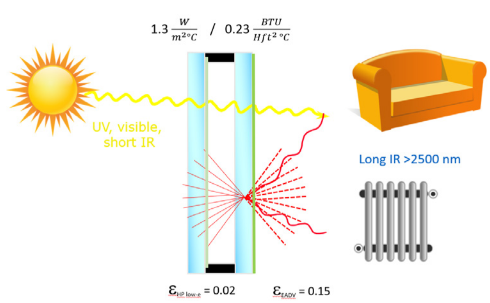


Glass is opaque to long IR (the waves greater than 2500 nm in length) that are emitted by heating devices or by furniture re-emiting long IR. Glass will absorb and re-emit long IR at 84%. The re-emited heat energy is lost equally between the exterior and interior. Long IR retention is 42%

The use of Pyrolithic coating allows only 15% of the long IR to escape to the exterior. Long IR retention is 69% and U-Value improved to 1.9 W / m^2C.

The use of a Low-e coating allows only 2% of the long IR to escape to the exterior. Long IR retention is 82% and U-Vlaue improved to 1.7 W / m^2C.

Low-E Coating & Pyrolithic Coating



A lesser known use of coatings is to use Pyrolithic Coating on Surface 4 and Low-e Coating on Surface 2. This provides the ultimate energy retention, but is difficult to clean and carries a greater risk of condensation. This is a good alternative when argon cannot be specified, such as Aspen.

The use of a Low-e coating allows only 2% of the long IR to escape to the exterior. Long IR retention is 83% and U-Value improved to 1.3 W / m^2C.

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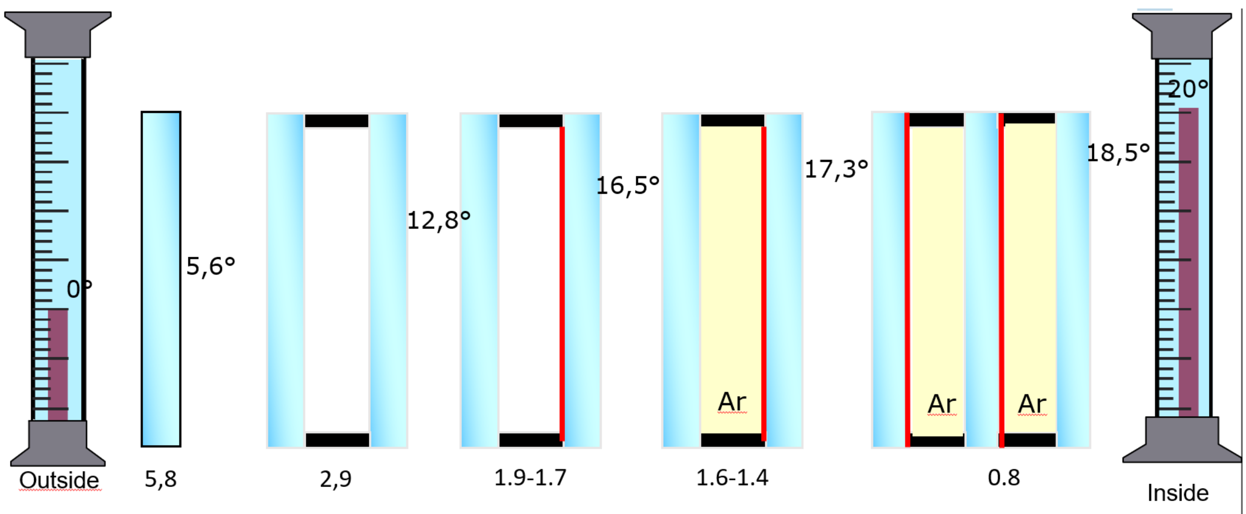
THE EFFECTS OF ARGON

We have established that double or triple glazed units improve thermal efficiency. We have also proven that performance coatings further compound the effectiveness of the glazed units, and improved thermal efficiency.

Adding the inert gas argon into the Insulated Glass Unit's cavity is the third step in providing ultimate thermal performance of an IGU. Argon's heat capacity or thermal conductivity is 33% less than dry air, making it an ideal choice to limit the effects of convection within the cavity.



Going back to the established U-Values, it is evident that the argon can improve a standard double glazed, Low-E coated unit by roughly 17% and if moving to a triple by up to 52%, resulting in almost near identical internal temperature on the glass.

One could sit by a triple glazed, coated unit with argon and not feel a "chill."

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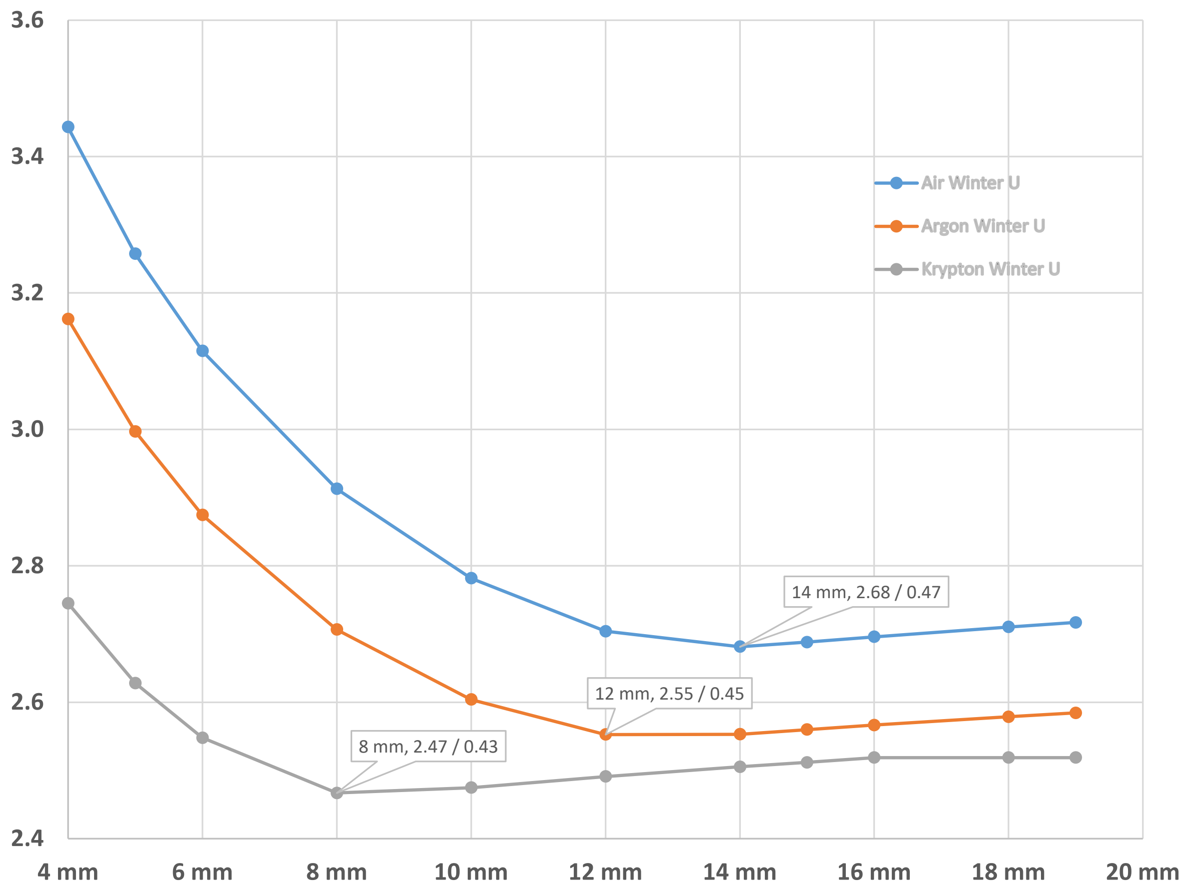
THE EFFECTS OF SPACERS

It is clear that the addition of an inert gas such as argon further increases the efficiency of the window, but the volume of the gas in the cavity must be considered as well. There is an optimal spacer thickness, and thus volume of glass. Both glass thickness and the type of gas used in the cavity are considered.

To use less space is to degrade the U-Value, and to used anymore will not further improve the U-Value.



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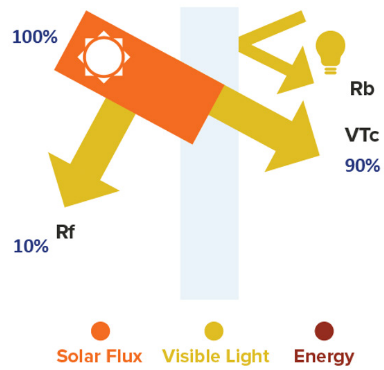
SOLAR CONTROL & GLAZING

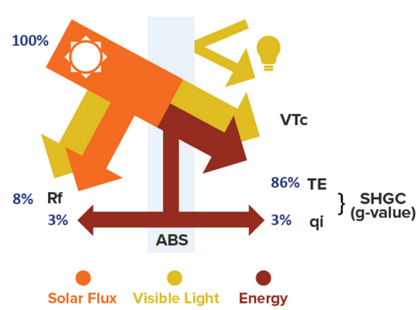
Solar control of glass is a measure of reflection, visible light transmission, and energy transmission of through glass by the sun. These measurements should be used in conjunction, but not dependent on thermal efficiency (U-Values). Instead, think of Solar control as the:

A) Amount of light
B) Amount of energy resulting in solar heat gain (that is the amount of energy entering through to the interior, resulting in re-emitted Long IR, increasing heat.

STANDARD PIECE OF GLASS
A piece of glass with no coating will allow 90% visible light transmission and reflect the other 10%.



In terms of energy, a piece of glass will allow 89% of ultraviolet, visible and short IR energy into the building, while 3% is radiated outward and 8% is reflected. The 89% is the Solar Heat Gain, and would be represented as 0.89.



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COATINGS EFFECT ON SOLAR CONTROL

Performance coatings not only effect the thermal efficiency of the glass, but the light transmission and energetic properties of the glass.

Using the example of Saint-Gobain XTREME 70-33 - Diamant:

```
BERKELEY LAB WINDOW v7.7.1.0 Glazing System Thermal and Optical Properties 12/11/20 10:

ID       : 90
Name     : Saint-Gobain XTREME 70-33 - Diamant
Tilt     : 90.0
Glazings: 2
KEFF     : 0.0437
Width    : 24.700
Uvalue   : 1.35
SHGCc    : 0.29
SC       : [illegible]
Vtc      : 0.71
RHG      : 222.37


Layer Data for Glazing System '90 Saint-Gobain XTREME 70-33 - Diamant'

ID     Name             D(mm) Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2 Keff
------ --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
Outside
 21056FCL XTREME 70-33#  6.0 .300 .445 .545 .777 .061 .059 .000 .840 .018 1.00
       9 Air (10%) / Ar 12.7 SF6:    0%       Ar:    0%                     .023
 11010 DIAMANT 6mm.SGG#  6.0 .889 .079 .079 .909 .082 .082 .000 .837 .837 1.00
Inside


Environmental Conditions: 1 NFRC 100-2010

          Tout   Tin  WndSpd   Wnd Dir    Solar  Tsky  Esky
           (C)   (C)   (m/s)             (W/m2)  (C)
          -----  ----  ------  --------  ------  ----  ----
Uvalue   -18.0  21.0    5.50  Windward     0.0 -18.0  1.00
Solar     32.0  24.0    2.75  Windward   783.0  32.0  1.00

Optical Properties for Glazing System '90 Saint-Gobain XTREME 70-33 - Diamant'

Angle      0     10     20     30     40     50     60     70     80     90 Hemis

Vtc   : 0.710 0.714 0.704 0.692 0.675 0.640 0.560 0.408 0.192 0.000 0.594
Rf    : 0.111 0.104 0.101 0.104 0.116 0.140 0.187 0.293 0.525 0.999 0.170
Rb    : 0.131 0.125 0.124 0.128 0.142 0.173 0.238 0.386 0.660 1.000 0.214

Tsol  : 0.274 0.276 0.272 0.267 0.261 0.247 0.217 0.158 0.075 0.000 0.230
Rf    : 0.462 0.458 0.457 0.458 0.465 0.478 0.503 0.562 0.701 0.999 0.491
Rb    : 0.527 0.524 0.522 0.523 0.528 0.539 0.567 0.634 0.766 1.000 0.555

Abs1  : 0.260 0.263 0.268 0.271 0.270 0.271 0.277 0.277 0.222 0.001 0.266
Abs2  : 0.003 0.003 0.003 0.003 0.003 0.004 0.003 0.003 0.002 0.000 0.003

SHGCc: 0.294 0.296 0.292 0.288 0.281 0.268 0.238 0.179 0.091 0.000 0.250

Tdw-K   :  0.376
Tdw-ISO:   0.556
Tuv     :  0.245



      Temperature Distribution (degrees C)
        Winter          Summer
       Out   In        Out   In
       ----  ----      ----  ----
Lay1 -16.2  15.0       40.8  41.3
Lay2  13.2  13.5       27.7  27.5
```

Compared to non-coated glass visible light transmission is reduced from 90% to 71%, resulting in more habitable environment with less glare and intense light.

Compared to non-coated glass the Solar Heat Gain is reduced from 89% to a whopping 29%, resulting in interior temperatures that fluctuate dramatically less, providing more predictable temperatures and less stress on HVAC systems and increasing the enjoyment of the environment.

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SUMMARY

These are the key takeaways regarding thermal efficiency and solar control of glass.

THERMAL EFFICIENCY

Glass thickness: Thicker glass will reduce thermal loss due to Conduction. Extremely thick glass is the only solution to achieve an appreciable U-Value. Though thicker glass should merit some consideration in thermal efficiency, it should be used to best satisfy size (area) vs. windload considerations.

Glazing: The greater the number of glazed units within an IGU the better the thermal efficiency. This is because dry air is 88% less thermally conductive than glass. Thus, creating a cavity between two pieces of glass vastly improves thermal efficiency.

Single Glazed 6mm - U-Value:	**5.8 W / m²C**
Double Glazed 6mm - U-Value:	**2.7 W / m²C**
Triple Glazed 6mm - U-Value:	**1.8 W / m²C**

Coatings: The addition of coatings to an IGU will reflect long IR (heat energy) back toward the interior.

Double Glazed 6mm - No Coating U-Value:	**2.7 W / m²C**
Double Glazed 6mm - Pyrolithic U-Value:	**1.9 W / m²C**
Double Glazed 6mm - Low-e U-Value:	**1.7 W / m²C**
Double Glazed 6mm - Low-e & Pyrolithic U-Value:	**1.3 W / m²C**

Inert Gas: The third addition of argon gas, further increases the thermal efficiency.

Double Glazed 6mm w/ argon - Low-e U-Value:	**1.4 W / m²C**
Triple Glazed 6mm w/ argon - Low-e U-Value:	**0.8 W / m²C**

Spacer Thickness: Spacer thickness has a dramatic effect of U-Value, but diminishing returns and even negative returns if too large. On a 6mm Double Glazed IGU for example, optimal the optimal thickness is

Double Glazed 6mm w/ air - U-Value:	**14mm | 2.7 W / m²C**
Triple Glazed 6mm w/ argon - U-Value:	**12mm | 2.55 W / m²C**

THERMAL EFFICIENCY CONCLUSION

The thermal efficiency of glass greatly increases based on:

1) Each additional piece of glazed glass.
2) The Coatings applied to the glass, and the number of times. i.e. two coatings on a triple.
3) Using an inert gas to further reduce loss due to convection.
4) Using an optimal spacer thickness for the glass thickness, glazing type, and gas type.

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SUMMARY

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SOLAR CONTROL

Coatings control the visible and energetic properties of the sun on and through the glass. Each manufacturer will specify the coating characteristics through standardized measurements including:

> **SCHG** - The amount of heat gain due to short IR energy. The value is represented from 0 to 1 and can be converted to a percent.
>
> **Vtc** - The amount of visible light transmission. The value is represented from 0 to 1 and can be converted to a percent.
>
> **Rf** - The reflectiveness of the surface of the glass. The value is represented from 0 to 1 and can be converted to a percent.

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