As discussed in document **ST-1C**, heat transfer can occur through radiation (including solar energy absorptance), convection and conductance. This Technical Guidance Document outlines the properties and performance of various glass types with regards to heat transfer, as well as thermal insulation for energy conservation.

U-VALUES

One of the key parameters of interest when considering energy conservation is the U value. Within Europe, for the centre pane of a glazing unit, this is determined in accordance with EN 673 [1]. Emissivity values, which are a key factor within these calculations, are determined in accordance with EN 12898 [2].

A U value is essentially the inverse of the thermal resistance of an element, and is defined as the steady-state density of heat transfer as a rate per degree Kelvin temperature difference between the environmental temperatures on either side.

CALCULATING U VALUES

As per EN 673, the centre pane U value of a glazing configuration is determined from the external and internal heat transfer coefficients (h_e, h_i), and the total heat transfer coefficient for the glazing (h_t), as follows;

$$\frac{1}{U} = \frac{1}{h_e} + \frac{1}{h_t} + \frac{1}{h_i}$$

The external heat transfer coefficient is pre-defined by EN 673 for the purposes of comparative values, as 25 W/m^{2}K, and is considered for glazing in a vertical inclination.

The internal heat transfer coefficient is determined from radiative (h_r) and convective (h_c) heat transfer coefficients, and so can consider low emissivity inner surfaces. The convective heat transfer coefficient is defined as 3.6 W/m^{2}K, and the radiative heat transfer coefficient, as follows;

$$h_r = \frac{4.1 \cdot \varepsilon}{0.837}$$

The total heat transfer coefficient is in turn determined from the heat transfer rate of the glass components and the gas space;

$$\frac{1}{h_t} = \sum_{1}^{N} \frac{1}{h_r + h_g} + \sum_{1}^{M} t_j \cdot r_j$$

Where; h_r Radiative Heat Transfer Coefficient (W/m^2.K)

h_g	Cavity Gas Heat Transfer Coefficient (W/m^2.K)
t	Pane Thickness (m)
r	Pane Resistivity (m.K/W)
N	Number of Cavities
M	Number of Panes

Radiative, conductive and convective heat transfer coefficients are discussed within document **ST-1C**. For soda-lime-silicate glass, the resistivity is taken to be 1.0 m.K/W.

INFLUENCING PARAMETERS

There are several key parameters that will influence the overall glazing centre pane U value, specifically gas types, cavity widths, glass coatings and the number of panes.

CAVITY GAS & WIDTH

Options are available for the cavity gas fill, most commonly Air or Argon in standard units, Krypton in slim units and Xenon in more specialist or demanding applications.

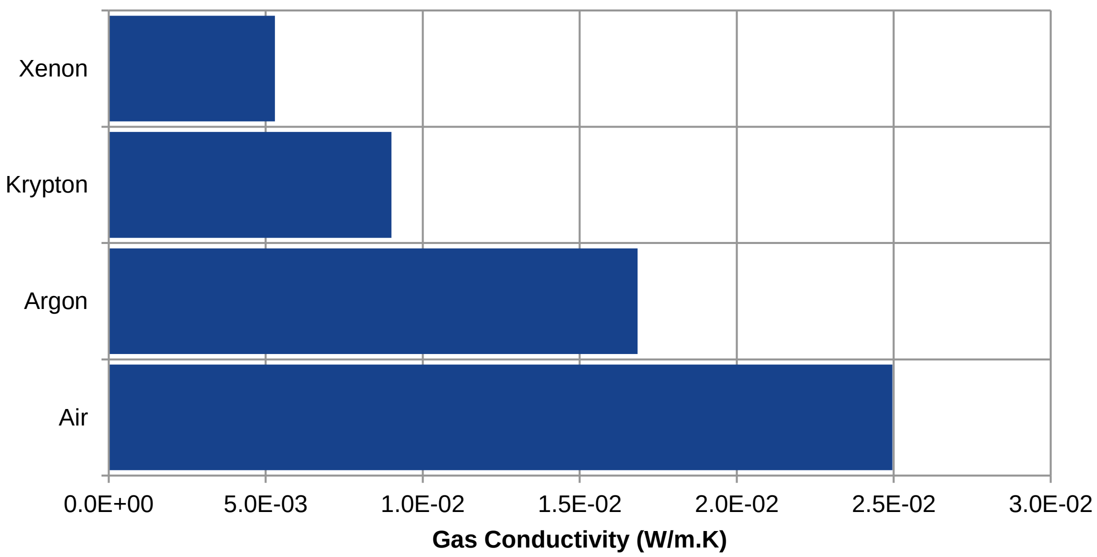

Figure 1 - Gas Conductivity

It should be considered that as the performance of the gas is dependent on cavity width, using Krypton in a 16 mm cavity width unit, for example, brings a negligible benefit over Argon. The optimum cavity width for each gas is shown below for a unit comprising 2 panes of 4 mm float glass with one surface having a 1% emissivity coating.

Table 1 - Optimum Cavity Widths (DGU) for Selected Gas Types

Gas Fill	Air (100%)	Argon (90%)	Krypton (90%)	Xenon (90%)
Optimum Cavity Width (mm)	15.5	14.7	9.7	6.7

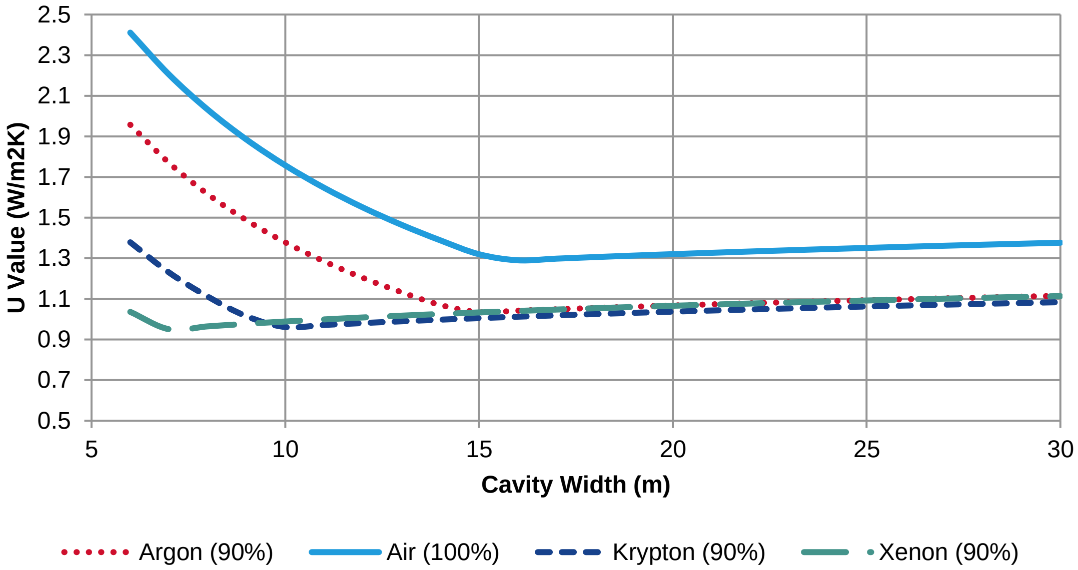

Figure 2 - Cavity Gas Fill Comparison with a 1% Normal Emissivity Coating

SURFACE EMISSIVITY

Lower surface emissivity will reduce the U value. with coatings such as SGG PLANITHERM TOTAL+ and SGG PLANITHERM ONE T offering significantly improved thermal insulation when compared with uncoated glass. The below chart shows the relationship between coating emissivity and U value for a unit with a 16 mm Argon (90%) filled cavity.

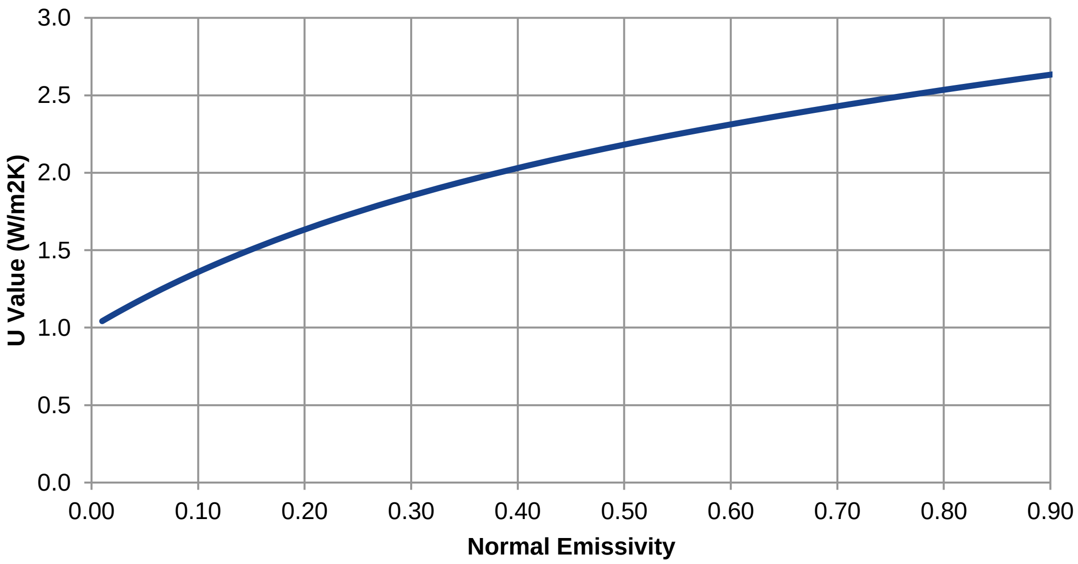

Figure 3 - U Value Comparison with Varying Emissivity

LOW-EMISSIVITY COATINGS ON BOTH SURFACES OF A DOUBLE GLAZED UNIT

When cavity widths are increased, the U value will also increase, and at certain cavity widths. For example, a product that may offer a U value of 1.0 W/m²K with a 16 mm cavity Argon (90%) filled cavity, may only offer 1.1 W/m²K with a 20 mm Argon (90%) filled cavity.

To compensate for this, sometimes using two low-emissivity coatings is suggested. If a 20 mm Argon (90%) filled cavity is considered, with 2 panes of 4 mm float glass, and a single 1% normal emissivity coating is used, the resulting U value would be 1.068 W/m²K, which, with rounding as per EN 673, would be declared as 1.1 W/m²K.

The addition of another 1% normal emissivity coating onto the other cavity facing surface, in the same configuration, would yield a U value of 1.048 W/m²K, which, with rounding as per EN 673, would be declared as 1.0 W/m²K.

Although the rounded difference is 0.1 W/m²K, the actual calculated difference is 0.02 W/m²K, so 20% of what is declared. When considering this as an option, it would be recommended that it be considered alongside the actual expected improvement with regards the modelling of any building performance, as well as the costs associated with an additional low emissivity coated pane. The differences are shown for a range of cavity widths within in Figure 4.

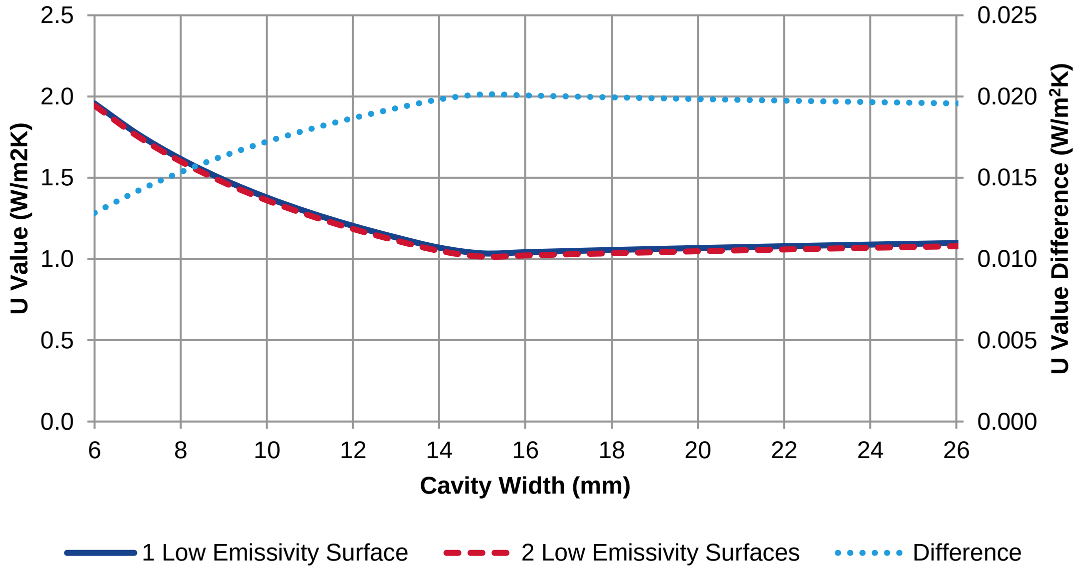

Figure 4 - U Value Improvement with Dual Low Emissivity Coated Surfaces

SURFACE 4 LOW EMISSIVITY COATINGS

Another way of achieving a lower overall U value, is to apply low emissivity coatings to Surface 4, or the innermost surface, of a double glazed unit. As the coating would be exposed to the internal environment, as well as contact during cleaning, it would typically have to be a more durable coating, commonly pyrolitic.

If we considered a unit comprising of two 4 mm panes with a 1% emissivity coating facing an Argon (90%) filled cavity, with either float glass or a 14% emissivity pyrolitic coated glass facing internally, this would achieve a U value of 1.042 W/m²K or 0.945 W/m²K respectively.

However, from a technical and aesthetic perspective, any gains in thermal insulation should be considered against;

- The loss in natural heat gain due to an additional coated pane within the unit,

- The loss in natural heat gain due to the lower solar factor resulting from the requirement to place the 1% emissivity pane outermost to the unit, in a surface 2 position,
- Haze effects common with pyrolitic coatings due to the sputtering of materials onto soft glass.

TRIPLE GLAZING

Triple glazing helps to optimise thermal insulation, and for 16 mm Argon (90%) filled cavities, with 1% emissivity panes, U values as low as 0.5 W/m^2K can be achieved.

As with double glazing, there are optimum cavity widths, depending on the gas type. The optimum cavity width for each gas is shown below for a unit comprising 3 panes of 4 mm float glass with both cavities having a surface with a 1% emissivity coating.

Table 2 - Optimum Cavity Widths (TGU) for Selected Gas Types

Gas Fill	Air (100%)	Argon (90%)	Krypton (90%)	Xenon (90%)
Optimum Cavity Width (mm)	19.6	18.5	12.2	8.5

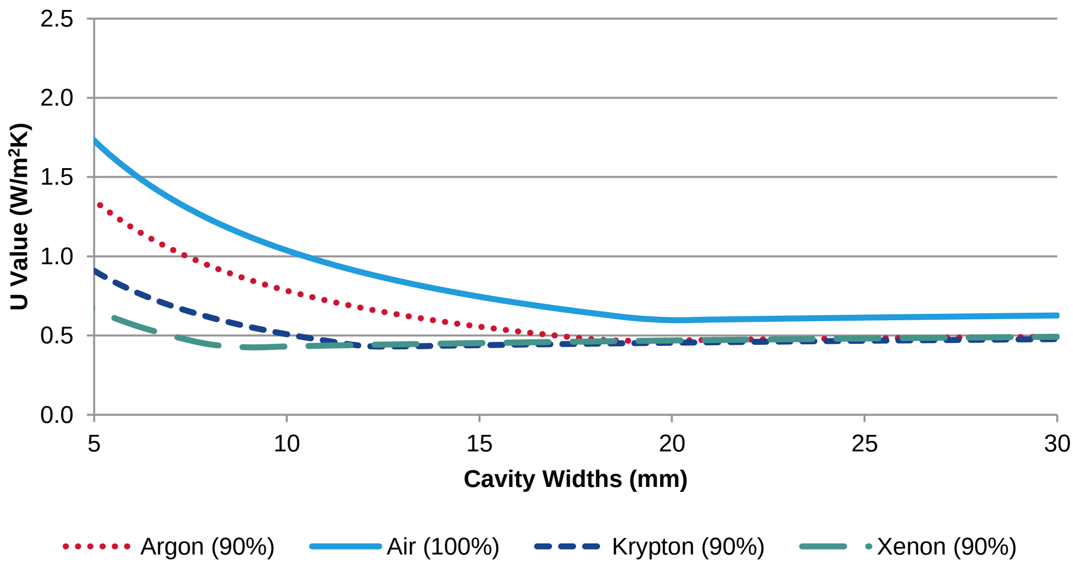

Figure 5 - Cavity Gas Fill Comparison with a 1% Normal Emissivity Coatings

GLAZING CONFIGURATIONS WITH MORE THAN 2 CAVITIES

Theoretically, a glazing configuration could include more than 2 cavities, and so be quadruple glazed, or greater. However, as the number of cavities increases, the improvement in U value decreases. Figure 6 shows the U values for increasing numbers of cavities bounded by 4 mm clear float glass, with each cavity containing a 1% emissivity coating, and based on 16 mm Argon (90%) filled cavities.

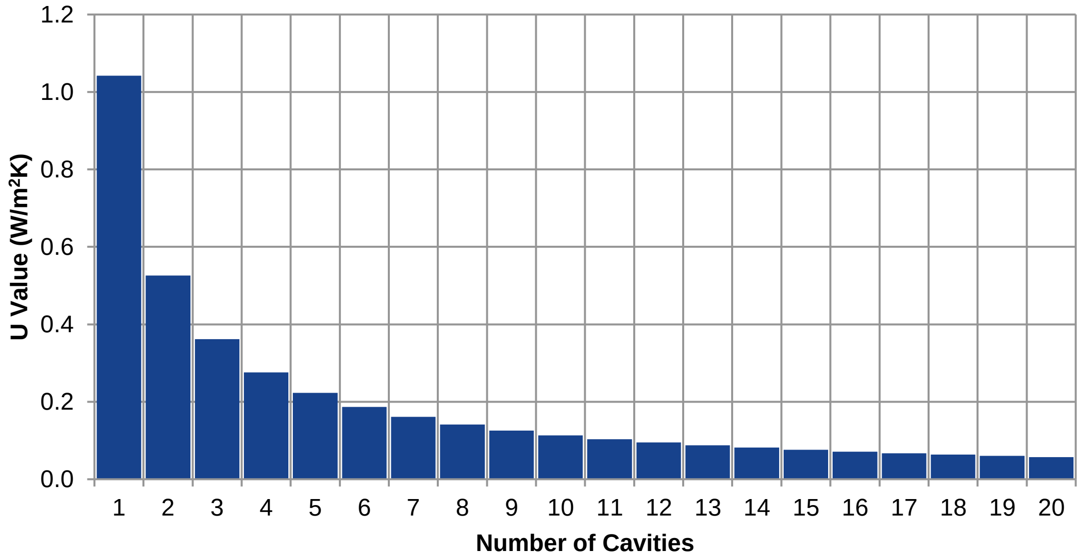

Figure 6 - U Values for Multiple Glazing Cavities

UNCOATED, AIR FILLED UNITS

For interest, a comparison can be made between glazing configurations using no low emissivity coatings, and with 20 mm Air filled cavities, and thermally efficient double and triple glazed configurations. The below shows the U values achieved with uncoated glass, and 20 mm Air filled cavities;

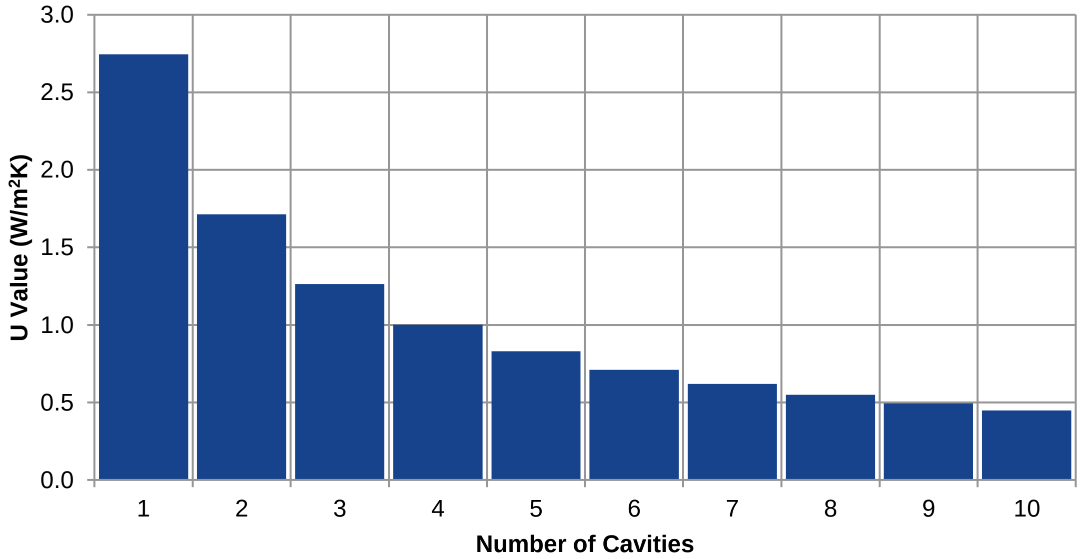

Figure 7 - U Values for 20 mm Air Filled Glazing Cavities with Uncoated Glass

A double glazed configuration based on two panes of 4 mm float glass, one with a 1% normal emissivity coating, and a 16 mm Argon (90%) filled cavity will achieve a U value of 1.0 W/m^{2}K. From Figure 7, in order to achieve this with no coatings and 20 mm Air filled cavities, this would require 4 cavities, so 5 panes of glass. Or, a quintuple glazed unit.

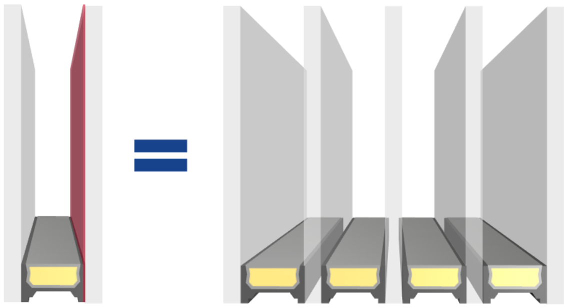

Figure 8 - Equivalent DGU Coated to IGU with No Coatings

A triple glazed configuration based on three panes of 4 mm float glass with both cavities having a surface with a 1% emissivity coating, and being 16 mm and Argon (90%) filled, will achieve a U value of 0.5 W/m^{2}K. From Figure 7, in order to achieve this with no coatings and 20 mm Air filled cavities, this would require 9 cavities, so 10 panes of glass. Or, a decuple glazed unit.

Figure 9 - Equivalent TGU Coated to IGU with No Coatings

REFERENCES

[1] European Committee for Standardization, EN 673:2011 - Glass in building. Determination of thermal transmittance (U value). Calculation method, CEN, 2011.

[2] European Committee for Standardization, EN 12898:2001 - Glass in building. Determination of the emissivity, CEN, 2001.