2009-03-06, Björn Karlsson, University of Lund

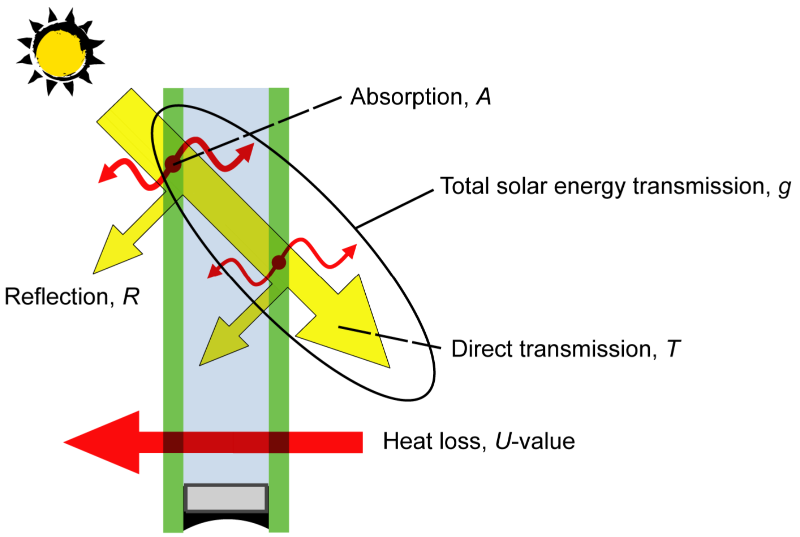
Energy advantage for fully reversible windows

Abstract
Solar radiation entering the room consists of a part which is directly transmitted through the glass and a secondary part which is absorbed in the glasses and released inward. The solar energy absorbed in the outer glass is delivered to a large extent externally, while the solar energy absorbed in the inner glass is primarily delivered into the room. This means that the g-value depends on in which order the glass panes are placed. The total solar energy transmission, g-value, for a window with an absorbent glass can vary by up to 0.30 units by turning the window. The maximum g-value is obtained when the absorbent glass acts as the inner glass. This effect can be used to reduce cooling needs for well insulated windows during the summer and reduce heating costs for windows equipped with solar control glass during the winter.

The report shows how a well insulated window with relatively high LT (light transmission) lowers the g-value by 0.21 during the summer by turning the window. The g-value of the window varies between 0.52 and 0.32. This means that the cooling needs in summer decreases by about 70 kWh per m² glass area.

A solar control glass equipped window with a low U-value and LT achieves 0.26 units higher g-value during the winter by turning the window. The windows g-value varies between 0.16 and 0.43. This means that the heating demand in winter is reduced by about 70 kWh per m² glass area.

Parameters to characterize the window's energy performance.
Figure 1 illustrates the parameters that define the window's properties. Transmittance factor T indicates the proportion of incoming solar radiation, which is directly transmitted into the room. T_{vis} indicates transmittances factor of visible light weighted by the eye sensitivity curve. The Absorptance factor A indicates the proportion of incoming solar radiant heat that is absorbed into the glasses. The g-value indicates the sum of direct solar energy transmission plus absorbed radiation emitted to the room. The U-value provides a measure of the window's thermal insulating capacity. The heat balance of a window can be described as absorbed solar radiation reduced with heat loss through the window:



$P = g * I - U * (T_{room} - T_{ambient})$

Figur 1. T, g, T_{vis} och U are the parameters to characterize the window's energy performance.

The g-value

Solar energy entering the room consists of a part directly transmitted through the glass and a secondary part which is absorbed into the glasses and released inward. Figure 2 shows how some of the radiation is absorbed and heats the glass. This heat will be partly released inside and partly outside.
The g-value is defined as follows:

$$g = \frac{(\textit{Direct Transmittance} + \textit{Trancemittance absorbed in the glass and released to room as heat})}{(\textit{Solar radiation on the window})}$$

The direct transmittances factors T_{sun} and T_{vis} and U-value are independent of the order in which the glasses are placed. The solar energy absorbed in the outer glass is to a large extent released externally, while the solar energy absorbed in the inner glass is primarily released internally. This means that the g-value depends on the order in which the glass panes are placed. This effect is exploited in the turnable window.

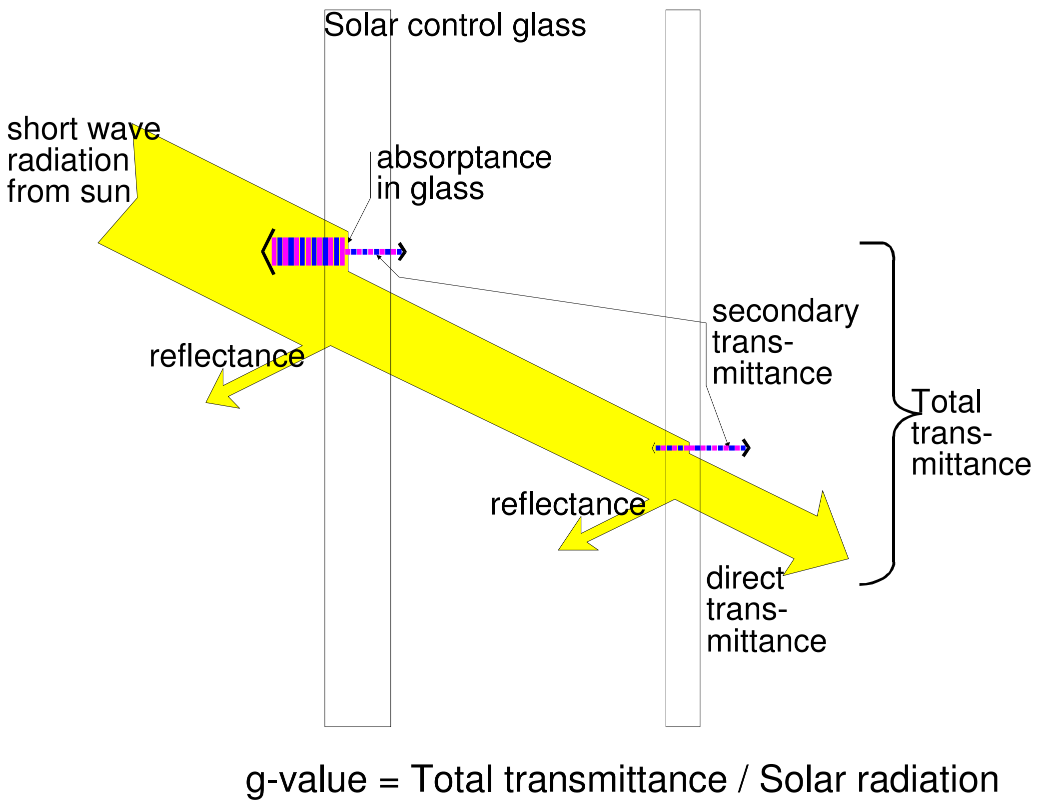


Figure 2. The total amount of solar energy which is delivered to the room is the sum of direct tranmitted solar radiation and solar radiation that heats up the glass by absorbtance and is delivered to the room as heat.

Figure 3 shows the g-values for two windows, which consists of a non-absorbent and a highly absorbing glass. The g-value to be significantly higher for the window that has the highly absorbing glass as the inner glass.

A solar control window should have the absorbent glass as exterior glass, while a window that utilizes solar energy for heating should position the absorbing glass as inner glass.

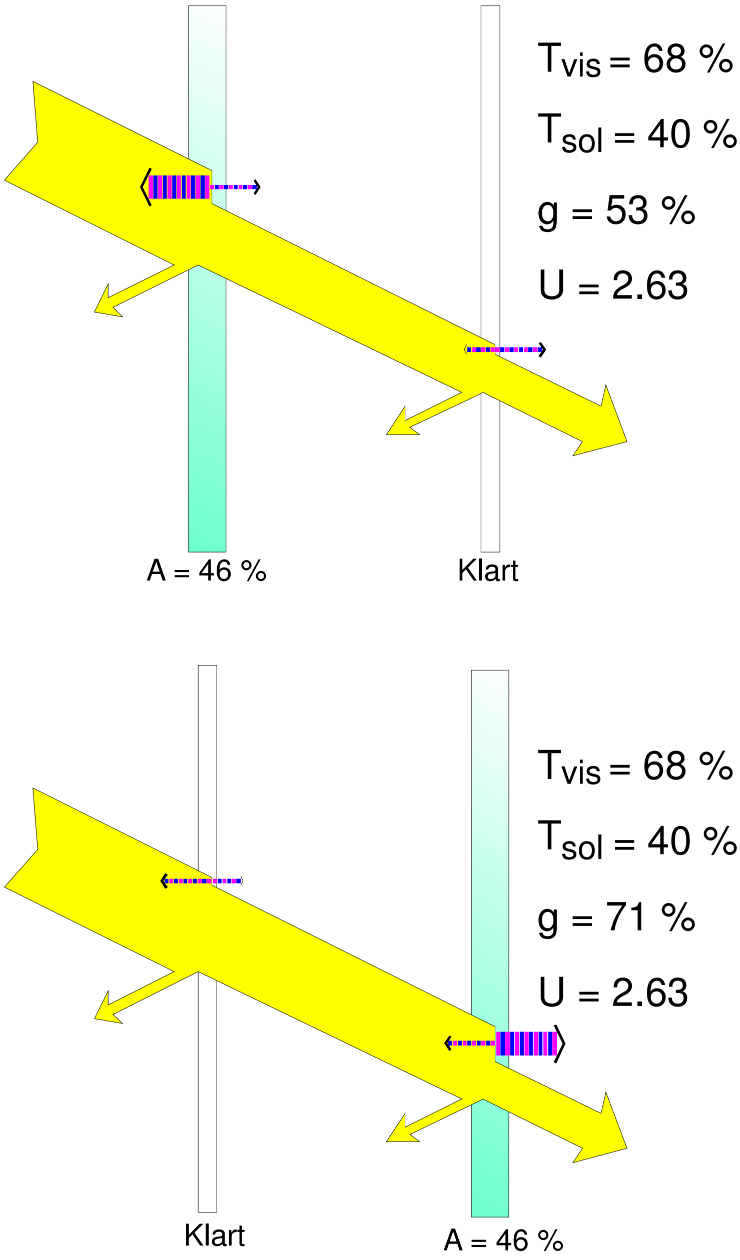


Figure 3.
a) A window consisting of an absorbent outer glass and a non-absorbent inner glass. This is referred to in the report as a summer mode.
b) A window consisting of a non-absorbent outer glass and an absorbent inner glass. This is referred to in the report as a winter mode
(The glasses in a and b are identical but arranged in reverse order)

The positioning of the glass panes has no effect on the direct transmittance of visible light T_{vis} and solar energy T_{sun}. Heat loss coefficient U is also the same for the winter mode and summer mode.

A large part of solar radiation absorbed in the inner glass is released into the room. This means that the window b) with absorbent inner glass has g-value = 71%, while the window a) with absorbent outer glass has g-value of 53%.

Reversing an insulated glass unit to reduce cooling needs during summer.

An energy-saving windows combines a low U-value with a relatively high g-value. This is accomplished by using glass that is coated with low emissivity films. These films reduce the heat losses which consists of long wave heat radiation.

An energy efficient window with the following 3-glass specification has been built:
Outside: PN-Optitherm(S3)4mm-15Ar-Clear4mm-15Ar-OptifloatGreen6mm: Inside

PN-Optitherm-S3: A 4mm glass with a silver-based low emissivity layer.
Ar15: A 15mm wide gap filled with 90% Argon gas.
Clear 4mm: A 4mm clear standard glass.
Optifloat Green: A 6mm glass with strong absorptance in the infrared wavelength range, ie the part that the eye can not perceive.

This window is designed in a conventional manner with the exception that the usual inner glass has been replaced by an absorbent glass.

This window has the following characteristics of the glazed part:

Table 1. Parameters for Optitherm Energy Windows in winter mode

U-value	***Tvis***	***Tsun***	***g-value***
0.95 (W / m^2 K)	0,604	0,246	0,532

The Swedish Energy Agency labels windows in energy classes A to G. Class A means that the U-value for the entire window including the frame is 0.9 W / m² K. Class G means that the U-value for the entire window including the frame is 1.5 W / m²;K. They rated as the windows are recommended to have T_{vis} exceeding 0.62 and g-value in excess of 0.52. This means that a window according to Table 1 should be given a classification of Class B or C depending on the characteristics of the frame and sash.

Energy simulations for this window has been completed with the calculation programmeme Parasol. An annual energy balance for a south facing window in a room in Stockholm has been estimated. The programmeme simulates the energy balance in a room with a floor area 9m2 and ceiling height of 240 cm. The room's outer wall area is 7.2 m2. The other walls are interior walls and assumed to have no heat loss. A window with the glazed area of 1 m2 is intalled in the outer wall. Relationship between window area and floor area is 0.11. Room temperature is allowed to vary between 20° and 25°. This means that heat is added when the temperature is below 20° and cooling is added when the temperature exceed 25°. The in the room developed energy from appliances and people is assumed to be 5 Wm^2. Ventilation flow is 3 litres/s, equivalent to a 50% turnover per hour. No recovery of the heat content of the outgoing air is included in the simulations.

For the simulations the window was specified according to Table 1. The programme calculates the window U-value, g-value and T_{sun}. The visible transmittance T_{vis} were obtained from calculations carried out by Pilkington.

High thermal insulating windows are built to minimize heat loss and maximize the benefits of solar radiation during the heating season. However, this can lead to excessive solar heat transmission in need of solar control in the summer period. This effect can be countered by the window turned from winter to summer mode so that the absorbent glass becomes the outside glass. It reduces the window g-value and the total transmittance of solar energy. The parameters of the window in summer mode is shown in Table 2.

Table 2. Parameters for Optitherm Energy Windows in summer mode

U-value	***T-vis***	***T-sun***	***g-value***
0.95 (W / m^2, K)	0,604	0,246	0:32

g-value is reduced 0:53 to 0:32. Δg =- 0:21

Figure 4 shows the results of simulations of cooling in the window installed in the summer and the winter mode position. The figure shows (kWh/month) that the cooling load is reduced when the absorbent glass sits in the outer glass pane and has a lower g-value.

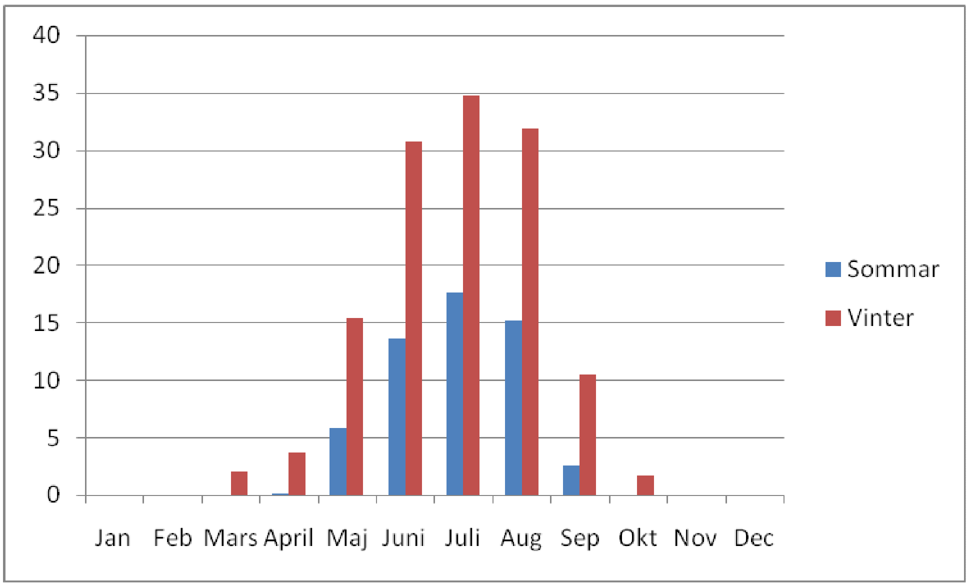


Figure 4. Simulated cooling requirements of a window according to Table 1 in winter mode with the absorbing glass as the inner glass and in Table 2 in summer mode with the absorbing glass as the outer glass. The result is expressed in kWh per square meter of window area.

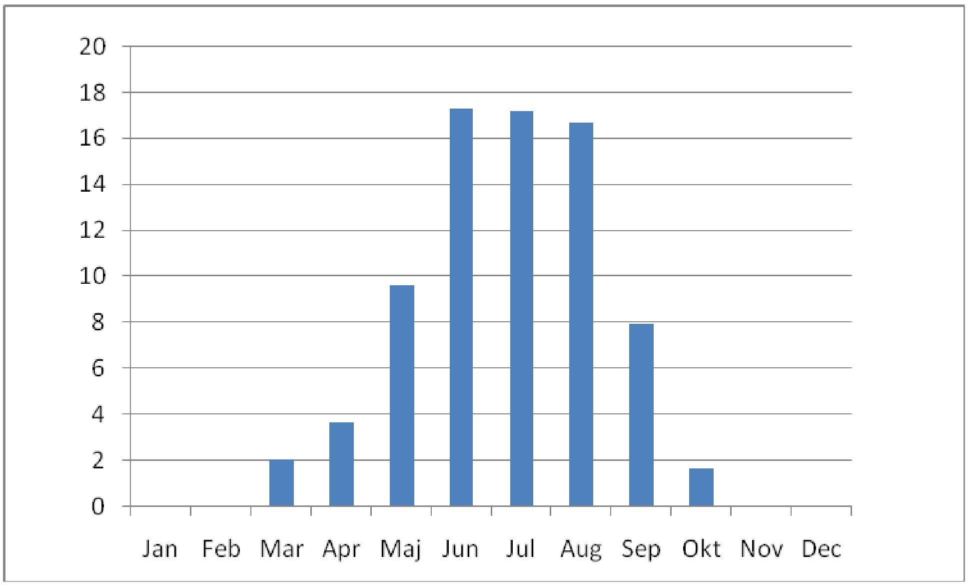


Figure 5. Reduced cooling requirements of a window in summer mode, according to Table 1 compared to winter mode. The result is expressed in kWh/m² of window area.

Figure 5 shows the reduced cooling needs for the window in table1 in summer mode, in comparison with the window in winter mode. The figure shows the difference between winter- and summer position in Figure 4.

Conclusion: If the window is in summer mode during the period from May to September it reduces cooling needs by about 70 kWh/m² window area. It does not effect heating requirements if the window is in winter mode during the period from October to April.

Turning a solar control glass equipped window, to reduce heating requirements during the winter period.

A solar control glass window should combine a low g-value with a relatively low U-value. This is accomplished by using glass with low emissive coating. These coatings simultaneously lower solar heat transmittance and U-value. This means that modern solar control glass windows reduce both excessive solar heat and heat losses.

A solar control glass window with the following specification has been built:
PN_Suncool 30/17: Outside 6C(30)-15Ar -4-15Ar-S(3)4 Inside

PN_Suncool 30/17*: A coated solar control glass with the visible transmittance 0,30.*
15Ar*:* A 15mm wide gap filled with 90% Argon.
4: *Optifloat Clear a* 4mm standard float glass.
Optitherm-S3: A 4mm glass with a silver-based low emissive coating.

This window is designed in a conventional manner. The dual low emitting coatings provide the window with low: direct solar transmittance T_{sun}, total sun transmittance - g and a very low U-value.

This window has the following characteristics of the glazed part:

Table 3. Parameters for Suncool 30/17 window in summer mode

U-value	***T-vis***	***T-sun***	***g-value***
0.60 (W / m^2 K)	0:27	0:12	0:16

Energy simulations for this window have been completed with the programme Parasol. The simulations show that the window is an effective solar control window. The low U-value provides enhanced thermal insulation. The low g-value means that the solar radiation during the heating season can not be used to reduce heating requirements.

Simulations have been carried out to analyze how much energy for heating that can be saved by turning the window from summer to winter mode during the heating season. Table 4 shows the calculated parameters of the window in winter mode. The g-value increases with 0.26.

Table 4. Parameters for Sun Cool Brilliant windows in winter mode

U-value	***T-vis***	***T-sun***	***g-value***
0.60 (W / m^2, K)	0,604	0:12	0,425

g-value increased from 0.16 to 0.425. $\Delta g = +0.26$.

The results of energy simulations are shown in Figure 6. The higher g-value of the window in winter mode means that the need for additional energy for heating is reduced.

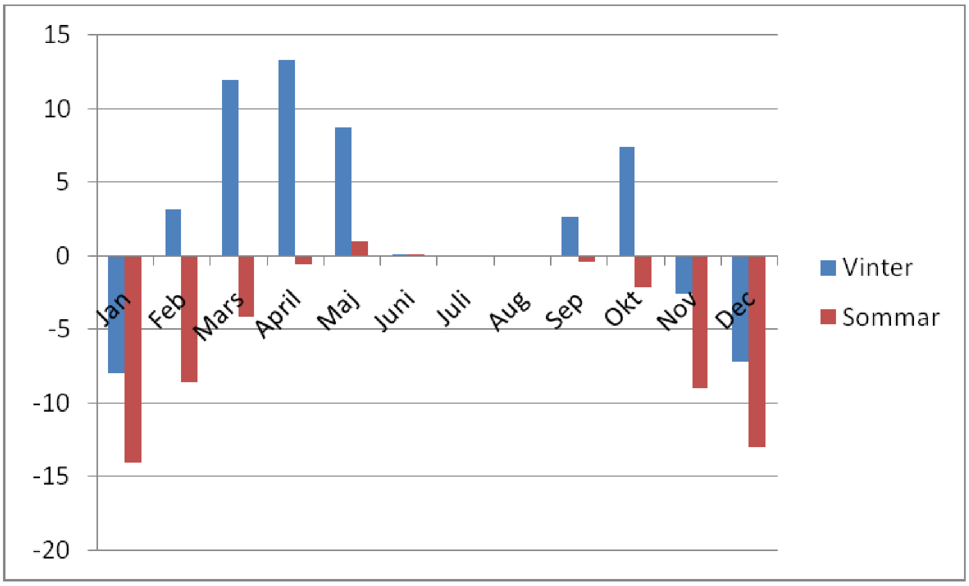


Figure 6. Simulated heat contribution from a window in Table 3 in summer mode with the absorbing glass as the outer glass and in Table 4 in winter mode with the absorbing glass as the inner glass. The result is given in relation to the window, replaced by a wall. Positive value means that the window gives a contribution to the heating requirements. Negative value means that the window creates a heating load.

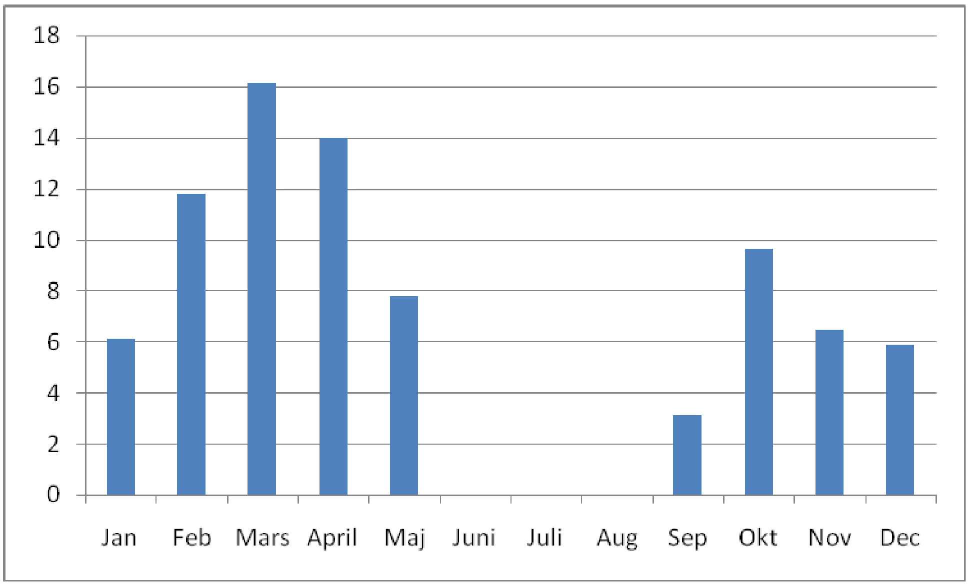


Figure 7. Reduced heating of a window according to Table 3 in winter mode in comparison to summer mode. The result is expressed in kWh per square meter of window area.

Figure 6 shows the reduced cooling needs for the window in tabell3 in winter mode, in comparison with the window in summer mode. The figure shows the difference between winter and summer location in Figure 6.

Conclusion: If the window is turned into winter mode during the period October-April heating needs will be reduced by about 70 kWh per square meter of window area. This will Not effect your cooling needs if the window is in summer mode during the period from May to September.

Conclusions.

The total solar heat transmittance, ie g-value, for a window with an absorbent glass can vary up to 0.30 in a turnable window. The maximum g-value is obtained when the absorbent glass acts as the inner glass. This effect can be used to reduce cooling needs for an energy window during the summer and reduce heating requirements of solar control glass windows during the winter.

A window with high thermal insulation and a relatively high light transmission –$T_{vis,}$ can reduce the g-value by 0.21 during the summer by turning the window. The g-value of the window varies between 0.52 and 0.32. This means that the annual cooling demand decreases by about 70 kWh per square meter window.

A solar contol glass window with a low U-value and T_{vis} achieves a 0.26 higher g-value during the summer through turning the window. The g-value of the window varies between 0.16 and 0.43. This means that the annual heating requirement is reduced by about 70 kWh per square meter window.