greenTEG

gSKIN® application note: U-value Glass Measurement

Introduction

Windows are responsible for 10 to 20% of the heat losses in a building during winter time (Axel-Lute, 2009). The thermal performance of a given window glass can vary a lot. U-value may range from 5 W/m²K for single glazed windows to 0.7 W/m²K for triple glazed windows (VFF, 2014). This means that a lot of energy and costs can be saved by replacing a poorly insulated and outdated window with a window according to the latest standards. However, the exact thermal performance of the glass within a window is hard to examine which makes analysing the cost-effectiveness of replacement difficult. In-situ measurement data can therefore be of great value. As with other building envelopes, reliable in-situ measurements of glass can be conducted using heat flux meters. However, as the thermal behaviour of glass differs from that of walls, a different measurement approach is required.

The use of heat flux sensors for U-value measurements is a reliable method to gain U-values as shown by several case study conducted by scientists around the world, including ones from ETH Zurich and greenTEG R&D. In this case study we show the U-value measurement of a double glazed window in an apartment building with a gSKIN heat flux sensor. The measurement had been conducted during night to omit the influence of day light radiations, according to the guidelines for glass measurements provided in ISO 9869. To analyse the effect of daylight on the U-Value, an additional measurement was made during daytime.

The goal of this case study is to obtain insights in the thermal behaviour of glass and the influence of this behaviour on heat flux measurements. Furthermore, it shows how the U-value relates to the value expected after visual inspection and how much energy can be saved by replacing a window in this particular case.

Measured object

The measured window is part of an apartment building from the 1990s and its width is 50 cm and the height is 90 cm. The window is located at the south side of the building. It is a double glazed window with a PVC frame. A metal roll-down shutter is placed 10 cm from the window on the outside. This exterior window shutter can be (partly) closed during the night or day to control the amount of light entering the room. Since these shutters are always down, either open or closed, they are included in the system which is measured. The apartment has a total of 8 m² of window glass facing the outside. The apartment building has not been renovated yet and the observed window has not been replaced since the construction.

Measurement set up

The set-up is described in ISO 9869, whereas heat flux sensor is attached to the inside of the window and he inside temperature sensor is placed next to it, approximately 3-5 cm from the window surface. The outside temperature is placed directly on the other side of the window, also with a distance of 3-5 cm towards the window surface.

The night measurements were all started a couple of hours after sunset and stopped early in the morning (to be in line with ISO 9869). The third measurement was stopped right after sunset but this did not have any influence on the measurement outcome. The day measurement has been started in the morning and stopped at the beginning of the evening before sunset. During the measurement there was no activity in the room. The measurements were evaluated with the greenTEG Software (V1.00.03).

Figure 1: Measurement set-up: Window with metal exterior shutters; Heat flux sensor with 2 temperature sensors, one inside and one outside, both roughly 2 cm away from the glass.

Measurement evaluation

Night measurement

Results of the three night measurements are shown in the following figure. The three graphs include the heat flux, the inside temperature, the outside temperature and the U-value. All parameters are relatively constant in all three measurement.

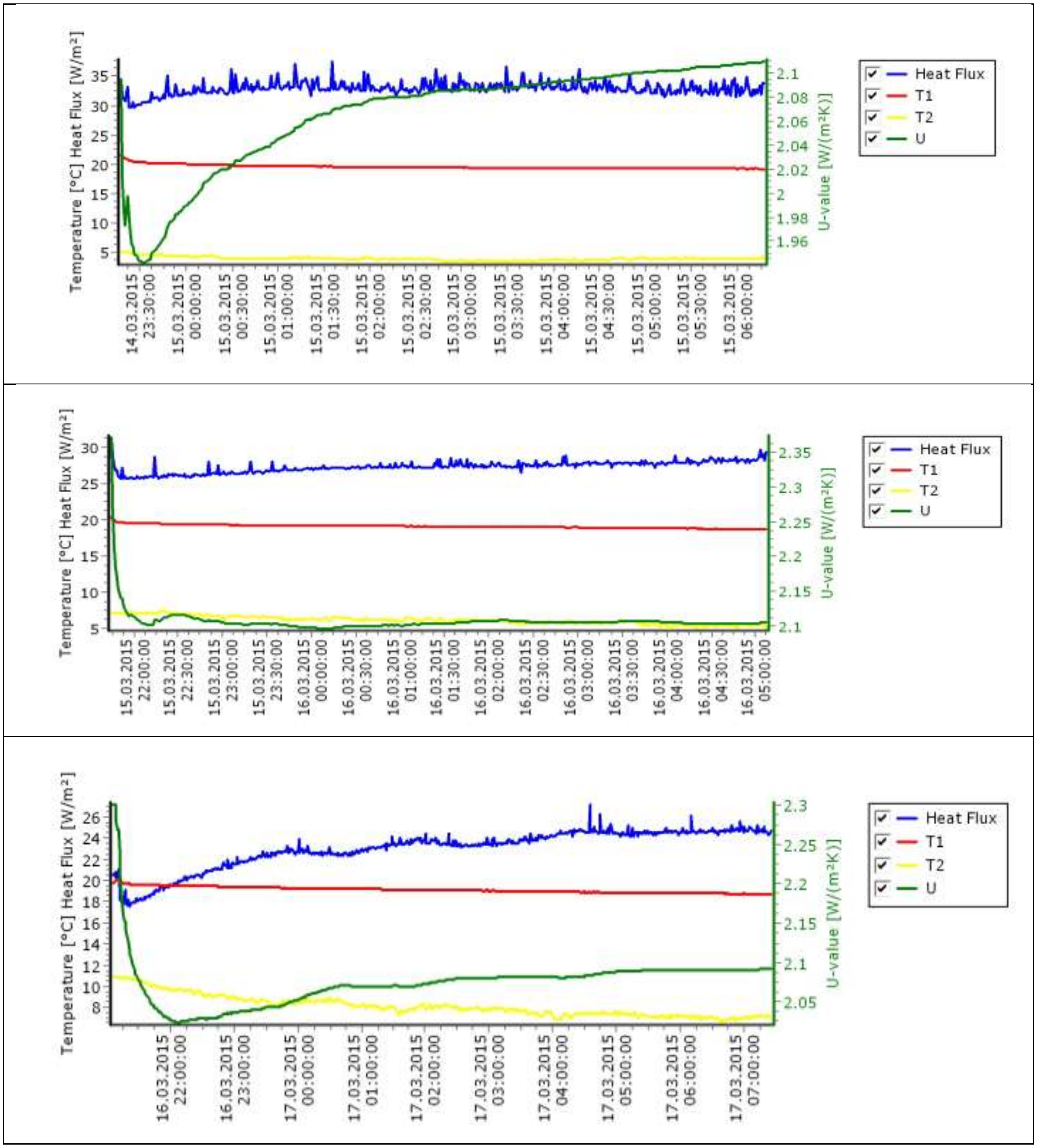

Figure 2: Results of the 3 different night measurements, difference < 5%, in line with ISO 9869 (Report on basis of greenTEG Software v1.00.03, 2015)

The following table shows the U-value of all individual night measurements including the standard deviation over its measurement time. An average U-value and standard deviation is provided based on the three measurements.

Table 1: Results of the 3 different night measurements.

	U-value (W/m².K)	Std. Dev.
1st night measurement	2.11	4.4%
2nd night measurement	2.10	1.7%
3rd night measurement	2.09	3.2%
Average	2.10	3.1%

The window measurements conducted during three subsequent nights have led to very similar U-values differing between 2.09 and 2.11 W/m²K. This is a difference of less than 1% which means that the criteria stated in ISO 9869, a maximum difference of 5%, are easily met. Hence these glass measurements are in line with ISO 9869. The fluctuation of the derived U-value during each measurement is very limited. The average standard deviation during the measurements is only 3,1%. Also, a stable value is reached in an early stage as can be seen in figure 2. This indicates that a measurement time of only a few hours provides already a reliable U-value.

Day measurement

The following figure shows the results of the day measurements. Strong fluctuations can be seen in the heat flux, outside temperature and U-value.

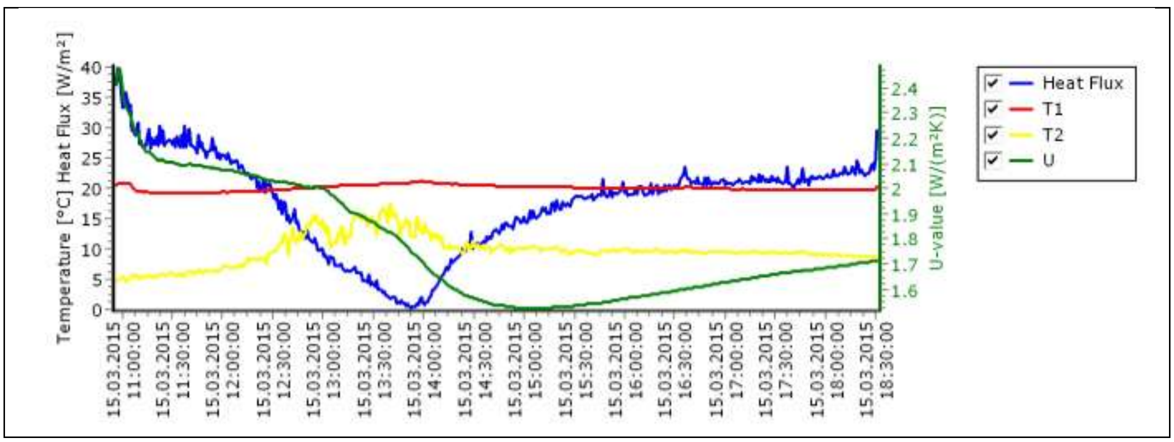

Figure 3: Results of the day measurement, incorrect U-value due to solar radiation (Report on basis of greenTEG Software v1.00.03, 2015)

In the following table the U-value of the day measurement and the standard deviation are stated and compared with the average of the night measurements.

Table 2: results of the night and day measurements.

	U-value (W/m².K)	Std. Dev.
Day measurement	1.71	22.1%
Average night measurements	2.10	3.1%

The daytime measurement deviate significantly from the other 3 measurements and has a high standard deviation. This has to do with the influence of the solar transmittance. The graph in fig. 3 clearly shows the impact of the sun. The day started cloudy with no sunshine and the measured values are around 30 W/m^2. However, around 12.00 the sun breaks through which causes the measured heat flux to drop to around 0 W/m^2. The heat radiation going from the inside to the outside due to the temperature difference is now completely compensated by the solar heat transmittance. After 14:00 clouds were blocking the solar radiation again and the measured heat flux was moving slowly to a value of 25 W/m^2 again.

To summarize, with a daytime measurement one cannot only measure the heat losses due to heat radiation but also the heat gains due to solar radiation. Therefore, daytime measurements might be valuable if the complete thermal behaviour of a window has to be analysed. However, for an accurate and reliable U-value measurement according to ISO 9869 only a night measurement as is described above should be conducted.

Heat cost saving calculation

Taking into account the known characteristics of the window and the standards of the time of installation (1990s) a U-value between 1.7 and 2.8 W/m^{2}K could be expected. This is a very wide range which does not allow an accurate energy efficiency or costs calculation. Due to the in-situ U-value measurements, exact data is now available to calculate the energy and cost savings that could be gained by replacing the glass. Note that these calculations do not include the frame and therefore not represent the energy and cost savings for the whole window. The U-value of the frame can be measurement by the gSKIN heat flux sensors as well.

The average U-value over the three nights is 2.10 W/m^{2}K as shown in table 1. This means that the U-value can be improved significantly by placement of either the best insulating double pane glass (1.1 W/m^{2}K) or triple pane glass[a] (0.7 W/m^{2}K)

In table 2 the current reference situation is compared to the situation in which the current glass is replaced for double or triple glass. In order to calculate the heat losses the average number of heat days of the last two years in the north of Switzerland (weather station Zürich-Kloten) are taken into account. For calculating the cost savings a heating price of € 0,10/kWh is taken into account. Note that the cost savings shown in table 3 are based on several assumptions and therefore only an indication of the actual savings in this specific case. The exact replacement costs depend on the type of window frame and other specific circumstances. The replacement costs stated in table 3 are an indication of the total costs including the labour costs. The payback time is calculated by dividing the replacement costs by the cost savings.

Table 3: energy and cost comparison different window types

	U-value (W/m^{2}K)	Heat loss[1] (kWh/year m^2)	Cost Savings (€/year m^2)	Replacement costs[2] (€/m^2)	Payback time (years)
m^2 glass	2.1	174	-	-	-
m^2 double gl.	1.1	91	~ € 8,-	€ 120,00	~ 14
m^2 triple gl.	0.7	58	~ € 12,-	€ 160,00	~ 14

[1] Data degree days: Location: Zürich-Kloten; Base temperature: 19 °C; www.degreedays.net
[2] Indication of costs including labour costs; Source: www.dubbelglas-weetjes.nl/hr-glas/driedubbel-glas/

[a] U-value measurements of triple pane glass with known thermal properties have been conducted for verification. The results of these measurements came close to the U-value data provided by the manufacturer. E.g. for a triple pane glass of BS Fenster with an official U-value of 0,6 W/m^{2}K, values were measured ranging between 0,63 and 0,68 W/m^{2}K. For details, contact us directly at info@greenteg.com.

The payback time of the replacement of the current glass for double or triple glass is around 14 years in both cases. This is a long time compared to other methods to reduce energy use in buildings (e,g, lighting). However, since the life span of a window is very long, the investment will pay itself back. In addition to the energy and cost perspective of replacing the windows, other factors might also be considered in the decision making process. Other reasons include for example noise reduction, prevention of condensation, the reduction of cold radiation near the window and sustainability awareness. All these factors should be taken into account when considering double or triple glass. Noise nuisance is an issue in this specific building block and might be a reason for replacement. Due to the described measurements, the data is now available to estimate the costs for double/triple glass which would lead to energy costs savings and other benefits such as noise reduction. In this case would a replacement of all the outdated double glass in the apartment (8 m^2) for high quality double glass requires an investment of around € 1000,- (8 x €120,-) and would lead to energy savings of roughly €64,- (8 x €8,-) per year. Based on this information the building owner can make an informed decision about a replacement of the windows.

Guidelines for set-up

Performing a U-value measurement of a window using a U-value KIT is very simple. For the main part the instruction described in the instruction manual can be followed. However, a few points should be taken into account while performing glass measurement.

- Reliable U-values can only be obtained if the measurement is conducted after sunset and stopped before sunrise. If it is not practical to set up the measurement in the evening, the timer function can be used to postpone the start of the measurement for several hours. This allows one to set up the measurement in the afternoon. Alternatively, in the csv-file data points obtained during daytime can be removed. This makes it possible to only analyse the data of a few night hours.
- Artificial light has also a large impact on the outcome of a window measurement. For reliable results it is therefore crucial that all lights in the room are switched off during the whole measurement time.

Conclusion

The U-value KIT can be very well used to perform precise in-situ U-value measurements. Measurements conducted during the night under stable conditions show reliable values already after a few hours. Daytime measurements are very much influenced by (indirect) solar radiation and do not provide a reliable U-value. Measuring in-situ U-values of glass can be valuable as the range of thermal characteristics of glass can vary broadly while the exact characteristics of installed glass are not always known. Gaining exact data on U-values for glass allows a precise cost-benefit analysis for window replacing.

References

Axel-Lute, M. 2009; Three steps to super-efficient windows; Green America, retrieved at: April 2, 2015 from http://www.greenamerica.org/livinggreen/windows.cfm

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