U-Value Measurement for Building Standard Verification

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Introduction

In Switzerland the so called *MINERGIE Standard* certifies buildings which fulfill very high energy-efficiency requirements. To reach the *MINERGIE Standard* a building must have a U-value of 0.15 W/(m^{2}K) or below. This high standard is often met by using high-tech insulation materials which are expensive and need to be installed properly in order to take full effect. Unfortunately, this is not always the case and sometimes building contractors even use cheaper insulation materials than claimed. As a result, the required thermal insulation standard is not reached. In such cases it is difficult to prove sub-standard materials, without taking (drilled) core samples of the wall. The house presented in this study was suspected to have low quality

Figure 1 New constructed building at which the U-values had to be measured.

insulation material built in, because the construction firm went bankrupt and no detailed plans of the wall constructions were available. The local township insisted on a verification of the *MINERGIE Standard*, because the house was built in a commercial zone. Reliable estimations could not be performed due to the missing documentation, and core drillings would have damaged the new building. The *MINERGIE Standard* authority therefore commissioned a local building physicist and greenTEG to measure the U-value of various building elements. Because the greenTEG measurement device uses a highly sensitive heat flux sensor, it allows for accurate measurements even when having very low heat fluxes (e.g. high thermal insulation).

Description of the building and the measurement setup

The new building which had to be certified can be seen in figure 1. In total, the U-values of five building elements were required: roof, outer wall and at three different points in a side room. For the measurements the gSKIN U-Value Kit was used which allows assessing the U-value in accordance with ISO 9869 through a heat flux and two temperature measurements. Furthermore, at one point the wireless gO Measurement-System[1] was used which uses the same U-value measurement technology, but allows for wireless measurements.

Measurement at the outer wall

For the U-value measurements at the outer wall three measurements with the gSKIN U-Value Kit have been conducted right next to each other and a fourth one with the gO Measurement-System (gOMS) (see figure 2). All measurements were performed from the 08.12.2017 to the 11.12.2017.

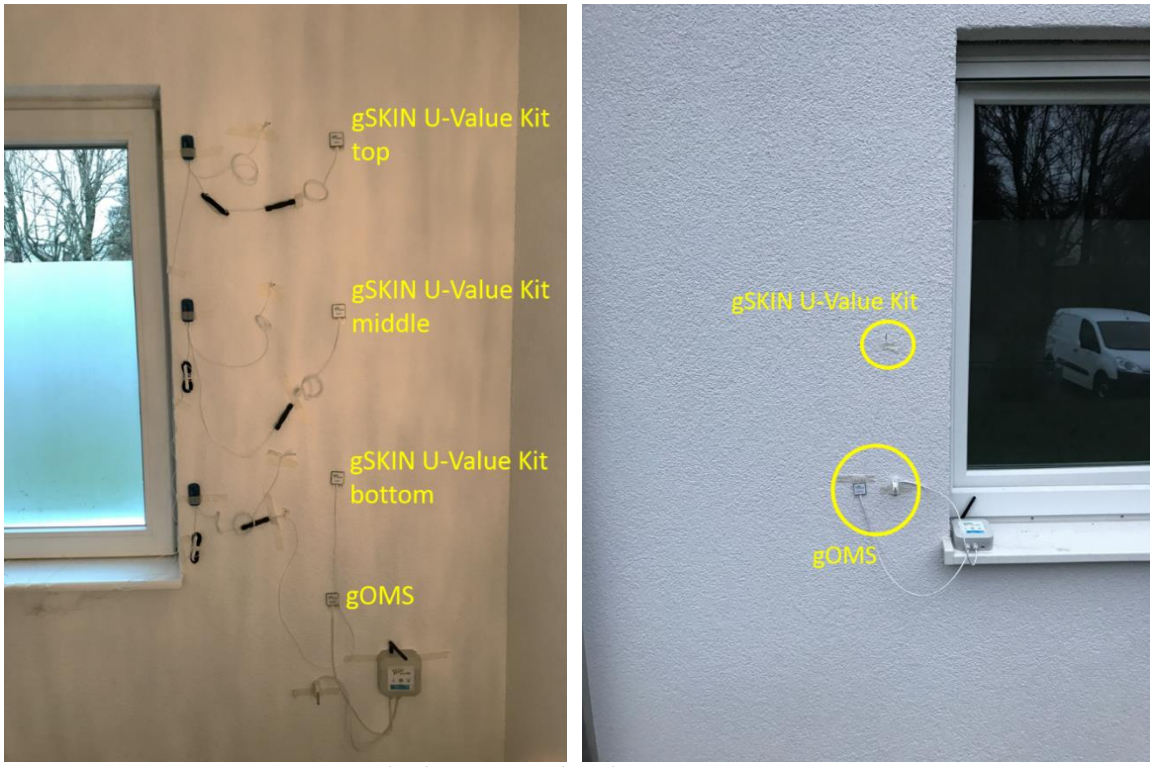

Figure 2: Measurement set-up inside (left) and outside (right) at the outer wall

The inside and outside temperature sensors were placed directly opposite. The overall measurement period was 72h and all measurements completely fulfilled the ISO 9869 norm criteria. The results can be seen in table 1. In figure 3 the measurement curve of the bottom measurement point with the gSKIN U-Value Kit can be seen. The inside temperature was relatively constant over the entire measurement period and no significant irregularities in the heat flux can be observed. Furthermore, the measurements correspond very well with the estimations made by the building physicist and fulfill the *MINERGIE Standard* requirements, except for the topmost measurement point. The reason why the results for this point are higher than for the others can be explained through slight inhomogeneities of the wall or the

[1] For more information visit: https://www.greenteg.com/gO%20Mess-System/

measurements.

Measurement point	Measured U-Value	Estimated U-Value	Deviation
gSKIN U-Value Kit top	0.16 W/(m²K)	0.138 W/(m²K)	+16%
gSKIN U-Value Kit middle	0.13 W/(m²K)	0.138 W/(m²K)	-5%
gSKIN U-Value Kit bottom	0.14 W/(m²K)	0.138 W/(m²K)	+1%
gO Measurement-System	0.14 W/(m²K)	0.138 W/(m²K)	+1%

Table 1 Measurement results outer wall

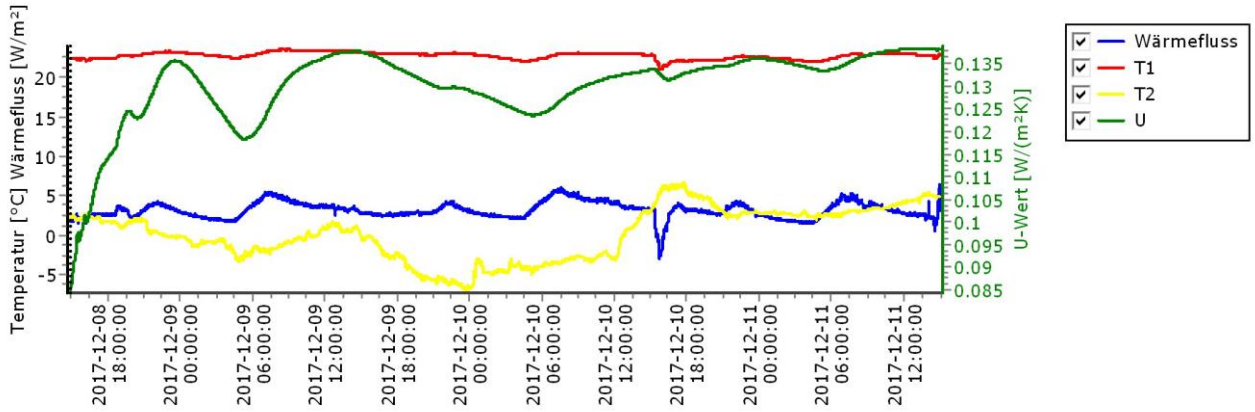

Figure 3 Measurement curve (bottom measurement) outer wall

Measurement at the roof

For the measurement at the roof, three spots next to each other were selected. The first measurements took place between the 08.12.2017 and the 11.12.2017, but had to be repeated due to heavy snow fall and because the measurement in the middle got interrupted. The second measurements took place between from the 11.12.2017 to the 14.12.2017.

Measurement Point	Measured U-Value	Estimated U-Value	Deviation
gSKIN U-Value Kit left (8.12-11.12)	0.68 W/(m²K)	0.213 W/(m²K)	+219%
gSKIN U-Value Kit right (8.12-11.12)	0.8 W/(m²K)	0.213 W/(m²K)	+275%
gSKIN U-Value Kit left (11.12-14.12)	0.69 W/(m²K)	0.213 W/(m²K)	+224%
gSKIN U-Value Kit middle (11.12-14.12)	0.65 W/(m²K) (does not fulfill ISO 9869)	0.213 W/(m²K)	+205%
gSKIN U-Value Kit right (11.12-14.12)	0.85 W/(m²K)	0.213 W/(m²K)	+299%

Table 2 Measurement results at the roof

The results can be seen in table 2. During the second measurement period (8.12-11.12) the U-values were slightly lower which can be explained through the snow on the roof which has an insulation effect (similar to an igloo). Moreover, the U-values between right and left deviate which can be an indicator for not properly installed insulation material (e.g. inhomogeneous insulation). While the measurements on the left and on the right fulfill the ISO 9869 conditions, the one in the middle didn't. The reason was that the R-value calculations fluctuated too much.

However, this condition is very strict and considered that the other measurements did fulfill the ISO 9869 completely and all measurements were clearly too high to be lower than the maximal allowed U-value, this measurement has not been repeated.

Summarizing the above it can be said that all measured U-values varied widely from the estimated values. The U-values measured between the 11.12.17 and the 14.12.17 on average are 0.52 W/m^{2}K or 143% above the estimated values and failed to meet the *MINERGIE Standard* requirements.

Measurements in the side room

In the side room the U-value of the roof, outer wall and inner wall (adjacent to the garage) had to be measured (see figure 4). The first measurement period was between the 08.12.17 and 11.12.17. The measurement at the roof had to be repeated between the 11.12.17 and 14.12.27 due to heavy snow fall.

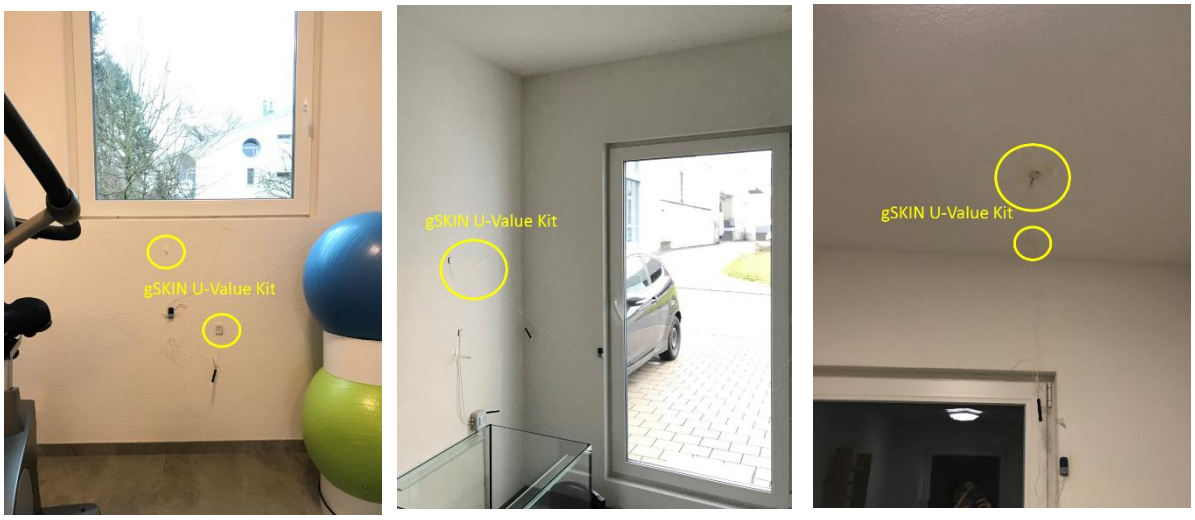

Figure 4 Measurements in the side room

Measurement point	Measured U-Value	Estimated U-Value	Deviation
gSKIN U-Value Kit outer wall (8.12-11.12)	0.59 W/(m^{2}K)	0.26 W/(m^{2}K)	+127%
gSKIN U-Value Kit garage wall (8.12-11.12)	0.73 W/(m^{2}K)	N.A.	N.A.
gSKIN U-Value Kit roof (11.12-14.12)	0.78 W/(m^{2}K)	0.2 W/(m^{2}K)	+290%

Table 3 Measurement results in the side room

All results can be seen in table 3. As for the previous measurements at the roof, the estimated values differed significantly from the measured values. Apart from the measurement at the roof, the ISO 9869 conditions were fulfilled. The measurement at the roof did not fulfill the ISO 9869 requirements, because the outside temperature fluctuated heavily during the measurement period and the temperature sensor was exposed to direct sunlight in the morning of the 13.12.17 (see figure 5). Nevertheless, the measurement was not repeated, because the high heat flux clearly indicates that the U-value is too high and additional measurement would only have been time and cost-consuming, with no prospect for a U-value below 0.15 W/(m²K) (*MINERGIE Standard)*

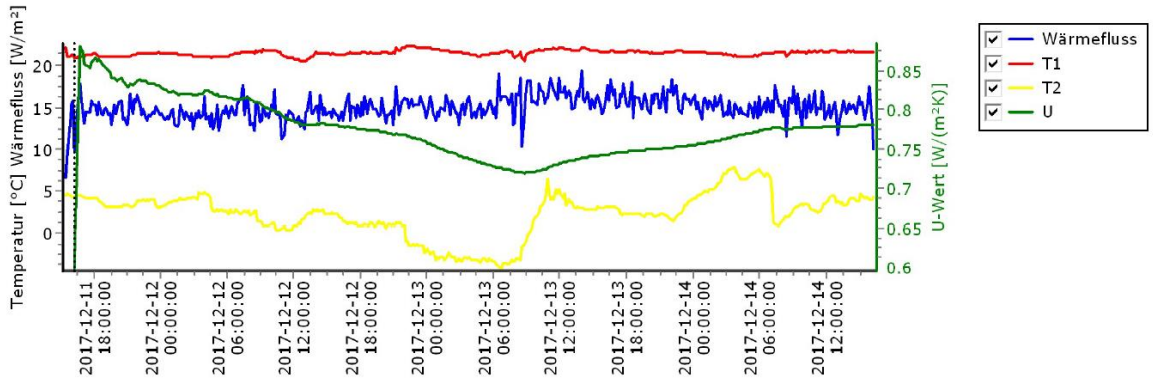

Figure 5 Measurement curve of the roof of the side room

Summary

Overall eleven U-values have been measured at a new building to verify the *MINERGIE Standard* requirements. All U-values, except for the U-value of the outer wall, were significantly too high to fulfill the requirements. Consequently, the insulation of the roof and the entire side room had to be improved in a costly refurbishment.

This case study demonstrates how inaccurate estimated U-values can be when no construction plans are available. Thanks to greenTEG's simple, non-invasive U-value measurement approach it was possible to determine the U-value of all building elements in an accurate and reliable way.

The reason why some of the measurements did not fully fulfill the ISO 9869 conditions was mainly due to the difficult measurement conditions (sudden change in the weather, ranging from *föhn wind*[2] to heavy snow fall). For a highly accurate planning of the refurbishment the measurements at the roof of the side room would have had to be repeated.

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In case of questions or suggestions please contact the authors directly.

[2] Dry and warm wind, find more information on: https://en.wikipedia.org/wiki/Foehn_wind