# HOW HEAT ESCAPES THROUGH THE WALL

The heat transfer coefficient (U-value) is a key parameter for planners and builders. Recommendations for renovations proposed by energy consultants are often based on this value. Thanks to a novel method, the U-value of a wall, a roof or a window front can now be determined with a non-invasive method on site. The measurement method can be used to renovate of old buildings and buildings protected under historic preservation laws, a study co-financed by the Swiss Federal Office of Energy shows.

The energy certificate issued to buildings in the Swiss Cantons (‹Gebäudeausweis der Kantone›; GEAK for short) is now well-established proof that provides information on the energy efficiency and energy consumption of a building and serves as an important decision-making aid for buyers or tenants. In its detailed version (‹GEAK Plus›), the GEAK also provides suggestions on appropriate refurbishment steps on how a building can be improved from an energy standpoint. The countrywide GEAK database contains 44'000 buildings. In order for this database to remain up-to-date, the Energy Briefing Letter (‹Energiesteckbrief›) for each building must be confirmed or renewed every ten years at the latest.

Werner Hässig, owner of the *hässig sustech gmbh*, demonstrates, how the outdoor temperature sensor of the gSKIN measuring kit has to be installed on the outside wall. Foto: B. Vogel

A technical report about the results of a research project in the field of buildings and cities, which was financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine Haustech (issue August 2017).

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**Swiss Federal Office of Energy SFOE**

Expert knowledge is required to create a GEAK or a GEAK Plus. For the preparation of such an energy certificate, the energy consultant inspects the building in question, looks at planning documents and energy bills and procures additional information as required. If the construction documentation of the property concerned is partially or completely missing, the energy consultant must partly rely on assumptions when drawing up GEAK. This applies to, among other things, to the quality of the thermal insulation. If reliable building data are not available for the building, the energy consultant relies on standard guideline values, which are created by GEAK software - an internet-based calculation tool - or corrects these using the SFOE component catalog.

## Real U-Values of Old Buildings Lie Deeper

The U-value quantifies the heat transfer of walls, roofs, windows and floors. With the GEAK software, a U-value of 1.4 W / m²K is assumed for walls of old buildings (built before 1975). Whether this value depicts reality realistically has raised many discussions in the past; building experts have expressed the concern that the value is too high. Experts argue the U-value of the buildings erected before 1975 could be lower in fact, so their walls would be better insulated than the values given by the GEAK calculation tool.

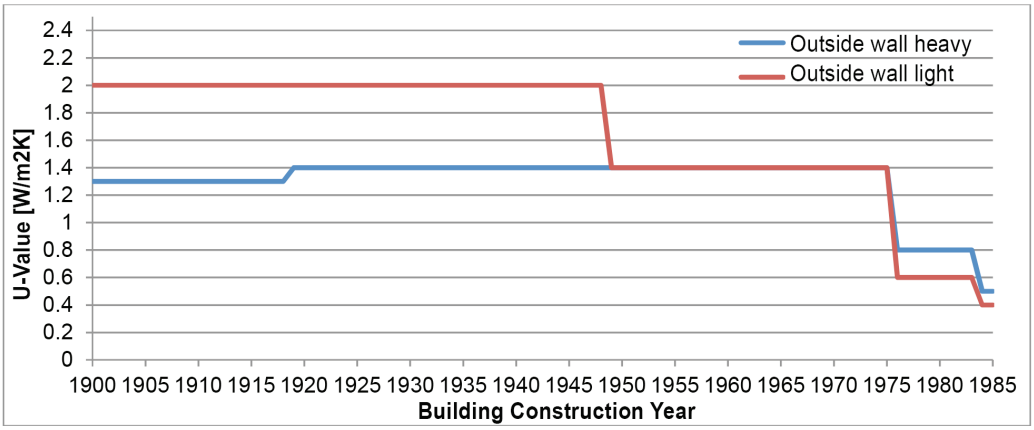
**The Energy Label**

**Typical characteristics of GEAK classifications of energy labels**

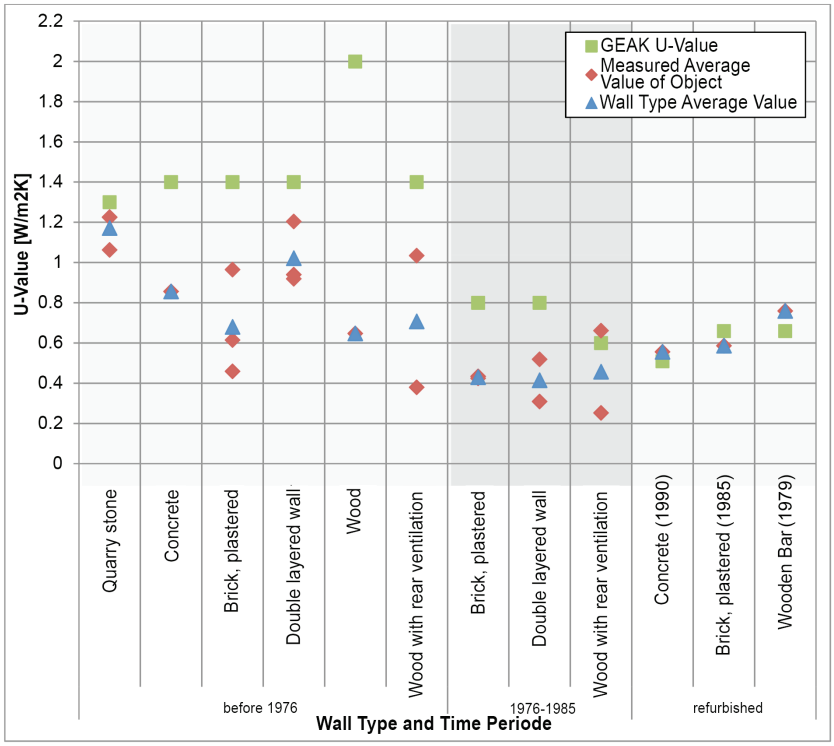
| | Efficiency of Building Envelope | Total Energy Efficiency |
|---|---|---|
| A | Outstanding heat insulatation. Windows with triple heat insulation glazing. | Highly efficient building technology for heat generation (heat and warm water) and lighting. Excellent equipment. Inclusion of renewable energy |
| B | New building compliant with the legal requirements for category B. | Compliant with new building standards respective to building envelope and building technology. Inclusion of renewable energy. |
| C | Old building with comprehensively renovated building envelope. | Comprehensive renovation of an old building (insulation and building technology). Mostly inclusion of renewable energy. |
| D | Old building retroactively insulated well and comprehensively, but with remaining thermal bridges. | Old building largely renewed but with clear gaps or without adoption of renewable energy. |
| E | Old building with considerable improvement in insulation including new window insulation. | Partly renewed old building with new heat generation, for example, and new equipment and lighting. |
| F | Building, partly insulated. | Building partly modernized. Installation of new components or inclusion of renewable energy. |
| G | Old building with highly deficient retroactively installed insulation and with high renovation potential. | Old building with out of date technology and without inclusion of renewable energy and with large potential for improvement. |

A key component of GEAK is the energy label: it characterizes the efficiency of the building envelope as well as the overall energy efficiency of the examined building from A (very efficient) to G (less efficient). Illustration: GEAK

This assumption is now confirmed by a new study commissioned by the Swiss Federal Office of Energy and with the financial support of three insulation producers (Flumroc AG, Isofloc AG, Agitec AG). The planning office of *hässig sustech gmbh* (Uster) measured the U-value of 32 predominantly unrenovated old buildings and then compared these measured values with the reference values used by the GEAK calculation tool. The conclusion of the study: "The results show that the U-values used in the GEAK tool are 50 to 60% higher than the measured U-values. As a result of these large deviations, the authors recommend that the U-values of the GEAK for walls with a construction year before 1976 should be reduced from 1.4 to 1.0 W / m²K. In the case of walls with a construction date between 1976 and 1985 it is advisable to reduce the GEAK U-values to 0.6 W/m²K (currently the values for heavy walls and light walls are at 0.8 and 0.6 respectively)."




The graph shows values for the U-value stored in the GEAK calculation tool. These guideline values provide energy consultants with the basis to prepare GEAK. Since 1975, energy regulations mandate thermal insulation for buildings, which is why the graph shows improvement in thermal insulation from that time onwards (ie a lower U-value). By way of comparison, today's Minergie A-construction typically has a U-value of 0.15 W / m²K. Graphic: Final report UFELD




The graph clearly shows the main result of the study: the measured U values (red) are generally much lower than the values stored in the GEAK calculation tool (green). The values shown in blue represent the result from a calculation of the U-value with material-lambda-values from the building material characteristic table of the SIA (SIA 279). These computational values often agree well with the measured values. Graphic: Final report UFELD

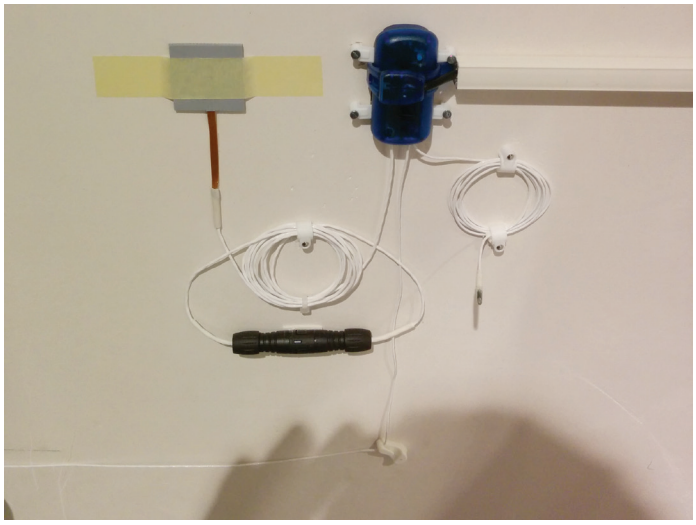
## Realistic Values Strengthen Credibility

The results mean that when energy consultants must rely on the GEAK calculation tool because of incomplete construction documentation, have thus far considered the insulation protection of buildings too pessimistically - and consequently tend to suggest renovation requirements that are unnecessarily extensive. This obviously poses disadvantages for building owners. "It was also partly intentional to be conservative in the U-values stored in the GEAK tool in order to drive energetic redevelopments," says Dr. Dipl. Ing. ETH / SIA Werner Hässig, Managing Director and owner of *hässig sustech*. "However, the calculated U-values should be chosen as realistically as possible, otherwise the credibility of the GEAK suffers," says the building physics expert.

"The study has produced interesting results and it gives us an opportunity to review the values produced by the GEAK software tool and to correct extreme cases," says GEAK President Ulrich Nyffenegger, energy engineer FH SIA / STV and today Head of the Office for Environmental Coordination and Energy of the Canton of Berne. However, the scope of the values the GEAK association is able to adjust is limited: GEAK bases its values on the material values (lambda values) reported in the building catalog of the Swiss Federal Office of Energy (SFOE). "The GEAK has adopted these values and deliberately adopted the most unfavorable case. We trust that the energy consultants will correct these values while creating GEAK in light of the concrete circumstances, " says Nyffenegger. The GEAK President admits that the SFOE component catalog lambda-values, especially for components without SIA monitoring, is too poorly estimated. «The SFOE should take the study as an opportunity to revise the component catalog,» says Ulrich Nyffenegger, «GEAK would then take the adjusted values into the GEAK. software».

## Measurements with Mobile Measuring Kit

The determination of the U-value is not trivial. In the past, if the construction materials and structures used were known, the values were calculated on the basis of the SFOE component catalog. In the case of incomplete or missing construction documentation, the construction technique of walls was determined by means of drilling in order to carry out the calculation. Of late, a measuring device makes it possible to determine the U-value of walls and other building parts (in situ), without affecting the wall. This non-invasive measuring instrument, called gSKIN U-value measuring kit, was developed by Zurich-based company greenTEG, a spin-off from ETH Zurich. The gSKIN measuring kit consists of three sensors, which are attached on both sides to the component to be measured (for example a wall). A data logger records the measured values, and analysis software then determines the U-value from them. With the measuring kit, the U-value



The gSKIN measuring kit as attached to the inner wall during a measurement: data from the heat flow sensor (gray) and the temperature sensor (at the bottom right) are collected in the data logger (blue). The cable at the lower left leads to the second temperature sensor, which is installed on the outer wall. Data collected in the data logger are later transferred to a computer and evaluated by the associated software. Photo: greenTEG

can be determined with an accuracy of +/- 20% during a three-day measurement period (see textbox p.4 and 5).

**The Pitfalls of Measurement**

The study by *hässig sustech* takes into account old buildings with different wall types. As a rule, these were brick walls without thermal insulation. The brick was either plastered or covered with a non heat-insulating -cement fiber-board (Eternit) or wood covered. Even if a double brick wall was present (double-shell masonry), the intermediate gap was not included as thermal insulation.

Through experience, Werner Hässig and his co-worker Sara Wyss have learned that the measurement of the U-value has some pitfalls. For example, the U-value is higher when one measures at a point where there is mortar instead of brick underneath the plaster. Effects such as the reflection of the neighboring house can also affect the measurement. When using the measuring instrument, a specialist who knows how to assess the results is therefore always required, says Werner Hässig. "The meter is a useful tool for assessing the condition of older buildings that are to be renovated. Especially in the area of buildings holding a historic preservation designation, the measuring method has great application potential because there are often only incomplete or no planning documents at all."

- The **final report** on the project ‹Field measurements of U-values for the verification of the U values deposited in the building energy certificate (GEAK)› (UFELD): https://www.aramis.admin.ch/Texte/?ProjectID=37271
- For further **information** on the project, please contact Rolf Moser (moser [at] enerconom.ch), Head of the SFOE Research Program Building and Cities.
- For further **research papers** on research, pilot, demonstration and flagship projects in the subject area of buildings and cities: www.bfe.admin.ch/CT/gebaeude.

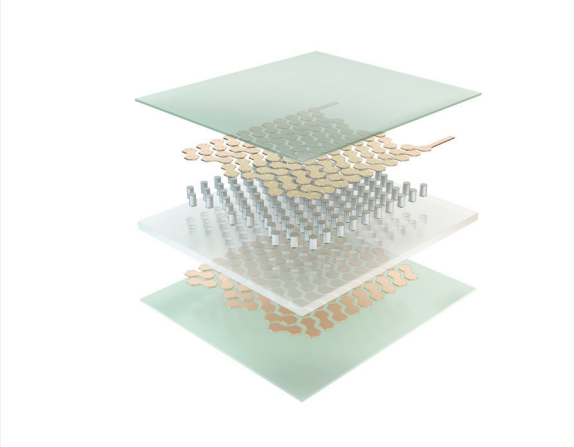
## A MEASURING INSTRUMENT TO DETERMINE THE U-VALUE

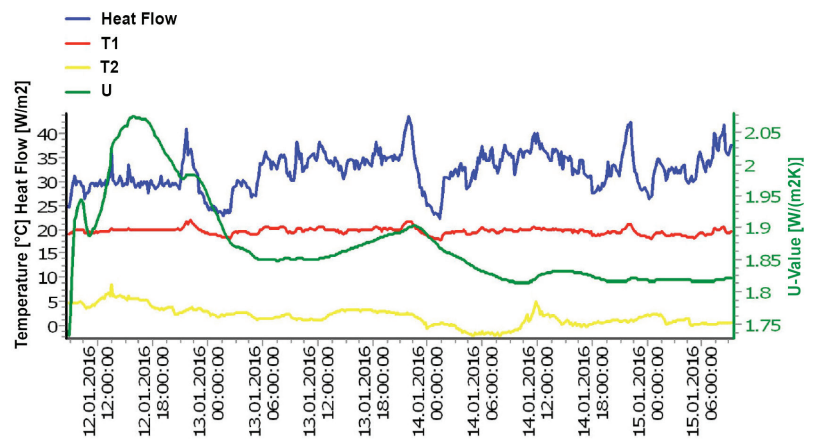
The innovative element of the gSKIN measuring kit is the heat flow sensor: the 3 by 3 cm thick and 2 mm thick plate is placed on the inner wall of a building and measures how much heat flows out of the warm interior through the house wall. Technically speaking, the sensor is a thermoelectric generator (TEG): If there is a different temperature on both sides of the TEG, a voltage develops and a current flows. The strength of this measuring current is dependent on the temperature difference, the materials used and the temperature range in which it is measured. The greenTEG company uses the measuring current in the gSKIN measuring kit to determine the U-value via an algorithm.

The U-value (heat transfer coefficient) describes the heat transfer through a material (e.g., a wall). The U-value puts the heat flow through the wall into a relationship to the wall surface and to the temperature difference (therefore the unit W/m²K): the higher the U-value, the poorer the thermal insulation of the wall. For the measurement with the gSKIN measuring kit on a wall, the heat flow sensor and one of the two temperature sensors are installed on the inside. At the same position, the second temperature sensor is placed on the outside. The heat flow sensor now measures how much energy (in Watts) flows through the wall. With the software, the U-value can be calculated from the measured internal and external temperatures as well as the heat flow.

The heat flow sensor must be protected from direct sunlight. For the measurement, a minimum difference of 5 °C between inside and outside temperature is necessary (which is not an issue during the cold season). Although usable data are available after two hours of measurement, it is advisable to measure over a longer period of time in order to compensate for fluctuations. The ISO 9869 standard describes how a U-value measurement should be performed. For a U-value measurement to be ISO-compliant, it should be measured for 72 hours. The graph (illustration on the right) shows how the U-value (green line) during the course of measurement can be ever more precisely determined.

The heat flow sensor of the gSKIN measuring kit is based on the Seebeck effect (also: thermoelectric effect). In the technical implementation of the greenTEG sensor, cylindrical elements made of semiconductors with different Seebeck coefficients (‹thermopairs›) are placed side by side and connected to one circuit. The two semiconductors must be appropriately doped with






foreign atoms, one that is n-doped, the other p-doped. If there is a temperature difference between the top and bottom of the cylinders, a current flows. In order to generate a relevant measuring current, a plurality of thermopaars are connected in series. The diagram (illustration on the left) shows the construction scheme of a TEG from the company greenTEG: The perforated holes are recognizable in the middle foil; These are filled by electrochemical deposition with thermopairs, which are subsequently provided with contacts and connected in series at the top and bottom. The entire assembly is protected with a protective film (green) at the top and bottom.

TEG can be used to generate a measuring current, as is the case with the gSKIN measuring kit. TEGs can also be used to supply power for various applications, for example for the regulation of a heating valve. (See technical article ‹Der Thermostat wird energieautark›, available at www.bfe.admin.ch/CT/strom). BV

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Version: September 2017