gSKIN® Application Note: Building Physics

Get to know the thermal behaviour of your building

Did you ever wonder how much of your heating bill is caused by badly insulated windows or walls? Or how much energy you can save by adjusting the temperature level in a room? Use the gSKIN® Heat Flux Sensor to get answers to these and many more questions. The gSKIN® U-Value KIT features:

Figure 1: gSKIN Heat flux sensor

- **Easy read-out**
"Use greenTEG's solution to get your measurement results directly."

- **Simple mounting & integration**
"The sensor is compact, small and thin. You just tape it to the place where you want to measure the heat flux."

- **Robust**
"The sensor is robust and withstands harsh environmental conditions. This allows for easy handling and makes it re-usable."

Why use a heat flux sensor?

A building is a complex **thermal system. Thermal energy is entering the building via the heating system and solar radiation. Energy leaks to the outside through the roof, walls, windows and other thermal bridges such as balconies, into** the soil and through exchange with ambient air (fig. 2). In order to fully understand this thermal system and optimize it (for example to reduce heating costs), precise data is required.

Use the gSKIN® Heat Flux Sensor to:

- Compare the amount of **heat transferred through different walls**
- Calculate the **overall heat transfer coefficient (U-value)** of walls or windows and find out if you have a **well-insulated building**
- Quantify the **energy balance** of a room: How much energy is coming from the heating and where is energy lost?
- Calculate **energy provided by the heating radiator** to forecast your **heating costs**
- Optimize your heating and cooling control through enhanced insights
- Analyse the **thermal behaviour** of rooms and buildings at different temperature levels

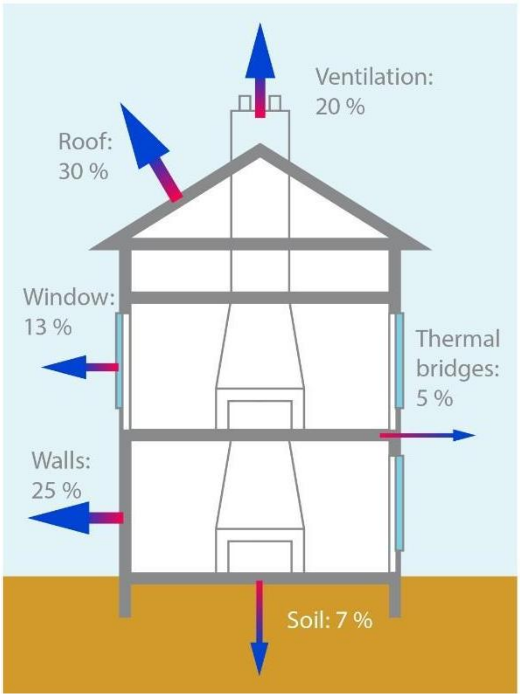

Figure 2: Heat lost from a building on a Swiss winter day in % of total

Measuring: How to get results for different applications

Materials needed

To execute heat flux measurements the following equipment is required:

- Heat Flux sensor
  - e.g. gSKIN XO 67 7C
- Measurement device
  - GreenTEG Datalogger
  - Other multimeter / datalogger
- Adhesive tape
- Temperature sensors (Only required for U-value measurement)

All these items are included in the U-Value KIT and can be bought at the greenTEG website.

General remarks

- Thermal energy efficiency studies in buildings require a certain temperature difference between the interior and exterior of a building to achieve good results. With the gSKIN® Heat Flux Sensor, you are able to get precise information with a temperature difference as low as 5°C (see Appendix 2, Table 2 for more detailed information)

- Place the sensor on a representative surface. If you can produce a thermal image (with an infrared camera), it will help you find appropriate spots. General spots of interest are:
  - Walls facing all four cardinal directions. This allows you to check for and measure the difference between the walls
  - On the floor of the lowest level (heat transfer with the ground)
  - Under the roof (in many buildings large amounts of heat are lost through the roof (see figure 2).
  - Windows and window frames (take care that your measurement is not distorted by solar radiation by only measuring during nights)

- Measure the heat flux at the interior of the building preferably. If you place the sensor on the same spot on the inside, you will measure the same values as if it was placed on the outside. Values measured outside might get distorted due to external conditions (wind, rain, etc).

- Some walls have inhomogeneous insulation qualities (i.e. different building material layers, walls with pipes). To obtain more significant measurement results, use an IR camera to check for inhomogeneous parts, and if there are any, use multiple sensors on the same wall and average their values.

Measurement set-up

The following figure (3) illustrates a typical measurement setup:

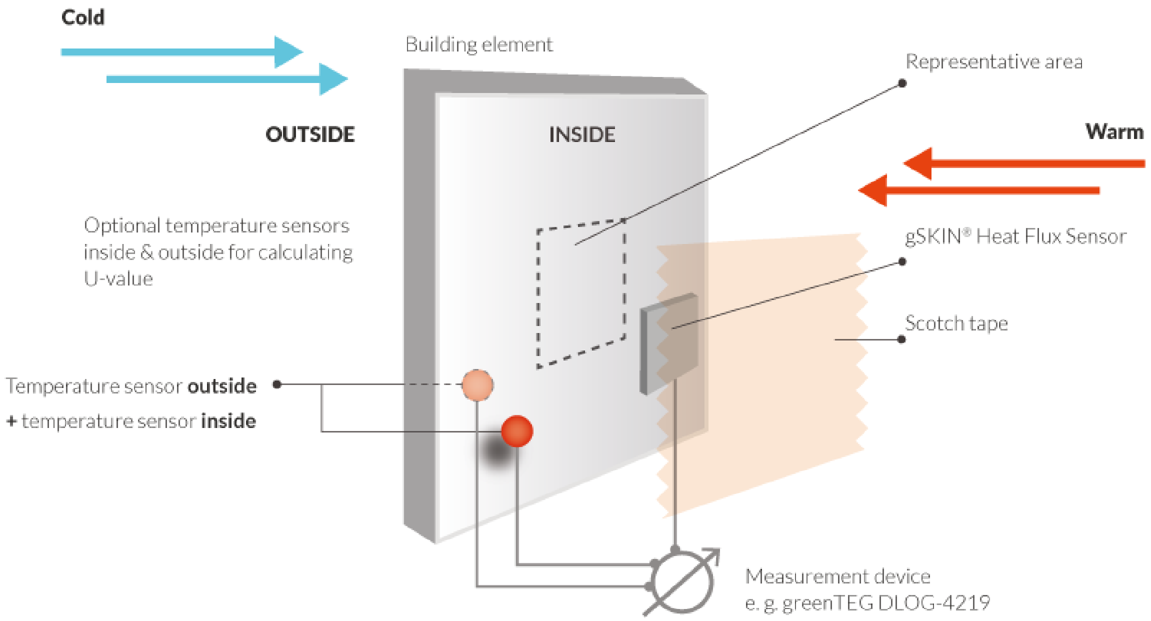

Figure 3: Depiction of a typical measurement set-up

To set up a measurement, follow these steps:

- Select a representative area (**A**) of the surface you want to study
- Ensure that the area of interest is flat, dry and free of dust[1]
- Mount the sensor e.g. the gSKIN XO 67 7C (**B**)
- Fix the sensor at the wall e.g. with adhesive tape (**C**)
- If you want to calculate the U-value of a building element, you also need to mount 2 temperature sensors (**D**): one sensor to measure the inside temperature and one sensor to measure the outside temperature. Make sure that they are placed roughly across the wall from each other and close to the heat flux sensor. Both sensors have to be positioned in the air to get the corresponding temperatures

[1] Maximum accuracy for scientific purposes can be achieved by making the surface of the sensor exposed to the air mimic the surrounding wall/window surface (e.g. if the surface is covered with black paint, you will get maximum accuracy by painting the sensor with the same paint)

Reviewing the measurement data and calculating the heat flux

- Use the greenTEG DLOG **(E)** to capture results of the heat flux measurements.
- If you use another data logger, multimeter or other read-out device, make sure that your device has a resolution of 1 µV or higher. Follow these instructions:
    - Connect the gSKIN® Heat Flux Sensor to your measurement device and record the output voltage U
    - Calculate the heat flux φ using the sensor-specific sensitivity S (included with your gSKIN® Heat Flux Sensor)
    - The equation for calculating the heat flux is:

$$\varphi = U / S$$

where

φ	Heat Flux in W/m^2
U	measured voltage in V
S	sensor-specific sensitivity in $\mu V/(W/m^2)$

Interpretation of your measurement results

How to calculate heating costs?

Based on the measured heat flux, you can calculate how much thermal energy is lost and how heating costs are affected by this. Here is an example of a badly insulated concrete wall.

Figure 4: Badly insulated buildings are expensive

- You have set up your measurement as described previously and got a heat flux of **50 W/m²**. This is a typical value for a concrete wall on an average winter day in Europe (temperature difference between inside and outside of 15 °C)
- Now calculate the area of interest (e.g. wall, window or floor). In our example, we measured a concrete wall with an area of 2,5 m by 6 m which is **15 m²**.
- Now we can calculate the thermal power flowing through the whole wall by multiplying the heat flux (50 W/m²) by the area (15 m²). Therefore, thermal power **of 750 W** is flowing through this wall.[2]
- Now we want to find out how much of our monthly heating bill is caused by this wall. We can do this by multiplying the power (750 W) by the hours of a month (720 h). The result is the energy flowing through this wall over 1 month (assuming an average temperature difference of 15 °C between the inside and outside environment). In this example the energy loss is **540 kWh**.
- By multiplying this lost heat with your cost for 1 kWh of thermal energy (or by using a standard value of **0.10 €/kWh)** you can estimate the value of the lost energy. In this wall-example, one would have to pay **54 €** of the overall thermal energy bill per winter month for this poorly insulated wall.

[2] We assume that the heat flux is homogeneously distributed across the whole area.

- You can compare this with your thermal energy costs if a better insulated wall were installed. A well-insulated wall would have a heat flux of **5 W/m²** under the same conditions. Calculating the energy costs as described above, you will find a value of **5,40 €** for the lost energy in this situation. This means that a better insulated wall could save you up to **50 €** per winter month.
- The same method can be used to estimate the heat energy emitted by a radiator or by a badly insulated pipe.

How to calculate the U-value[3]

To measure the U-value directly, follow these steps:

- Set up the measurement with two additional temperature sensors as shown in Figure 3. The greenTEG DLOG (E) calculates the U-value directly based on the measured heat flux and the measured temperatures.
- The U-value can also be calculated manually with the following equation:

$$\text{U-value} = \varphi \; / \; \Delta T \qquad [\,W/(m^2K)]$$

where

U-value	overall heat transfer coefficient in $W/(m^2K)$
ϕ	mean value of all heat flux data points in W/m2
ΔT	mean value of all temperature difference data points in °C

- Table 1 in Appendix 2 lists some typical values for building materials and gives you an indication of the quality of building materials. Further values are stated for how much thermal energy is lost (W/m^2) with a temperature difference of 10°C for each specific material.

[3] For a detailed description of U-value measurements and evaluation, refer to greenTEG's U-Value case study.

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Appendix 1: Equipment specifications

Figure 5: Picture of gSKIN®-XO 67 7C (left) and DLOG-4219. (right)

All specifications for greenTEG's Heat Flux Sensors and Data Loggers can be found on the greenTEG's webshop. Visit http://shop.greenteg.com/shop/building/ to get more information.

Appendix 2: Specifications for different building materials

Table 1 gives an overview of the specifications and typical measurement results for different building materials:

- Material specific **thermal conductivity**: Low values are good for insulation purposes and large values indicate a material which conducts heat better (e.g. 2 W/(mK) for concrete materials). This value is linked to single materials and cannot be given for combinations of different elements, e.g. double glass.
- Material **thickness**: For the concrete and brick wall we have assumed a thickness of 25 cm, for the insulated wall 44 cm and for windows 2.5, 5 or 7.5 cm.
- **U-value**: Describes how much heat flows through a specific section . This value is calculated from the heat conductivity of the element or composite layers, the thickness and the inside and outside thermal resistances. The U-value of the insulated wall is based on the specifications outlined in EnEV 2014.
- **Typical heat flux** for a ΔT of 10 °C for validating results.

Building material	λ (Thermal conductivity) [W/(mK)]	Thickness [m]	U-value [W/(m^{2}K)]	Heat flux at ΔT=10 °C [W/m^2]
Concrete[4]	2	0.25	3.39	33.9
Brick[4]	0.58	0.25	1.36	13.6
Insulated wall[4]	-	0.44	0.24	2.4
Glass[5]	0.8	0.025	5.8	58
Double glass[5]	-	0.05	1.4	14
Triple glass[5]	-	0.075	0.8	8

Table 1: Typical specifications and measurement results for different building materials

[4] Source: U-wert.net, Insulated wall consists of following materials: Gypsum plaster, solid brick, lime cement render, plaster, polyester insulation.

[5] Source: VFF, Mehr Energie sparen mit neuen Fenstern, March 2014

Appendix 3: Example for long-term measurements

Figure 6 shows a typical modern Minergie-certified Swiss residential building where we conducted an exemplary long-term measurement of more than 72 hours (in this case 166h, ISO confirmed already after 72hrs). One measurement every 10 minutes is sufficient in order to obtain accurate results. Shorter measurement periods reveal robust results, but do not follow the ISO 9869 standard. Figure 7 shows the corresponding report, heat flux, inside and outside temperatures and the derived U-value of a wall. Furthermore, the data collected from the measurement can be used to monitor the thermal behaviour of the building.

The measurement shows that:

- The heat flux (blue) reacts to the differential between the inside and outside temperatures.. In this case, the Southwest facing wall received significant solar gains at noon on the first measurement day. Nevertheless, the corresponding U-value only varies slightly throughout the full measurement period (min. 0,12 – max 0,22 W/m^2K)
- The U-value of the measured wall is 0,14 $W/(m^2K)$, which describes a very well insulated building, i.e. a Minergie certified building in Switzerland (see Figure 6)

Figure 6: Swiss Minergie-certified building used for long-term measurement

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Measurement result:

Logger data:

Serial No:	316512
Type:	U-value measurement kit
Sensitivity:	11.1 uV/(W/m²)

Latest measured values

Heat Flux (HF):	3.2 W/m²
Inside temp. (T1):	22.5 °C
Outside temp. (T2):	4.5 °C
Measurement time (t):	166.17h

U-value summary:

U-value (U):	0.14 W/(m²K)
Std.Dev.U:	2.8 %
dU24:	2.74 %

U-value measurement in line with ISO9869 requirements!

Additional comments:

Südwfassade

Measurement overview over t=166.17h

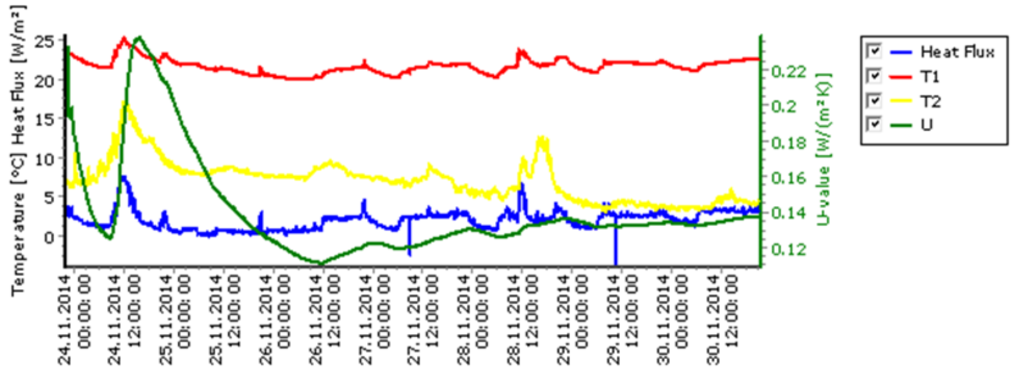

Figure 7: Heat flux, inside and outside temperatures and U-value measurement on a wall of a typical modern Minergie-certified Swiss residential building. The figure was created using the software included in the U-Value Kit

Disclaimer

The above restrictions, recommendations, materials, etc. do not cover all possible cases and items. This document is not to be considered to be complete and it is subject to change without prior notice.

Document information

Pictures by greenTEG AG and flickr

Revision History

Date	Revision	Changes
5. April 2013	0.1 (preliminary)	Initial version
17. May 2013	1.0 (first published)	Completed content
9. July 2013	1.6	Revised tables
12. August 2013	1.7	Measurement data added
11. February 2014	2.5	Revision of symbols, figures and tables
12. December 2014	2.6	New software report figures, general updates
4 February 2015	2.7	Revision Heat flux calculations, general updates
25 February 2015	2.8	Text revision
17 March 2015	2.9	Screenshot new software