



SmartHTC: User Guide

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1. Introduction

SmartHTC measures the overall thermal performance of buildings using some basic building information and measurements of energy use, internal temperature and local weather. The thermal performance of the building is characterised by its Heat Transfer Coefficient, or HTC.

1.1. What is an HTC?

The Heat Transfer Coefficient (HTC) encompasses all of the heat lost from a dwelling during the winter, through the walls, roof, floor and windows, and by air movement from outside to inside the home. That makes it the ultimate barometer of how well the home keeps heat in and cold out.

1.2. What is SmartHTC?

At its heart, SmartHTC is a cloud hosted algorithm. SmartHTC is technology agnostic so that users can choose to use hardware provided by BTS or their own, and choose to use BTS' browser interface at SmartHTC.com or integrate SmartHTC into their products via our APIs.

The algorithm has a set of required inputs, additional inputs can also be provided to improve the accuracy of the HTC measurement. In addition, BTS can work to improve the algorithm based upon any additional data which may be available.

There is a small set of required information about the building for SmartHTC, and some optional additional information. The required information has been designed such that it is all available from an EPC certificate.

If the optional additional information is provided it will increase the accuracy of the HTC measurement, and decrease the accompanying confidence interval. The effect of including each piece of additional information on the HTC and CI is different for each calculation, but will rarely be larger than 5%.

Required Information	Optional Additional Information
Floor area	Built form
Location	Party wall area
	Attachment
	Boiler winter seasonal efficiency
	Window dimensions and orientation
	Glazing type, overshadowing and frame type
	Number of occupants

As for the building information, there are required and optional data inputs for SmartHTC. All data must be provided to SmartHTC in half-hourly increments, with the exception of energy meter readings. Where smart meter data is not available, it is still possible to use SmartHTC by providing service meter readings taken at the start and end of the internal temperature monitoring period. This is an important provision at this time as smart meter data is not yet available in all houses.

Required Data	Optional Additional Data
Energy consumption at the service meter	Internal temperatures in up to 10 locations
Internal temperature in one central location	Internal relative humidity in up to 10 locations
	Smart meter data
	Onsite electricity generation
	Electric Vehicle energy use
	Heat pump heat output
	Heat pump electricity consumption
	Disaggregated heat input for space heating
	Disaggregated heat input for water heating
	Local external temperature
	Local global solar irradiance
	Metabolic gains
	Presence of occupants

The more data is provided the greater the accuracy of the HTC measurement and the smaller the confidence interval. Providing more data, in particular smart meter data and more internal temperature measurement locations (particularly in larger buildings), can significantly reduce the size of the confidence interval. In some cases, the size of the confidence interval can be reduced by more than 25% by providing more data.

Energy use and temperature data must cover a period of at least 21 days and when the temperature inside the building is significantly higher (more than 7°C) than outside.

1.3. Why is SmartHTC needed?

20% of all energy use in the UK is for heating homes, this makes it the single biggest user of energy, it's a big cost to residents and a big contributor to the country's carbon emissions. The problem is that homes have been shown to routinely perform worse than expected, and often by a significant amount (an average of 60% underperformance in the largest study undertaken). We need measurement of thermal performance to understand how to more efficiently heat our homes, and to design methods and policies to improve their performance. *You can't manage what you can't measure.*

1.4. What problem does SmartHTC solve?

Up to now, the only tests to measure the thermal performance of dwellings have required that the building be vacated for at least a couple of days which is impractical for occupied homes. SmartHTC uses smart meter data and measurements of internal temperature collected while the residents are in the house, and analyses this to measure the HTC. Our testing has shown that this is comparable with the industry-established tests, but much less invasive and as a consequence less expensive.

1.5. What could SmartHTC be used for?

Accurate knowledge of thermal performance enables a wide range of opportunities, here are some examples of how SmartHTC has been used so far:

- ❁ Better, tailored, advice on how to heat a home and the effect of retrofits
- ❁ Stock assessment and targeting of retrofit works
- ❁ Quality assurance on retrofit works and new build homes
- ❁ In-situ demonstrations of thermal performance improvement products
- ❁ Information to assist in remediation of complaints regarding heating costs
- ❁ Quantification of the effect of energy improvement or fuel poverty alleviating measures.

2. Data Collection

2.1. Building Survey

A building survey may be carried out as part of the SmartHTC process to assess additional building specific information can be gathered which will improve the accuracy of the HTC measurement (see 1.2).

During the survey:

- ❖ Measure the internal dimensions of each room (floor area and floor to ceiling height), the area of each window and orientation of the house. Note the window type (single, double or triple glazed).
- ❖ Measure the area of the party wall if there is one.
- ❖ Visually identify the heating system equipment and determine the rated efficiency. For typical heating systems using a gas or oil boiler, the 'SAP winter seasonal efficiency' is used. There is a lookup function for this at SmartHTC.com.
- ❖ Make a note whether there are any unmetered secondary heating facilities, such as solid fuel stoves, open fires or gas fires. Check that the boiler for the heating system is contained within the heated envelope of the house.
- ❖ An additional airtightness measurement would allow the total heat loss to be broken down into fabric and infiltration components, BTS provide Pulse to carry out airtightness measurements.

2.1. Building Information

If a building survey is not carried out the essential information and much of the optional additional information can be gathered from an Energy Performance Certificate (EPC) for the dwelling.

EPC data can be gathered via API (epc.opendatacommunities.org/docs/api) or using the browser interface of the EPC Register (epcregister.com).

2.2. Monitoring Equipment

Add data must be in 30-minute intervals for input to the SmartHTC calculator.

- ❖ *30 Minute energy consumption data:* This is most easily collected from smart meters. Various methods to collect Smart meter data are available to different groups, the most common are through the DCC (for SMETS2 and adapted SMETS1 meters) or through a Consumer Access Device (CAD) installed in the dwelling. BTS can assist in collecting smart meter data via either method if required. The cumulative consumption over the 30-minute period in units of kWh should be recorded.

If only daily energy consumption data is available, this can simply be divided equally over the 30-minute periods in a day (i.e., total energy consumption divided by 48) with no loss of accuracy in the SmartHTC calculation.

- ❖ *Service meter readings:* If 30-minutely data is not available service meter readings can be taken at the start and end of a period of temperature monitoring instead. The monitoring must still be carried out over a period of at least 21-days during winter with an internal-external temperature difference of greater than 7°C.

The meter readings are simply read from the display of the service meter, the reading at the start and the end of the period should be used for the calculation. Electricity readings must

be in kWh, gas readings can be in either kWh or m³. Some older gas meters may give readings in ft³, these must be converted to m³ to be used. Some meters also have a maximum reading, at which point then start again at zero, if this happens during the monitoring period calculate the total consumption and enter the starting reading as zero and the final reading as the total consumption.

- ❖ *Electricity export:* If there is onsite energy generation (e.g., solar PV panels) there may be electricity export from the building, this should be recorded and can be entered either as half-hourly data or total export for the monitoring period.
- ❖ *Electric vehicle charging:* If electric vehicles are charged from the supply measured by the building's service meters, then the electricity used for charging the vehicles should be entered for a SmartHTC calculation. This is because this energy is used outside of the house and does not contribute a useful heat gain. Data can be entered either half-hourly data or as total consumption for the monitoring period.
- ❖ *Heat pumps:* As the efficiency of heat pumps is variable depending on the conditions at the time of use, the electricity consumption and heat output of the heat pump must be provided. Disaggregated space heating and hot water data can be provided half hourly and total heat pump output can be provided for the whole period.
- ❖ *Internal temperature:* The aim is to record an accurate measurement of the mean internal temperature across the house. To avoid measurement errors, temperature sensors should be placed at approximately mid-height in a room and out of the direct influence of sunlight and heat emitters (e.g. radiators, electrical appliances or lights). The measurements must be taken using sensors that have an accuracy of $\pm 0.5^{\circ}\text{C}$, or better. The average temperature for the 30-minute period should be recorded, with a measurement interval of at most 5 minutes.

A minimum of one internal temperature measurement, located centrally in the house can be used in smaller houses (less than 100m² floor area and two stories). For greater accuracy up to 10 temperature measurements can be provided, for maximum accuracy a temperature measurement should be provided in every room with at least 1 per 12m² total floor area. As a rough guide for a typical house, five sensors, located in the kitchen, bathroom, lounge, main bedroom and by the thermostat will provide a good measurement.

Temporarily installed sensors can simply be placed in a building in out of the way areas to minimise the disruption to the occupant.

- ❖ *Internal relative humidity.* Relative humidity should be measured by sensors with an accuracy of minimum $\pm 3.5\%$, the sensors should be located in the same place and have the same measurement and logging frequency as the internal temperature sensors.

2.3. Temperature Sensors

There are many different options available to carry out temperature measurements, including sensors within smart technologies such as thermostats, internet connected sensors and standalone temperature loggers. In the vast majority of cases the sensor itself is a thermocouple or thermistor with an accuracy of $\pm 0.5^{\circ}\text{C}$ or better.

Remote connection to the data is valuable to enable the user to check that data is being collected as planned or automate the SmartHTC calculation process, but will not affect the HTC result given the same sensor location and measurement frequency.

BTS can provide standalone temperature and relative humidity loggers which output a csv file that can be directly uploaded to the user interface, these loggers are approximately the size of a box of Tic Tacs (left hand picture below).

In addition, BTS will soon provide loggers with Bluetooth connectivity (right hand picture below). These loggers can be configured and the data downloaded with a mobile phone app, the app can also be used to configure connection to a smart meter and to communicate all of the data to the SmartHTC calculator and return the HTC result. An optional hub will also be available which can be connected to WiFi to provide a remote connection to the sensors. The sensors themselves are slightly smaller than the standalone loggers.



3. Using the SmartHTC Calculator

Users have two options to interact with SmartHTC, either directly via our APIs or by using our browser interface (www.smart-htc.com). SmartHTC will return the calculated HTC and confidence interval based upon the input data provided, both in units of Watts per Kelvin.

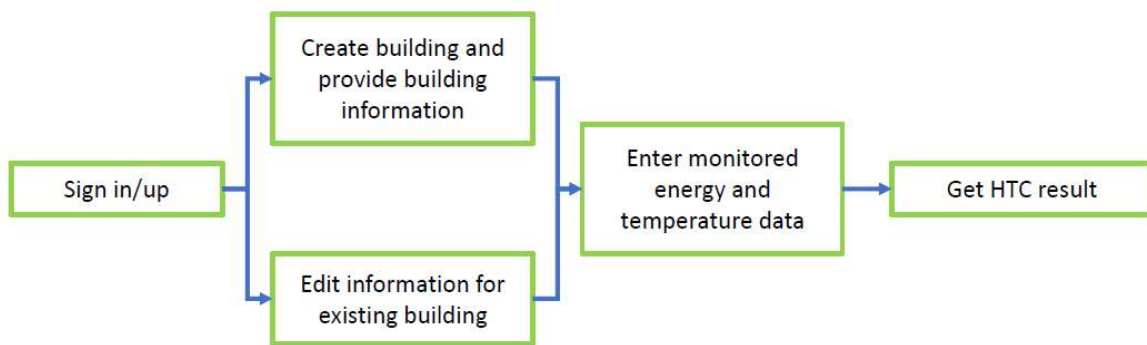
3.1. API

The API is a RESTful web service which uses Basic Authentication over SSL. All data is transferred in JSON format. Full API documentation is available on request.

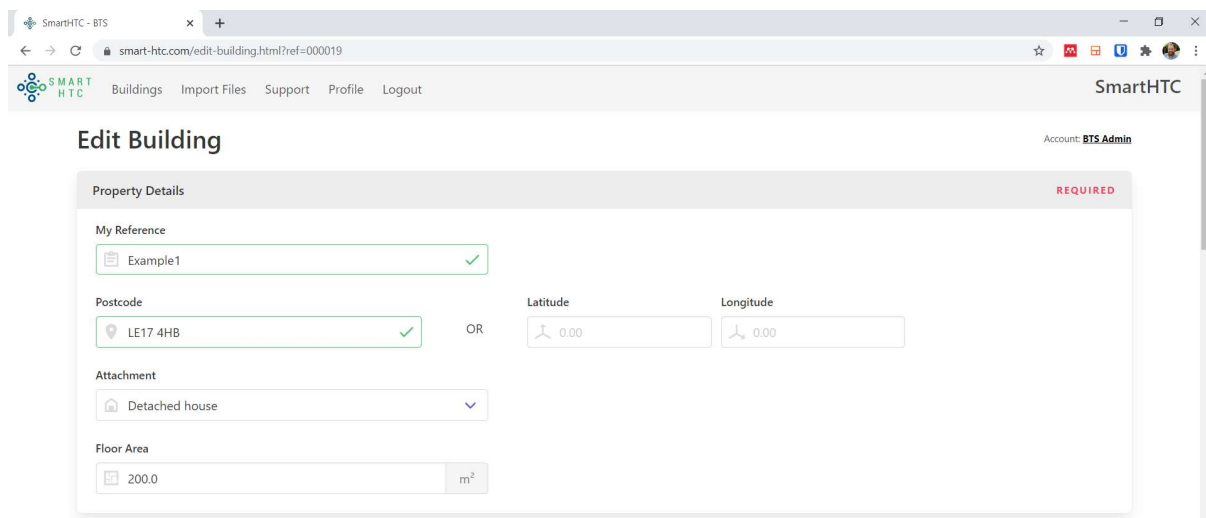
3.2. Browser User Interface

The SmartHTC UI is designed to allow a simple upload of the required input data and near instant return of the calculated HTC. It is intended to be used by new users to help them understand how SmartHTC works, and by users who don't wish to directly with the APIs.

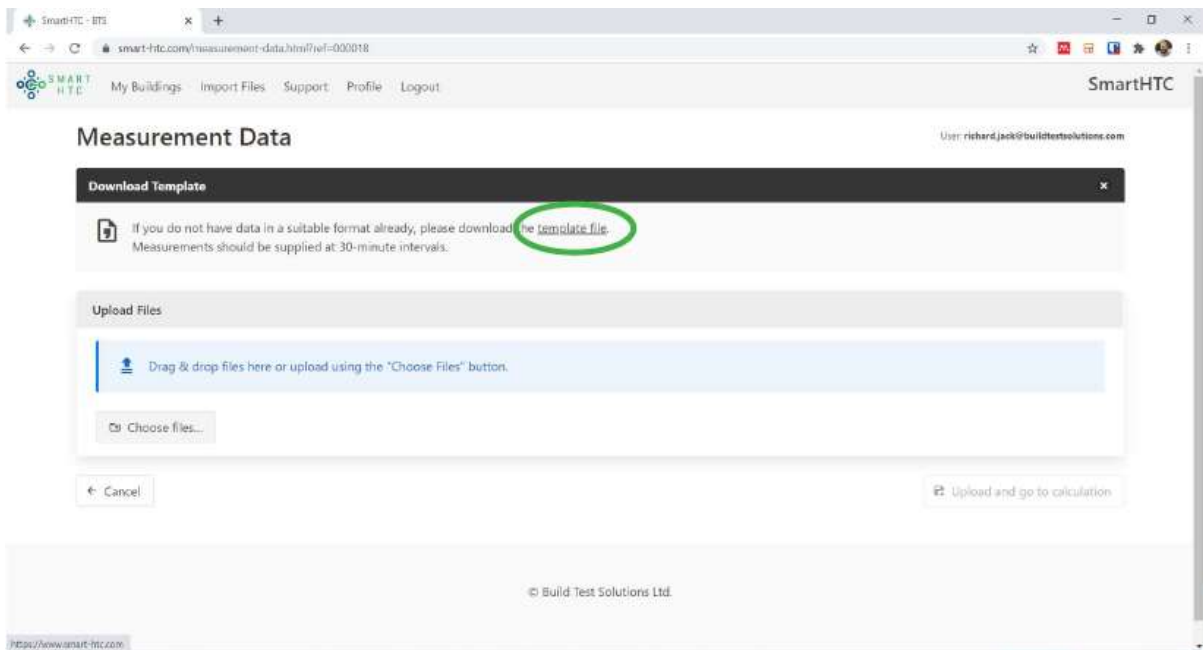
The UI is designed to carry out 1 HTC calculation at a time, so is more suitable for users carrying out small numbers of HTC calculations (in the 10s rather than 100-1000s). The UI follows a simple workflow allowing creation of buildings, upload of monitoring data and return of HTC results.



Building information is provided using a simple form with drop down boxes or input fields with in-built validation to ensure information is provided in the correct format.



To upload the monitoring data (energy, temperature, relative humidity etc.), a template csv file can be downloaded from the user interface then populated by the user. This populated csv file is uploaded to the interface which automatically processes the data ready to be sent to the SmartHTC calculator.



Once the building information and monitoring data has been uploaded the HTC and CI are calculated and returned.

3.3. Heat Pumps

Heat pumps, whether air, water or ground source, have a more variable efficiency than other heating systems. As such it is necessary to enter their heat output, rather than electricity input, for an accurate SmartHTC calculation.

If you have half-hourly heat pump output, this can be entered using the space heating and domestic hot water (dhw) fields in the measurements JSON. In this case it is important that the electricity consumption of the heat pump is subtracted from the total electricity consumption for the building, in order that the energy input to the heat pump is not counted twice, i.e.:

Electricity consumption in SmartHTC calculator = total consumption – heat pump consumption.

If you do not have half-hourly data, but do have total heat output and electricity consumption of the heat pump over a period of temperature monitoring, then you can still use the meter readings endpoint.

3.4. Energy Consumption Outside the Building's Heated Envelope

SmartHTC is based on an energy balance across a building, if there is significant energy use outside of the heated envelope of the building that could cause an inaccurately high SmartHTC measurement.

This is only a problem if there is a large amount of energy consumption outside of the building, with the most likely examples being an outbuilding(s) or a hot tub. In these cases, SmartHTC can still be used if the external energy consumption is monitored and subtracted from the total energy consumption. This is not a problem for the vast majority of buildings, such as a garage or shed with a power supply with irregular plug-in loads and lighting. In those cases, no special actions are required.

4. Interpretation and use of HTC Measurements

Without context a measured HTC value provides limited insight. The value in the HTC measurement is released by further analysis such as comparisons, normalisations or by using the measured HTC as an input to further energy modelling.

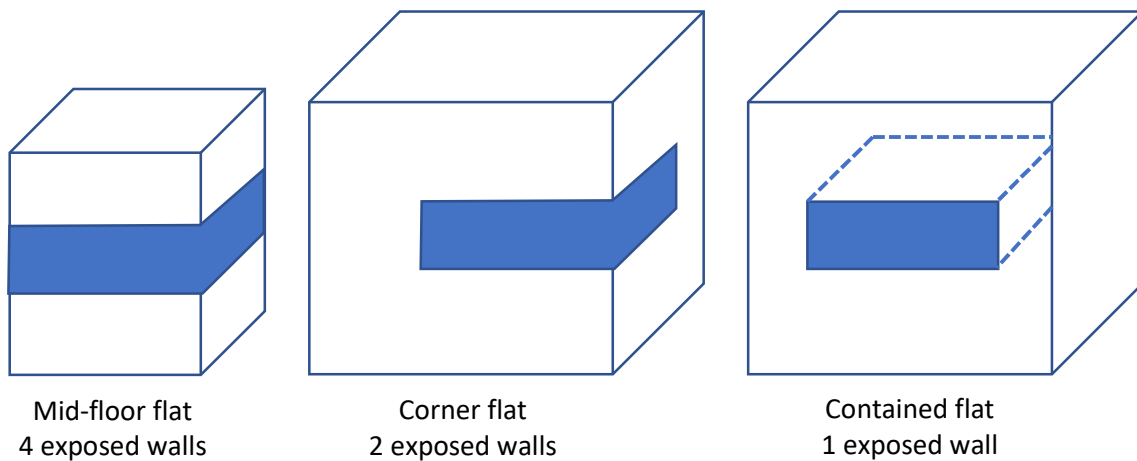
4.1. Normalising the HTC and Comparison with Other Dwellings

The HTC is not normalised by any factors, as such it is dependent upon the size and shape of the dwelling as well as its thermal performance. In order to compare directly between dwellings, it is necessary to normalise the HTC by some measure of the dwelling's size.

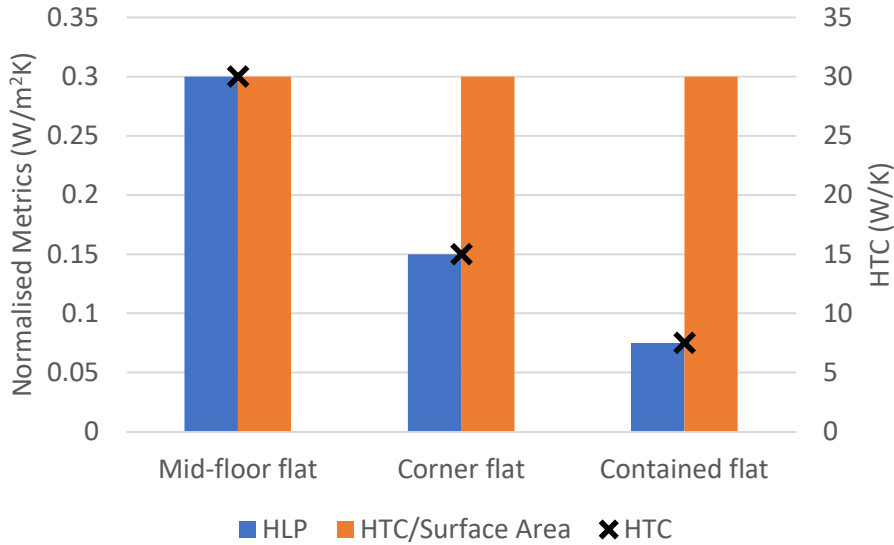
Different methods can be used to normalise the HTC, the most obvious of which would be to divide by the floor area or exposed surface area. The most common method to standardise an HTC value is to divide it by total floor area, resulting in the Heat Loss Parameter (HLP) with units of W/m^2K .

The choice of normalising factor effects the resulting metric. The HLP gives a measure the thermal performance per usable space, but it is related to the built form as well as the actual performance of the fabric. By contrast, normalising by exposed surface area gives a better measure of the thermal performance of the materials but not of the building as a whole.

The effect of different normalisation methods can be demonstrated by a worked example. Consider the same size apartment (100x100x2.5m) with the same construction in three different configurations (to simplify the example it is assumed that there is no heat loss through the party walls, roof or floor):



	<i>Mid-floor flat</i>	<i>Corner flat</i>	<i>Contained flat</i>
<i>Exposed wall area</i>	100	50	25
<i>Wall U-value (W/m^2K)</i>	0.3	0.3	0.3
<i>Floor area (m^2)</i>	100	100	100
<i>HTC (W/K)</i>	30	15	7.5



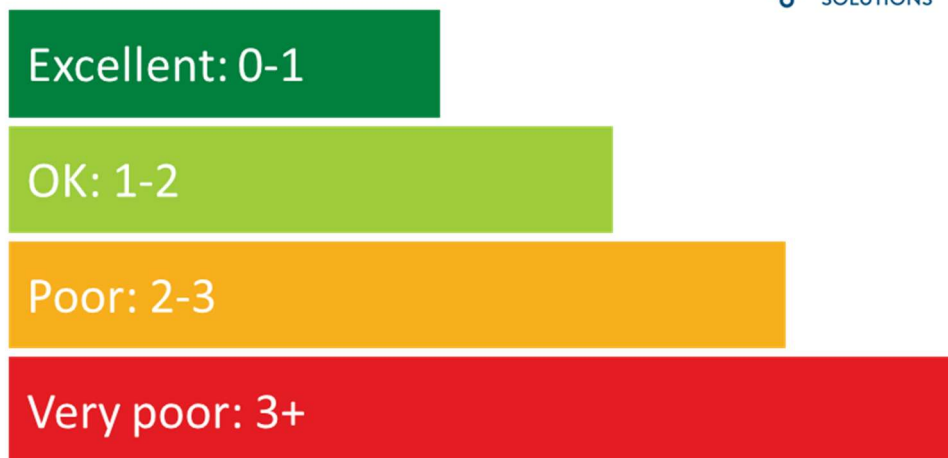
In the example the HTC and HLP are highest for the mid-floor flat and lowest for the contained flat, this simply reflects that there is greater heat loss area and hence greater heat loss. Comparing the HLPs would accurately reflect that the contained flat would have the lowest heating cost, but hide the fact that the building fabric is the same in each case. By contrast, normalising by surface area accurately reflects that the fabric is the same for each dwelling but does not reflect the importance of built form.

After the HTC has been normalised the performance can then be directly compared with other dwellings, in this process it's important to think about which metric to use based on what the comparison seeks to achieve. There are lots of different comparisons which could be applied, for example the performance of different building fabrics or methods could be directly compared and evaluated.

4.2. What's a Good HLP?

BTS have proposed a simple scale to allow a quick interpretation of the thermal performance of a building based on the HLP.

Heat Loss Parameter Scale



For reference, we can consider the HLP of a two-storey detached house with different levels of thermal performance. For simplicity of calculations in this example, the house is a 5x8x5m box.

EXAMPLE	ELEMENT	PERFORMANCE	HLP
EXISTING SOLID WALLED HOUSE	Solid walls (U-value)	1.6	4.16
	Double glazed (U-value)	2.2	
	Solid floor (U-value)	0.6	
	100mm loft insulation (U-value)	0.3	
	Not very airtight (m ³ /m ² .h@50Pa)	12	
RETROFITTED SOLID WALLED HOUSE	Solid wall with 150mm EWI	0.23	1.57
	Double glazed	2.2	
	Solid floor with 80mm insulation	0.28	
	300mm loft insulation	0.14	
	Fair airtightness	6	
2016 BUILDING REGULATIONS PART L LIMITING FABRIC PERFORMANCE¹	Walls	0.3	1.82
	Windows and doors	2	
	Floor	0.25	
	Roof	0.2	
	Airtightness	10	
FUTURE HOMES PART L CONSULTATION LIMITING VALUES	Walls	0.3	1.56
	Windows and doors	2	
	Floor	0.25	
	Roof	0.2	
	Airtightness	10	
PASSIVHAUS EXAMPLE²	Walls	0.13	0.93
	Windows and doors	0.88	
	Floor	0.2	
	Roof	0.14	
	Airtightness	0.6	

4.3. Comparison with Predicted Performance

The HTC is the standard metric for thermal performance and is calculated in most energy models, including the UK's Standard Assessment Procedure (SAP and RDSAP). This makes a direct comparison between predicted and measured performance relatively simple, and provides an easy insight into the 'performance gap'.

A comparison with predicted performance is useful for quality assurance, and can be even more illuminating if the performance is compared before and after a retrofit measure. The calculated HTC of a building can be entered into SmartHTC.com which will then provide a comparison between calculation and measurement, this will show if there is a 'performance gap' for the building.

4.4. HTC as an Input to Energy Models

The thermal performance of a building is interesting with respect to the performance gap and build quality, but is still quite an abstract concept. The measured HTC can be used as an input to energy models to more accurately calculate predicted energy consumption and costs, and in turn more accurately predict the effect of retrofit measures or changes in heating practises.

¹ The limiting values given in Part L of the building regulations are the worst permissible performance levels for each element, to comply with the regulations it's likely that better fabric performance levels would be required, and hence result in a better HLP.

² Roughly based on the elemental performance from this project described on the Passivhaus Trust UK website, https://www.passivhaustrust.org.uk/UserFiles/File/UK%20PH%20Awards/2015/2015%20posters/UKPHAwardsPoster_Retrofit_Admirals%20Hard.pdf