Approaching Near Zero Energy
in Historic Buildings

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Energy Pathfinder
T3 Energy monitoring and management

A Guide to Energy Assessment and Monitoring Methodologies

1. Introduction

This document is intended to be a brief guide to energy assessment and monitoring methodologies. It describes the methodologies used at some of the Energy Pathfinder demonstrator sites but is written to inform members of the public as well as building professionals. It therefore provides an overview of how each methodology works, gives a sense of the relative financial and time commitment associated with them, and outlines the level of specialist knowledge required to undertake the assessments and interpret the results.

Monitoring can be an important part of a retrofit project. The different methods chosen to carry out the monitoring can give an insight into the condition of a building's fabric as well as its energy efficiency before and after retrofit. Existing buildings, and particularly historic buildings, are usually different in terms of their construction and materials compared to current construction norms. Monitoring methodologies can help to assess the improvement to a building's energy performance in a quantifiable way. They can also help to maintain the health of a historic building's fabric while maximising its energy efficiency. Similarly, they can help direct the design of energy saving measures so they will have a minimal impact on the cultural significance of a building, particularly where they have statutory protection through the planning process.

There is a wide variety of different monitoring methodologies. For the purpose of this report, the monitoring methodologies were split into different categories. Energy metering is simply the monitoring of the actual energy being used within a building. Fabric measurements are used to assess the energy performance of building fabric, such as by examining internal and external conditions of the building, before and after any retrofit works. This can include U-Value testing (how fast heat transfers through a structure or individual materials, such as walls, insulation etc.) or air-tightness testing.

Access to the building may be necessary for a more accurate assessment of its energy performance. Monitoring for comfort and health of both the building fabric and its occupants includes considerations of the indoor environment, such as monitoring volatile organic compounds (VOCs) as well as indoor temperature and humidity. This can also include subjective qualitative measuring using occupant surveys. Lastly, simulations are a chance to test retrofit measures and energy efficiency in a virtual environment using different software and parameters. These can often help in the decision-making process and predict likely energy usage after the retrofit.

Each measuring methodology in this report has a short summary at the beginning showing important considerations, the level of expertise required, as well as approximate cost, and a summary at the end setting out any pros and cons.

Contents

2. Energy metering

OPERATION: GENERAL USER | INTERPRETATION: GENERAL USER | COST: LOW
OTHER CONSIDERATIONS: READINGS OF AT LEAST A YEAR ARE NECESSARY TO SHOW TRENDS

Energy metering is perhaps the easiest and most basic measurement when it comes to energy monitoring. The values are retrospective, showing the electricity and gas used for space heating, hot water, as well as electrical appliances and lights. The energy used in the building can be measured using different methods. It is important to consider what is using up the electricity and gas in order to get a good appreciation of how the energy is being used, particularly in a non-domestic situation. Similarly, it is important to show when the readings were taken, as energy use in winter will be considerably higher than in the summer months.

2.1 Reading of energy meters

The easiest way of looking at energy use is to read and note down the usage from the energy meters. This is often necessary in a domestic setting in order to pay for the energy used. In managed buildings, these readings can be based per rented unit or as a total, so further calculations may be necessary.

Past readings can be available via energy bills which should set out the meter readings they are based on. These can help to identify long-term trends of energy use and help to give a more accurate average. A colder winter might be balanced out by a warmer winter where less space heating was necessary.

Another system in use throughout Europe uses Smart Meters which automatically collect the meter readings and display the use and cost in real time. These can give an on-demand visual comparison of the energy use over time. The meter is generally updated at least every 15 minutes and can therefore give much more detailed time-of-use data.

2.2 Country specific metering programmes

In some of the countries, specific systems can help with the reading of energy meters. An example provided by Energy Pathfinder partners is the Danish ‘Energy Key System’ used at the Viðareiði Vicarage, Faroe Islands. Here, the meter readings are fed into a central system which can then be accessed and analysed as needed. A similar system is used in the Finnish demonstrator buildings.

2.3 Clamp-on meters

In situations, where metering data is not available, it is possible to purchase and use a clamp-on energy meter. As with readings taken from standard energy meters (2.1 above), these meters measure the energy used in the building and will need a certain measuring period of at least one year to be meaningful.

For electricity, these are typically installed at the point where the mains cable enters the house, often at the fuse box. Gas flow meters are slightly more expensive and need to be positioned where the mains gas supply enters the house. Similar meters exist for other sources of energy, and it is important to consider what needs to be measured before deciding on the appropriate apparatus.

Uses: determining the energy use of a building

Pros: non-invasive test; easy to do and interpret

Cons: requires readings for a year or more; can be complex with multiple users of a building

3. Fabric measurements

These are measurements of the energy performance of the building's fabric. The methodologies considered here are all in-situ measurements and do not include measurements done in a laboratory. It is important to consider which of these might result in giving the most useful information. Another consideration is how invasive the methods would be, both for the building's fabric or its occupants in cases where measuring is ongoing for a longer period of time.

3.1 U-values

OPERATION: EXPERT USER | INTERPRETATION: TECHNICAL USER | COST: MEDIUM-HIGH
OTHER CONSIDERATIONS: NEEDS SUFFICIENT TEMPERATURE DIFFERENCE BETWEEN INTERIOR AND EXTERIOR

The *U-value* is the measure of heat transmittance through the thickness of a material, expressed in W/m^{2}K. Therefore, measuring the U-value can give a good idea of heat loss through building elements, such as insulated or uninsulated walls, or through individual materials such as glass. The better the insulation properties of a material are, the lower its U-value figure will be.

The U-value is measured by attaching temperature sensors to both sides of the fabric and measuring heat flow. This should be monitored over a number of days, ideally, through different seasons. Here, it is important to get a consistent value, with a standard deviation of less than 5%.

Fig. 1: U-values being measured with a temperature sensor (in red) on the inside of the roof at Holyrood Park Lodge © HES

To achieve accurate measurements, the energy differential should be more than 5°C between a building's exterior and interior. If the exterior temperature is lower than the interior, this would need to be consistent for the whole measuring period. In practice, this means that most of these measurements are done in the colder months when daytime exterior temperatures are lower than interior temperatures.

Carrying out U-value measurements requires technical equipment and a specific software. It is usually therefore, undertaken and interpreted by an expert user.

U-value measurements are often combined with other energy monitoring methodologies. For example, U-value measurements can be used as a baseline for simulations, such as hygrothermal measurements and energy efficiency predictions (see section 3.2). These can be used to predict the actual U-value of building components where these figures are not available. Carrying out in-situ U-value measurements in selected locations in a building can improve the accuracy of the models.

Uses: establishing the thermal efficiency of a building's fabric

Pros: non-invasive test

Cons: requires expert equipment, software and knowledge; relatively expensive; based on few individual locations within the building

3.2 Hygrothermal monitoring

OPERATION: EXPERT USER | INTERPRETATION: EXPERT USER | COST: HIGH
OTHER CONSIDERATIONS: THIS NEEDS TO BE MONITORED FOR AT LEAST ONE YEAR

Hygrothermal monitoring is the testing of moisture in relation to temperature within the building fabric. This is mostly relevant when insulation is going to be installed for example, as it can change how moisture travels through a building's fabric once insulated. This is because insulation materials introduce extra layers of material that can prevent the natural drying action of the building fabric. This is the case both for internal and external insulation.

More specifically, interventions such as the introduction of wall insulation (particularly internal insulation) can reduce the temperature of the wall itself. The important factor here is the dew point, which is the temperature at which water condenses on colder surfaces or within the fabric. As the external wall fabric becomes colder (due to reduced heat transfer), the dew point is reached more easily. As such, water is more likely to condense within the fabric and this can lead to fabric decay and mould.

Hygrothermal monitoring can be used before retrofit to give a baseline of the conditions within the building fabric. These in turn can be used to inform the design options for retrofit or show if a period of drying out is necessary. For example, if the building fabric is found to be wet before any retrofit works, the specification of impermeable or vapour-closed internal insulation would not be appropriate. Monitoring can also be carried out after the refurbishment to monitor the effect the retrofit measures have on the fabric. This can highlight any moisture issues early on.

Because the internal moisture and drying rate varies over the year, it is beneficial to monitor this for at least one year, if not for multiple years.

Method

Hygrothermal measuring is done by inserting probes to different depths within the building fabric (Fig. 2). These usually measure the relative humidity and temperature. This is done in a few places around the building and possibly at multiple points and heights on a wall.

Fig. 2: Loggers measuring two points in this wall, at the top of the cable and nearer the loggers.

The probes are connected to logging software which collects the measurements at regular and defined intervals. The measurements can then be used to determine the dew point, if necessary.

Once in place, it is recommended that the setup is checked periodically to prevent any faults in the equipment impacting on the results. As seen in Figure 3, a fault resulted in no measurements for about one month.

Analysis

Analysis of the results from monitoring is usually done by an expert user who can interpret any trends in the data.

When looking at hygrothermal results in relation to building fabric, an important threshold to consider is 75% relative humidity. Above this level, the building fabric is liable to develop mould, which in turns leads to decay, particularly in organic material such as timber and internal linings. Higher humidity in these materials is also more likely to attract certain pests such as wood boring beetles. As well as causing damage to the building's fabric, decay and mould can have a negative impact on the health of a building's occupants.

It should be noted that it is normal for relative humidity to exceed the threshold for periods of time, particularly during the winter months. This is illustrated in the diagram in Fig. 3 where the relative humidity was above 75% for a couple of months (orange to blue lines).The diagram, however, also shows that the humidity reduces again during the summer months and does not remain above the threshold for long.

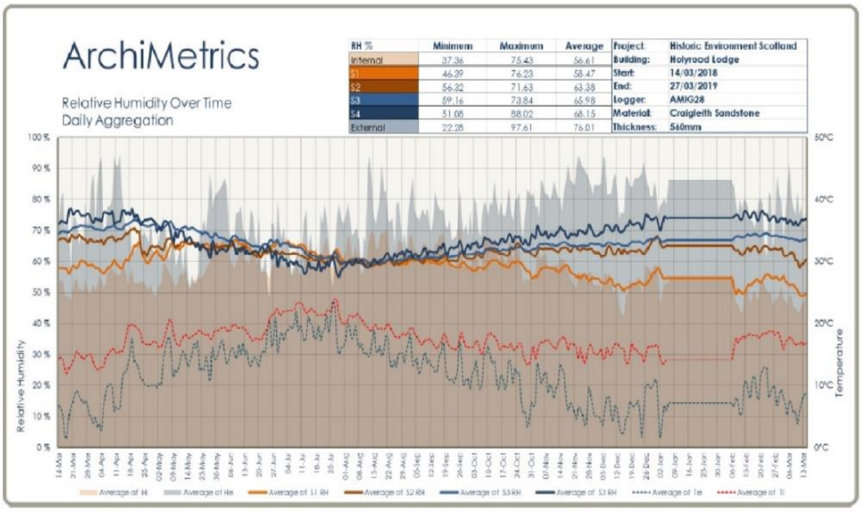

Fig. 3: A period of measuring showing the conditions over one year after refurbishment.

Uses: establishing whether the environment within the wall fabric presents a mould or decay risk before or after refurbishment

Pros: can give definite results where excessive moisture is a problem

Cons: invasive; needs to be monitored for at least a year

3.3 Thermal imaging

OPERATION: GENERAL USER | INTERPRETATION: TECHNICAL USER | COST: LOW

OTHER CONSIDERATIONS: NEEDS SUFFICIENT TEMPERATURE DIFFERENCE BETWEEN INTERIOR AND EXTERIOR

Thermal imaging (or infrared thermography) uses a lens to see temperature differences on a surface. It makes any differences in the temperatures across a façade visible in the form of different colours which means that heat loss through the building fabric can be identified and interpreted. It is especially useful for looking at images before and after a retrofit as it can show how much heat is being lost in comparison. As can be seen in Figure 4, the comparison highlights the reduction in heat loss (insulation level) achieved by the retrofit. The method can also be used during the installation of insulation in a wall cavity as a way of confirming that the cavity is properly filled and that all areas have a sufficient level of insulation. Internally, thermal imaging can also reveal areas cooled by draughts around doors and windows.

EXTERNAL PRE-REFURBISHMENT					
Date	Time	External Air T	Internal Air T	Wind Speed	Conditions
24th January	8.20 – 9.05 am	9 ˚C	18 ˚C	2.0 m/s	Dry
EXTERNAL POST-REFURBISHMENT					
Date	Time	External Air T	Internal Air T	Wind Speed	Conditions
7th February	8.45 – 9.25 am	4 ˚C	15 -20 ˚C	1.0 m/s	Dry

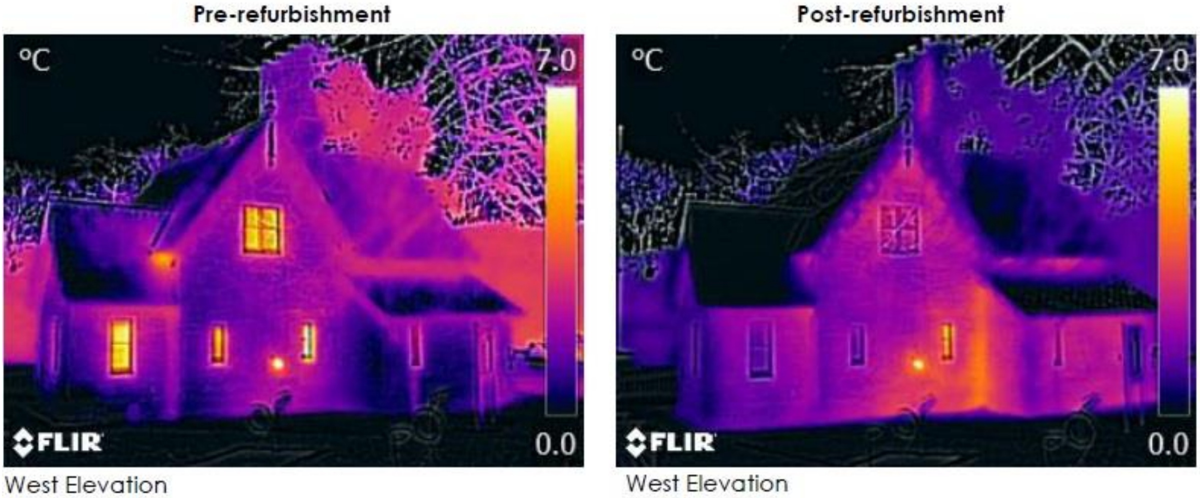

Fig. 4. Holyrood Park Lodge before and after refurbishment. The darker roof and windows show the improvement in insulation. Note that the climatic conditions when the images were taken were very similar.

Analysis

While capturing the thermal image is relatively easy, a number of things should be considered. Thermal imaging needs a significant temperature difference between the exterior and interior temperatures to work effectively. In order to achieve the necessary temperature difference, thermal imaging can only realistically be done in winter. In the above example (Fig. 4), the measurement was done in January/February and the temperature difference was more than 10℃. It is also important to take images in a way that avoids sun glare and wind chill. As such, some instruction is necessary for the user taking the images to achieve consistency in conditions on both occasions and thereby capture the most useful data.

To aid the analysis, one should record the conditions when the images were taken and any other factors which might lead to misinterpretation. For example, the images can record different temperature readings due to the presence of devices or particular weather conditions. These can include lamps, external electric devices such as alarms, and areas of wall warmed by the sun. Surfaces can also appear colder due to moisture in or on the wall, or due to being cooled down by wind. An image taken in wet weather will record colder surfaces than one taken during a dry, sunny day.

With all of the above in mind, images can very easily be misinterpreted by an inexperienced user. It is therefore vital that conditions are fully recorded when the images are taken and that an experienced user is engaged. This will ensure that the interpretation is as accurate as possible and best reflects the building's environmental conditions and performance.

Equipment

Compared to some of the other fabric measurements, thermal imaging requires very little equipment. Good quality images can be achieved with relatively affordable thermal cameras. Some of them can be attached to and operated through mobile phones (Fig. 5) or are integrated in so-called rugged mobile phones developed for the construction industry. Others are standalone devices, ranging from relatively simple and cheap devices to sophisticated and more expensive ones (Fig. 6), but there is a considerable price difference between these two types. The important considerations are the resolution of the thermal image and the accuracy of the temperature recorded, but the availability of cheaper devices means that this form of fabric monitoring is accessible to a wider range of services.

Fig. 5: A thermal camera attached to a smart phone.

Fig. 6: A higher spec thermal camera.

Uses: establishing areas of heat loss through the fabric and locating areas prone to draughts.

Pros: can be affordable, can be done relatively quickly and by general users with some instructions.

Cons: images can show false results due to exterior conditions; images may be misinterpreted by an inexperienced user

3.4 Air pressure testing

OPERATION: TECHNICAL USER | INTERPRETATION: TECHNICAL USER | COST: MEDIUM
OTHER CONSIDERATIONS: THE WIND CAN IMPACT THE RESULTS OF THE TEST

Air pressure testing can reveal the rate of air leakage from a building and is commonly used to show how much heat is lost in this way. It is also referred to as air tightness testing.

Air pressure testing is done using a *door blower test*. All openings, such as windows, doors, loft hatches and chimneys are sealed, and air is pumped into the space to create a higher air pressure than the exterior. The fan, usually installed in one of the external doorways (Fig. 7), measures the air needed to maintain a constant pressure, which equates to the volume of air lost through the fabric and any cracks. Some of these seals are then removed and the test is then repeated. The differential between the two measurements will show how much air is lost through those elements which are no longer sealed.

Fig 7. The fan installed in the sealed external door.

Analysis

The test and analysis are usually done by a specialist firm with the required equipment to do the test and the expertise to interpret the results. Since this is required for modern construction projects, there are many companies who have the necessary equipment. Any special requirements for existing and historic buildings need to be discussed in advance.

Analysis of the results needs to take into account the construction type of the building. Historic buildings are often less airtight due to the nature of traditional materials and construction methods. These include suspended timber floors with vented underfloor areas, and chimney flues which may act as natural ventilation stacks. During testing, these need to be sealed along with the windows and doors in order to discount them in the findings. The companies chosen to undertake this kind of testing should show an understanding of the nature of historic buildings and plan for it during the test.

Other Tests

A leak test can be done alongside the blower test. Smoke is distributed within the building and followed. The smoke will find any small areas of leakage and therefore highlight cracks and areas prone to draughts.

Uses: determining air leakage through fabric and locating any cracks or draughts

Pros: non-invasive test; only takes one day; common to find companies doing this

Cons: developed for modern buildings so results in historic buildings can be expected to be considerably higher

4. Indoor comfort

Indoor comfort is an important aspect in retrofit because the fundamental purpose of a building is to provide a comfortable environment for its inhabitants. Indoor comfort is derived from a combination of the temperature and relative humidity in a space as well as its air quality. Indoor air quality is dependent on various elements in the air that often include carbon dioxide (CO_2), volatile organic compounds (VOCs) and particulate matter (PM). Qualitative surveys of the building's users can also help to build a picture of indoor comfort.

4.1 Temperature and humidity

OPERATION: GENERAL USER | INTERPRETATION: GENERAL USER | COST: LOW
OTHER CONSIDERATIONS: MONITORING SHOULD BE DONE FOR AT LEAST A YEAR

Temperature and humidity are the basic measurements for indoor comfort. Normally, a comfortable temperature range is between 18℃-22℃, although this is subjective. The relative humidity comfort range is between 30-60%, which is similar to that needed to maintain healthy building fabric and prevent mould growth.

The temperature and humidity can be monitored using widely available sensors. Some of these can save the measured data at regular intervals, so it can either be downloaded or viewed on the device itself.

Perceptions of a comfortable temperature may also be affected by other factors. For example, downdraughts caused by air movement across colder elements like windows can make the room feel colder than the temperature might indicate.

Similarly, the heating source can make a difference to the perceived room temperature. While conventional water-based systems heat the air in a room, radiant heating heats up the objects and people, raising the perceived room temperature. Radiant heat sources include solar gain through windows or heat coming from a stove. The same is true for heat coming from below, such as from underfloor heating. Both methods can make the indoor environment more comfortable for users at lower air temperatures.

Heating can also have an impact on the humidity, as higher temperatures generally lower the relative humidity in the home.

4.2 Indoor air quality

The monitoring of indoor air quality generally refers to measuring the percentage of any chemicals present in the air, such as carbon dioxide (CO_2). In greater concentrations, CO_2 can lead to a feeling of 'stuffiness' in a building. Normal outdoor levels of CO_2 are around 400-450ppm (parts per million) and levels below 1000ppm are considered a good indoor environment. Anything above 1500-2000ppm is considered bad indoor air quality and can result in headaches, sleepiness and loss of attention.

Volatile organic compounds (VOCs) can include a wide variety of chemical compounds found in a building. These can come from, for example, off-gassing (leaking of chemicals into the environment) from newly introduced materials, such as insulation or furniture, or can more typically be derived from normal domestic activities and aerosols used for cleaning.

Analysis of particulate matter (PM) is often also included in air quality monitoring. This is the sum of solids and droplets suspended in air and are split up into different categories based on their size. These are generally PM_{10} and $PM_{2.5}$ which are less than 10 micrometres and less than 2.5 micrometres respectively. They can come from combustion outside, such as traffic, and from inside the home, such as from cooking, candles and stoves.

The measuring of radon should also be mentioned here. Radon is a natural gas which can come from the ground in certain geographic locations and enters the house from below. Ventilation is required to disperse and minimise the concentration of this gas in the house. Some indoor air quality monitors measure radon in addition to the other parameters. If this is a concern in a particular location, it may be advisable or necessary to monitor it.

Combined monitors

OPERATION: GENERAL USER | INTERPRETATION: GENERAL USER | COST: LOW

There are a variety of relatively affordable combined monitors available. Some of these have internal storage to save the data whereas others may only display the readings in real time. These often monitor temperature, humidity, CO_2 and VOCs (Fig. 8) and usually feature a 'traffic light' system warning building users when conditions are not within the recommended range.

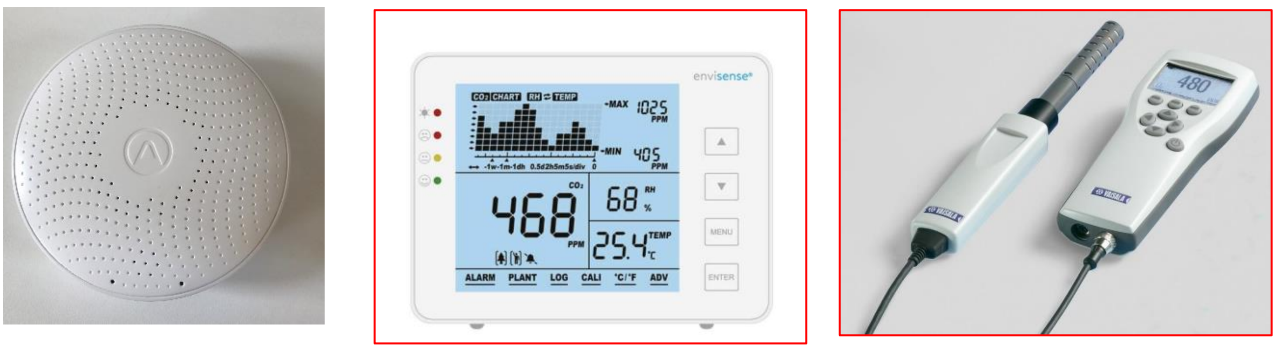

Fig. 8: Three different combined monitors, a battery-operated logger with 'traffic light' system (left), a mains operated display device, also showing temperature and humidity (middle), and a handheld device (right).

A benefit of these monitors is their easy setup. They are also usually relatively small and can be mounted to a wall or placed on convenient surfaces. The devices often self-calibrate their sensors over a number of days, making the data more accurate over longer periods of time.

Full analysis

OPERATION: TECHNICAL USER | INTERPRETATION: TECHNICAL USER | COST: MEDIUM-HIGH

More in-depth monitoring can be achieved with specialised equipment and analysis methods. This includes dedicated CO_2 loggers in conjunction with air particle sampling, usually carried out on different occasions at different times of the year. Air sampling is done by trapping air within the room for a certain amount of time and capturing and analysing the particles.

This process can determine not just the quantity of total VOCs, but also the make-up of these and possible origins. It can then produce a much clearer picture of the indoor environment in a particular room or space to inform decisions on making improvements.

Full air sampling and analysis requires technical knowledge and laboratory equipment for accurate analysis and interpretation of the results, making it much more expensive. The test equipment is considerably bigger and will need to remain in the room for a certain amount of time (usually a few hours) when testing is done.

Uses: Determining chemical and other pollutants present in the indoor environment

Pros: can be affordable and easy to use for a general user

Cons: cheaper systems give less accurate data; more accurate measurements can be quite expensive

4.3 User surveys

OPERATION: GENERAL USER | INTERPRETATION: GENERAL USER | COST: LOW

OTHER CONSIDERATIONS: USER SURVEYS CAN BE VERY SUBJECTIVE AND SHOULD BE USED IN CONJUNCTION WITH OTHER MONITORING METHODS

In addition to the above methods, it can be useful to do user surveys. This will give information about the comfort levels of a building as perceived by its users. The results of surveys can reflect the numerical data gathered (e.g. if it is perceived to be stuffy and the CO_2 level is high) or can be in opposition to it (e.g. the temperature is perceived to be too high or too low even though it is within the range suggested above).

User surveys can be a useful tool as the inhabitants' comfort is the main aim of any building. It should be noted, however, that user comfort is difficult to measure since the scale, as well as the measure, are subjective. This means that any user survey results should be analysed in conjunction with measured values and be compared with survey results from other users of the same or similar buildings. The more surveys that are available from a building, the more accurate the data and trends will be.

There are different ways of demonstrating user comfort. This can be done in scales or 'spider diagrams' (Fig. 9). When sufficient data is available, bar charts or line graphs can also be a useful way to show the data. However, this would usually be referring to the calculated percentage or comparison, rather than the exact answers given by the participants.

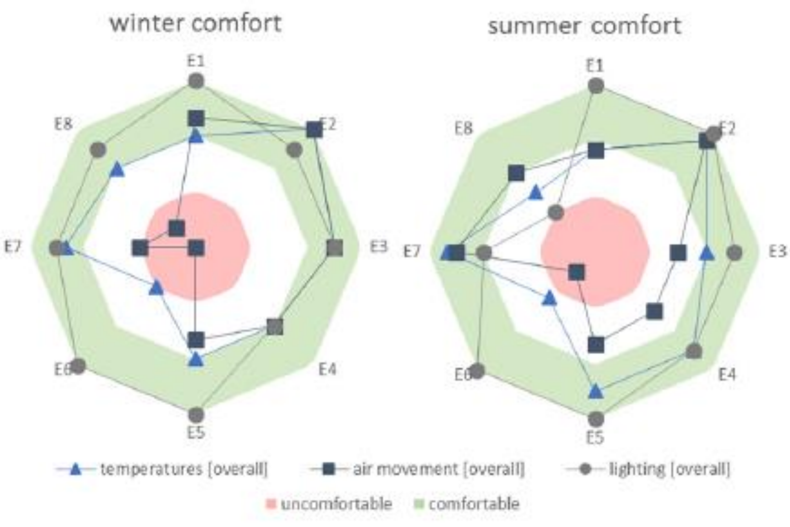

Fig 9: The comfort ratings of eight similar dwellings, as reported by the inhabitants. These varied considerably between the dwellings, though the same dwelling often reported similarities between summer and winter comfort. The scale is non-numerical.

Uses: establishing the perceptions of comfort experienced by users of a building

Pros: can be gathered without equipment; can be more relevant than quantitative surveys for user comfort

Cons: data is subjective and qualitative

5. Simulations

Some of the results mentioned in the previous sections can also be approximated using different simulation methods. This can be a helpful indication of the likely results ahead of a refurbishment, or a more cost-effective method of assessing the building fabric. Similar to the physical measurements, the different simulation measures can vary in the complexity of analysis and the accuracy of results

5.1 Country-specific energy efficiency simulation

OPERATION: TECHNICAL USER | INTERPRETATION: GENERAL USER | COST: LOW
OTHER CONSIDERATIONS:

Many countries now have a methodology to assess the energy efficiency of their building stock as mandated by the EU Energy Performance Building Directive. These are called ‘Energy Performance Certificates’ in the UK and have similar names in other countries. These assessments can estimate the amount of energy likely to be needed by a building based on a set of standard assumptions. It should be noted that there is an absence of sufficient available data on the performance of some traditional materials, and therefore assumptions are made that some historic building elements will perform in the same way as those in a new building. Later additions and alterations to an existing building must also be considered.

The result of the simulation usually gives the building a banding from A (most efficient) to G (least efficient). The scale underlying these bands differs between different countries. For example, the UK uses the Standard Assessment Procedure points system (SAP points, see Fig. 10), while systems in other countries assess the energy used per m^2. Often, these reports are a necessary requirement when a property is to be sold, rented, or is publicly accessible.

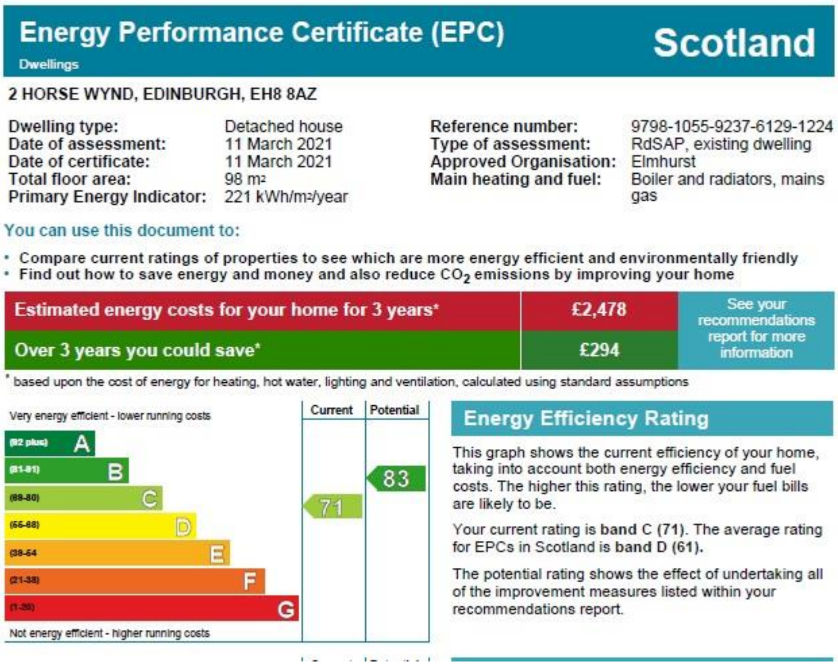

Figure 10: An example of an EPC statement from Scotland, showing building details as well as the energy efficiency rating.

It should be noted that these assessments, while giving a very good indication, are not completely accurate, since they do not take into account individual preferences and habits as regards energy use. However, when looking at the data nationwide, it can give an overview of the energy efficiency of a country's building stock.

The assessment can be supplemented with measured energy performance values of the building fabric, such as measured U-values. This requires more knowledge of the software, and not every assessor will be familiar with this. However, using physical measurements can make the results more accurate.

5.2 Other energy simulation software

OPERATION: TECHNICAL USER | INTERPRETATION: TECHNICAL USER | COST: MEDIUM
OTHER CONSIDERATIONS:

More detailed energy simulations can be achieved by using more complex software. With this, the model can be tailored to the individual building and its elements. The model is created by inputting the different building elements, which are then considered individually. This is particularly beneficial for historic properties with alterations and non-standard building elements (as compared to modern construction).

Any previous fabric energy performance measurements, such as U-values of individual building elements, can usually be incorporated into the model, making it more accurate.

Energy simulation software can be used to determine the most efficient zoning scenarios. Zoning is the practice by which different parts of a larger building can be split and managed independently. For example, unused areas of a building can be heated (or cooled) less in order to save energy. Simulating the zoning in a building can determine how to make its energy management as efficient as possible.

Uses: determining the expected energy efficiency and consumption of a building

Pros: not invasive; often cheaper and faster than measuring the fabric

Cons: result is not based on real life, but on a series of assumptions; can be inaccurate

5.3 Hygrothermal simulation

OPERATION: TECHNICAL USER | INTERPRETATION: TECHNICAL USER | COST: MEDIUM
OTHER CONSIDERATIONS:

As with the other simulation methods, hygrothermal simulation is done using different software programmes. Here, the building elements are put in, often as layers, and weather data is used to simulate the likely moisture exposure of the individual build elements. More sophisticated software will allow for more complex calculations to be executed. For example, some programmes use an average seasonal weather pattern, while others use hourly climate data based on the past weather in a certain area. Similarly, some programmes may consider the build-up of a building's elements as a single mass, while others take into account the different layers of finishes, insulation and walling. The additional layers can make the model more accurate, as it can take into account the characteristics of the mortar in stone buildings, for example, and the effect a render might have.

Hygrothermal simulation is often considered when energy efficiency retrofits are planned, as mentioned above in section 3.2. The simulation enables considering different scenarios and materials before fitting them to the building. It can predict possible problems of mould and moisture accumulation or if a chosen proposal is likely to be appropriate.

Uses: determining expected moisture load in building fabric

Pros: not invasive; often cheaper and faster than measuring the fabric

Cons: result is not based on real life, but on a series of assumptions; can be inaccurate

6. Further reading

Energy performance of Buildings Directive, European Commission (2010), Energy performance of buildings directive | Energy (europa.eu)

TECHNICAL PAPER 6: Indoor Air Quality and Energy Efficiency in Traditional Buildings, S. Halliday, Historic Scotland (2009).

TECHNICAL PAPER 12: Indoor Environmental Quality in Refurbishment, R. Hobday, Historic Scotland (2011).

TECHNICAL PAPER 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools, J. Little, C. Ferraro & B. Arregi, Historic Scotland (2015).

TECHNICAL PAPER 34: Energy Consumption and Behaviour Profiles for Eight Traditionally Built Dwellings, J. Stinson, J. Bros Williamson, C. Garnier, J. Currie, Historic Environment Scotland (2020).

Refurbishment Case Study 37: Holyrood Park Lodge, Historic Environment Scotland (2020).