Optimised Retrofit

Linc Cymru
Energy Performance Measurements Case Study

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BUILD TEST SOLUTIONS

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1. Introduction

In addition to the whole home assessment protocol being developed under the Optimised Retrofit project, Build Test Solutions and others have been commissioned to showcase what is possible by means of directly measuring the performance of homes pre and post retrofit.

Ordinarily building performance measurement is considered high cost, complex and disruptive but a range of new and emerging methods have changed that situation. The benefits of in-situ measurement include:

- Measuring the **baseline performance** of a property prior to any retrofit works. Helping to target investment and specify optimal interventions e.g. insulation and ventilation strategy and identification of space heat demand with regards to considering a new heating system or heat pump.
- Measuring at key gateway stages **during the retrofit process**. For example, by means of signing off the airtightness or wall insulation prior to final fix and decoration taking place.
- Measuring **post completion of the retrofit works** as a means of quality assurance and validation that the intended design outcomes have been delivered in practice. This might form the basis of procurement arrangements with contractors or simply serve as a means of validating impact of investment.
- **Moving away from relying on visual surveys and assumed levels of elemental performance**, such as those used in Energy Performance Certificates (EPCs) which have been shown repeatedly to be prone to significant inaccuracy for an individual house.
- Accurate knowledge of the thermal performance of a house allows better **risk analysis** of the likelihood of fuel poverty and mould growth, allowing proactive remedial measures.
- Performance measurements enable additional **funding opportunities** from policies such as the Energy Company Obligation (ECO) and the Social Housing Decarbonisation Fund (SHDF).

The vast majority of asset management processes for building efficiency and condition surveys are based on visual surveys, yet no two properties are ever the same. Surveys such as EPCs aren't able to accurately reflect the true performance of properties, nor reliably quantify the impact of investments with regards to energy, CO_2 or running cost savings.

In order to demonstrate the latest innovations in in-situ measurement, Sero commissioned Build Test Solutions to carry out a series of thermal performance and air tightness measurements on five homes in Newport managed by Linc Cymru.

This short report presents the detailed results and seeks to summarise key considerations for social housing providers on the Optimised Retrofit project considering undertaking measurements during the 2021/22 winter heating season.

2. SmartHTC: Thermal Performance Assessment

SmartHTC measures the thermal performance of a building whilst the property is occupied and used by the resident as normal. The technique has been developed to be non-intrusive, simple, low cost and highly scalable. The data input required is internal temperature taken from temperature sensors and meter readings taken at the start and end of a 21-day period in winter. SmartHTC measures the heat loss from a property, in order to do so it must be at least 7°C warmer inside than out so that there is enough heat loss to measure.

The data is processed by online software and the result is the Heat Transfer Coefficient (HTC). The HTC is a measure of the overall thermal performance of a dwelling, including heat transfer through the building fabric and by air movement. The HTC is a measure of the rate of heat transfer through a building per degree of temperature difference between inside and out, so a building with an HTC of 100W/°C would require a constant heat input of 1kW to maintain a temperature 10°C warmer inside than out.

A higher HTC means that there is more heat transfer, i.e., worse performance. In a UK winter a high HTC leads to more heat loss and hence a greater heating requirement to keep the building warm. The HTC is not normalised by any measure of the size of the building, so that a bigger house will tend to have a higher HTC than a smaller house of the same construction. For that reason, the HTC is often divided by the total floor area of the building so that the thermal performance of different buildings can be directly compared, this is known as the Heat Loss Parameter.

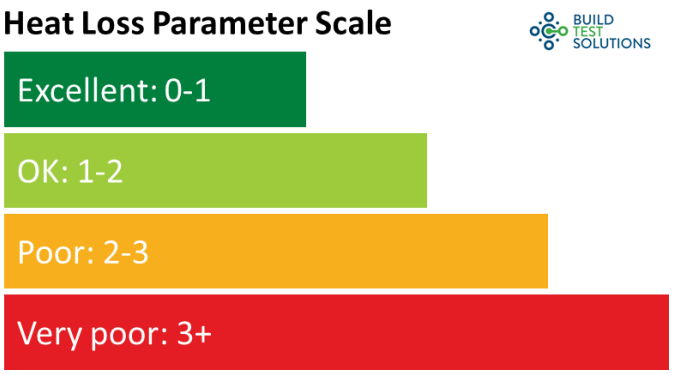

Figure 1: BTS' Heat Loss Parameter scale, giving a ranking of thermal performance.

The five homes tested in Newport were all void properties at the time of testing, it's possible to apply SmartHTC testing in void properties but it can cause some complications which were experienced in this case. In order to carry out a SmartHTC test it's necessary to measure the energy input for the period of the test, but unfortunately service meters were not working in one property and removed in another during the period of the testing meaning that a measurement could not be carried out. In a third property the gas meter did not have any credit so that there was no heating and it wasn't more than 7°C warmer inside than out (a requirement of the measurement). These issues highlight practical constraints on testing in void properties, which would not typically be encountered in occupied dwellings.

The HTC was successfully measured in two properties, in each case the measured performance was significantly better than that predicted by an EPC assessment (Table 1). It's quite common for older buildings to have better than expected energy performance, while newer houses more commonly have worse than predicted performance. Despite having better than predicted performance, the Heat Loss

Parameter of each falls in the 'poor' section of the BTS rating scale indicating that there is room for significant improvement through retrofit.

	SmartHTC (W/°C)	Heat Loss Parameter	EPC-predicted HTC	Performance Gap
18 St Julian Street	170 [-39, +31]	2.3 (Poor)	305	-44%
51 St Mary Street	123 [-49, +32]	2.0 (Poor)	175	-30%

Table 1: Thermal performance measurements.

The actual performance of the buildings should be considered in any retrofit designs to avoid the 'pre-bound effect', whereby it is difficult to achieve the anticipated improvements in thermal performance, energy demand and CO2 equivalent emissions post-retrofit as the performance was better than expected before the retrofit was carried out[1].

Specific to these two cases, further diagnostic testing, in particular U-value measurement of the external walls, would be the best next step in order to better understand the specific factors influencing the thermal performance of the building. The houses are both pebble-dashed on the exterior which makes it very difficult to identify the wall construction from a visual survey, this is evident from a review of existing EPCs for buildings of the same construction on the same street which vary in the which wall type the buildings have.

3. Air Permeability

Air permeability was measured using BTS' Pulse equipment. High air permeability means that there is high level of uncontrolled air movement between inside and out, resulting in heat loss, draughts and discomfort. Lower air permeability of course means a lower level of uncontrolled air movement which is good from an energy efficiency standpoint but must be balanced with adequate provision of controllable purpose provided ventilation.

The Pulse test is a compressed air-based alternative to the blower door fan testing method. Pulse provides three main advantages over the traditional fan technique. It's quick and simple to operate, low disruption and thus well suited to testing occupied homes and perhaps most crucially of all the device measures air leakage directly at low pressures that are representative of ambient conditions. The measurement therefore provides an extremely useful insight into the background air change rate and thus ventilation needs for the building in question.

For comparison with statutory limits for air permeability, which are currently stated at an internal-external pressure difference of 50Pa, the Pulse results are provided at both 4Pa and extrapolated to 50Pa. In the three tests carried out in Newport two of the houses had comparatively low air permeability, 74 Jones Street and 51 St Mary Street. Additional ventilation may well be required if the air permeability of either of these houses is further reduced, and this should be born in mind when considering a retrofit. The air permeability of 20 Blewitt Street was much higher, showing a very large amount of uncontrolled air movement, remedial work to reduce this would reduce heat loss and consequently energy demand.

For these properties an rdSAP EPC assessment would assume an air permeability of 15 $m^3/h.m^2$@50Pa, for each building, quite accurate in for 20 Blewitt Street but more than twice the actual air leakage for the

[1] https://www.arct.cam.ac.uk/Downloads/introducing-the-prebound-effect-the-gap-between-performance-and-actual-energy-consumption-minna-sunikka-blank-and-ray-galvin

other two properties. This highlights the importance of onsite measurement to properly manage retrofit programs.

	Air Permeability @4Pa (m^3/m^2h)	Air Permeability @50Pa (m^3/m^2h)
20 Blewitt Street	3.31	16.1
74 Jones Street	1.24	6.41
51 St Mary Street	1.23	6.38

Table 2: Air permeability Pulse measurement test results.

4. Mould Risk Indicator

To accompany SmartHTC and Pulse, BTS have also developed a Mould Risk Indicator in collaboration with SOAP Retrofit and Loughborough University. The Mould Risk Indicator analyses measurements of internal temperature and relative humidity, together with information about the building and external weather to assess the mould risk within a property.

The output of the Mould Risk Indicator is a risk score, ranked from 0-100 with 100 representing extremely high risk. The data upload and results are accessed through a browser based interface which provides an overview assessment for a stock of buildings (Figure 2), and detailed results for individual buildings and rooms.

In the stock management view the risk for each room is shown in a red-amber-green colour scale, the majority of the houses monitored showed some mould risk. 51 St Mary Street had particularly high mould risk, this is very likely to be associated with a serious leak which had recently occurred in the bathroom and was still in the process of drying out at the time of the monitoring.

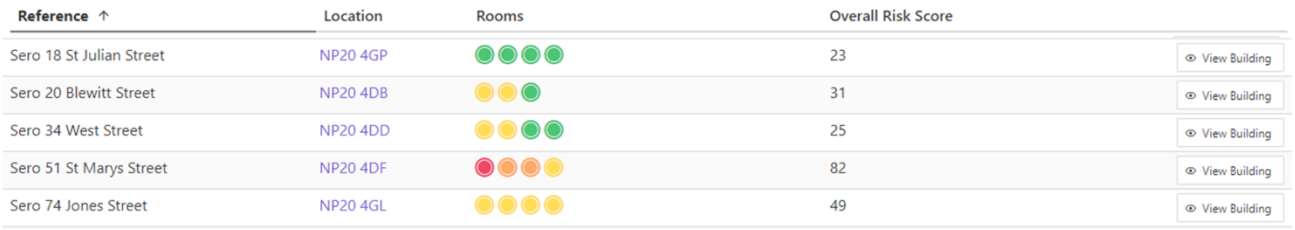

Figure 2: Mould Risk Indicator results for the buildings monitored in Newport.

The properties were vacant at the time of the monitoring and mostly had relatively low internal temperature, this tends to increase the mould risk by reducing the dew point in the building. On the other hand, occupancy tends to introduce additional moisture to a building through things like washing, respiration and cooking; so, it is worrying to see a high mould risk in these properties.

One of the key driving factors for high mould risk is cold internal surfaces on which condensation and moisture can gather, and poor (high) U-values are a significant causal factor for this. For these mould risk assessments an assumed wall U-value taken from the rdSAP assessment was used of 1.7W/m²K, however, the overall thermal performance of the buildings is significantly better than expected so it's possible that the wall U-value is better than predicted by rdSAP. If this is the case, then the mould risk would be reduced, a U-value measurement would provide additional information which can be used in the Mould Risk Indicator.

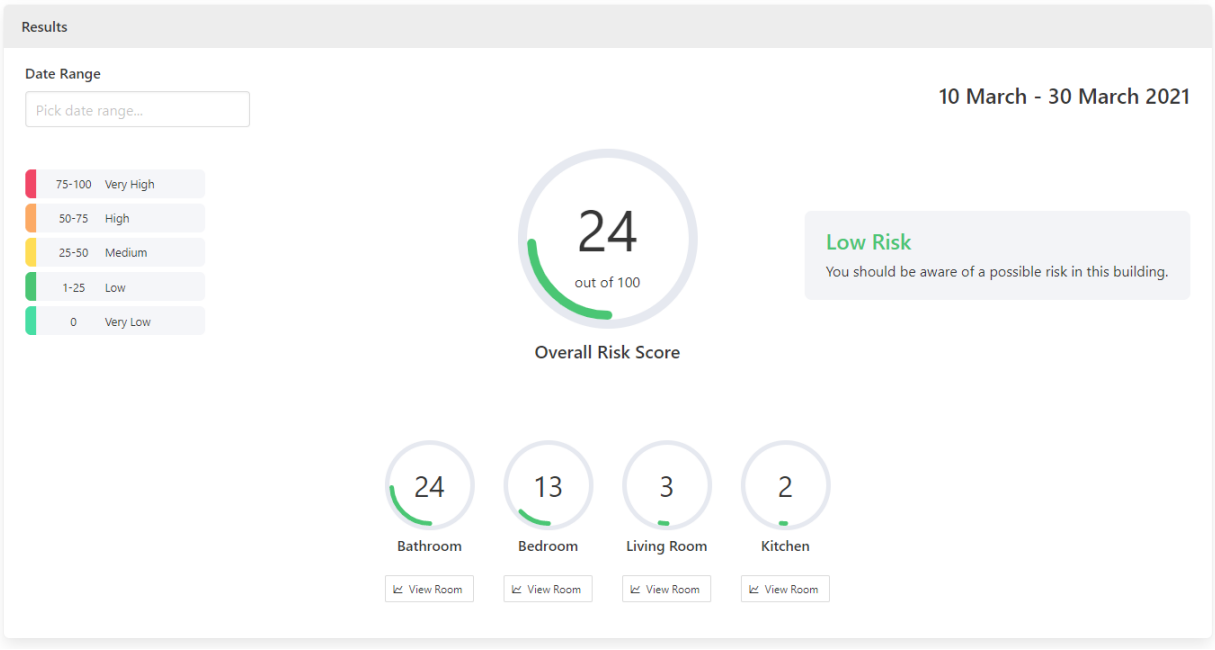

Figure 3: Mould Risk Indicator results for 18 St Julian Street.

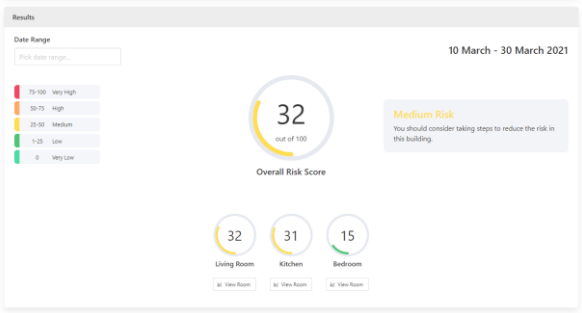

Figure 4: Mould Risk Indicator results for 20 Blewitt Street.

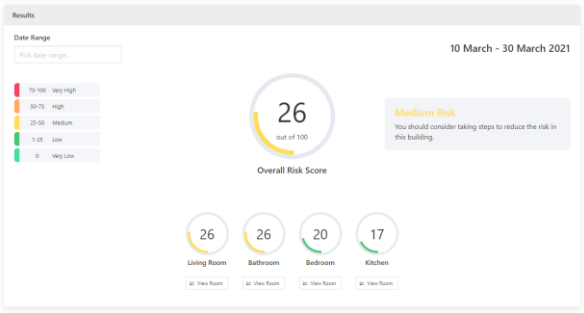

Figure 5: Mould Risk Indicator results for 34 West Street.

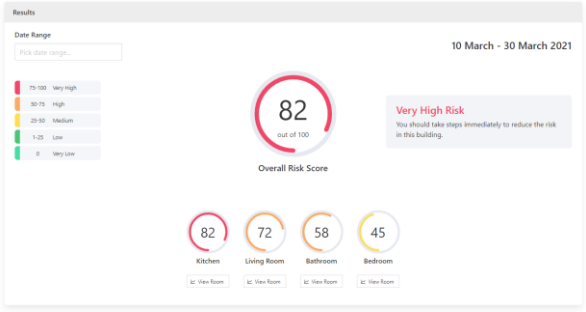

Figure 6: Mould Risk Indicator results for 51 St Mary Street.

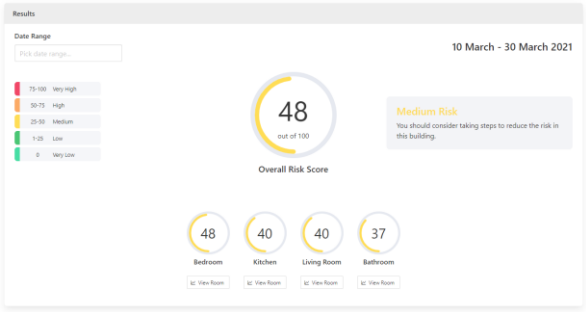

Figure 7: Mould Risk Indicator results for 74 Jones Street.

4. U-Value Measurement

Although not carried out as part of this particular study, another diagnostic test that could be applied is U-value measurement. These measurements could be a useful next step in understanding why the measured thermal performance (HTC) varied so widely from the predicted value.

A U-value is a measurement of the heat loss through building elements (floors, walls, ceilings, windows and doors), it is a measure of the rate of heat loss per degree of temperature difference between inside and out. For visual assessments such as for EPCs, the type of construction is assessed by eye and then a lookup table is used to determine the assumed U-value, bespoke calculations can also be carried out if more detail is known about the wall construction. As for overall thermal performance, however, the performance of particular elements varies widely due to variations in material performance and construction quality. U-value measurements enable the user to understand if the actual performance is as predicted, enabling better design, targeted retrofit works and quality control.

BTS provide two methods to carry out U-value measurements, either using heat flux plates or using our new Heat3D iOS app and associated hardware. Until this point the vast majority of U-value measurements have been carried out using heat flux plates, and there is an International Standards Organisations method to do so. The BTS U-value Measurement Kit provides the hardware and a remotely accessible online portal to carry out U-value according to this method. The standard requires that sensors are in place for at least three days, and realistically will need to be left in place for a week to ensure a satisfactory measurement.

Figure 8: U-value measurement equipment in place.

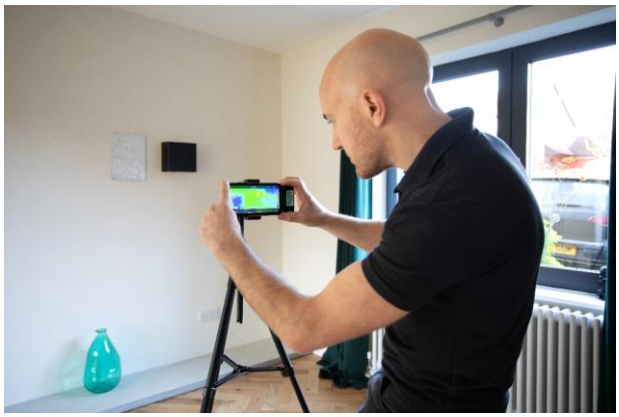

Figure 9: Setting up for a Heat3D time-lapse survey.

There are however limitations of measurements taken using heat flux plates, as the equipment is slightly invasive and only measures in the location that the heat flux plate is located while performance can vary across the surface. To address these limitations, BTS have developed Heat3D, this is an iOS app that works with a FLIR One infrared camera plugged into an iPhone or iPad. The app creates an accurate 3D model of the room with quantified heat loss across all external surfaces, a survey takes around 15 minutes to complete and highlights areas of varying performance. Additionally, an hour-long time-lapse survey can be undertaken to measure a wall's U-values, dramatically reducing the required testing time and providing measurements across the whole surface.

5. Embedding Measurement into Retrofit Projects

Despite the obvious benefits of measuring the performance of buildings pre, during and post retrofit, there are some important considerations that the Optimised Retrofit project participants should consider:

1. Thermal performance measurement of properties requires a positive heat flow from inside to out and is therefore typically best carried out between the months of October and March, inclusive. This can require careful planning, especially when upgrades work might be planned for installation during the summer period.

2. For maximum value and insight, we recommend at least measuring prior to retrofit works and again post works; allowing for direct comparison of the before and after performance of a property.

3. The measurements demonstrated by this case study can all be carried out in occupied homes, access is required and in the case of SmartHTC temperature sensors must be left in the property for a period of 21 days and meter readings must be taken at the start and end of the period. This requires two visits, for the property to be heated and for function energy meters (smart or dumb) to be present.

4. It is important that the condition of the property at the time of measurement is representative. For example, it is not sensible to seek to measure the fabric thermal performance of the building whilst works are taking place and changes are actively being made e.g. stripping out, replacing windows, adding insulation etc.

5. Measurements can be taken quickly and non-invasively, meaning that the cost and disruption is not significantly higher than traditional building survey methods. For maximum benefit it often makes sense to combine these processes to reduce the amount of access required to people's homes and to embed measurement within an asset management system.

6. Relying solely on visual surveys, design expectations and predicted performance introduces a significant risk of unintended consequences and unexpected performance. Performance measurement provides a method to understand and mitigate this risk.

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