Better Data, Better Buildings: Using Measured U-Values to Drive Performance and Compliance

Justification and method for U-value measurements to be an allowable input to energy modelling for EPCs and other heat loss calculations

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1. Executive Summary

The inclusion of in-situ U-value measurements as an allowable input to energy models such as RdSAP, HEM, and SAP, used in generating Energy Performance Certificates (EPCs) and for conducting heat loss calculations (according to BS EN12831) would deliver a step-change in the accuracy, reliability, and policy value of energy assessments across the UK's building stock.

U-values describe the rate of heat transfer through part of a building, e.g., its floor, walls, windows, and roof. A lower U-value means there is less heat loss, and hence less energy required to keep it warm inside when it's cold outside, or cool inside when it's warm outside. U-values are a key input to any energy model, and the accuracy of the input U-values has a direct impact on the accuracy of the model's outputs.

Current practice relies heavily on assumed U-values based on visually assessed construction types, with minimal in-situ measurement. Analysis of past field trials, however, shows these assumptions carry significant uncertainty. The **uncertainty in the estimation of a U-value of a construction of a known type is shown to be 45% at best, and over 100% for some constructions**. These estimates do not include the uncertainty in correctly identifying the construction type using a visual survey, which is particularly problematic in older buildings with complicated, unknown, and undocumented fabric.

Measured U-values offer a scalable, accurate, and robust solution. They are practical at scale, with costs and disruption similar to that of airtightness testing. Similar apparatus as surrounds airtightness measurements to ensure verification and quality control, including competent persons schemes and appropriate training, are required and are well under development.

Energy models currently accept U-values as a discrete, manually adjustable input, though this is typically permitted through U-value calculations only. Consequently, integrating measured U-values would be a simple change, not requiring changes to existing energy models or software.

When used as inputs to energy models, U-value measurements reduce uncertainty and can materially affect EPC ratings. Modelling found that the **observed uncertainties in U-value estimation for various wall types affected SAP ratings by 5–10 points**; similar uncertainties in other key U-value inputs, such as floors and roofs, would have a similar further impact.

Incorporating U-values into EPC assessments would deliver multiple long-term benefits:

- Greater accuracy in assessing energy performance
- Improved targeting of retrofit funding, especially for fuel-poor households
- Enhanced quality assurance of retrofit works, based on real in-situ performance measurements rather than just paper-based assessments

- A growing evidence base to refine energy models over time through comparison of assumed and measured values.

Case studies included in this paper demonstrate that U-value measurements are not only viable, but also scalable, and deliver clear value across both policy and practice. This paper calls for the energy modelling community, government, and accrediting bodies to enable their formal inclusion, unlocking higher standards of building assessment in the transition to net zero.

1.1. Proposed Changes

A brief addition to the RdSAP conventions would enable the input of U-value measurements. These conventions should be carried forward to HEM when it is introduced.

U-values are already a customisable input to energy models, so no existing models or software require updates to enable this change. Competent persons schemes for U-value measurement should be established, or existing U-value competency schemes should be expanded to include in-situ measurement to give a reasonable assurance of measurement quality.

The changes we propose are given below in red.

RdSAP 10 conventions - 3.08:

The U-values of existing elements (walls/roofs/floors, etc.) must be the RdSAP default values (e.g. entered "as built") and must not be overwritten unless specific documentary evidence of the thermal conductivity of individual materials of the building element of the property being assessed is provided and was undertaken in accordance with BR 443 "Conventions for U-value calculations" (BRE, 2006) or by an in-situ measurement following ISO9869.

The U-value is that of the whole element, including any added insulation.

Documentary evidence applicable to the property being assessed (see convention 9.02) must be provided and recorded if overwriting any default U-value. This evidence shall be either:

- *relevant building control approval, which both correctly defines the construction in question and states the calculated U-value; or*
- *a U-value calculation produced or verified by a person with suitable expertise and experience; or*
- *A U-value measurement carried out by a person with suitable expertise and experience.*

Evidence of suitable expertise and experience can be demonstrated by, but is not limited to, membership of a recognised U-value calculation or measurement competency scheme or OCDEA1 or Level 4 non- domestic energy assessor membership, or any other process recognised by Accreditation Schemes/Approved Organisations and Government.

2. Justification

Field trials have shown that U-values can vary significantly even among visually identical constructions. This variability undermines the reliability of the standard lookup tables currently used in Energy Performance Certificates (EPCs), which aim to provide average values for different construction types and ages. This issue applies equally to EPCs for domestic and non-domestic buildings, and all other energy modelling relying on U-value inputs, including heat loss calculations for heat pump sizing. The upcoming change from SAP and RdSAP to HEM will not alter this situation, with HEM also using U-values as a key input to describe the thermal performance of the building.

In practice, however, they can be significantly inaccurate for individual homes. Analysis of data from previous field trials shows that, even when the construction type is correctly identified, the predicted U-value of a known construction type may only be accurate within ±40%, with some cases exceeding **±100%**. These uncertainties can lead to meaningful errors in the SAP rating, the core metric used in EPCs, shifting scores by 5–10 points based solely on wall U-values.

Allowing direct measurement of U-values would enable far more accurate and reliable EPC assessments. Not only are these measurements now relatively affordable, costing a few hundred pounds at most, but they are also minimally disruptive to building occupants, making them viable at scale. Given that major retrofit decisions and government funding schemes often rely on EPCs, the cost of measurement is small relative to the potential financial and environmental implications of getting the rating wrong.

Furthermore, routine use of measured values would contribute to a better understanding of real-world building performance, gradually improving the accuracy of energy models over time. As noted by a 2018 BEIS study[1] in which the U-value of a sample of solid walls was measured:

> *"this research has highlighted the continual need to challenge the 'book values' which are in use on a daily basis, and that our level of understanding as expressed through theory needs to be regularly validated with new experimental data."*

2.1. How Accurate are U-value Lookup Tables?

The current method for assigning U-value inputs to RdSAP is lookup tables based on a visual identification of the construction type and age. The values in this lookup table are based upon a combination of U-value calculations and the results of what field trials are available.

[1] BRE (2016). *Solid wall heat losses and the potential for energy saving*. Available at: https://assets.publishing.service.gov.uk/media/5c409bd6ed915d389d28176f/WP2_Nature_of_solid_walls_in-situ_v3.2b.pdf.

There are very few large-scale field trials of in-situ U-value measurements, which means that there is currently relatively little insight into how accurate the values in the lookup tables are.

The major field trials that have been published include:

- A study published by Historic Scotland focusing on the in-situ performance of non-standard solid walls, written by Baker in 2011[2]
- A BRE study reported by Hulme & Doran in 2014, including in-situ measurements of several wall types[3]
- A follow-up study by the BRE reported in 2016[1], focusing on better understanding the variation in observed and expected performance of solid walls
- The Building Performance Network's State of the Nation report, written by Gupta and Gregg in 2020[4]

The first question we ask is, how representative, *on average,* are the lookup table values? To do this, we compare the mean measured U-value for each wall type studied with the typical RdSAP assumption for that wall type.

There are mixed results, with close agreement for samples of older walls, but significant differences for non-standard solid walls, and newly built walls and roofs. It is possible to accurately represent the average U-value of a construction type, but this doesn't currently apply consistently across different construction types. The table also highlights that there has been very little in-situ measurements to verify the assumed performance of construction types, the sample sizes are small, and the construction types covered don't come close to covering all of the options in RdSAP. There is a massive knowledge gap in how building elements actually perform in-situ compared to their assumed performance when generating EPCs.

The U-value of non-standard solid walls, which are generally older walls of brick or stone, is overestimated in the current lookup tables, i.e., their performance is better than currently assumed. These buildings are also often difficult to retrofit, so if their performance is consistently better than currently assumed, this could significantly reduce the size of retrofit challenges, such as getting all buildings to reach EPC C.

[2] Baker (2011). *U-values and traditional buildings: In situ measurements and their comparisons to calculated values*. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=16d0f7f7-44c4-4670-a96b-a59400bcdc91
[3] Hulme, J & Doran, S. (2014). *In-situ measurements of wall U-values in English housing.* Available at: https://assets.publishing.service.gov.uk/media/5a804b9eed915d74e33f99a7/In-situ_u-values_final_report.pdf.
[4] Gupta & Gregg (2020). *State of the nation review: Performance evaluation of new homes*. Available at: https://building-performance.network/wp-content/uploads/2020/06/State-of-the-nation-report-June-release-FINAL-UPDATED-1.pdf

Study	Element Type	Sample	Mean Measured U-Value (W/m²K)	Typical RdSAP* U-Value (W/m²K)	Mean Measurement /RdSAP
Hulme & Doran, 2014	Solid wall, standard	85	1.57	1.7	92%
BRE, 2016	Solid wall, standard	50**	1.74	1.7	102%
Baker, 2011	Solid wall, non-standard	46	1.27	1.67	76%
Hulme & Doran, 2014	Solid wall, non-standard	33	1.28	2.2	58%
Hulme & Doran, 2014	Uninsulated cavity	50	1.38	1.5	92%
Hulme & Doran, 2014	Insulated cavity	109	0.67	0.7	96%
Gupta & Gregg, 2020	Newly built walls	62	0.23	0.28	82%
Gupta & Gregg, 2020	Newly built roofs	20	0.21	0.18	117%

*RdSAP values are taken from RdSAP10 specification (13/02/24)

- Solid wall U-values are taken from Table 6.7, 200mm-280mm wall thickness
- Non-standard solid walls are assumed to be 330mm thick (as per original study) with the value given the mean of values calculated using the equations for *sandstone or limestone* and *granite of whinstone*
- Uninsulated cavity and insulated cavity values are taken as Age Band D, as per original study

** This study applied rigorous checks based on destructive investigation and moisture content readings to try to find a particularly homogeneous sample, reducing the original sample of 73 to 50 for which full results were given.

Table comparing the mean average measured performance with the RdSAP assumed performance from a series of U-value measurement field trial studies.

One important note is that the Hulme and Doran study in 2014 and the following BRE study in 2016 provided the evidence to revise the RdSAP lookup table for solid walls from the previous assumption of 2.1W/m²K to the new, and more representative, figure of 1.7W/m²K. Without this evidence, the average U-value for this construction would be 17-25% different from the assumption, which demonstrates the value of developing large samples of U-value measurements to better understand real-world performance.

The next question we ask is, *how representative is RdSAP for individual buildings*? This is a slightly more difficult question to answer, associated with how variable the U-value of the different walls of the same construction type are. This analysis assumes that the wall construction type has been correctly identified, and doesn't include the uncertainty associated with incorrectly identified construction types.

To address this question, the following metrics are used:

- The Standard Deviation is a commonly used measure of the dispersal of the sample, giving an indication how far from the mean value the results typically were.
- To give the Standard Deviation more context, the Coefficient of Variation is used and presented as a percentage. This is the Standard Deviation of each sample divided by its mean.
- The Prediction Interval is a statistical range within which a future observation is likely to fall, with a certain level of confidence (95% in this case). This stat gives us an indication of how confidently we can predict the next U-value of each wall type, given the sample of measurements we have. As for the Standard Deviation, this has been put into context by dividing it by the mean U-value for the sample and showing that as a percentage.
- Finally, the Prediction Interval has been used to show the bounds within which we can be 95% confident that the next U-value of each wall type can be predicted.

Here we see that there was very significant variation in each sample. There is less variation in performance in the 2016 BRE study, this is unsurprising because additional filters were applied to that sample to seek as homogenous a sample as possible. This included moisture content measurements and partial disassembly of the walls to determine the presence of air gaps.

Given these results, we can only confidently predict the correct U-value for a particular construction type to within **40% at best** using lookup tables and a visual survey, and for some construction types can only be accurately predicted to within **>160%**. The impact is greatest for newly built walls and roofs as a percentage, but this is driven to some extent by those U-values being small numbers, so that very small changes make a large percentage difference. The largest absolute range in possible U-value is for non-standard solid walls, which is unsurprising given that they tend to have the most uncertainty in their construction from a visual survey alone and mark these out as a particularly strong use case for measured U-values.

Broadly, the analysis shows that there is a very large variation in the performance of visually similar walls, so that it's simply not possible to accurately ascertain their U-value with any confidence from a visual survey and lookup table alone.

Study	Wall Type	Standard Deviation (W/m^{2}K)	Coefficient of Variation (St Dev/Mean)	95% Prediction Interval {% of mean}	95% Prediction Interval Bounds
Hulme & Doran, 2014	Solid wall, standard	0.32	30%	0.63 {40%}	0.94-2.20
BRE, 2016	Solid wall, standard	0.21	12%	0.42 {24%}	1.32-2.16
Baker, 2011	Solid wall, non-standard	0.47	37%	0.93 {74%}	0.33-2.20
Hulme & Doran, 2014	Solid wall, non-standard	0.42	33%	0.84 {65%}	0.44-2.12
Hulme & Doran, 2014	Uninsulated cavity	0.30	22%	0.59 {43%}	0.79-1.97
Hulme & Doran, 2014	Insulated cavity	0.23	34%	0.45 {68%}	0.22-1.12
Gupta & Gregg, 2020	Newly built walls	0.17	74%	0.34 {146%}	-0.11-0.57
Gupta & Gregg, 2020	Newly built roofs	0.17	81%	0.34 {163%}	-0.13-0.55

Table describing the variation in performance across samples of similar wall construction across several U-value measurement field trial studies. The 'Prediction Interval' describes the range across which one can be 95% confident of predicting the U-value of the next example of a construction type given the data sample previously collected.

One way to reduce these wide prediction intervals is to increase the sample size of studies. The large uncertainty currently seen is partly due to limited data on how wall performance varies in practice. A major benefit of allowing measured U-values to be included in EPCs is that, if results were lodged systematically, the number of comparisons between assumed and measured values would grow rapidly. This expanded dataset could then be used to refine and improve the assumptions underpinning RdSAP more broadly.

2.2. Impact on RdSAP & EPCs

Editing the U-value of large thermal elements of a building's construction, such as the main wall, floor, or roof, would have a significant impact on the results of the RdSAP calculation. To investigate this effect, a typical semi-detached dwelling was modelled in RdSAP10, and the U-value of the main wall was then adjusted to match the upper and lower 95% prediction interval bounds from the largest study of each wall type. This gives us an idea of the size of the impact on the RdSAP outputs of the calculated uncertainty in the U-values.

The size of the impact depends, of course, on the level of uncertainty in the U-value, with a range from 5-9 points in the SAP rating. In all but one case, the difference between the U-values would cause a shift from one band to another. Significant impacts occur, which could make a material difference to retrofit and transactional decisions about the building and clearly demonstrate the value in using the correct U-value input to get a more accurate set of results.

Wall Type (study)	**U-Value (W/m^2K)**	**EPC Rating**	**EPC Band**	**Annual Energy Cost**
Solid (H&D)	0.94-2.2	68-62 (6)	D-D	£1,024-£1,230 (£229)
Sold, non-standard (B)	0.33-2.2	71-62 (9)	C-D	£898-£1,253 (£355)
Uninsulated cavity (H&D)	0.79-1.97	69-63 (6)	C-D	£994-£1,213 (£219)
Insulated cavity (H&D)	0.22-1.12	72-67 (5)	C-D	£874-£1,058 (£184)
H&D - Hulme & Doran, 2014; B - Baker, 2011				

Table showing the impact on EPC outputs given the uncertainty in the U-value input for various construction types, the difference between the upper and lower bounds is shown in brackets.

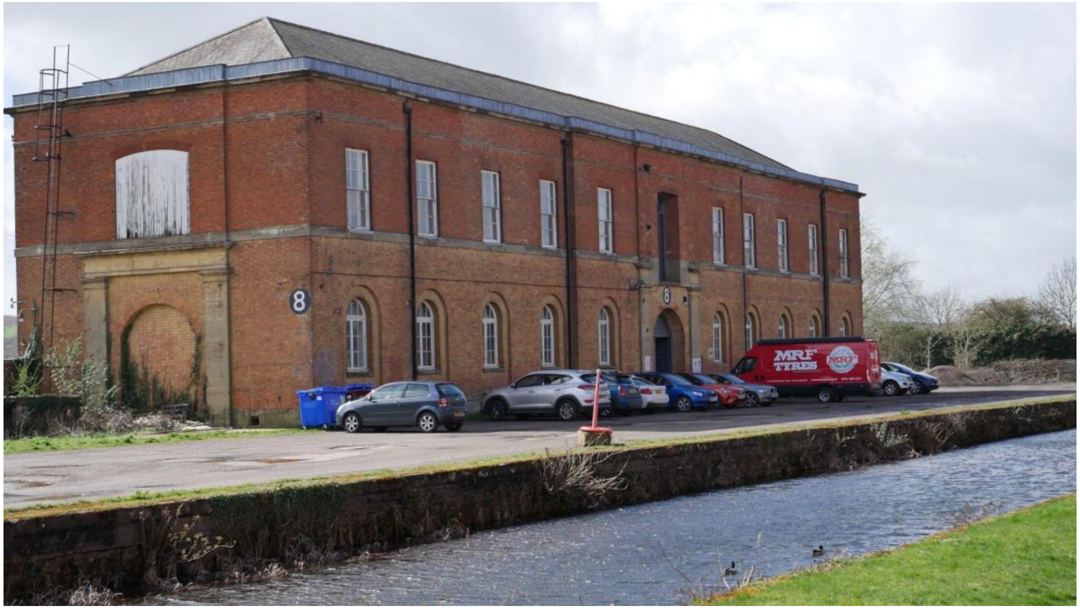
One further benefit of using the correct inputs is that the retrofit recommendations made in the EPC could also be updated in two ways:

- More accurate estimates of EPC rating and annual bill savings
- If the measured U-value is better than expected in the lookup tables, it may mean that an insulation recommendation is not triggered that previously would have been (if the same limiting U-values are used)
- If the U-value is worse than expected in the lookup tables, it may trigger a recommendation that previously wouldn't have been made

2.3. Impact on SBEM and Non-Domestic EPCs

The impact on non-domestic buildings could be even larger than that for domestic buildings, given that they're generally larger and sometimes have very large floor, wall, and roof areas, which are all prone to inaccuracies in their U-value input.

To investigate this, the BTS office was modelled in SBEM. The office is one unit of four in an 18th-century, solid-walled building. As for the RdSAP modelling in the previous section, the U-value of the main wall was adjusted in the model to match the upper and lower 95% prediction interval bounds for the wall type.



The BTS office is the lower left unit in this 18th-century former ammunition depot. Internally, it is split roughly in two with an insulated office unit and an open workshop area.

Even with this relatively small light industrial unit, the range in EPC score, band, and predicted annual CO_2 emissions is enormous across the range of possible U-values for this wall type. The range of possible rating bands is from C to F, and the predicted annual CO_2 emissions vary by 77%.

Wall Type (study)	**U-Value (W/m^2K)**	**EPC Rating**	**EPC Band**	**Annual CO_2 (tonnes)**
Solid, non-standard (B)	0.33-2.2	75-134 (59)	C-F	23.6-42.0 (18.4)
B - Baker, 2011				

Table showing the impact on EPC outputs given the uncertainty in the U-value input for this wall type, the difference between the upper and lower bounds is shown in brackets.

To give a more direct example for this particular building, the measured U-value of the main wall is 0.9 W/m^2K, significantly lower (better) than the assumed U-value of 1.7 W/m^2K. Using the assumed value, the building receives an EPC rating of E instead of the D rating it would get using the actual measured U-value. The table below demonstrates that this, in turn means that the predictions of energy use and carbon emissions for the building are also significantly overestimated for the building. This illustrates how sensitive EPC scores, banding, and predicted annual CO_2 emissions are to assumed versus measured fabric performance.

	Assumed	Actual	Difference
U-value (W/m²K)	1.7	0.9	-89%
EPC Rating	118	93	-27%
EPC Band	E	D	1
Predicted Primary Energy Use (kWh/m^2.yr)	396	312	-27%
Predicted CO_2 (tonnes)	396	312	-27%

Table showing the difference in U-value and EPC outputs between using the assumed and actual main wall U-value for the BTS office.

2.4. Practicalities

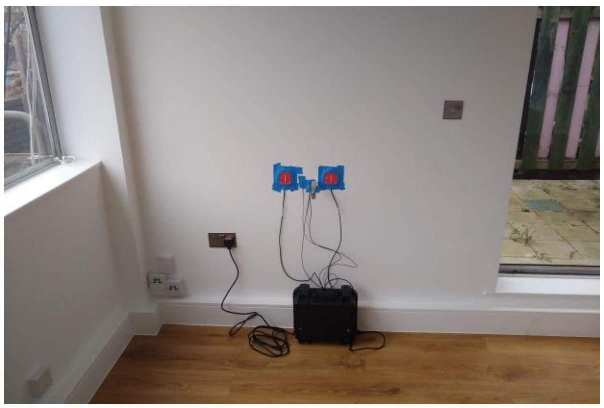
To justify changing current business-as-usual approaches to U-value assessment and allow measurement as an option, it makes sense to consider whether measurements could be carried out at scale. The scalability of the measurements is reliant on their cost and disruption being practical, as the only in-situ measurement currently in widespread use and given their recent inclusion in RdSAP10, it makes sense to draw some parallels with airtightness testing.

Equipment for U-value measurement is considerably less expensive than for airtightness testing (which costs around £5,000-£6,500), and is likely to significantly fall given wider usage. However, the time needed for U-value testing and analysis is slightly longer. The expected cost of a U-value measurement would be in the hundreds of pounds, similar to, or slightly higher than, an airtightness test due to the extended time required. While this cost might appear substantial compared to typical EPC expenses, it is relatively minor when considering the overall cost of retrofitting and associated funding decisions that rely on the EPC.

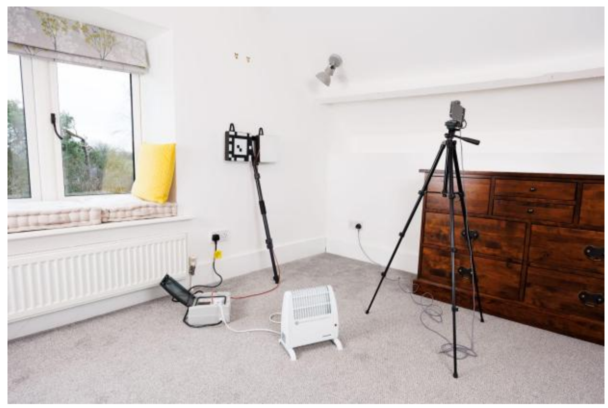
There are two International Standards Organisation (ISO) standards for in-situ U-value measurement, ISO 9869-1:2014 for measurements using heat flux plates and ISO 9869-2:2018 for measurements using infrared imaging. These form straightforward and well-accepted documents to adopt as requirements for U-value measurements for regulatory use.

Measurement Type	Measurement Period	Relevant Standard	Equipment Cost
Heat Flux Plates	Min 3, typically 7 days (building can be occupied as normal)	ISO9869-1	c.£3,000
Infrared	1 hour (room in which testing takes place should be vacant)	ISO9869-2	c.£3,000

Table providing indicative measurement period, cost, and relevant samples for the two main U-value measurement options.



Example heat flux plate setup



Example infrared U-value setup

Energy models currently accept U-values as a discrete, manually adjustable input. However, adjustments are typically permitted only through U-value calculations. Consequently, integrating measured U-values would not necessitate alterations to existing energy models or software. The only required change would be to conventions, clarifying the appropriate use and application of U-value measurements.

2.5. Verification and Control

As for airtightness testing, for proper confidence in the collection and reporting of reliable and accurate measurements, people reporting measurements should be properly trained and accredited through competent persons' schemes. These should include adequate training to ensure that members understand the technical background of U-value calculation and measurement, as well as appropriate equipment user training.

The evidence requirements for airtightness testing form a sensible guide for U-value measurement. With each measurement a report would be required to allow auditing and verification, the report should include (as a minimum):

- The measured U-value
- Key input measurements, such as heat flux, internal and external temperatures during the measurement period
- A unique reference for the measurement
- The address of the building tested, and the location of the measurement within that building
- A photograph of the measurement equipment in place

Preferably, U-value measurements would be lodged alongside the surveyed construction details in a central database. This would facilitate the gradual creation of a database comparing expected and actual U-values, providing feedback to enhance industry knowledge.

2.6. Importance of Energy Models

Energy models have always been a central part of the management of the energy efficiency of buildings, and will continue to be so. Energy models are necessary to make informed decisions on the overall energy efficiency of buildings or to predict the effect of a retrofit. Greater use of in-situ measurements does not sit at odds with this; in fact, they are perfect complements to each other, with the in-situ measurements helping to increase the accuracy of energy models' outputs.

3. Use cases

3.1. More Accurate EPCs and Energy Models

Allowing measured U-values in EPCs and other models would significantly improve their accuracy and reliability. EPCs based on actual thermal performance rather than assumed values would provide a more trustworthy reflection of a building's energy efficiency. This, in turn, would strengthen their role as a foundation for key policy tools, including retrofit funding schemes and minimum energy efficiency standards.

Accurate U-values also lead to more precise heat demand calculations, which are critical for designing effective heating systems. By reducing uncertainty, there's less risk undersizing systems, with its risk of cold homes and dissatisfied residents, or oversizing, which can result in unnecessary capital costs and disruption caused by unnecessary emitter upgrades. Incorporating measured values would help ensure heating systems are appropriately designed for each specific property, improving outcomes for households and installers alike.

3.2. Quality Assurance

Traditional quality assurance methods for retrofit, which rely heavily on paper-based assessments and assumed values, are inherently limited. They often fail to capture the true pre- and post-retrofit performance of a building. In contrast, in-situ measurement of U-values provides an objective, evidence-based benchmark for evaluating success. This enables a more rigorous assessment of whether the intended energy performance improvements have been achieved.

The use of measured data can lead to better policy outcomes by providing accurate feedback on the effectiveness of materials, installation practices, and design choices. Over time, this evidence base can inform improvements in retrofit processes and standards. It also helps to reduce the risk of unintended consequences, such as moisture issues or poor thermal comfort, that can result from poorly designed or implemented interventions. These risks have contributed to well-documented challenges with quality assurance in schemes such as the Energy Company Obligation (ECO).

Mould risk is exacerbated by poor and unexpected thermal performance, which can result in cold spots on walls, which attract greater surface water activity and, in turn, mould growth. This is primarily a significant health risk, but is also a significant remedial cost which could be effectively identified and treated proactively using U-value measurement.

3.3. Better Targeted Retrofit Spending

Measured U-values can help ensure that retrofit funding is directed where it will have the greatest impact. Under current practices, buildings with better-than-assumed U-values may be incorrectly prioritised for energy efficiency upgrades, leading to inefficient use of limited resources. This undermines the effectiveness of policy measures aimed at reducing emissions or tackling fuel poverty.

Conversely, buildings that perform worse than expected - often due to hidden construction issues or degradation - may be overlooked by standard assessment methods. As a result, these homes may continue to perform poorly, leaving residents at greater risk of high energy bills and cold, unhealthy living conditions. By incorporating measured data into the assessment process, retrofit programmes can more accurately identify the buildings most in need of intervention, improving both the fairness and impact of public spending.

4. Case Studies

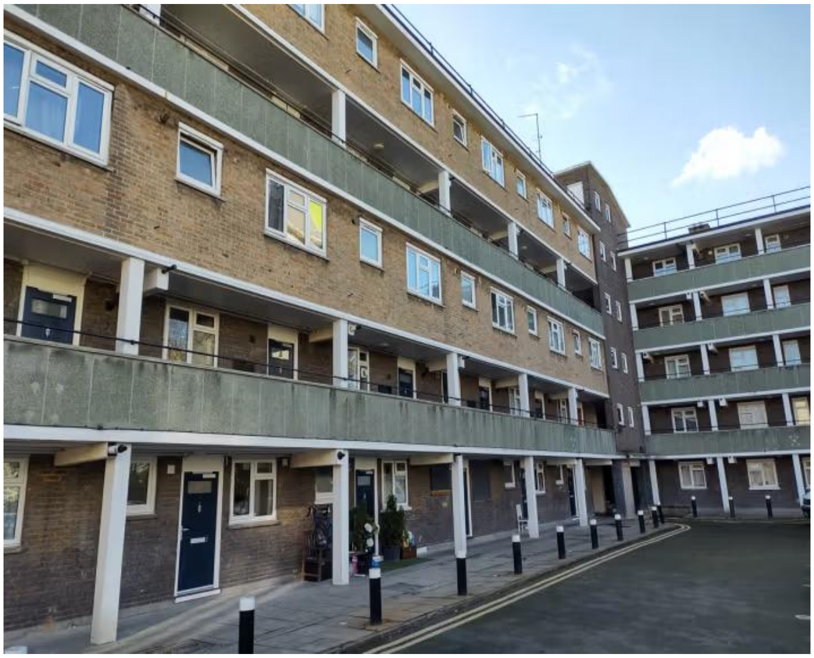
Although U-value measurements are not yet clearly recognised as an input to energy modelling, they are already well established and somewhat widely used across the building sector. These case studies clearly demonstrate the value of U-value measurement, and also their practicality for use at scale.

4.1. Retrofit Design and Quality Assurance

The Lancaster West Estate is a large estate forming part of the Royal Borough of Kensington and Chelsea's social housing estate. The estate is made up of a mix of medium-rise blocks of flats built in the early to mid-20th century.

The estate is receiving a major retrofit overhaul after Kensington and Chelsea Council secured grants of more than £20 million towards its mission of transforming Lancaster West into a model 21st-century social housing estate.

The council acquired infrared U-value measurement equipment and trained staff to conduct site measurements. To meet the demand from retrofit designers, they also commissioned U-value measurements from an external contractor. More than 100 U-value measurements have now been carried out, primarily performed in occupied flats across the estate, using both heat flux plate and infrared methods. The findings were shared with the architectural design teams to inform their retrofit strategy and design.



Treadgold House on the Lancaster West Estate before retrofit works

The U-value measurements on Treadgold House, showed particularly high heat loss through the floors associated with excessive thermal bridging caused by the solid concrete walkways. This insight contributed to the retrofit design in which these areas were enclosed, eliminating this thermal bridge.

The Lancaster West team is repeating U-value measurements as the retrofit works are completed for quality assurance and feedback to the retrofit design of other blocks across the estate.

4.2. New Build Quality Assurance

Previous field trials have demonstrated that thermal performance in new build homes is highly variable in practice, as detailed in Section 2.1. Projects conducted at Energy House 2.0 at the University of Salford[5], in collaboration with major developers Barratt and Bellway, illustrate the value of performance measurement in driving design and process improvements.

In these studies, full-scale homes were constructed within a climate-controlled chamber and subjected to rigorous testing. This same approach, particularly the targeted use of in-situ U-value measurements, can be applied to homes built for sale, offering a practical route to enhanced quality assurance.

Results revealed significant localised underperformance driven primarily by construction practices rather than material specifications. In the Bellway home, for instance, the measured roof U-value was over 50% worse than the design intent. The issue stemmed from insulation being disturbed post-installation to access services, a sequencing error that was easily resolved once identified through measurement. By adjusting the construction order, future performance was improved with minimal cost or complexity.

In the Barratt house, poor thermal performance was identified at the intermediate floor junction, caused by voids in insulation and resulting in thermal bypass. U-value testing highlighted the problem and informed a revision to the design details to eliminate this issue in subsequent builds.

These examples show how targeted U-value measurement offers a practical and cost-effective way to close the performance gap and improve the long-term efficiency of new homes through iterative design and construction refinement.

[5] Fitton, R., Diaz Hernandez, H., Farmer, D., Henshaw, G., Sitmalidis, A., & Swan, W. (2024). Saint Gobain & Barratt Developments “eHome2” Baseline Performance Report. Salford: ERDF & Innovate UK. Available at: https://salford-repository.worktribe.com/output/2313140
Fitton, R., Diaz, H., Farmer, D., Henshaw, G., Sitmalidis, A., & Swan, W. (2024). Bellway Homes "The Future Home" Baseline Performance Report. Salford: ERDF & Innovate UK. Available at: https://salford-repository.worktribe.com/output/2313227

4.3. Heritage Buildings

Heritage buildings can be particularly problematic when considering retrofit measures, as the specifics of the construction are often unknown, and there are often stringent limitations on what retrofit measures can be installed based on Listed status. U-value measurement can be a vital tool for better understanding the building and calibrating energy modelling to improve retrofit design.

One such example is The Arc, a public, multi-use cultural space in the heart of Winchester's conservation area, comprising a Grade II* listed building and modern extension. Owned by Hampshire County Council and managed and run as part of Hampshire Cultural Trust's (HCT) portfolio, The Arc is one of the trust's more challenging buildings to decarbonise. But with a strategic goal to reach net zero by 2030 across scope 1 and 2 carbon emissions, HCT needed a decarbonisation plan for the space.

The Arc, a Grade II listed public space in Winchester, for which U-value measurements were used to inform a retrofit plan*

To understand the true building energy performance of The Arc, while keeping it open for public use, Beyond Carbon used Build Test Solutions' (BTS) Heat3D infrared U-value measurement technology to carry out unobtrusive U-value measurements across the spaces. Kate Brown, principal consultant at Beyond Carbon, said:

> *"The measured U-value data gave us confidence that investment in retrofit would have the right impact on The Arc. It produced a closely calibrated energy model of the*

> *building, verified against energy bills, instead of having to make a set of assumptions about a huge set of inputs that make up energy use, such as air leakage, window performance, heating operation, and the number of people using and visiting the space."*

The measurements threw up some surprises. The extension was found to have very variable performance, with some areas performing better than expected but one area performing 89% worse than expected. This measurement revealed a thermal bypass that could be remediated by retrofit.

The older walls were found to perform dramatically better than expected, with U-values between 0.74-0.81W/m^{2}K, just over half as much heat loss as expected. Here, the results confirmed that costly and disruptive intervention would not be necessary in the original part of the building.

Caroline Johnson, head of projects and facilities at HCT, said:

> *"One of the most surprising findings was the difference between the calculated and actual U-values of the building's walls. Using equipment to measure thermal performance gave us far more accurate data. What stood out most was the newer part of the building performed worse than expected in terms of heat loss, giving us a clear idea of where to use investment."*

Without measurement data, it would be easy to assume the oldest parts of the building – such as the original walls – should be the first areas to tackle. However, insights showed there were more low-cost fixes that would be more effective in improving energy efficiency.

4.4. Feedback to Improve Energy Models

Earlier in this paper, two studies investigating the in-situ performance of solid walls commissioned by the Government and carried out by the BRE were described. In the first study (Hulme & Doran, 2014), it was noted that the mean measured U-value of solid walls was significantly better than predicted in RdSAP at the time (mean measured value of 1.57W/m^{2}K across 85 walls, compared with the predicted value of 2.1W/m^{2}K).

A follow-up study (BRE, 2016) carried out further in-situ measurements (this time the mean measured U-value was 1.7W/m^{2}K across a sample of 50 walls), along with detailed destructive testing and U-value calculations. This follow-up study found two causes for the lower-than-expected U-values:

- The most significant was that there was commonly a small air gap in the construction, contributed to by gaps between the two leaves of brickwork and air gaps in the frogs in the bricks. When included in the U-value calculations, this explained most of the difference between in-situ measurements and previous calculations.

- The bricks were found to be drier in-situ than they had been assumed to be.

Following these two studies, the assumed U-value in the RdSAP lookup table was adjusted from 2.1W/m^{2}K to 1.7W/m^{2}K. This is a brilliant example of knowledge gained from in-situ measurements being fed back into energy models to improve their average accuracy. This change accurately reflected that solid-walled buildings had better energy performance than previously thought, and less opportunity for improvement through retrofit.

U-values will remain as a key input after the change from RdSAP to the Home Energy Model (HEM), and the accuracy of the inputs will remain as critical as it is for RdSAP currently.

5. What Next?

We propose the following actions:

Short term (within the next year):

- RdSAP conventions should be updated to allow the input of U-value measurement, given reasonable assurance of measurement quality, in line with current requirements for airtightness measurements
- These conventions should be carried forward to HEM when it is introduced
- U-values are already a customisable input to energy models, so no existing models or software require updates to enable this change
- Competent persons schemes for U-value measurement should be established, or existing U-value competency schemes should be expanded to include in-situ measurement

Medium term (next 2-3 years):

- Quality assurance methods for policies funding fabric retrofit measures should be reviewed so that in-situ measurement can be used, PAS2035 may provide the most sensible document to include this process
- A database of U-value measurements, along with their assumed value from the existing lookup tables, should be generated and regularly reviewed to continuously improve the lookup tables

Long term:

- Building Regulations should be reviewed to include quality assurance using in-situ U-value measurements