Future Homes Hub: Building Performance Evaluation Call for Evidence

Build Test Solutions Response

BUILD TEST SOLUTIONS

January 2022

Building Performance Evaluation Call for Evidence

As we move to higher standards of fabric efficiency and increased use of electric heating (heat pumps or direct electric) with the introduction of the Future Homes Standard, homes will increasingly be sensitive to any sub-optimal performance. As a consequence, it will be important that new homes perform as intended and that we have appropriate mechanisms to understand performance and provide feedback; with a strong preference for methods that can be used before occupation and all year round.

The government is already considering how to move to an assessment approach that better reflects performance. For example, the 2020 Energy Performance Certificate (EPC) Action Plan states:

"EPCs will need to move from a reflection of the features of a building (fabric, services and installed improvement measures) to a true measure of 'in use' building performance. This can be based on more sophisticated building modelling that takes actual energy consumption into account (while remaining a measure of building performance and not occupant behaviour)."

on new build homes, it states:

"We will review the changes needed for SAP 11, expected to be rolled out in approximately 2025, to make EPCs more accurate, which could include considering the potential role of SMETERs [measurement technologies participating in a Government R&D programme] data in SAP."

The Future Homes Hub is therefore reviewing potential approaches to reflect 'as built' performance. This call for evidence is to gain an understanding of current and 'in the pipeline' building performance evaluation: technologies, techniques, capacities, capabilities, challenges, gaps and opportunities.

1. Are you aware, or the developer, of a technology that measures as-built home performance? If so, please offer a brief summary of what is being measured, the equipment involved, how long for, test conditions and the output.

Build Test Solutions are a business dedicated to the cause of developing a range of technology solutions concerning cost effective measurement of as-built performance. Established in 2016, the primary focus of our work to date has been on techniques for specifically measuring building fabric performance - a conscious decision given the influence fabric performance has on total energy consumption and CO2 emissions, as well as the simple fact that the building fabric will typically have an operational life of 50-100 years vs. heating, ventilation and cooling systems that might serve said fabric being serviceable items, replaced on a 10-15 year cycle. Our technologies include:

SmartHTC: a cloud hosted algorithm that uses in-use energy consumption data alongside internal temperature data to measure total building heat loss (otherwise referred to as the Heat Transfer Coefficient or Heat Loss Parameter as per SAP - the sum of all losses from conduction, radiation and convection via the fabric, infiltration and ventilation). Crucially the algorithm is technology agnostic and thus can integrate with existing smart home devices and smart meters with cost comparable to an EPC lodgement ~£5-10 per property when applied at scale. The algorithm requires 30 minute interval temperature data and total energy consumption for a minimum 21 day period in winter and the property can continue to be lived in and operated as normal during this time. If smart thermostats already logging temperature data exist, no additional hardware is required. The output is a HTC value directly comparable to a SAP worksheet output alongside a calculated measurement uncertainty interval. This is an ideal metric to judge if a building is performing as expected or whether further diagnostic testing is required to identify the cause of unexpected performance. If properties are unoccupied, we see scope to significantly shorten the required 21 days but retaining the underlying benefits of low cost and little to no hardware requirements. Lastly, using the same datasets used to calculate SmartHTC this solution also incorporates feedback on other key metrics including overheating risk in line with TM59 and mould/condensation risks.

Pulse: A compressed air alternative to the blower door fan used for measuring air leakage. The primary innovation here being that the device measures air leakage rates directly at ambient pressure levels (4Pa). The test therefore does not exert undue stress on the building envelope and presents what the true background air leakage is under occupied conditions. Pulse is also very accurate at measuring effective leakage area i.e. the geometric opens as presented with say, vents open vs. vents closed/sealed and thus also has scope for use under Part F as well as L. The test is quick (20 seconds) if using pre-charged air receivers but the technique is currently unable to identify the air leakage points. For this we have developed an accompanying **'Leak Checker'** product which is a small low cost window mounted fan aimed at site teams, for them to check and rectify air leakage points during the build process, thus ensuring a robust primary air barrier and ensuring 100% pass first time post build compliance testing. The current culture of using mastic and expanding foams to get a pass at point of handover screams poor quality construction and is damaging.

Heat3D: A thermography based means of measuring the U-value of complete wall elements. Rather than the incumbent heat flux plate method which requires a minimum of 3 days and only measures the energy flows through an area the size of a coaster, Heat3D comprises a thermal imaging camera mounted on a tripod in front of a wall taking time lapse shots for a period of 1 hour. The thermal images are calibrated by a series of targets that incorporate a temperature sensor and the output is both a highly visual thermograph of the entire wall as well as a plot of measured U-values at 500mm intervals. This therefore both presenting but also helping to quantify issues such as cold spots, thermal bridging, high timber fraction and so on. In order for there to be an adequate measurement signal, the property must be warmer than outside, with the lower the U-value, the higher the temperature difference required. A U-value of 0.3 W/K.m2 would generally require there to be a temperature difference between inside and out of 10oC.

U-value Measurement System: A complete set of testing equipment to carry out U-value measurements using heat flux plates according to the standard ISO9869 testing methodology. The equipment includes heat flux plates that are temporarily attached to an opaque building element (practically, anything apart from a window) for a period of at least 3 days, they measure the U-value of the construction at the location of the heat flux plate. In comparison to Heat3D, heat flux plate measurements are more invasive, require more expensive equipment and only measure the U-value at one location. They do, however, allow measurement of elements other than walls (floors and ceilings) and give results with a lower uncertainty interval by a long recognised testing methodology.

3. How (if at all) will the technology cover the following:

a. annual performance?

Space heating demand accounts for approximately 60% of total energy use in the home and thus understanding the true fabric performance will have a considerable bearing on understanding not only annual performance but also on how the building fairs over its entire lifetime. Fabric intervention being costly and a one in 50+ year event.

b. daily / weekly performance?

As above, understand space heating demand and you’re left with only heating system issues or occupancy driven high/low consumption.

c. diurnal peak loads/flexibility of loads (to aid electricity supply availability/access to time of use tariffs)?

Space heating = principal peak demand load on a heat pump, for example. Hot water always occupancy related and must be planned for based on size and nature of the property.

d. Comfort (over / underheating)?

Fabric performance and air tightness, with corresponding servicing strategy = comfort. SmartHTC also incorporating a TM59 based under and overheating risk assessment based on in-situ measured temperature data.

e. Ventilation?

Pulse = background air leakage under ambient conditions, thus understanding of the impact this will have on how best to balance and commission ventilation systems. Reliance on natural ventilation via trickle vents and underpowered intermittent fans has surely had its day!

f. air quality?

As above. Pulse not providing a direct measure of contaminants in the air, only background air change rates. SmartHTC and its mould/condensation risk facility uses relative humidity as one of its proxies but again, not strictly air quality/pollutants.

4. About the technology:

a. Is the performance measured prior to occupation or during?

Can be used for either.

b. Are all homes tested or just a sample?

To be determined by the person/organisation carrying out the measurement. In our opinion HTC and airtightness measurements should be carried out on every building with the results used to identify buildings which have unexpected performance (differences from that predicted by an energy model, e.g. SAP or PHPP), buildings with unexpected performance should then be the target of further diagnostic testing to identify the causes. Diagnostic testing could include air leakage detection, U-value measurement, thermographic surveys and ventilation rate measurement.

c. How long is the period of testing?

SmartHTC: 3 weeks, during winter. The building can be occupied during measurement.
Pulse: 10 minutes
Heat3D: 1.5 hours
U-value measurement system: Minimum 3 days, during winter. The building can be occupied during measurement.

d. What are the test conditions (including can the test occur at any time of year)?

Heat loss measurements (HTC and U-value) require a positive temperature difference between inside and out, and so are generally limited to winter (Oct-Mar, inclusive). Airtightness measurements can be carried out at any time of year.
e. If the test is during occupation, or people/workers may be present during the test period, how does the test disaggregate their impact on the result?
SmartHTC: That’s part of the algorithm, which takes into account occupancy variables including appliance use, hot water use, metabolic heat gains and window opening so that the output result is a measurement of just the thermal performance of the building (it’s HTC).
Pulse/Leak Checker/U-value measurement system: Occupancy does not impact these measurements.

f. If the test is during occupation how is personal data protected?

All data is stored in BTS’ systems in an anonymised format, with no personal data stored. Energy consumption and temperature monitoring data are collected as part of SmartHTC measurements, which could be considered personal data, but are stored against the postcode only so that the data cannot be related to a particular person.

5. Can the results be disaggregated to aid diagnosis?

Yes. We document this topic more fully in our own building performance measurement handbook which we would be happy to share with the FHH.

Comparison of the overall measured thermal performance (HTC) of a building with the predicted value provides an overall assessment of whether the building is performing as expected or should be the focus of further diagnostic testing. HTC measurements alone can also be used as a diagnostic tool across a larger sample of buildings, comparing the performance of things like different materials, building methods, or even construction teams.

When combined with an airtightness measurement, the overall heat loss can be broken down into heat loss by infiltration or fabric + ventilation. This allows diagnosis of whether the predicted infiltration heat loss is as expected, with the input of calculated or measured ventilation air provision the heat loss can be further broken down into the 3 major constituent parts: fabric, infiltration and ventilation. This is a useful process to diagnose causes for performance gaps, and also to understand in a retrofit situation whether it is suitable to make a building more airtight and what additional ventilation is required.

If the heat loss breakdown identifies that there are discrepancies between the predicted and actual fabric performance, U-value measurement tools can then be used to diagnose which element(s) are not performing as expected. Heat3D can also be used to identify possible locations of missing or dysfunctional insulation and location of greater than expected thermal bridging. As a suite of tools this provides for complete diagnostic testing of the thermal performance of the building.

6. Can you share case study examples where the technology has been deployed?

Yes, very happy to provide examples upon request. There are also some examples available publicly:
https://www.airex.tech/news/2020/12/15/airex-smart-air-bricks-energy-savings-impact-validated-under-first-ever-eco-demonstration-action-field-trial-1

https://buildtestsolutions.com/wp-content/uploads/2021/10/210714-Crossway-Performance-Measurement.pdf

https://buildtestsolutions.com/wp-content/uploads/2021/10/210715-RBKC-Lancaster-West-Retrofit-Performance-Measurement.pdf

https://buildtestsolutions.com/wp-content/uploads/2021/11/211020-The-Beacon-Retrofit-Report-GSHP-and-SmartHTC-Web.pdf

Very often with new build, measurement results are commercially sensitive and under non-disclosure. Overall, our datasets are in the very low thousands of buildings (HTC, air tightness, U-values), with significant scope to scale further, faster.

7. Is the building performance evaluation approach commercially / logistically available now? If so, please describe the specific product or service offered with practical examples and the number of homes that have received the service (or been measured) to date. If not, can you advise what barriers you have to roll out, how these might be overcome and when you are expecting to have a commercialized offer (assuming circumstances don't change)?

As a private limited company we are resolutely focused on the building performance measurement solutions we develop being both practical to use and commercially viable. Our SmartHTC, Pulse, Leak Checker and Heat3D solutions are all available to buy and use today and we pride ourselves in having achieved price points that allow the tools and techniques to be adopted at scale.

Our two main commercial delivery models are 1) to simply sell physical measurement equipment that others can then use to offer the service and/or measure their own buildings. Clients here include energy assessors, building surveyors, consultants, architects as well as developers, contractors and housing associations. Secondly, our solutions such as SmartHTC are digital based and so whilst can be offered as a measurement service, they can also integrate directly with smart home devices or monitoring platforms offered by others. Here the model is pay-per-use, with charging based on the calls made to the algorithm via APIs.

The barriers to widespread adoption are in fact fairly limited. What's required in order to boost the rate of uptake is quite simply clear policy and regulatory signals that encourage measurement of true performance and penalise the use of less reliable predictions and estimates. The holy grail is for regulation to be entirely outcomes based, with any approach to construction permissible provided the delivered goods perform at a set level in-use.

8. What independent validation of the technology outputs or metrics has been undertaken? Include any detail of relevant Government R&D scheme involvement where possible.

A key aim of BTS is to provide tools which have been thoroughly tested and validated prior to introduction to the market.

Pulse: Many academic papers have been published on the underlying physics, a major field trial has been carried out in conjunction with the University of Nottingham and the technology has been verified by the BRE under the Environmental Technology Verification scheme. A library of evidence is available to download here: https://buildtestsolutions.com/wp-content/uploads/2020/07/Pulse-Test-Reports-as-submitted-to-UK-Government-June-2020.zip

SmartHTC: SmartHTC has been validated through academic research at Loughborough University and has been independently validated through the BEIS sponsored SMETER program (https://www.gov.uk/guidance/smart-meter-enabled-thermal-efficiency-ratings-smeter-innovation-programme). BTS have carried out our own extensive validation exercise, which has been independently verified by building physics consultancy SOAP Retrofit, a report is available here: https://buildtestsolutions.com/wp-content/uploads/2021/01/BTS_SmartHTC-Validation_Full-Report.pdf.

U-value measurement system: This product provides U-value measurements according to the long standing and internationally recognised ISO9869-1:2014 standard (https://www.iso.org/standard/59697.html).

Heat3D: Heat3D has been through an extensive validation process in conjunction with the University of Salford with comparative testing against ISO9869 measurements, a report of which is available here: https://buildtestsolutions.com/wp-content/uploads/2021/12/Heat3D-Validation-Report-v1.2.pdf. The technology has also been reviewed by the National Physics Laboratory, with an overview report available here: https://buildtestsolutions.com/wp-content/uploads/2021/10/M4R-10230-Heat3D.pdf

9. What is the claimed accuracy & precision (repeatability) of the technology for a single home and, if appropriate, across a sample of homes? How has this been determined? Is the output calculation calibrated against historic benchmark studies or validated by measuring against an onsite measured metric…or both or another approach? Does the calculation offer a good description of how a home will perform in varied weather conditions? If so, how? How is/will the ongoing test integrity be assured?

Pulse: Although a lot of focus has been placed on assessing the Pulse technique on the grounds of how it compares to the incumbent blower door fan technique, the two methods measure air leakage at different pressure levels, with the Pulse including the front door as part of the test. More useful insights into its accuracy and precision include having carried out repeat tests in over 150x homes, demonstrating a mean RPD of +-5%. BRE have already carried out a series of known opening tests where Pulse measured the geometric area of the introduced opening to within 3.7% on average, compared to the blower door fan at 7.8%. Another BRE test carried out included pressure crossover testing with the fan i.e. chamber testing where both fan and Pulse were used to measure air leakage at the same pressure level, with the average difference in the overlap determined at 6%, well within the combined uncertainty of both instruments. All of this work is publicly available on the BTS website, linked above.
As a technique, Pulse is generally less susceptible to wind and buoyancy effects than the fan method, although currently we advise following the same guidelines for both methods. Lastly test integrity is assured with Pulse software scrutinising the data and auto assessing test quality on a number of factors inc. data fit, flow exponents and achieved pressure range. None of the data or these factors can be tampered with by operatives.

SmartHTC: The accuracy of SmartHTC is dependent on the building being measured and the amount of information provided for the calculation. With a full set of monitoring data the accuracy

of the measurement is approximately +-15%. The uncertainty of the calculation is higher for buildings with very low heat loss, buildings with low external area compared to party surface area and in cases where limited input data is provided. The accuracy of the measurement is calculated on a bottom up basis, based on the uncertainty contribution of all input parameters. The uncertainty calculation has been verified by comparison with a benchmark measurement value (provided by a coheating test) in more than 40 buildings.
The repeatability of SmartHTC measurements has been tested by repeat measurements in a large sample of buildings, the mean RPD across 700+ SmartHTC measurements was less than 1% demonstrating very repeatable measurements in the same building across a wide range of different weather conditions. Much more detail on the accuracy and repeatability of SmartHTC is available in the Validation Report available on the BTS website and linked to above.
Lastly, integrity is assured again by the algorithm assessing data quality and ensuring the required mean temperature delta's and other test quality parameters are met prior to presenting a result.

U-value Measurement System: The uncertainty of U-value measurements using heat flux plates according to ISO9869-1:2014 is calculated in the testing methodology to be between +-14% and +-28%.

Heat3D: Heat3D can accurately measure U-values with a precision of 0.1W/m^{2}K. The accuracy of a particular measurement is dependent upon the rate of heat loss being measured, which is dependent on a combination of the U-value of the element and the temperature difference across it. As a general guide, for U-values above 0.2W/m^{2}K and temperature differences of larger than 10°C the uncertainty of the measurement will be in the region of +-15%. The uncertainty of a measurement is calculated in each case based on a summation of the constituent uncertainties, the validity of the uncertainty calculation has been demonstrated against ISO9869 U-value measurements in the field and in the laboratory. Much more detail on the accuracy and repeatability of Heat3D is available in the Validation Report available on the BTS website and linked to above.

10. Where possible, describe any public sector procurement processes (e.g. social housing, local, or national, Government tenders) for fabric or services measurement and verification services the technology has successfully participated in? Please detail either new-build or existing home projects.

Pulse measurements have been accepted as a compliant method for airtightness testing in the forthcoming revision of Building Regulations in England. Pulse measurements are also used in PAS2030 & PAS2035 compliant processes for determining whether additional ventilation is required as part of retrofit measures.

Pulse, heat flux plate U-value measurements and SmartHTC measurements have all been used to demonstrate the performance of new products through the ECO3 Innovation Demonstration Action pathway. These measurements are also being used for BPE activities through the BEIS Social Housing Decarbonisation Fund.

11. Does your approach provide insights into the householders experience of living in the home and interacting with any equipment (this is either in combination with a technology referred to above or as an independent exercise/study)? Describe the approach you use including, but not limited to:

a. how the studies are undertaken?

Measurement as a service (point in time testing) or via integration with existing smart devices in homes.

b. who undertakes them?

Energy assessors, building surveyors, consultants, air tightness testers. Alternatively it's remote via smart home technology providers, metering and monitoring solution providers and/or utility companies and similar such service providers.

c. what information is shared with the householders and how?

Varies significantly; in the case of SmartHTC it can be as simple as a number or ranking. Otherwise it's a short electronic report.

d. approach to data protection?

Building owner and occupier (energy consumer) consent followed by wholly blind processing and storage of any data i.e. only a data processor, not a controller with the measurements not needing to know property location or occupier details at anywhere near a personal level. Perhaps more of a challenge for those commissioning the measurement who invariably will combine both the measurement and the location/occupancy information for a given property.

e. is it on a sample basis or all homes?

Varies subject to client requirements and objectives.

f. how this could be applied at scale?

As detailed elsewhere in this response. Measurement as a service via existing professionals and/or via smart home device integration.

g. what insights are typically gained?

Building fabric performance (split by fabric, infiltration and ventilation losses). U-value measurement system and Heat3D then heat loss via individual wall, floor and roof elements.

12. Are there other new home performance parameters that should be considered by the Future Homes Hub?

One would be the Heat Loss Parameter scale we currently use with our clients as part of SmartHTC. This is HTC normalised by building floor area and is already calculated in SAP. Build Test Solutions have however put a ranking scale to this which we would be delighted to see adopted more widely.

Related would be the make a concerted effort to segment the building performance measurement challenge into three parts - one of understanding the performance of the building fabric, occupants and building services. To continue to talk in terms of total kWh/yr is unhelpful given it shines no light on the respective ‘performance’ of the constituent parts. Again, this is why we are such strong advocates of HTC being the ultimate barometer from which everything else stems.

Another would be to generally improve recognition of what air leakage reported at 50 Pa pressure difference (pressure and depressure) actually means compared to infiltration and air leakage under more normal pressure differences. Initial acceptance of Pulse has been on the premise that its results are extrapolated up to 50Pa and yet this is then extrapolated back down again within SAP energy models in a bid to reflect reality. There’s a lot of talk about the marriage between air tightness and ventilation and yet as an industry we seem hell bent on avoiding conversations about the air leakage rate of homes expressed as air changes per hour at 4 Pa ambient pressure difference.

13. How do you think the Building Regulations could evolve from the current approach in terms of ‘a compliant design’ (with some on site testing such as air permeability) into one in which ‘as-built’ building performance is demonstrated?

Measured thermal performance, represented by either the HTC or HLP, provides a clear route forwards for demonstrating as-built performance in-situ. This is in line with existing Government plans, as demonstrated by the EPC Action Plan and the SMETER project. There are now multiple testing methods which have been demonstrated to be accurate and cost-effective for us on a wide scale.

HTC measurements should also work together with existing airtightness and ventilation rate measurements to break down and compare predicted and actual fabric, infiltration and ventilation heat loss for every building. This would allow quality control over energy performance, but also highlight possible issues with air quality, mould and overheating risk to enable more informed building management and retrofit.

Mechanisms must then exist that ensure issues of underperformance are recognised, understood and acted upon. Continuous improvement feedback loops on the topic of as-built performance are currently lacking throughout the industry.

14. Do you think there is potential “deemed to comply solution” to BPE, along the lines of Robust Details for Part E? If so, please describe how you think it would look?

Our experience to date is that no two buildings are ever the same, both in the new build and retrofit/refurbishment market. With there having been such little culture of measurement to date, the causes and effects of variations in performance are currently little understood. The matter is complex with issues of product performance (lab to real world), installation and workmanship (particularly detailing and interfaces), wetting and drying, deviations from design inc. product substitution as well as inaccurate initial performance estimates and associated models. In retrofit the issue is exacerbated as buildings have generally had a series of often poorly documented interventions over their lifespan which can cause large performance differences for apparently identical buildings.

In our opinion, if such a scheme were to exist, early years would have to place significant emphasis on measuring a very high quantity of homes with issues of underperformance best dealt with through enforcement of improved quality management and continuous improvement standards. Our hope from this would be that in time a deemed to comply scheme could lessen its sampling, with developers instead choosing to measure a sample of their own homes themselves, just as with any other quality control regimes run internally by those in the manufacturing, automotive, aviation and electronics sectors.

There are presently very few developers/contractors that have a culture of in-house performance measurement, verification and associated feedback loops. Partly because the tools and techniques to measure have historically been impractical and costly but also because the consumer has typically been more readily drawn to other aspects. If we are serious about our net zero obligations along with the transition to the electrification of heat, the matter of measuring, understanding and acting on true as-built performance only becomes ever more important.

Contact

enquiries@buildtestsolutions.com
www.buildtestsolutions.com

Build Test Solutions Ltd, 16 St John's Business Park, Lutterworth, Leicestershire, LE17 4HB