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Comparison of whole house heat loss test methods under controlled conditions in six distinct retrofit scenarios

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ABSTRACT

The accurate assessment of buildings to assess their performance across a range of parameters is an essential part of understanding both new and retrofit buildings. The growing understanding of the performance gap in terms of its assessment and characterisation relies on effective methods of analysis. Here, we evaluate an experimental whole house method, known as QUB. As with many whole building approaches the method establishes heat loss through transmission and ventilation losses.

This study compares QUB against an alternative, established, whole house test known as coheating. It was applied in a whole house test facility under controlled conditions. The test property, a solid wall pre-1919 UK archetype, was retrofit using a set of commercially available products and then the retrofit was removed in stages. At each of these stages a QUB test, which commonly takes one night, and coheating test, which can take few weeks, were applied. The objective of the study was to provide a comparison between the new method and more established method in terms of accuracy.

The two methods showed close agreement in terms of results, suggesting that the quicker test has great potential as a more practical and economic test. There were higher levels of uncertainty with the QUB method due to shorter measurement periods. The lack of full boundary conditions within the test facility should be considered a limitation in applying the findings directly to the field. However, this study indicates the potential for QUB in validating performance, warranting further investigation.

1. Introduction

The *performance gap* describes the difference between the predicted and actual thermal performance of buildings. Whole building heat loss tests show that dwellings can experience 60% or greater heat loss than designed [1,2]. This can be attributed to a wide variety of reasons ranging from the design and construction of a building to its use by occupants [3].

The final energy consumption in the domestic sector is 27% of total UK final energy use [4]. This has major implications for policy, such as energy efficiency and fuel poverty targets. An understanding of the actual performance of buildings, taking into account the identified performance gap issues, is essential if we are to deliver policy targets and positive outcomes for occupants.

The drivers for energy consumption are manifold. Consumption of energy use in the EU is largely driven by demand for space heating, with an average figure across the EU member states of 68% of final energy consumption in the household sector [5]. Interactions between the fabric, systems, controls and occupants form complex relationships to determine overall energy use.

The performance gap is compounded by the difficulties of monitoring domestic properties in the field, with many tests proving intrusive and difficult to implement, particularly in occupied properties [6].

Fabric is a major contributor to the overall efficiency of a property when considering heating loads [7]. In retrofit, where existing buildings are raised to higher standards of energy efficiency, in particular, a fabric first approach is recommended [8]. Understanding the building fabric can be approached through qualitative methods such as thermography, or quantitative methods, such as in situ U-values measurements. However, there are also a number of approaches that are used to investigate the whole building performance.

The heat loss from an entire building envelope can be quantified using the Heat Loss Coefficient (HLC). The HLC is the rate of heat loss in Watts from the entire thermal envelope of a building per Kelvin of temperature differential between the internal and external environments (ΔT) and is expressed in units of W/K.

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Table 1
List of existing methods to estimate the HLC.

Method	Length of test period	Description
Coheating [9]	7–21 days	Quasi steady state test using electrical heaters and fans to create a stable internal temperature whilst outdoor conditions remain variable. Power input to maintain an elevated temperature is used to calculate a global heat loss figure for the building.
QUB [10]	2 days	A dynamic test using electrical heating to increase the temperature in the building and then allow to cool over 2 periods after sunset. Power input is monitored along with internal and external conditions to calculate a global heat loss figure.
P-STAR [27]	3 days	The methodology is like Coheating methodology with the exception that three internal conditions are created, one heating period (16 h), one cooling down period (16 h) and finally a heating period. Power input, internal and external environmental conditions are measured during these periods. Using this dynamic pattern identification can be made of the HLC of the building alongside the thermal mass levels.
PRISM [28]	1 Year	Meter readings are taking over a year long period, the heating fuels for the building; this data is then adjusted using a degree day methodology/weather normalisation. From here a W/K figure can be calculated alongside an annual prediction of heating fuel consumption, given typical weather conditions.
ISABELE [19]	15 days maximum	Following a short (1/2 day) period of no heating, a controlled power is injected into the building to meet a certain increase the temperature to a given set point (minimum of 2 days). Then a final stage of temperature decrease, with the heating switched off is recorded. The test records power input, internal and external conditions which allow a global heat loss figure to be calculated. The test can last between 5–15 days depending on the fabric of the building.

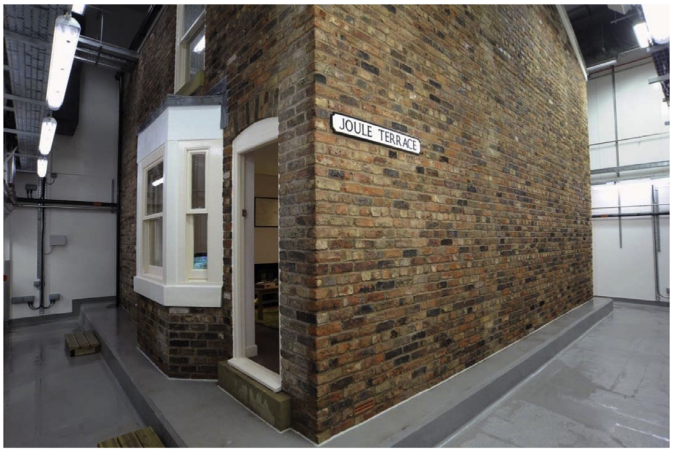

Fig. 1. The Salford Energy House within its environmental chamber.

The HLC is an aggregate of the total fabric transmission and background ventilation heat losses from the thermal envelope. A non-exhaustive list of available methodologies is provided in Table 1.

In this paper we compare two methods of estimating the HLC of a dwelling in a unique testing facility at the University of Salford. This facility allowed the HLC to be estimated by both methods at six stages of retrofit under exactly the same conditions. The first method is one of the current leading approaches, the coheating test, which can take 1–3 weeks [9]. The second method, which is currently under development, is the QUB test, which takes 1–2 days [10]. This has the potential to take the HLC methodology from a research focused tool to wider practical applications. We first start by describing the test house and then the different retrofit stages performed. We continue by presenting both coheating and QUB methodologies. Finally we compare and discuss the results obtained.

2. The energy house

The Salford Energy House is a full scale pre-1919 solid-wall Victorian end-terrace house constructed inside an environmentally controlled chamber at the University of Salford [22]. The construction of the Salford Energy House Test Facility was achieved by using reclaimed materials and methods of the time. An adjacent house is also present so that the effects of a neighbouring property can be explored during experiments. A picture of this environment is shown in Fig. 1.

The environmental chamber is a large reinforced concrete structure. The dimensions are 11.1 m wide, 9.3 m deep and 7.4 m high. This gives a chamber volume of 763 m^3. The chamber walls are insulated with 100 mm PIR foam insulation to the walls and ceiling and 35 mm expanded polystyrene insulation to the floor element (reinforced concrete slab on short bored piles). This helps to isolate the chamber from external influences such as wind, rain and solar gain. The chamber has the ability to maintain a constant temperature between the range $-12\,°C$ and $+30\,°C$ with an accuracy of $\pm 0.5\,°C$ at a 5 °C setpoint. The chamber is cooled by an air handling unit that is supplied with cooling by 4 No. condenser units, with a total of 60 kW of cooling (15 kW per unit). This is supplied to the chamber via a ducted HVAC system. This system reacts to the heat load of the house in the chamber and maintains a setpoint of $\pm 0.5\,°C$.

The Energy House Baseline case had the following construction:

- Solid brick walls 225.5 mm thick arranged in English bond (with every fifth course being a header row), with 9 mm mortar joints 12.5 mm hard wall plaster to inside face of wall with 2 mm skim as finishing coat. Magnolia paint to internal face of wall.
- The house is built off a reinforced concrete raft with no insulation added. A 200 mm gap exists between the house and this raft; this forms a ventilated floorspace and allows for a constant airflow beneath the house. The floor is suspended on 200 mm timbers and is finished off with 22 mm floor boards (non-interlocking and non-sealed).
- The windows are double glazed units of a type found circa 2000. The doors are UPVC of amid range type, in terms of thermal performance.
- The roof is a timber rafter and purlin roof with 100 mm insulation at the time of the initial tests. A layer of mineral wool insulation. There is a small amount of eaves ventilation, sarking felt is installed.
- The party wall is a solid wall construction to match the external walls, and remained unplastered on the neighbouring side.

The construction of the neighbouring building is as follows:

- This building has a layer (60 mm) of closed cell foil backed insulation, to the external facing walls only, and not the party wall.
- The external facing walls are solid brick as above.
- The gable of this building is concrete block (2 skins of 100 mm with a 20 mm air gap).
- The loft has 200 mm of insulation.
- The doors are single skinned timber panel doors; the rear door is half glazed with single glazing.