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The staged retrofit of a solid wall property under controlled conditions

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ABSTRACT

Retrofit of hard to treat properties has been highlighted as a policy challenge to reduce energy consumption in the UK. This study undertook an experimental staged retrofit of a pre-1919 UK solid wall property under controlled conditions. The property is housed within an environmental chamber, where the conditions were held at a constant 5 °C during the test to reflect UK average winter temperature, with all other boundary conditions removed. The retrofit was undertaken using commercially available products and at each stage a number tests were conducted to evaluate the performance, with the results for the coheating tests and in situ U values being reported here. The results show that the deep retrofit undertaken led to a 63% reduction of heat loss from the building, with the technical feasibility of staged retrofit clearly demonstrated from a heating energy efficiency perspective. The calculation of cost savings suggests that a whole house deep retrofit may not be financially feasible if supported only by energy savings. The use of controlled conditions did allow each stage to be measured and compared in a way that has not been achieved in the field, allowing for effective comparison of each stage previously only fully explored in models. There are limitations of the methodology driven by the lack of boundary conditions, specifically around air movement and longer term performance issues, which are best addressed in the field.

1. Introduction

The understanding of the energy efficiency impact of different domestic retrofit measures is an important part of decision-making when designing and installing a retrofit. Here, we report the results for a staged energy efficient retrofit of a solid wall property under controlled conditions in the Salford Energy House (SEH) facility. The SEH is a whole house in a climate-controlled chamber. The purpose of the experiment was to evaluate a staged retrofit, to understand the impact of individual retrofit measures, and to assess the underlying reasons for performance, particularly where this may diverge from expected performance. Work within the context of an environmental chamber gives a consistent test environment, which allowed controlled experiments to be undertaken on each stage of the retrofit, to provide comparable test conditions at each stage, something that can be difficult to manage in the field.

A set of commercially available products were used for the upgrade. To undertake the study, the research team, which included the University of Salford, Saint Gobain, who provided funding for the research, and Leeds Beckett University, used the Salford Energy House [37,52,50]. The SEH is a complete UK Victorian style property, including a “conditioning void” to recreate the conditions found in a neighbouring property, built within an environmental chamber.

This work does share similarities with the work undertaken by the CALEBRE Project [43], which also undertook a staged retrofit on a property. However, there are a number of key differences; the first is the property was not coheated at each individual stage of the retrofit; secondly, the coheating for the Salford Energy house project was carried out under controlled conditions; and finally the archetype for the Salford Energy House experiment was a solid wall, rather than a cavity property, meaning different measures were analyzed. It should also be noted that this was the first major experiment conducted within the Salford Energy House and as such there were a number of methodological issues that were addressed by the team, however, these are reported elsewhere [21].

2. Background to retrofit in the UK

At the time of the research (2013), the UK was engaged in a number of government-funded programmes to support energy efficiency in the existing stock. Some of the earlier policy initiatives focused on the carbon emissions of new build properties through the planning system and UK building regulations. The focus of these actions was very much designed to address issues of climate change mitigation. However, with studies indicating that some 65–80% of the stock currently standing would still be standing in 2050

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[42,54,53] and the UK's target for an 80% reduction in emissions as stated in the Climate Change Act 2008, the issue of retrofit was brought to the fore. The UK has greater issues with poorly performing housing stock in terms of energy efficiency when compared other European countries [46]. The existing stock had not been entirely ignored, as retrofit was funded through programmes such as Warm Front [12] and the previous version of the supplier obligation, the Energy Efficiency Commitment (EEC 1 and 2; 2002–2008). The EEC has been viewed as the start of a supplier obligation that considered climate change mitigation as a policy objective [59,57]. The EEC was replaced by the Carbon Emissions Reduction Target (CERT) in 2009 [36], which was specifically targeted towards climate change mitigation, and the Communities Energy Savings Programme [13], which was a policy focused on low income areas [55]. In 2013, these were replaced by the Energy Company Obligation, which had three main components; one focused on carbon emissions, one on area-based programmes and one on the fuel poor [58,64]. These were supported by a market led policy instrument, known as the Green Deal [15,14,16]. The Green Deal was designed to allow people to fund retrofit without the need of paying the upfront cost, with payment for the capital works being paid through a charge on the electricity meter. The Green Deal and ECO were roundly criticised for their failure to deliver widespread retrofit [47] in comparison to previous programmes.

A clear understanding of the performance of potential of retrofit interventions is required for these policy tools to function successfully. The Green Deal, in particular, relied on flows of energy savings to meet the ongoing payment for capital works, which established a "Golden Rule", whereby no install would cost more than it saved over its life. However, the work around performance gap has established that, for a wide variety of reasons, direct performance relationships between improvements and households can be difficult to establish on a case by case basis [38]. These technical issues contributed to the suspension of a number of policy initiatives, including the Green Deal and the establishment of a UK Government review, Each Home Counts [3]. This report raised a number of recommendations with regards to a better understanding of performance and quality within the retrofit market, which have direct relevance to this study.

3. Evaluating the performance of retrofit improvements

The energy efficiency impact of retrofit on a dwelling-by-dwelling basis is often measured at the whole system, rather than at the specific improvement, level. This is because that staged retrofit studies are difficult to manage in occupied properties. Projects monitor the overall performance of homes through long-term monitoring campaigns, such as the work undertaken in Retrofit for the Future [27] or the work of Jones et al. [41]. These monitoring campaigns consider the performance of occupied properties, usually using a range of tests, such as air permeability, thermography or measured in situ U values, combined with measurement of external and internal environments and measured energy consumption [22]. These studies can suffer from project management issues such as lack of pre-retrofit data, often resolved by modelling [41], loss of data [63] or small sample sizes, which make it difficult to conduct the requisite sensitivity analysis to understand the impact of different retrofit elements. Chapman et al. [10] Pennyland Study highlight the issues of statistical significance in drawing strong conclusions from these kinds of studies when establishing the impact of individual issues on the energy performance of a property.

Work has also been undertaken using high level stock models to assess the impact of retrofit measures. Work by Jenkins and Palmer and Cooper [36,49] use high level stock data and energy consumption data to identify the potential impact of policy initiatives. The UK Government National Energy Efficiency Database [8] uses national data from energy suppliers, energy efficiency measure recording and property and occupant characteristics to analyse the impact of individual measures based on large samples. These approaches are focused to policy decision making rather than at an individual property level.

At property level, modelling approaches such as those undertaken by Simpson and Banfill, as part of the CALEBRE Project [43,61], can provide insight into the impact of individual retrofit measures and their order. However, with modelling, risks around assumptions of the performance of building elements can lead to discrepancies, as found in Marshall et al. [45]. Interventions can be undertaken on unoccupied houses and measured in detail, as seen in Gillott et al. [25] and Hall et al. [28], both of which consider improvements to the E.ON House under the CALEBRE project. This study most closely reflects the experiment under discussion. However, this property was a cavity archetype and, while the results show this case can be defined as a deep retrofit, based on modelled Standard Assessment Procedure (SAP) savings of 72%, different measures were applied and a different methodological approach was taken. While field-based coheating tests are undertaken to assess the measured HTC of the property, these were not specifically targeted at understanding the impact of individual measures, but rather comparing the pre and post retrofit stages, as well as the impact of MVHR performance [66].

The performance gap, the difference between modelled and actual energy performance, is an issue which has been well established over the recent years in both new build and retrofit [39]. Work establishing the performance gap in new build homes against the statutory models [26,56] and the performance of individual elements against their modelled performance [17,18,60] leads to a number of possible conclusions as to the source of the performance gap. Firstly, the building is not built as the model suggests, which as highlighted in the Zero Carbon Hub Report on performance gap and might considered the classic definition of the term. This can be due to issues such as changes to design, replacement of materials or poor workmanship (ZCH, 2013). Secondly, we might consider that the assumptions within the model or the model itself are incorrect, such as the assumed U values not reflecting in situ values [65,45]. Finally, we could also identify that the process of measurement or analysis is itself incorrect [63]. It can be seen that both measurement and modelling present performance gap challenges in understanding the energy saving impact of different retrofit measures.

The effective understanding of the performance of sustainable retrofit improvements has been a major challenge for policy makers in this area. In the UK, the reliance on models to establish payments under Green Deal or the Energy Company Obligation, has meant their accuracy has had implications for homeowners who may make decisions based on these models and businesses whose products performance is specified. However, as stated previously, the development of robust experiments in the field can be problematic. The purpose of the Salford Energy House was to make an attempt to control these variables and allow effective before and after monitoring of retrofit improvements under identical conditions to provide benchmarks to help understand the level of improvement made by retrofit technologies.

4. Methodology

Testing at a whole building level under controlled conditions is very much in its infancy. Many of the techniques are the same as those that might be applied in building performance evaluation in the field, but the nature of the facility creates a number of different types of decisions concerning research design than might be found in the occupied properties. The series of tests that were