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Tailoring domestic retrofit by incorporating occupant behaviour

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Abstract

Energy savings from building retrofits often fall short due to occupant behaviour. Current retrofit guidance may be significantly undermined due to standardised behavioural assumptions used in modelling calculations. This paper investigated the impact of household behaviour on the effectiveness and optimum ranking of domestic retrofit measures. It compared the energy saving potential from eight single retrofit measures across five household behavioural patterns, using a case study dwelling and dynamic building simulation modelling. The results confirmed that behavioural impact is significant in optimising retrofit strategies, suggesting tailoring domestic retrofit by incorporating occupant behaviour is vital for realising the energy saving potential.

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Keywords: Energy retrofit; domestic building; occupant behaviour; tailored approach; behavioural pattern

1. Introduction

The domestic sector accounts for just under a third of total energy use in the UK, representing a significant opportunity for combating climate change [1,2]. Given that building new homes is very limited in scope, energy retrofit of existing homes is therefore vital to achieving the government's goal of carbon emissions reduction by 80% by 2050 [3]. Currently, actual energy savings achieved from building retrofits often fall short of expectations; this

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phenomenon is widely recognised as the performance gap or rebound effect [4,5]. The size of the performance gap can be larger than 100% and can vary greatly depending on the specific dwellings and occupants [5]. Closing this gap is thus imperative for realising the much-needed savings.

A major reason for the significant differences between predicted and actual energy savings is occupant behaviour [6,7]. While much effort has been devoted to making a house more energy efficient, the complexities of the occupants and their homemaking practices have often been ignored [8]. Standardised behavioural assumptions are commonly used for home energy audits and policy interventions aiding in energy efficiency improvements [9]. Subsequently, the calculations based on these assumptions could undermine the validity of retrofit guidance [10].

Occupant behaviour in buildings has a significant influence on energy use [11-13]. Better incorporation of household behaviours in estimating domestic energy performance can thus improve the reliability of modelling predictions and subsequent home retrofit recommendations. A large body of research on occupant behaviour and building energy performance has focused on building design and operation stages. Behavioural impact on domestic retrofits needs further exploration. A few studies to date suggested that occupant behaviour exerted great influence on the effectiveness of energy efficiency measures [20-22]. In particular, Wei et al [20] showed that occupant heating behaviour had a significant impact on energy savings. Other behavioural parameters such as indoor air temperature and internal heat gains also strongly influenced savings [21]. In addition, Marshall et al [22] revealed that similar savings could be achieved through combinations of less expensive and less invasive energy efficiency measures. However, the question arises as to whether the optimal ranking of individual retrofit options would vary in terms of the energy saving potential when occupant behaviour differs.

The aim of this research is to investigate the impact of occupant behaviour on energy saving potential and optimal selection of retrofit measures in domestic buildings. The hypothesis is that the optimal rankings of individual retrofit measures for achieving energy saving may differ widely from one household to another depending on occupant behaviour. This will be demonstrated through comparing the savings from a range of measures across different behavioural patterns, using a case study dwelling and dynamic building simulation. By examining further the relationship between occupant behaviour and retrofit measures, this work introduces the idea of tailoring domestic retrofit using behaviour. It will aid a transition to a more occupant-centered research agenda with respect to developing domestic retrofit strategy.

2. Methods

The analyses described below employed dynamic simulation modelling to assess the impact of occupant behaviour on the energy saving potential of retrofit measures. The modelling processes were carried out using the validated energy simulation tool, Integrated Environmental Solutions - Virtual Environment (IES-VE). This tool provides sufficient capacity to test scenarios related to different energy efficiency improvements and behavioural patterns. A case study dwelling (Fig. 1) was modelled based on a pre-1919 medium-sized energy-inefficient mid-terraced house located in Cambridge, UK. The house was west facing; its total floor area was 99.41 m^2 and total volume was 299.98 m^3. The input parameters for the dwelling model (Table 1 and 2) were derived from the Energy Performance Certificate (EPC) of the house as well as IES-VE default data or published data (ASHRAE and CIBSE Guide).

To represent the variety of occupant behaviours, this modelling incorporated five behavioural patterns (Table 1). These patterns were created using the data obtained from a survey and literature. The survey took place in Cambridge between January and March in 2015, using both face-to-face and postal methods among 400 households selected based on the availability of EPCs. A resulting 78 usable cases were processed using factor analysis and statistical pattern analysis to generate behavioural patterns [23]. The patterns consisted of household usage of heating, space, and appliances. They were segmented based on the degree of household usage. Rather than trying to be all encompassing, these behavioural patterns aim to reflect the diversity of typical UK household practices.

Coupled with five patterns of household behaviour, the modelled dwelling was applied with a range of energy efficiency improvements. A single measure was modelled for each behavioural pattern at a time. The subsequent energy saving from each measure was then compared across different behavioural patterns. The measures were selected from the existing technologies that were applicable to the modelled dwelling. They included building envelope and system upgrades, as well as smart meters and controls that could induce behavioural change towards