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Space heating preferences in UK social housing: A socio-technical household survey combined with building audits

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ABSTRACT

This paper provides an analysis of the relationships between dwelling, household, and motivation, behaviour and perception characteristics and winter heating setpoint temperatures (n = 111) and heating periods (n = 148 and 145) used in UK social housing. The work capitalises on primary data from a socio-technical household survey, undertaken in Plymouth, UK, during 2015, which was merged with building audit data collected by the social housing association managing the properties. The mean reported heating setpoint temperature was 20.9 °C and the average weekday and weekend day heating periods were 9.5 h and 11.2 h respectively. The results suggest that heating setpoint temperatures and periods vary greatly among UK social houses, but there are clear systematic variations according to dwelling, household, and motivation, behaviour and perception characteristics. The research could enable social housing providers, the government and commercial organisations to target energy efficiency measures (i.e. thermal upgrades) and social interventions (i.e. behaviour change) at those dwellings and households where their impact may be most beneficial. The results presented could also be used to better inform the assumptions of heating preferences in energy models, which could result in more realistic predictions of the space heating demands of social housing and the potential energy savings from refurbishment measures.

1. Introduction

Energy use in domestic buildings accounts for 29% of total UK energy consumption with around two thirds used for space heating [1]. Therefore, reducing heating energy use in housing is imperative if the UK is to achieve its commitment to reduce national carbon emissions by 80% of 1990 levels by 2050 [2]. In order to achieve these reductions, three key avenues exist, the refurbishment or replacement of the existing housing stock [3–5], decarbonisation of the domestic heating supply [6] and social interventions (behaviour change) to encourage more efficient use of energy [7,8].

In line with this commitment, the UK social housing sector in recent years has embarked on a large scale programme of thermal upgrades as well as the installation of more efficient heating systems and controls. A key funding mechanism for this work has been the Energy Company Obligation (ECO) [9], a government scheme which obligates large energy suppliers to deliver energy efficiency measures in domestic buildings, with a particular focus on low income and vulnerable households. However, the current £800 m a year scheme will end in March 2017 and will be replaced with a 20% cheaper scheme [9]. A better understanding of the dwellings (e.g. type, age, number of habitable rooms, etc.) and households (size, composition, health status, etc.) for which energy efficiency measures would be most beneficial could therefore be helpful for targeting and delivering schemes, such as ECO, despite their marked budget reductions.

In addition, recent studies have shown that actual savings from the energy efficient refurbishment of existing houses is often less than predicted [10]. This is referred to as the energy performance gap [11,12]. Among the wide number of contributing factors to the energy performance gap, the 'rebound' or 'take-back' effect [13,14] is evident, in which dwelling occupants choose to heat their homes to higher temperatures or for longer after refurbishment rather than benefit from the potential energy savings. This effect may be particularly strong for the social housing sector as the occupants are likely to have low or fixed household incomes and may therefore currently choose to operate their homes at lower internal temperatures at the expense of their thermal comfort [15]. These lower internal temperatures are unlikely to be reflected in the modelled predictions of the energy savings from the installation of energy

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efficiency measures and as a result energy savings could be overestimated [16–21].

A number of recent studies have stated that there is little guidance regarding the heating setpoint value (i.e. the thermostat setting used by a household to control the heating system) and heating periods (i.e. the number of hours that the heating system is on) which should be used for energy modelling of domestic buildings [16,17]. Furthermore, standardised heating patterns underpinning Simplified Building Energy Models (SBEM), such as the Building Research Establishment Domestic Energy Model (BREDEM) [18] and BS EN ISO 13790 standard [19] have been shown to misrepresent the variability of heating setpoint values and periods found in real homes [20–24].

In addition, another recent UK study [25] identified that attitudinal variables, specifically, people's attitudes towards using less energy to save money and whether they believed reducing their heating use would affect their thermal comfort were related to heating setpoint temperatures and durations used at home. The results showed that attitudes helped explain heating temperatures and durations, even when dwelling and household characteristics were controlled.

This paper aims to provide a better understanding of the effects of dwelling (e.g. type, age, number of habitable rooms, etc.), household (e.g. size, composition, health status, etc.), and motivation, behaviour and perception characteristics (e.g. affordability of energy bills, perceived control over energy use, heating related behaviours, etc.) on the choice of heating setpoint temperatures and heating periods in UK social housing.

The work reported in this paper capitalises on primary data collected during a socio-technical household survey, undertaken in Plymouth, UK, during 2015, which was merged with building audit records held by the social housing association managing the dwellings.

Social housing represents 17.4% of the UK housing stock and is therefore a significant target for energy efficiency measures. However, previous studies exploring space heating preferences have primarily focussed on owner-occupied and privately rented dwellings [20–25]. The social housing sector is an interesting sample of the population as households are likely to have low or fixed household incomes and as a result are keenly aware of the cost of energy [26] as well as at increased risk of experiencing fuel poverty [27]. The heating preferences of social housing residents may therefore vary from those observed in previous studies addressing other tenure types.

The results presented in this paper could be used in energy models which may provide more realistic predictions of the space heating energy demands of new-build and existing social housing undergoing thermal upgrades. In addition, the analysis could enable social housing providers, the government and other commercial organisations to target energy efficiency measures (i.e. thermal upgrades) and social interventions (i.e. behaviour change) at those dwellings and households where their impact may be most beneficial.

2. Literature review

2.1. Factors affecting household space heating preferences

Past literature has identified key factors that influence households' space heating preferences in domestic buildings [15,20,24,25,28–62]. A detailed international review and discussion of these factors and methods is provided by Wei et al. [17]. In their review, the drivers of space heating preferences were categorised as:

(i) Environmental factors (outdoor climate [28–33], indoor relative humidity [34], outdoor relative humidity [33] and wind speed [33])
(ii) Building and system related factors (dwelling type [20,24,30,35–38], dwelling age [30,31,39,40], dwelling size [30], room type [15,31,37,39,40–43], house insulation [24,29,44–46], type of heating system [32,39,47], type of heating control [24,35,40,42,48–51], type of heating fuel [30,31] and previous dwelling type [51])
(iii) Occupant related factors (age [15,40,46,47,51–57], gender [57], culture/race [30,59], education level [30,51], socio-economic classification [60], household size [15,42,46,54], household income [28,39,46,52,54], tenure [60,61], thermal sensation [46,60], perceived indoor air quality and noise [32] and health [46])
(iv) Other factors (time of day [28–30,35,37,42,46,52,62], time of week [42], occupancy [30,37,47,51,54,62], heating price [52,59], awareness of energy use [28,36,50] and attitudes about energy use [25])

The authors of the review found that no less than 27 factors potentially influence a household's space heating preferences, but at present, only 5 of the factors (outdoor climate, indoor relative humidity, occupancy, room type and time of day) are commonly considered when modelling a building's space heating demand and accordingly predicting potential energy savings from refurbishment.

2.2. Modelling household space heating preferences

Energy modelling is used to calculate the space heating energy demands of buildings and is based on a mathematical representation of a building's heat balance. The energy required to heat a building is dependent on the balance between six heat flows: heat from the heating system; heat transmission through the building's façade; external and internal heat gains; heat from ventilation and infiltration; and heat stored in or released from thermal mass. For domestic buildings, heat input from the heating system is related to the household's heating preferences: setpoint temperature (i.e. thermostat setting) and heating period (i.e. the period of time heating is on) as well as heat from ventilation.

In recent years, the representation of occupant behaviour in buildings has received increased research attention due to the significant influence it can have on the performance of buildings [63–66]. In relation to space heating preferences, studies have shown that predictions of a dwelling's energy demand are particularly sensitive to the heating setpoint temperature and the duration of heating used in the modelling [67,68]. However, as noted by Wei et al. [17], at present, there is little guidance regarding the heating setpoint values and periods that should be used.

Depending on which study is consulted, heating setpoint values and periods were typically chosen based on building standards [34], the researchers' personal experience/preference [69–72] or based on measured internal temperatures [73,74]. Although the latter method can help reduce the difference between assumed and actual setpoint values, this method has two main weaknesses, firstly, "*measured internal temperature is not the same as the setpoint due to effects such as overheating, intermittency, inertia, imperfect control*" [19], and secondly, longitudinal monitoring of internal temperature is often required to obtain reliable estimations of the setpoint temperature [17].

To further add to this issue, commonly used standardised heating patterns primarily underpinning Simplified Building Energy Models (SBEM), such as the Building Research Establishment Domestic Energy Model (BREDEM) [18], which is consistent with the BS EN ISO 13790 standard [19] have been shown to misrepre-