The influence of retrofitting and occupant behavior on the energy consumption and internal environment of Irish residential buildings

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Introduction

Improvement of the building sector’s energy efficiency is among the main priorities for environmentalists and policy-makers. Irish and European legislation, for example, requires all new buildings – and existing buildings that receive significant renovations – to be nearly zero energy buildings (nZEB) by end of 2020. A nZEB is a building that has a very high energy performance. The nearly zero or low amount of energy required shall come from a significant extent by energy from renewable resources, including those produced on site or nearby. As new builds represent less than 1% of the total building stock each year, retrofitting is recognised as the most immediate and cost-effective mechanism to reduce energy consumption and carbon emissions in the building sector. However, not enough is known about the effects of retrofitting on energy consumption and the internal environment in typical Irish residential buildings and few studies have taken into account the role of human behaviour in shaping these effects.

Methodology

This research combines extensive energy and internal environment monitoring data with surveys and observations of occupant behaviour. A social housing estate in a suburb of Dublin was identified as an ideal test case; 22 households agreed to participate and the project began in February 2015. The components of the research were as follows:

- Initial on-site survey of the technical characteristics of the houses, including thermographic imaging
- Use of data-logging instrumentation in (and regular site visits to) each house to record energy consumption, relative humidity, gas usage and electricity usage
- Face-to-face qualitative interviews and a questionnaire survey to capture the behaviour and attitudes (such as thermal comfort) of the house occupants

The houses were retrofitted by October 2015 and the three research components were repeated in February 2016. Images of the case study houses are shown in Figure 1(a)-(b). Figure 2 outlines the phases of the research including the data collection method.

Pre-Retrofit

The housing estate was constructed in two phases: 1994 and 2000. The houses constructed in 1994 are end- and mid-terraced houses constructed with concrete hollow blocks with interior floor batters and plasterboard. The 2000 houses are end-terraced, mid-terraced and semi-detached houses constructed with partially filled cavity walls. Both house types relied on gas for their main space and water heating requirements. Occupants complained of mould, dampness, draughts and poor heat retention.

The impact of occupant behaviour in the houses is highlighted by the varying gas usage and standard deviations of the different houses types pre-retrofit (Figure 3(a)-(b)). Theoretically a mid-terraced house should require less energy to operate compared to an end-terraced house. However the results show the opposite for the 2000 houses. There is also a large difference between the end-terraced and semi-detached houses constructed in 2000 despite having almost identical technical characteristics. The average daily pre-retrofit gas usage is taken from the 12th Feb 2015 to the 21st July 2015.

The gas usage of the houses effects their respective internal environments. The average daily temperature profiles and gas usage from the 12th Feb 2015 to the 13th Mar 2015 of the lowest and highest gas users of the houses constructed in 2000 are given in Figure 4(a)-(b).

Post-Retrofit

Upgrade retrofit works were completed by October 2015. Attic insulation was installed along with new windows, front and patio doors, hot water tank, thermostat and gas boiler to a very significant extent by energy from renewable resources, including those produced on site or nearby. As new builds represent less than 1% of the total building stock each year, retrofitting is recognised as the most immediate and cost-effective mechanism to reduce energy consumption and carbon emissions in the building sector. However, not enough is known about the effects of retrofitting on energy consumption and the internal environment in typical Irish residential buildings and few studies have taken into account the role of human behaviour in shaping these effects.

Conclusions

There is a lack of published research into monitoring the effectiveness of case study buildings, in order to reduce the energy consumption and greenhouse gas emissions using data logging instrumentation. Moreover, it remains unclear whether the effectiveness of a retrofit strategy is more suitable for different habitats based on their demographic and socio-economic profiles and whether the habitants of these buildings will alter their energy consumption using tailored and effective engagement actions to motivate changes in their energy consumption behaviour. This research is adopting an innovative methodological design that combines engineering and social sciences expertise to address these. Subsequent phases of the project will extend this method to 13 one-off rural houses in Mayo, enabling a comparison of urban and rural. In addition, tailored engagement actions to motivate changes in energy behaviour within households and communities that would result in reduced energy consumption will also be developed. Furthermore, the proposed project will generate policy recommendations regarding more targeted retrofitting efforts and measures to boost public confidence in the effectiveness of retrofitting schemes. Combining the data collected on energy consumption, temperature profiles of individual rooms, thermal comfort surveys and findings from occupant surveys will allow the most effective measures to be identified that consider the profiles of both the physical building and its occupants.

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Figure 1(a) End- and mid-terraced houses constructed in 1994 and Figure 1(b) end- and mid-terraced houses constructed in 2000

Figure 2 The three phases of the research including data collection method

Figure 3(a) Average daily pre-retrofit gas usage for each of the house types of 1994 (left) and Figure 3(b) average daily pre-retrofit gas usage for each of the house types of 2000 (right)

Figure 4(a) Average daily pre-retrofit temperature of the house with lowest gas usage constructed in 2000 (left) and Figure 4(b) average daily pre-retrofit temperature of the house with highest gas usage constructed in 2000 (right)

Figure 5(a) Average daily pre- and post-retrofit gas usage for each of the house types of 1994 (left) and Figure 5(b) average daily pre- and post-retrofit gas usage for each of the house types of 2000 (right)

Figure 6(a) Average daily post-retrofit temperature of the house with lowest gas usage constructed in 2000 (left) and Figure 6(b) average daily post-retrofit temperature of the house with highest gas usage constructed in 2000 (right)