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The actual performance of aspiring low energy social houses in the United Kingdom

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Abstract

This paper compares the actual energy performance of six flats and two houses built to low energy standards (Code for Sustainable Homes Levels 4 and 5) with a near identical flat and house built to minimum compliance only (Building Regulations). As low energy homes are only recently emerging in the United Kingdom housing stock, and even fewer are subject to Post Occupancy Evaluation, little is known about their actual energy use in operation. The results show that low energy dwellings may consume more energy than expected and the behaviour of the occupants residing in low energy homes plays an important role in determining their actual energy consumption.

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Keywords: Low energy social houses; Measurement; Energy use; Post Occupancy Evaluation; Building performance

1. Introduction

In the UK around 25% of carbon dioxide (CO_2) emissions come from dwellings [1]. Reducing CO_2 emissions from housing is imperative if the UK is to achieve its commitment to reduce national CO_2 emissions by 80% of 1990 levels by 2050 to help tackle the threat of global climate change. In UK domestic buildings, these emissions primarily arise from the energy required for space and water heating [1]. In recent years, there has been significant tightening of Part L1A of the Building Regulations in order to improve the energy performance of new build homes. In addition, a number of voluntary standards for the sustainable design and construction of new homes have also been prevalent. One such standard was the Code for Sustainable Homes (CfSH). The most recent version of the CfSH was published in 2010, however, in July 2015 the CfSH was scrapped by the UK Government but it is now expected to be

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incorporated into the mandatory Building Regulations. The potential to reduce CO_2 emissions from housing has been identified in many previous studies [2,3]. The expected energy performance of new build homes in the UK is currently assessed by energy modelling at both the design and completion stages. After completion, Post Occupancy Evaluation (POE) can be carried out to measure the actual energy performance. There is however growing evidence that the actual energy performance of new build homes is often higher than predicted at the design and completion stages. This is referred to as the energy performance gap [4].

This paper compares the actual operational energy performance of six flats and two houses built to low energy standards (CfSH Levels 4 and 5) with a near identical flat and near identical house built to minimum compliance only (Building Regulations). As low energy homes are only recently emerging in the UK housing stock, and even fewer are subject to POE, little is known about their actual energy use in operation. The main aim of this work was to investigate whether dwellings constructed to higher energy performance standards actually use less energy.

2. Methodology

This study presents an analysis of the energy consumption (electricity and gas) of seven near identical flats and three near identical houses, in terms of layout and building services, during their first year of occupation (November 2013 – October 2014). The main variations between the dwellings were the standard to which they were constructed and their orientation. The flats and houses were located on a new-build social housing estate in Torquay, a town in the South West of the UK.

Six of the flats studied were constructed to Code for Sustainable Homes (CfSH) Level 4 and the other to Building Regulations (BR) only. Two of the houses were constructed to CfSH Level 5 and the other again to the BR only. On paper, the CfSH flats and houses investigated exceed regulatory compliance and could therefore be regarded as 'low energy' homes. CfSH Level 4 relates to a 25% and Level 5 a 100% improvement in thermal efficiency over that mandated by Part L1 of the 2010 Building Regulations. The BR flat and house provided a minimum benchmark (i.e. control dwellings) against which the energy use of the CfSH dwellings could be compared. The CfSH flats and houses were characterised by low U values, high air tightness, high levels of insulation and triple glazing. Table 1 provides a summary of the specifications of the flats and houses investigated in this work.

To collect the energy use data from the dwellings, an automated monitoring system was installed in the flats and houses. The data were collected as part of a larger POE to assess the actual operational performance of the dwellings. The monitoring system captured gas and electricity use, internal and external temperature, occupancy and the opening and closing of windows and doors. The electricity and gas consumption of the dwellings were collected using pulse output sensors, which were connected to the dwellings' mains gas and electricity meters. The pulse output sensor counts the number of pulses from the meter, which relate to a certain amount of energy passing through the meter. For domestic meters each pulse corresponds to 1 Wh (1000 pulses per kWh). The energy consumption data were transmitted by radio frequency (RF) to a data hub every 5 minutes, which are located in the loft spaces of the dwellings. The data hub exports the data to a remote server every hour using General Packet Radio Service (GPRS). The data can then be accessed by the researchers via any Internet enabled device.

Table 1. Specifications of the flats and houses

Dwelling	Flats 1-6 (CfSH4)	Flat 7 (BR)	Houses 1-2 (CfSH5)	House 3 (BR)
External walls (W/m^{2}K)	0.10	0.24	0.10	0.26
Floors (W/m^{2}K)	0.13	0.18	0.13	0.19
Windows (W/m^{2}K)	1.20	1.80	0.70	1.80
External doors (W/m^{2}K)	0.55	0.55	0.55	0.55
Roof (W/m^{2}K)	0.10	0.14	0.10	0.14
Main heating	Combination boiler 91% efficiency and gas saver	Combination boiler 91% efficiency	System boiler 90% efficiency	System boiler 90% efficiency
Heating control	Time and temp zone control	Time and temp zone control	Time and temp zone control	Time and temp zone control
Ventilation	MVHR	Central extract	MVHR	Central extract
Generation	0.55kWp PV	-	3kWp PV	-
Airtightness (m^3/hr.mr)	2	5	2	5

3. Results

3.1. Electricity consumption

The monthly electricity consumptions for the monitored flats and houses are shown in Fig. 2. The annual electricity consumptions of the CfSH flats ranged from 1243 kWh to 3582 kWh. The average annual electricity consumption of a CfSH flat was 2332 kWh. The comparison BR flat used 3537 kWh of electricity in the first year of occupation. The BR flat used more electricity than five out of the six CfSH flats. The percentage difference in electricity consumption between the BR and CfSH flats ranged from –1% to +185%.

The monthly electricity consumption results showed that in general the BR flat consumed more electricity than the CfSH flats every month. The main anomaly to this pattern was CfSH Flat 6, which had consistently higher monthly electricity consumptions than the other CfSH flats, as well as a significant increase in use in the months from July to October. This higher monthly trend of electricity use was subsequently reflected in the higher annual consumption in this flat. The monthly electricity consumptions of the flats showed little evidence of any seasonal variation in use. It could be expected that during the spring and summer months, electricity use would decrease due to reduced need for artificial lighting because of increased daylight hours, occupants spending more time outside, going on holiday and consuming lighter summertime meals. Only CfSH Flats 2 and 4 showed some seasonal variation in electricity use. Also noteworthy, is the trend of electricity use in CfSH Flat 5, where from November 2013 to April 2014 the electricity consumption was relatively stable or even decreasing. However from May 2014 to October 2014 the electricity use greatly increased and stabilised at this higher level of demand. The monthly electricity consumptions in CfSH Flats 1 and 3 were steady throughout the first annual monitoring period.

The CfSH houses consumed 3326 kWh and 4921 kWh respectively during the first year of monitoring. The average annual electricity consumption of a CfSH house was 4124 kWh. The annual electricity consumption of the comparable BR house was considerably less at 1645 kWh. The BR house used 51% and 67% less electricity than the CfSH houses over the same annual period.

The BR house had significantly lower monthly electricity consumptions than both of the CfSH houses. The monthly electricity consumptions in the BR house were generally consistent throughout the year, with a slight reduction in usage evident in the summer months (June-August). The monthly electricity use in CfSH House 1 was much more erratic, increasing and decreasing in consecutive months. In the months of May and June the electricity consumption in the dwelling was significantly lower. CfSH House 2 had a greater electricity use than the other two dwellings in every month of the annual monitoring period. The monthly consumptions showed a seasonal trend, with electricity use lower in the summer and higher in winter, and decreasing and increasing during the shoulder seasons (Spring and Autumn).

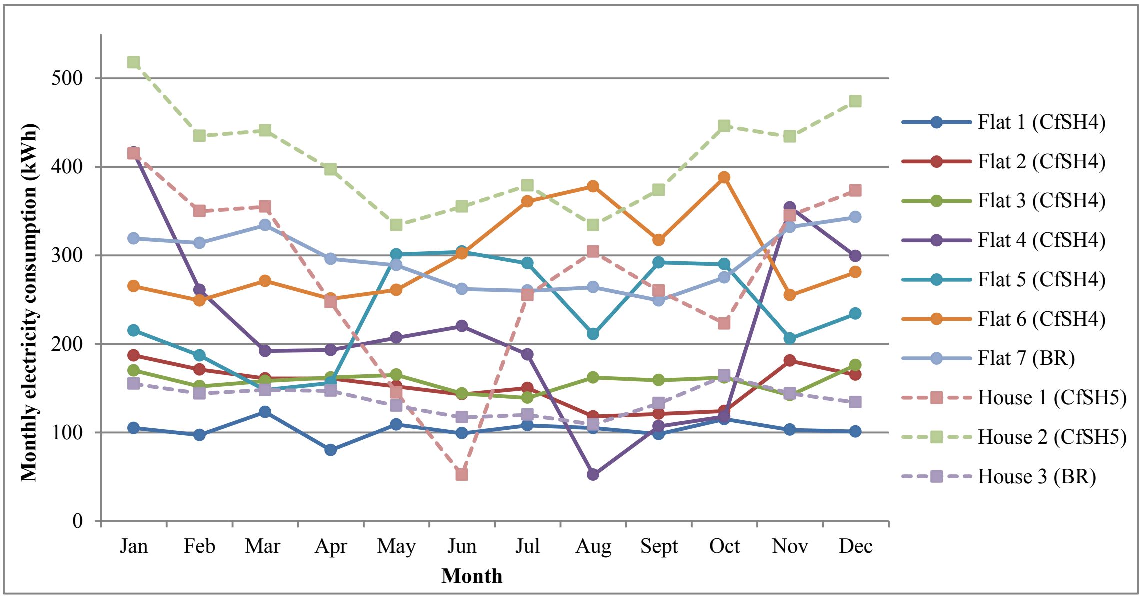

Fig. 1. Monthly electricity consumptions for flats and houses

3.2. Gas consumption

The monthly gas consumptions for the monitored flats and houses are shown in Fig. 3. The annual gas consumptions of the CfSH flats ranged from 1640 kWh to 3302 kWh. The average annual gas consumption of a CfSH flat was 2170 kWh. The BR flat used 5283 kWh of gas in the first year of monitoring. The BR flat used significantly more gas than all of the CfSH flats monitored. This result may be due to the improved construction standards of the CfSH Level 4 buildings. The BR flat used between 60% and 222% more gas than the CfSH flats over the same annual period. The results showed that the BR flat consumed more gas than the CfSH flats every month, which was subsequently reflected in the higher annual gas consumption.

The monthly gas consumptions of the flats showed a general seasonal variation in gas use, higher in the winter and lower in the summer. This consumption pattern is expected due to the colder winter time outdoor temperatures and thus higher space heating energy demand. CfSH Flat 1 was the main exception to this seasonal pattern of gas consumption and instead had a more even monthly gas use profile.

The CfSH houses 1 and 2 consumed 7672 kWh and 14995 kWh of gas respectively during the first year of occupation. The average annual gas consumption of a CfSH house was 11334 kWh. The annual gas consumption of the BR House 3 was 7960 kWh, which was similar to CfSH House 1, but almost half of that used by CfSH House 2. This result is perhaps unexpected, as the CfSH houses, with their higher energy performance standards, should have reduced gas consumption for space heating, compared to the BR house.

The monthly gas consumptions for the houses demonstrated a seasonal variation in gas consumption. This is expected due to space heating demand being higher during the winter months and lower in the summer months. The CfSH House 2 was found to have used more gas in every month than the other two houses monitored. By comparing the monthly gas consumptions of CfSH House 1 with BR House 3 it can be seen that the BR house did in fact tend to use more gas during the winter months (December-February) than the CfSH dwelling, which may result from the higher energy performance standards of the CfSH house. In fact, the CfSH house used more gas during the summer which perhaps indicates a higher hot water rather than space heating demand.

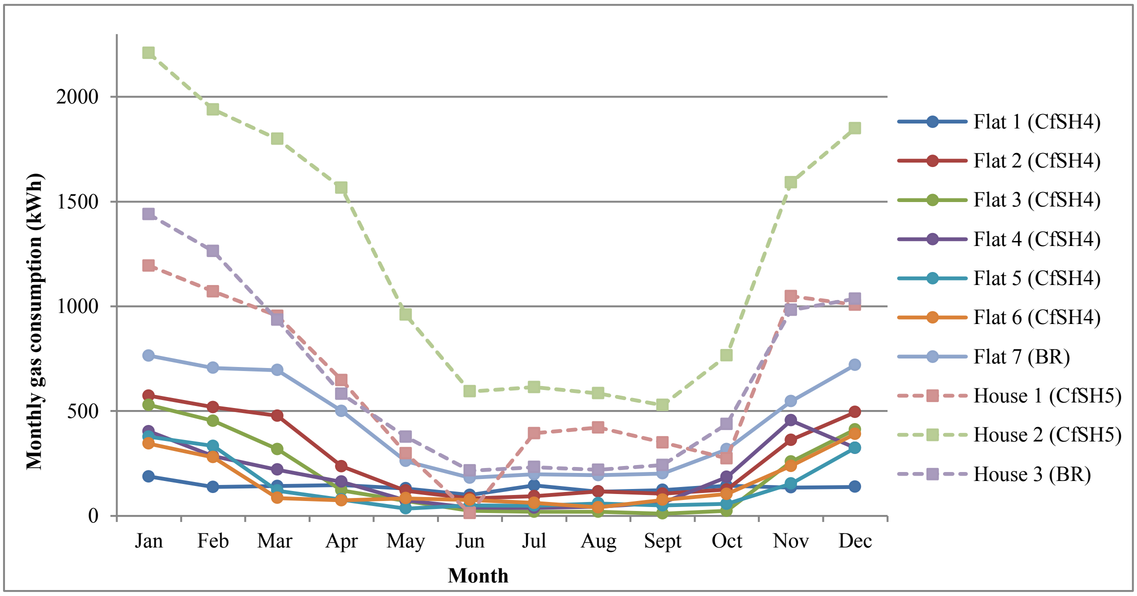

Fig. 2. Monthly gas consumptions for flats and houses

4. Discussion

The findings presented in this paper were obtained from a small sample of low energy (CfSH) and minimum compliance (BR) dwellings. Some unexpected results regarding their energy consumption during the first year of occupation were identified. Of particular note, the CfSH houses had similar or higher gas consumptions than their comparison BR house. This result was surprising as the CfSH houses are on paper 100% more thermally efficient than the equivalent BR house. The CfSH flats did however conform to expectations and used less gas than the comparable BR flat. A large range of annual electricity consumptions were observed between the CfSH flats, however, in general, these consumptions were less than the comparison BR flat. The BR house had a lower annual electricity demand than both of the CfSH houses.

The anomalous results obtained in this study are likely to be related to the unique characteristics of the occupants residing in the dwellings and their operation of the building and its systems, rather than the actual results that might be expected if averaged over a larger population of dwellings. The energy use of individual dwellings will be affected by a range of factors [5,6], which should be considered alongside the monthly and annual energy consumption data. Further work is currently being undertaken to normalise the energy consumption data presented in this paper, in relation to the occupancy period, duration of window and door opening, and duration, temperature and space of the dwelling heated using the data collected from the additional sensors installed in the flats and houses.

5. Conclusions

The results of this study show that dwellings built to low energy performance standards may consume more energy than expected. As near identical dwellings were investigated in this study, the findings suggest that the behaviour of the occupants residing in low energy homes plays an important role in determining their actual energy consumption.

Acknowledgements

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Biography

Dr Rory Jones is a Research Fellow in the Building Performance Analysis Group of Architecture and Built Environment at Plymouth University, UK.