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INVESTIGATING THE INFLUENCE OF PHYSICAL AND OCCUPANT FACTORS ON ENERGY AND ENVIRONMENTAL PERFORMANCE OF FOUR IDENTICAL MODERN FLATS IN UK

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1. INTRODUCTION

This paper uses a real-world socio-technical building performance evaluation (BPE) approach to investigate the influence of physical factors (form, orientation) and occupant factors (number of occupants, occupancy pattern, heating schedule) on gas and electricity use (during the heating period) of four new-built modern flats located in the same housing development in Southeast England. The study is designed to provide new evidence to understand the causes of the variation in actual energy use of dwellings built to the same construction standards (building fabric thermal performance) and occupied by residents with similar economic status (high income). The four flats were designed and built to higher thermal standards: measured air permeability was $4m^3/hm^2$ against the permitted value of $10m^3/hm^2$.

2. METHODS AND CASE STUDY FLATS

In-situ monitoring of indoor environment and energy performance of four flats was carried out using established techniques of BPE [1,2]. Energy use (gas and electricity) was monitored every 5 minutes using remote metering, while indoor environmental conditions (air temperature, relative humidity, CO_2 levels) were monitored using data loggers. Data on occupant behaviour [3] (heating set-point temperatures, heating schedule and windows opening) were gathered using questionnaire surveys, activity log sheets (diaries) and semi-structured interviews along with physical monitoring of radiator temperature (heating patterns) and opening-closing of windows using state loggers. Monitoring and survey data were gathered during the heating season, from October 2017 to February 2018 (5 months). The four flats are located in the same block, but differ in terms of orientation, location (floor), size and occupancy (Table 1), comprising two bedrooms and three bedrooms, with northern and southern orientations, located on the top, middle and ground floors. Occupancy varies in terms of number and age of occupants, time spent at home and activities carried out (Table 1).

Flat	Total floor area (TFA)	Location	Orientation	No. of occupants	Age range	Occupancy type	Heating set point
N31	67	Top floor (4th)	NW - SE	1	46-55	Working from home	20 °C
N15	72	Mid floor (2nd)	NW	2.5	25-35	1 working from home 1-3 days per week, 3 people on weekends	22 °C
N33	86	Top floor (4th)	NW-NE-SE	1	over 65	Mostly at home	19/21 °C
N06	95	Ground floor	SE	1	56-65	Variable pattern during weekdays, guests on weekends	18/21 °C

Table 1: Physical and occupancy characteristics of the monitored flats

3. ENERGY USE: IMPACT OF PHYSICAL AND OCCUPANT FACTORS

Despite being constructed to same thermal performance standards, gas and electricity use in the four flats was found to vary significantly (Table 2). The total energy use (gas for space heating and hot water; and electricity use for appliances and lighting) of the four monitored months varied by more than 50% - from 3076kWh in flat N33 to 4830kWh in flat N15. Electricity use in N31 was nearly double that of N06, despite being smaller in size and inhabited by the same number of occupants (n:1). These results indicate that energy use may not be determined by dwelling size or number of occupants.

Flat	TFA	Total Energy used (kWh)	Gas use (kWh)	Electricity use (kWh)	External surface to TFA
N31	67	4237	2499	1738	1.40
N15	72	3076	2013	1063	0.39
N33	86	4830	3781	1050	1.48
N06	95	3530	2627	903	1.43

Table 2: Monitored energy use over the period October 2017 – February 2018

Interestingly strong association was found between gas use and ratio of external surface to total floor area – flat N33 had the highest gas use and external surface to TFA, while flat N15 had the lowest. This is probably because higher the external surface area, the higher is the heat loss, resulting in more space heating which forms the majority of gas consumption in the monitored months (heating season). For this reason, the flats located on top (N31, N33) and ground floors (N06) used much more gas than the mid-floor flat (N15) which had the least number of exposed sides. This happened even though N15 had the highest heating thermostat temperature set (22°C) and the largest amount of hot water use amongst all the flats. In terms of gas use, physical factors such as location and form appeared to be more significant than occupant related factors. Conversely, no correspondence between physical factors (size of the flat) and electricity use were found. Electricity use in N31 was found to be almost two times more than in N06 (Table 2) despite being smaller in size and having one occupant each. However in flat N31, as evident from the occupant and appliance survey, the occupant used a large number of electrical appliances constantly for entertainment (wide screen TVs and powerful sound systems) and ICT (desktop pc, laptops, tablet and smart phone).

4. DISCUSSION AND CONCLUSIONS

The present study has systematically shown how physical and occupant related factors influence actual energy use of modern flats designed to high thermal performance standards. Physical factors such as location (floor) and ratio of the external surface to the total floor area were found to have a significant influence on gas use (for space heating), much more than dwelling size or heating thermostat temperature. On the other hand occupant factors related to occupancy pattern, number and use of electrical appliances have a bigger influence on electricity consumption, which forms an important share of total energy use in low energy buildings.

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