Household survey: Energy use and interaction of occupants with building systems

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Executive Summary

The University of Southampton conducted a long-term study on home energy consumption and indoor environmental conditions with a bespoke monitoring kit developed for the project. The monitoring kit was installed in around 150 houses and flats in Southampton. Initial analysis shows considerable scatter in the differences in airtightness for different building types and Energy Performance Certificate (EPC) ratings. At the same time, 250 households (~300 participants) participated in a quarterly survey on travel, energy use, wellbeing and environmental attitudes. An intervention took place halfway through the survey period to assess and communicate the individual carbon footprint of participants and observe changes to their energy use behaviour. In the period following the intervention small changes were noticed in electricity and gas use and a shift from car use to public transport.

Success Metrics

- A bespoke monitoring kit was developed for this study filling a gap in the market for carbon dioxide monitoring, in conjunction with energy use, temperature and humidity.
- Installed in 150 homes, the kits have generated a wealth of data on energy use and indoor environment.
- A shift away from car use, an increase in walking and a reduction in leisure flights were all reported by participants who took had a carbon calculator interview relative to control group (significant at 10% level).

About

A quarterly questionnaire was used to collect data on the participants' travel, the "energy intensity" of their lifestyles, wellbeing and environmental attitudes. The "Carbon Footprint Calculator" tool was used as an intervention halfway through the study. The intervention had the form of an interview where the participants' footprint profile was created showing how different choices in everyday life affect their carbon emissions.

The energy use and environmental conditions study was based on the data collected from the monitoring kits (Fig. 1). The environmental conditions were usually monitored at the living room. The carbon dioxide levels increase as a result of people breathing. When they leave the room, in particular in the evening, carbon dioxide levels will start dropping until they reach the environmental ambient levels. The rate of this 'decrease' in combination with the air temperature and relative humidity profiles is expected to be representative of different building and window types but also occupants' energy use behaviour. At the same time the electricity usage profiles can be developed for different occupancy groups and demographic factors, such as the income level and the average size of families.

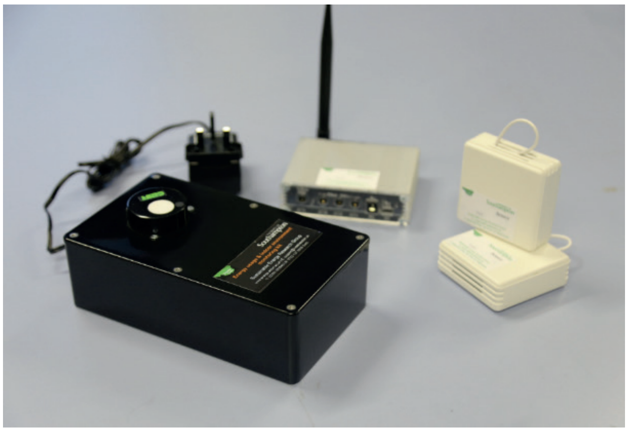

Figure 1. A monitoring kit was developed to collect temperature, energy consumption and carbon dioxide data from residential buildings in Southampton, UK.

Challenges

From 6,000 households randomly selected stratified by building type, 220 households qualified for the final sample, representative of a particular geographic classification within Southampton, and which participated in face-to-face and online surveys. The majority of the houses participated in the monitoring of energy and indoor environmental parameters (Fig. 2). Over 190 households completed the full two-year survey period, and around 150 participated in the energy monitoring.

The development of the bespoke monitoring kit was challenging, particularly dealing with power, memory and communication failures while keeping costs down. Selection and configuration of the software and hardware in combination with secure data storage and management required significant effort and time, not envisaged initially, but necessary to provide the data required by the study.

Data cleaning and analysis of the multi-gigabyte dataset is ongoing as the results need to be carefully interpreted within the building & occupancy context.

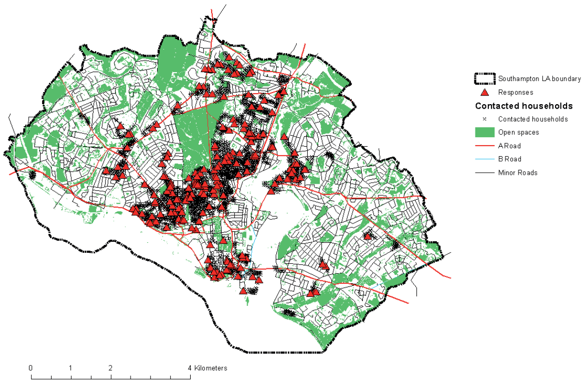

Figure 2. Distribution of the study participants in Southampton City, UK.

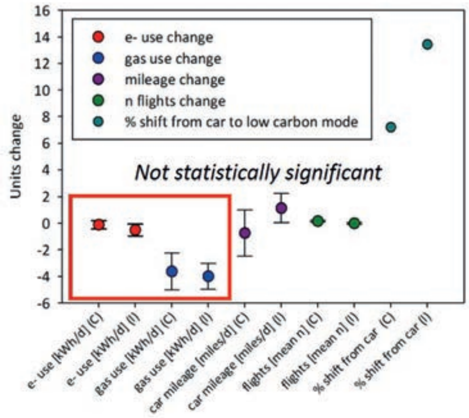

Figure 3. Impact of the intervention on energy use and travel habits. (C) control group, (I) intervention group.

Goals

The longitudinal study and the carbon calculator interviews reveal the impact of 'soft' interventions based around communicating carbon footprints and investigate how simple, low cost interventions can impact human behaviour.

The indoor environmental conditions will be used to assess measures of building energy performance, create occupancy and energy consumption profiles and identify occupants' interaction with building controls e.g. windows and thermostat.

Ventilation rates are a key missing element in the prediction of domestic energy performance. Unlike here, off the shelf energy monitoring systems do not monitor CO_2 levels. The CO_2 decay profiles for typical building types are attributed to a combination of user behaviour and the theoretical technical performance of the buildings.

How has this research helped?

Our research investigates how domestic buildings and their occupants use energy and how they interact with building systems in order to adjust their comfort. The results can inform decisions on "soft" interventions to achieve energy savings and reduce carbon emissions through changes in everyday lifestyle choices. The monitored data give an indication of the ventilation rates for different building types and EPC ratings. The interpretation of the data within the context of specific building properties and occupancy can inform design and policy regarding domestic building retrofits and managing demands on the electrical distribution network.

Results

In the period following the intervention small reductions were noticed with respect to the control group in electricity and gas use and also a shift from car use to public transportation. The reductions in electricity and gas use were not statistically significant but do at least show a pattern consistent with overall positive impact of intervention (Fig.3).

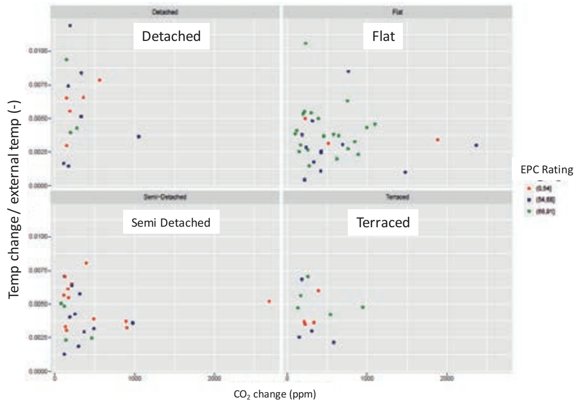

Figure 4. CO_2 decrease in relation with normalised temperature change (indoor temp / external temp) for different building types.

A first analysis of the observations shows that flats have smaller temperature changes than the other building types (Fig. 4). Due to their age and small heat loss areas most of them score high in EPC rating. However, the scatter of the CO_2 could be an indication of frequent window opening.

Interestingly, the temperature change appears to be lower for low rated houses while the CO_2 change is more spread and higher than the high EPC rated buildings. In general, this pattern shows that low rated EPC houses may not be heated to high temperatures while at the same time the houses are leaky (Fig. 5).

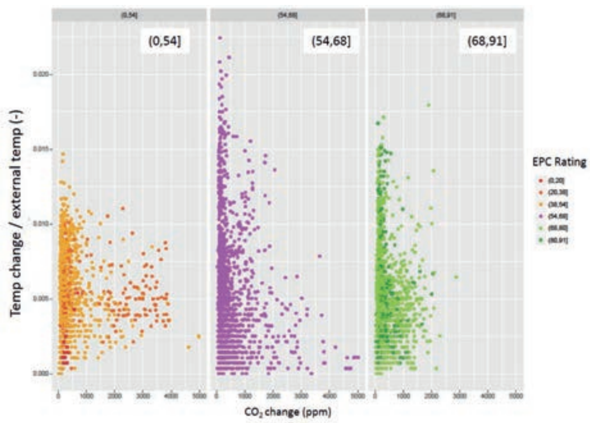

Figure 5. Distribution of house-nights with different EPC rating in relation to airtightness observations.