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The challenges of monitoring energy consumption to assess behavioural changes in occupants during renovation projects from a low budget point of view

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Abstract

This study presents the challenges of monitoring energy consumption to assess behavioral changes in occupants during renovation projects and how to develop a strategy to overcome those challenges. Three buildings containing seventeen flats in total were monitored during a period of over two years, monitoring energy consumption and internal temperature of the flats. The energy consumption for the flats was capture by the use of a Current Cost smart meter placed at the ground floor of each block of flats in a cover under stairs. Wireless sensors were clamped to each flat. The smart meters were not connected to the internet or a computer, but instead the data was stored in the internal memory of the equipment and manually downloaded to a computer at each data collection visit. For the purpose of double checking, meter readings were collected at the electricity meter to be able to compared the accuracy and success of the data collected by the Current Cost smart meters. The internal temperature of every flat was collected by mean of a LogTag temperature data. From comparing the Current Cost smart meter data versus the utility meter readings a huge range of overestimation and underestimation of the actual energy consumption was observed. Regarding the internal temperature monitoring, long periods of lost data was identified. The main factors contributing to these data lost were: Long periods between data collection, wireless signal drop offs, unplugging, tampering and removal of equipment. A normalized energy index, based on utility meter readings, internal temperature and outdoor conditions, was developed to overcome the loss of data and assess the effectiveness of the technology and the behavioral change in the occupants. The normalised energy index provides a methodology to evaluate technology and behavioural changes effect between flats and across seasons.

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Keywords: Monitoring; Renovation; Energy

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1. Introduction

The United Kingdom has agreed to a CO_2 emission reduction of 80% from 1990 levels by 2050 [1], while its housing stock is one of the eldest in Europe with 55% of dwellings dating from before 1960 [2]. To achieve this target, energy efficiency, low carbon technologies and behavioural changes projects are being deployed across the country and furthermore, all over Europe. Projects involved in reducing green house gases must be monitored to assess the impact, if any, of the implementations [3].

This study presents the challenges of monitoring energy consumption to assess behavioral changes in occupants during renovation projects and how to develop a strategy to overcome those challenges.

Air source heat pump has been found to reduce energy bills for domestic heating in the UK [4]. Air source heat pumps were used to retrofit two buildings, while a third building was continuing using electric storage heaters. Each building was fitting with a communal heat pump, serving space heating to eight flats in each building. Domestic hot water (DHW) was supply by electric immersion heaters on each flat.

The three buildings containing seventeen flats in total were monitoring during a period of over two years, monitoring energy consumption and internal temperature of the flats to provide quantitative data for the evaluation of behavioural changes on the tenants.

The aim of the project was to understand the effect of renovating the heating system, from electrical storage heaters to an air source heat pump with wet radiators, and behavioural changes in the occupants using the new technology.

The author's involvement in the project, relates to the data analysis, interpretation and liaison with the behavioural changes assessment, while the data collection described in this paper was carried out by a third party company.

2. Research Methods

Energy consumption and internal temperature was decided to be the quantitative data required to be able to quantify energy reduction for each flat but as well to assess the behavioral changes of the tenants following a series of intervention, which lay outside the scope of this paper.

The buildings and flats were far from being categorised as ideal candidates for a project of these characteristics. Insulation and airtightness levels were not optimal for the installation of air source heat pump to supply space heating to these flats.

While different energy monitoring solutions are available in the market with capabilities to capture a range of data at very small intervals, the monitoring strategy for this project was to have a low budget approach to expenditure but expecting to provide monitoring data at small intervals.

The approach taken to monitor energy consumption and internal temperature will be presented in the next two sections. Although some commonalities are share between the two monitoring approaches, the individual issues will be clearer presented having its own section

2.1. Energy Consumption

The energy consumption for the flats was captured by the use of a Current Cost EnviR smart meter [5] placed at the ground floor of each block of flats inside a cover under the stairs. Figure 1 shows the Current Cost EnviR smart meter, which according to a review on smart metering technology [6], belongs to group 1 providing real time energy consumption and a rough estimate of costing. Group 1 is the first step access level into smart metering, having a lower cost than groups 2 and 3 and very desirable in low budget projects. Wireless sensors were clamped to each flat's electricity meters. The Current Cost smart meters were not connected to the Internet or a computer, but instead the data was stored in the internal memory of the equipment and manually downloaded to a computer at each data collection visit to the buildings. Energy consumption was recorded at 24 hours intervals.

For the initial purpose of double checking, utility meter readings were collected for each electricity meter to be able to compared the accuracy and success of the data collected by the Current Cost EnviR smart meters, as utility meters provide the most accurate measure of actual energy consumption [7].

Fig. 1. Current Cost EnviR smart meter.

2.2. Internal Temperature

The internal temperature of every flat was collected by mean of a LogTag TRIX-8 temperature data logger [8] placed in each flat away from a direct heat source with the purpose of capturing the average temperature of the flat. Figure 2 shows the LogTag temperature data logger. The data loggers were set to record temperature data at 20 minutes intervals. The data must be manually downloaded to a computer via LogTag interface software and the data logger TRIX-8 unit reset to restart the monitoring process.

Fig. 2. LogTag TRIX-8 temperature data logger.

3. Results

3.1. Energy Consumption

The data containing the energy consumption recorded by the Current Cost smart meters and the utility meter readings for the 17 flats were analysed at an interim period during the project at the end of 2013. Table 1 shows the comparison of the smart meter data versus the utility meter readings recorded between March 2012 and October 2013, in six different periods according to the frequency of data collection. As it can be seen the discrepancy found in the Current Cost EnviR smart meter data was very disappointing with a huge range of overestimation and underestimation of the actual energy consumption as recorded by the utility meter reading. As such, it was found that no adjustment of the data was possible to be applied to rectify the lost of data. From that point on, only utility meter readings were collected from each flat for the data analysis and a normalised energy index methodology was developed to cope with the switch of data collection method while keeping the same aim to assess energy reduction and behavioural changes.

Table 1. Percentage discrepancy between smart meter data versus meter reading between March 2012 to October 2013.

		Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Flat	1	-58.5	-55.7	-50.4	-32.8	-56.5	-47.3
Flat	2	-22.1	-44.7	-47.6	-1.2	-38.1	-16.9
Flat	3	-13.5	-14.6	85.7	36.7	-17.5	13.9
Flat	4	-16.2	19.1	-68.8	34.4	-24.9	-1.3
Flat	5	-22.7	-22.3	-15.8	13.8	-36.1	-11.8
Flat	6	-14.5	-98.9	-125.8	82.5	-40.4	7.0
Flat	7	-13.4	-7.6	-52.2	8.6	-17.8	14.8
Flat	8	-1.0	-19.2	-20.6	23.0	-15.4	14.5
Flat	9	-4.3	21.2	-56.9	15.3	-20.9	-4.9
Flat	10	-11.6	-5.4	-58.4	11.1	-5.7	-18.4
Flat	11	-4.5	36.5	-34.6	18.2	-20.5	13.5
Flat	12	-8.2	-4.2	-67.0	8.2	-16.8	11.2
Flat	13	-31.3	60.2	-126.1	-68.4	-18.8	9.8
Flat	14						
Flat	15	-49.6	-628.6	44.8	-68.0	-15.6	29.1
Flat	16	-97.8	-80.9	-103.5	-61.3	-72.9	-69.1
Flat	17						

The main factors, which could have played a role in the discrepancy of the data collected by the Current Cost smart meters, were:

- Long periods between data collection leaving equipment unsupervised. This was accounting for an over reliance on the Current Cost smart meter internal memory.
- Drop offs of signal between the wireless connections from clamps at the electric meters to the Current Cost smart meter place in the ground floor under the stairs.
- Unplugging of equipment by third party contractor carrying out electrical work, such as installing and/or replacing meters.

High energy consumption by some of the tenants was observed during the analysis of the data. This increase in energy could be traced back to the use of electric heaters, as observed during data collection visits. The use of electric heaters corroborate the insulation and airtightness needs of the buildings, as the space heating may have not been able to be covered by the heat pumps.

3.2. Internal Temperature

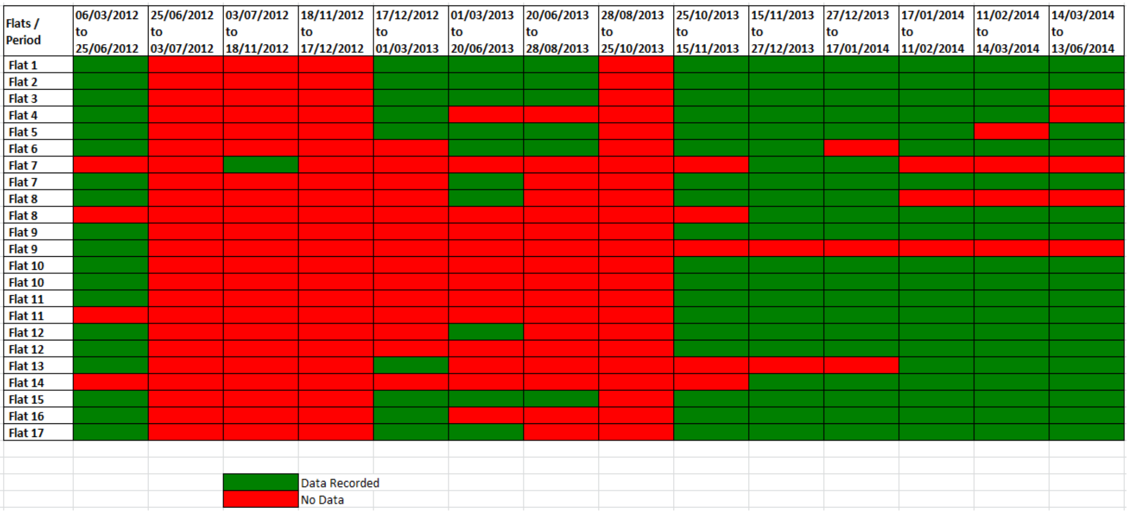
Table 2 shows the temperature data recorded for every flat and the periods were data was not collected. According to Table 2, for the whole duration of the project 50% of the data was lost and up to October 2013 the percentage of data lost rises to 75.5%.

The main factors, which could have played a role in the lost of temperature data, were:

- Long periods between data collection with equipment unsupervised. The LogTag data loggers were set to stop recording after memory full, instead or overwriting if run out of memory.
- Tampering of equipment by users, such as damaging the equipment or disappearance of equipment.
- Removal and/or disposal of equipment by third party contractors, such as during maintenance periods.

Where internal temperature data was missing, a yearly average value was calculated as an approximation. It must be noted that the used of internal temperature may be sometimes misleading as it was observed that some tenants would open windows to cool down the flat, instead of switching down or off the radiator.

Table 2. Internal temperature data collected and lost between March 2012 and June 2014.



4. Discussion

After the challenges presented in the results section in terms of data collection for energy consumption and internal temperature, the following data was taken forward for final analysis of energy reduction and assessing behavioural changes:

- Only data for the period between October 2013 and June 2014 will be analysed as after this period, the data was collected on a rough monthly basis.
- Utility meter readings data collected at rough monthly intervals was used for monitoring the energy consumption.
- Internal temperature data will be average out to accommodate for the missing data. When two sensors were used per flat, the most completed data set was selected.

A normalized energy index, based on utility meter readings, internal temperature and outdoor conditions, was developed by the author to overcome the loss of data and be able to assess the effectiveness of the technology and the behavioral change in the occupants. The normalised energy index provides a methodology to evaluate technology and behavioural changes effect between flats, across seasons and locations.

An initial description of the methodology for the development of the normalised energy index can be found in the literature [9].

The approach for the development of the normalised energy index is based on the following inputs, as shown in figure 3:

- Energy consumption in kWh taking from utility meter readings [7].
- Treated area in m2.
- Internal temperature in degree centigrade.
- Outdoor conditions depending on location, taking as degree days for the particular location [10, 11].

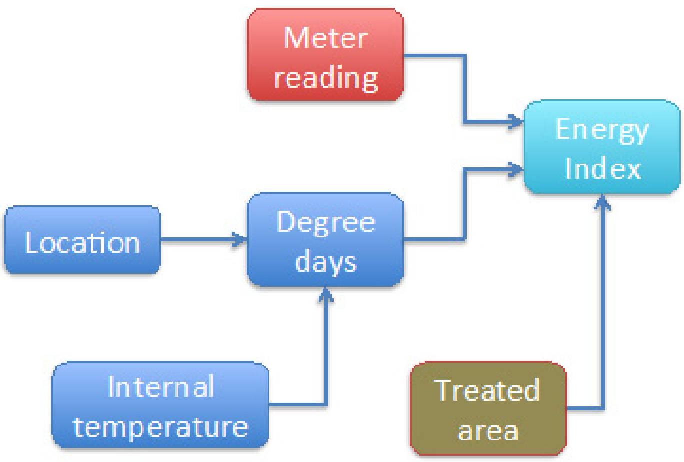


Fig. 3. Normalized energy index methodology.

The use of the normalised energy index methodology allows an easy methodology to numerically or graphically compare the energy performance of different properties energy professionals, tenants and social housing providers to monitor and assess energy consumption across properties, seasons and locations, the effectiveness of new retrofitted technology and/or the application of behaviour change strategies, while allowing a low budget approach to data captured and analysis. Furthermore, the normalised energy index methodology provides the valuable resource as a backup methodology in case of a smart meters data losses or inaccuracies.

5. Conclusion

This study has presented the different challenges happening during the process of monitoring energy consumption and indoor temperature from a low budget point of view. Furthermore, a methodology to overcome some of these challenges, data losses and inaccuracies, is described. The normalised energy index methodology presented in this paper provides a way forward to monitor and assess energy reductions due to behavioural changes from a low budget perspective.

Acknowledgements

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