Incorporating user behaviour preferences in the design of controls: experience of two Retrofit for the Future projects

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Abstract:
This paper is based on our experience with two pilot schemes under the Retrofit for the Future programme, sponsored by the Technology Strategy Board. We provided consultancy on appropriate upgrading measures, techniques of tenant engagement, and input to the design of controls. The aim was to enhance usability of the controls and support behavioural change to improve energy saving in the pilot schemes: our work has contributed to the design of controls which are currently being trialled.

Through tenant interviews and workshop exercise carried out in early 2010, we explored constraints and preferences in use of controls, and potential drivers for pro-environmental behaviour. Many of the key messages are echoed in recent studies by others. In contrast to some research, however, we conclude that differentiation between user groups with varying attitudes to sustainability is both useful and feasible.

Keywords:
Housing retrofit; energy efficiency; low carbon; occupant behaviour; controls usability

1 Introduction

1.1 Occupant behaviour and energy use in buildings

Improvements to the existing housing stock have long been recognised as a major opportunity for reducing the UK's fossil fuel use and thus its carbon emissions. A number of technological measures, including insulation (particularly of lofts and cavities) and plant upgrades, look feasible and cost effective for a proportion of the stock (Shorrock, Henderson and Utley 2005).

The same study gave an indication of potential savings from the installation of programmable heating system controls, where they were lacking – that is, in an estimated 10% of the stock in 2001. For an average dwelling, this could save 11.353

GJ/yr in delivered energy, or 223.4 kg C/yr. Furthermore, these figures do not take account of savings from replacing outdated controls, or using them more effectively.

There is a growing recognition that " ..long-lasting sustainable solutions must give primacy to user behaviour" (Stevenson and Leaman 2010). A number of studies have shown the potential savings from installing building control devices that give feedback to users, and enabling the users to take ownership of the information provided and act on it to run their homes in a comfortable yet economical way. Some instances are reported where savings have exceeded 20% (Darby 2000): a range around 5-15% is more commonly cited.

In a review of published studies, Abrahamse et al (2005) commented on methodological problems including small sample sizes in many studies but concluded the "Feedback appears to be an effective strategy for reducing household energy use in most studies reviews here, although some exceptions exist." Their study suggested that rewards (such as prizes) can have a positive initial effect on encouraging savings, but that this boost is likely to be short-lived. Furthermore, reporting of cumulative totals is more important that usage over a short period – particularly for heavy users of energy. Feedback in monetary terms is no more effective that reporting of environmental costs; and comparisons are only effective if combined with rewards in a competitive situation.

The design of control interfaces for greatest effectiveness is currently an active topic of research in the field of building energy use: an international comparison of studies in particular on smart metering is given by Darby (2010) and developments in the automation of user profiling by recording of responses are reported by Taherian et al. (2010). However, the importance of buy-in by users is stressed by other authors, for example Wallenborn, Orsini and Vanhaverbeke (2011): "The appropriate process is a matter of reciprocity: humans influence objects, and objects influence humans".

The design of control units themselves has been reported as an important factor by Hargreaves, Nye and Burgess (2010), in a study comparing three different units of varying level of complexity from one manufacturer. The visual appeal of the units is very important: they need to present information in a clear and transparent manner, and be flexible in siting for maximum visibility. Customisation to suit the varying concerns of users – financial, environmental, informational and technological – is relevant, and also their specific styles of engagement, which may be gender and age specific.

In the study of the projects described below, we aim to contribute to the growing body of work in this area. We carried out a consultation process with tenants collate a set of sample opinions regarding their specific needs, concerns and issues in terms of handling, managing and operating heating and lighting control systems, in particular renewable and low-carbon energy systems such as PV and solar thermal panels.

The consultation aims to use this information to feedback to the designers of future heating and lighting control mechanisms as part of the Retrofit for the Future project. This feedback will directly help to produce new control systems that meet the needs of this sample group. In addition it is hoped that the products can be produced efficiently and be marketable.

1.2 Retrofit for the Future programme

To explore fresh approaches to the challenges of the existing housing stock, the Retrofit for the Future scheme was launched in 2009 by the Technology Strategy Board, a public body sponsored by the UK Department for Business, Information and Skills. Through a competitive bidding process, the programme aimed to identify and fund a minimum of 50 retrofit projects in the social housing sector. These would be tested and monitored before and after retrofit, and the process fully documented, to feed into a database of good practice solutions. A key goal was to identify solutions with a potential for widespread application and thus significant levels of saving in energy use and CO_2 emissions (TSB 2009).

Two of our schemes were successful in the competition. For Scheme A, our role was in the design and implementation of a tenant consultation strategy to feed in to the design of controls. For Scheme B, we assessed potential upgrading measures for applicability and cost effectiveness, liaised with tenants and provided input to detailed design.

A central aim of both schemes was to enhance usability of the controls and support behavioural change to improve energy saving.

2 The retrofit projects: physical measures

The two projects are typical of the social housing stock in southern England. Scheme A consists of just one property, retrofitted to a very high specification to minimise energy use.

Scheme B, on the other hand, comprises two adjacent terraced houses in similar condition. The aim here was to carry out only the most cost-effective measures, that can be cost-effectively and rapidly deployed without unacceptable disruption to building occupants, to enhance opportunities for extensive rollout of the scheme.

2.2 Description of Scheme A

This is a retrofit of a single-storey, one-bedroom property. The property is located in central England, in a small village where mains gas is not available. It dates from the 1960s, and has poorly performing uPVC double glazing, retrofilled cavity brickwork, and a tiled roof.

The property belongs to a class dubbed “difficult to heat” by its owners, Aragon Housing Association. An analysis of the English housing stock shows that single-storey homes of this age are indeed among the poorest performers in the national stock (fig. 1).

A preliminary analysis of the national housing stock (based on data from the English House Condition Survey 2005) shows that Aragon’s problems with hard-to-heat postwar bungalows are quite widespread. There are around 2m bungalows in England, 170,000 of which are owned by RSLs: Aragon’s stock thus represents about 1% of these. Out of the national total, the majority – 1.4m - date from 1945 to 1980. Their average SAP rating, at 44, is one of the lowest of all domestic building types. For the 800,000 bungalows dating from 1965 to 1980, this type performs the worst of all for their age group, at a SAP of 42.

Those bungalows built between 1945 and 1964 score even worse – average SAP 41 – but slightly outperform detached houses of the same era. Nevertheless, there are more bungalows (around 600,000) than detached houses dating from those postwar decades, so their poor performance is particularly significant.

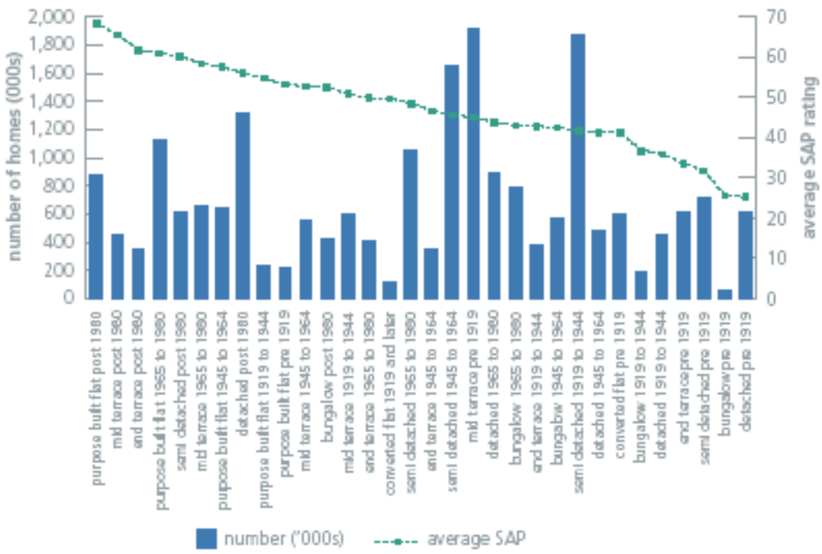

Figure 1.Average SAP and size of stock by housing types and age combined
(Source: EHCS, 2007)

The occupants of our demonstration property are a couple with adult children who do not live with them: one of the couple is over 60 and has mobility problems. Again, this profile is common among Aragon tenants: a recent survey for them of their tenant households showed that 48% of primary respondents were elderly and 49% had some level of disability. Among these, the most common issues were related to mobility (fig. 2).

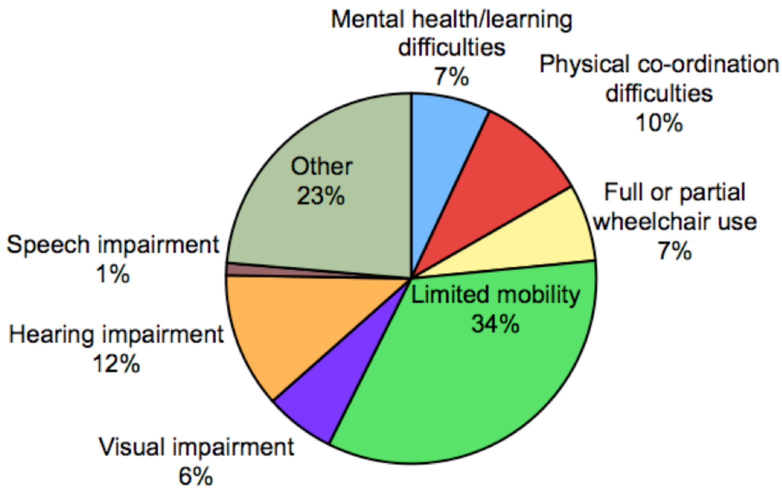

Figure 2. Disabilities reported by Aragon tenants
(Source: prepared from data compiled by Jassi, 2009)

Retrofit measures include:

- optimisation of glazing ratio, with some reduction of overglazing and addition of a sunpipe
- external insulation of walls
- insulation of roof to a high standard
- insulation of floor using an aerogel-based product
- heating and dhw provided by an air-source heat pump supplying a wet radiator system, with solar thermal assistance
- photovoltaic installation on roof

Figure 3. Retrofit ongoing in Scheme A.

2.3 Description of Scheme B

The scheme's two houses are located in a village close to the East coast, and owned by Flagship Housing Group. The 2-bedroom homes were constructed between 1920 and 1949, in a centre-terrace location. The houses are two story with a tiled roof; at the rear of the properties there is a single-story bathroom extension with a flat roof. The cavity brick walls had been filled post-construction but there was no insulation to the ground floor slab, and levels of roof insulation were also poor. One house had single-glazed windows while the other wasdouble-glazed, however, this had been installed prior to 2002 and did not fit with current standards.

Figure 4. East façade of one of the houses in Scheme B, before retrofitting.

A package of interventions was installed to improve the physical performance of the houses. This did not require the tenants to be relocated during the works - we see this as a key requirement of a scaleable approach to retrofit. The selected package comprises the following measures:

- additional loft insulation to minimum 270mm thickness
- perimeter slab insulation
- solar water heating panel of 2.8 m^2
- replacement windows, double glazed with low-e coating
- photovoltaics
- solar thermal panels
- space heating system supplied by air source heat pump
- upgrading of white goods to A+ rating

Together with influencing user behaviour, the combined effect of this package was projected to be a reduction in CO_2 emission from 84.42 to 24.16 kg/m^2 – a saving of 71.4%.

Each house is occupied y one adult and one child. The performance of the buildings is captured in real-time, and all performance information will be available in near-real time on an Internet-based portal.

3 Exploring the potential for behavioural change

For both schemes, tenant questionnaires were used to gather data on a range of issues including family composition, current lifestyles and attitudes to sustainability. In the case of Scheme A, this was followed up with a workshop for a tenant group which further explored what mechanisms for behavioural changes might be effective. Notional designs for a control interface were also tested on the group.

3.1 Surveys

Working with Aragon, we identified a small group of tenant or resident representatives. These were drawn from the following 4 demographic groups to give a cross-section of Aragon's tenants: elderly couple; elderly single person; young couple; young family.

We held 1-to-1 interviews from at least 2 tenants/families from each identified group. The purpose was to gauge opinion as to the issues, concerns, knowledge and capacity of Aragon tenants to use specific heating and lighting control mechanisms. This information helped to supply data for the wide group session outlined below.

We carried out 9 1-to-1 interviews in May 2010 and collated the feedback. Using a similar format, we also collected data from the tenants of the two pilot houses in Scheme B.

Characteristics of interviewees
While too small to constitute a statistically significant sample, we endeavoured to include in the respondent group a similar range of household types, age distribution and health issues to Aragon's stock in general. It is notable that all our respondents came from rural villages or small towns, corresponding to the location of most of Aragon's stock. This is in contrast to many social housing providers in the UK, and may have produced a bias towards pro-environmental behaviours in the respondent group (Berenguer and Corraliza 2005).

Our respondent households were 60% female. In four of the six households, the primary respondent was over 60 years old. Five households were white, with one of south Asian origin. Only one adult had received education above 16 years old.

Health issues
This distribution is fairly similar to that of Aragon's stock as a whole, with half of the respondents reporting no health issues. For the others, 3 have issues with limited mobility or physical coordination, 3 with hearing impairment, and 1 with visual impairment (fig. 5).

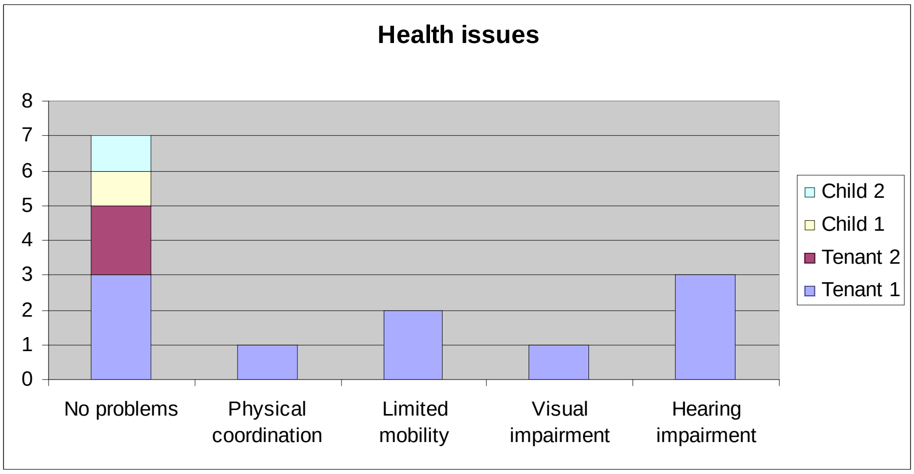

Figure 5. Health issues reported by members of interviewed households.
Source: project data, CAR Ltd.

3.2 Workshop

Working with Aragon, we publicised and recruited tenants and residents to attend an evening workshop, which took place approximately 3 weeks after the interviews. In the workshop we worked with a cross section of tenants to test out the results of the 1-to-1 interviews and identify issues, concerns re the use of heating and lighting controls.

It was an interactive session using various forms of media to test the attendee's opinions. Prototype products were presented to the workshop group for testing. Feedback was be recorded and presented back to the Project Team and the product designers. We also tested opinion on product handbooks/information sheets.

4 Findings and Discussion

Results from the survey and workshop were supplemented with a literature review on design of controls for domestic energy systems, drivers for behavioural change, and particular characteristics of the tenant groups.

4.1 Interview findings

- Attitudes to sustainability are mixed, with some having little awareness of relevant issues
- However, several have quite low-energy lifestyles due to economic constraints
- They commonly look to the landlord to propose energy efficiency improvements, and seem unquestioning of decisions
- Most are quite unsophisticated in the way they use current controls, are don't want further complexity

- There is a range of familiarity with technological gadgets: one or two don't use a mobile phone, or use a TV remote control just as an on/off device. Others (particularly the younger households) use computers and the internet regularly.
- Disability is a significant issue, and a constraint on the type of systems and controls that are appropriate to particular circumstances. Nearly half of Aragon tenants are elderly (approaching or beyond retirement age), and a similar proportion report disabilities.

4.2 Workshop findings

Attitudes

We carried out an exercise to investigate where the participants would locate themselves in terms of attitudes towards a range of possible sustainable lifestyle choices. This exercise was based on a categorization of attitudes to sustainability presented in the publication "A framework for pro-environmental behaviours" (DEFRA, Jan 2008).

We devised a matrix-style self-diagnosis exercise similar to tools we have used to explore pro-environmental behaviours in other contexts, for example energy management in non-domestic buildings. The output from this exercise was critical to our understanding of preferred information delivery modes.

Preferred information delivery

The discussion of controls led on from the previous exercise. We introduced the participants to an exercise in which they ranked their preference for the units in which their home energy use was reported. The nine different options used three primary indicators: carbon dioxide (tones), energy (kWh), and a non-environmental indicator (£, or pizzas). For each of these, there were three differing ways of considering results. Participants were also prompted to suggest alternatives.

A number of key points emerge from the workshop:

- carbon dioxide is not seen as a useful metric by this group
- money is the preferred indicator, closely followed by energy
- the slightly jokey suggestion of pizzas as an indicator was not popular (but not totally rejected)
- comparators were liked

The first of these points is somewhat of a surprise. Despite their generally high level of engagement with environmental issues, the group does not view carbon dioxide as a very meaningful indicator for their own domestic energy use. However, this is line with findings by Anderson and White (2009).

The group is generally money conscious – reflecting frugal lifestyles that are likely to be widespread among Aragon's customers (Jassi 2009).

Interest in comparative metrics ties in with the characterization found in the previous exercise: this could be very important in influencing the behaviour of particular groups. We disagree that “different users have similar needs” (Anderson and White 2009). For example, the idea of seeing how much money is being saved by comparison with the house’s potential, or energy by comparison with others in an energy-efficiency group, could be specially powerful for particular occupant sectors.

4.3 Implementation in design of controls

General points – controls need to be:

- well located, to facilitate interaction – not in an inaccessible or hazardous location, such as behind a door. This applies not only to control panels but also other elements of the environmental system, such as opening lights to windows.

- particular attention to location for those with limited mobility and physical co-ordination difficulties – up to a quarter of Aragon’s tenants.

- as simple as possible to understand, and override

- easy to read, and with robustly-designed switches (or equivalent interaction) – nearly half of Aragon’s primary tenants are at or approaching retirement age.

- If practicable, able to “learn” from previous control choices, and habits such as window opening.

Particular needs:

- for a number of tenants, visual feedback should be adapted for their needs, in terms of particularly large font or colour – around 3% are visually impaired to some extent.

- possibility of aural feedback (“talking controls”) for the blind, and those with low levels of literacy

- possibility of feedback in languages other that English – useful for perhaps 0.5% of Aragon tenants

- possibility of audible alarm to alert tenant or warden to dangerously low temperature/activity levels – for those with highly impaired mobility or other serious health issues

Research findings were incorporated in the design of control systems and interfaces for the two schemes (implemented by controls engineers). They are designed to provide essential information in an uncluttered layout, assist decision making, and enable time-series data to be accessed easily.

5 Conclusion and Further Research

Both retrofit schemes have been carried out, and monitoring is in progress. Informal feedback from tenants indicates that they are pleased with the physical works; they find their homes more comfortable and think the controls are informative and easy to use. More detailed data on energy use will be forthcoming.

The findings from our tenant interviews and workshop have reinforced the message that effective engagement with building users is a key not only to good design of environmental control system interfaces, but also encouragement of pro-environmental behaviours. Our findings on a number of detailed issues are in line those with those reported in the literature from contemporaneous studies (for example Hargreaves, Nye and Burgess 2010).

As a result of our consultation process, however, we stress the importance that simple self-diagnostic tools have a part to play in differentiating types of occupant with regards to environmental behaviour. We believe that this diagnosis can be useful in customising information provided to the building users, for maximum benefit.

Acknowledgement

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Photo credits: Figs. 3 and 4 – H. Mulligan

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