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## **Reducing energy use in social housing: examining contextual design constraints and enablers**

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# Reducing Energy Use in Social Housing – Examining contextual design constraints and enablers

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## Abstract

*Domestic energy use in the UK is rising. Because of the low rates of demolition, and the difference in efficiency between new and old houses, to reduce domestic energy use, the existing stock of homes must use and emit less. To achieve a substantial and rapid reduction in energy use we need to engage with occupants in meaningful and effective ways to prompt more efficient behaviour. Carbon, Control and Comfort is a three-year collaborative research project aiming to engage users in the design of control systems that they like, that allow them to create the comfort conditions they want and which, through using the technology and fabric of their homes more effectively, reduces their energy use. Drawing on the findings of a cross-disciplinary literature review, the paper explores how occupants' comfort practices impact upon energy use. It goes on to discuss the design constraints and socio-technical factors which could inform the development of devices or systems that enhance and promote energy reducing comfort practices.*

**Key words:** energy, comfort, design for sustainable behaviour.

## 1. Introduction

Domestic energy use in the UK has grown consistently over the last thirty years. As a percentage of UK consumption, it has risen from 25% to 30% over the 1970 to 2001 period. However, energy use per household has remained roughly constant, both in terms of total energy use and that proportion used for space heating [1].

Variability in energy consumption is affected by occupants' comfort practices. By working with users to understand their comfort practices, the energy use they entail, and how they are co-created by the technologies and behaviours of which they are made, it is possible to

design devices and systems that enhance and promote energy reducing comfort practices.

## 2. Comfort Practices and Energy Use

Increased use of energy-intensive appliances, the rise in single-occupancy households and disposable income, institutional factors (e.g. government policies, grants and incentives) and cultural developments such as increasing mobility of women, home-working and '24/7' living [2] have increased energy consumption, despite efficiency gains in other areas. Occupants' comfort practices as realised through their use of the building technologies (heating system, lighting, mechanical ventilation etc), fabric (doors, windows, etc) furnishing (curtains, floor coverings, etc) and clothing has an enormous effect on energy use.

The optimum household temperature is widely considered to be 21°C; however occupants have reportedly been satisfied with a wider range of temperatures [3]. Maintaining standardised comfort conditions is counterproductive as it fails to acknowledge differences in occupants' comfort levels and reinforces and naturalises unsustainable expectations [4].

Occupants deal with discomfort either by adjusting the environment to match their requirements (e.g. switching on the heat or opening a window) or by adjusting their requirements to match what the environment provides (e.g. putting on a jumper or increasing activity levels) [5]. Users' tend not to operate the most logically appropriate controls, but the most convenient, and often leave systems in their switched state rather than returning to the previous setting [6]. Their tolerance for discomfort due to low levels of heating and the time elapsed before taking actions to remedy the situation (e.g. by turning up the heat) can

relate to monetary or environmental concerns [7] familial norms [8] or even gender [9].

### 3. Design Considerations

To identify areas for improvement it is necessary to examine the limitations of current household energy management practices. Payment for energy is typically made in arrears upon receipt of a bill or via direct debit. Monthly or quarterly bills generally aggregate costs and consumption. Data on individual appliances energy usage are not provided and “without this specific information it can be difficult to identify the best strategy for conserving energy”; which appliances are inefficient and the relative cost of habits and behaviours such as leaving appliances on continuously [10]. Energy costs, particularly for low-income households, can impact on the behaviour of the person who pays the bill, however, other householders are less likely to be influenced by cost [11].

Aside from bills, access to information on household energy consumption is, prior to the UK-wide roll out of smart meters, limited to the household electricity meter, a static, largely antiquated device which displays limited aggregated data in a non-engaging manner and is often hidden away in a cupboard, and as such, unlikely to be consulted on a regular basis [12, 13].

Householders wishing to monitor energy consumption in more detail can choose from a vast array of ‘off-the-shelf’ feedback devices. Typically, these self-installed devices clip on to the power outlet mains and communicate wirelessly to a portable display providing data on home energy use. The majority display electricity consumption only, not gas. Feedback on only one utility can be counterproductive as it may distort behaviour. For example, occupants may boil water using the stove instead of the kettle to avoid using electricity as it being monitored [14]. Additionally, the majority of UK households have a central heating system (typically a boiler fired system with radiators) [15] which may be supplemented with portable electric heaters or fans to provide concentrated pockets of warmth or coolness, therefore feedback on both gas and electricity consumption is vital to understanding the impact of comfort practices.

The success of devices or systems in influencing behaviour toward energy-reducing practices can be dependent on the effectiveness of the design features employed, which are discussed in the following sections.

### 3.1 Metrics

A range of energy metrics can be displayed including power consumption in kilowatts per hour (kW/h), expenditure, or equivalent CO<sup>2</sup> emissions in tonnes. These metrics can be displayed in real-time, in comparison to previous monthly or annual consumption, other households, or a self-selected target reduction. Data can be presented as a cumulative total for the whole household or broken down by appliance or utility.

Data may be displayed in numeric, ambient (e.g. light, colour, sound), pictorial or abstract formats and delivered via dedicated devices or by ‘piggy-backing’ on existing products such as iPods and iPhones, digital televisions or internet applications. “It is unlikely that homeowners would be willing to invest in a unique mobile device that only reports on energy usage” [13, p. 2850], therefore, notwithstanding the short-lifespan of many electronic products, converging use with existing devices may be a viable way forward, offering environmental and economic benefits.

Users’ interest and energy literacy may dictate the extent to which they engage with, and interrogate data [16] therefore, it may be advisable to provide basic feedback as standard with the option to access more complex, detailed data when required.

The majority of energy monitoring devices on the market enable comparison of current with historic consumption, often via accompanying software, or comparison of one’s own household consumption with that of other similar householders [8]. Though the intent of both is to stimulate energy-reduction or conservation behaviours; the former is predicated on the assumption that greater awareness will lead to reduced consumption, the latter aims to stimulate competition and may help householders contextualise their consumption [2, 8, 14]. The relative effectiveness of different metrics has yet to be determined [14, 17]. However, evidence gathered from small-scale trials suggests that feedback on CO<sub>2</sub> emissions may not be as effective as householders may not be able to interpret how tonnes of CO<sub>2</sub> relate to their own energy use [14].

There is the potential for cost savings if appliances are used off-peak. Despite this, few studies [18-20] have explored the effect of providing time-of-use pricing to encourage “load-shifting” from peak to off-peak periods. The prototype energy monitor developed for Sexton et al’s trial [18], for example, provided time-of-use pricing information signifying peak and off-peak periods signaled to users via indicator lights. Additionally, the user could choose to access per KWH cost during each pricing period. Belley [19] took a different approach, developing a plug-in device which changes color to

indicate variations in energy production during the day; green for off-peak, blue during busy periods and orange to indicate peak hours in local production.

According to Darby [12] the case for real-time or time-of-use pricing in the residential sector has not yet been made in the UK. It seems that off-peak usage may be encouraged more in European countries, although with the advent of off-peak tariffs being offered by major UK energy providers, this may change. There are clear economic benefits to the consumer and clear drivers for utility companies to push consumers towards a shift in consumption to off-peak energy in terms of meeting demand during peak hours, however, it is not yet clear to what extent householders (not signed up to off-peak tariffs) are aware of and distinguish between peak and off-peak electricity and whether this informs their behaviour (e.g. conscious decision to run appliances overnight or at weekends).

The provision of appliance-specific feedback can enable householders to observe how a particular appliance, or the use of a particular appliance in different ways, affects their energy consumption and costs [8, 10]. However, devices currently on the market which enable individual appliance monitoring are, according to LeBlanc [10], “accurate but can be cumbersome” to use. The user may have to connect all data outputs from individual monitors to a central system or watch a screen on an individual unit plugged into an outlet under a desk or behind a TV unit, for example. In both cases, users must interrogate each individual monitor to record the data [10]. Fitzpatrick and Smith’s [14] findings indicated that centrally-located feedback relative to individual appliances was unanimously preferred over appliance-specific feedback devices. Although previously considered too costly to be widely implemented in the residential sector [12, 14] viable technologies for providing a breakdown of appliance-specific consumption are now commercially available e.g. [21].

Early interaction with real-time energy consumption displays is often playful, experimental and driven by curiosity to reduce consumption by, amongst other things, switching appliances on and off to see the load change [14]. The novelty, however, soon wears off as devices become ‘part of the furniture’. Consideration must, therefore be given to investigating ways of sustaining users’ interaction with energy monitoring devices to reduce the risk of newly formed behavioural changes reverting back to previous habits.

Additionally, householders’ ability to switch energy suppliers frequently and with relative ease, “means that any smart meters will have to be fully interoperable with each other” [17].

### **3.2 Visibility and Portability**

The limitations of existing energy meters, coupled with the invisible nature of energy consumption [8, 12] has prompted a wave of portable energy monitoring devices. Fischer [8] notes that feedback delivered directly after an action is taken could strength the links between action and effect, increasing awareness about the consequences of actions taken. Portable standalone devices, as opposed to those fixed in a static location, enable feedback to be given at the point of use e.g. in the kitchen whilst boiling the kettle or in the front room whilst watching TV. For this reason, energy consumption data displayed exclusively on a PC or via the television could be less effective as it is less likely to be viewed in real time.

### **3.3 Energy Consumption and Pay-Back Period**

The embodied and in-use energy consumption of the device or systems itself and the period of time required to recoup the purchase cost through energy savings must be calculated. Above all, the system or device must not consume more electricity than it allows users to save [10]. The use of non-rechargeable batteries should, if possible, be avoided in favour of renewable or self-generating power sources. Onzo’s sensor clip, for example, “harvests” its power from the cable to which it is attached, removing the need ever to replace its batteries” [22]. If not for environmental or economic reasons, non-rechargeable batteries should be avoided as it has been observed in prior in-home trials that users can fail to replace depleted batteries thus rendering the device redundant [23]. The provision of replacement batteries by post may be an option [16]. However, this presupposes that receiving free batteries will prompt householders to replace used ones.

### **3.4 Installation and Maintenance**

The complexity, size and connectivity of the device or system (e.g. if it communicates wirelessly or needs to be ‘hard-wired’ into existing controls) will affect whether it can be installed by the householder or if ‘expert’ installation will be required. Current estimates of the cost of installing smart meters in UK households, for example, equates to approximately £15 per household, per year, across a ten year period (2010-2020). Cost reductions achieved through discontinuing manual meter reading and dealing with customer complaints resulting from inaccurate estimated bills

should save suppliers £10 per household leaving £5 which is likely to be passed on to customers [24].

The cost and ease of installing an energy monitoring device or system will, particularly in a social housing context, be a prime concern for landlords. Additionally, practical issues such as the type of housing, construction (e.g. depth of wall thickness or type of insulation which may affect the signal of wireless devices), location of, and access to, the power supply meter and availability of technological infrastructure (e.g. broadband bandwidth) will warrant consideration.

#### **4. Socio-Technical Factors**

The users' ability to access and understand feedback on energy consumption and their willingness to act differently in response to external input can depend on several sociological and technical factors;

##### **4.1 Inclusive Design**

Reportedly, one fifth of the adult UK population has low literacy levels and suffers difficulties with basic maths and reading [25]. A more recent study found that low literacy levels were associated with socio-economic deprivation [26]. Consumer education will, most likely, be required to build energy literacy and familiarity with the device display and ensure information provided is comprehended and acted upon. The provision of information in accessible, understandable terms will be of even greater importance in households with low literacy levels. Therefore, the display of energy saving devices should be designed inclusively to ensure text or graphics are easily read and interactive features readily accessible and easily manipulated by a wide range of prospective users. For example, a graphical rather than numeric display may reduce the potential for excluding those users with low literacy levels and careful consideration of the size of the display may reduce the unnecessary exclusion of visually impaired users.

##### **4.2 New and Emergent Technologies**

Technologies such as Z-Wave [27], a wireless network for controlling lights, heating and air conditioning and appliances designed for low-speed controls such as turning a device on and off or raising or lowering a function and Coracle [28], a technology that can display appliances power consumption from measurements taken at a single central point, have been successfully integrated into energy monitoring devices and systems.

The capability of devices which depend on existing wireless internet technologies is, however, dependent on household connectivity. In 2008, 56% of all UK households had broadband, compared to 51% in 2007 [29] this reflects an upward trend. However, access is largely dependent on income and those living in social housing may not have broadband installed. A further trend is the use of social networking and microblogging services, such as Twitter, which utilize instant messaging, SMS or a web interface. German utility company Yello Strom, for example, keeps its customers informed by enabling Yello Sparsähler smart meters (designed by IDEO) to 'tweet' about energy use [30]. However, given the low statistical probability of internet access in less affluent households, it is questionable as to whether social networking and microblogging services would be widely used in the social housing sector. This may change, however, if plans outlined in the Digital Britain White Paper to ensure universal broadband access by 2012 are successfully implemented [31].

Even if access is increased there still remains the issue of technological literacy of older householders, who, in the context of this research, constitute a significant proportion of the social housing tenants to be studied in the next phase. A recent study, conducted by Ofgem, for example, reported that some of the elderly participants expressed "particular objections to accepting in-home displays, mostly on the grounds that they [did] not think they could operate the technology" [25, p.6].

##### **4.3 Management of Energy Provision and Data**

Recent reports have speculated that smart meters, due to be rolled out across UK households, will enable suppliers to maintain greater control of household consumption through direct, dynamic management e.g. switching off refrigerators for a few minutes during periods of high demand or when market prices are high [16]. Darby [17] highlights emerging controversy concerning the potentially invasive nature of direct management. However, anecdotal evidence from a recent energy monitoring trial illustrates that consumers may not even be aware that their appliances have been switched off for short periods of time [32].

A further concern is which parties will be privy to consumption data. In the context of social housing this could be tenants, landlords and energy providers. Furthermore security measures will need to be taken (particularly in the case of wireless networks) to ensure data are securely stored, transmitted and accessed.

#### 4.4 Automated vs. User Driven Control

One of the challenges of designing for sustainable behaviour is that users' actions can be difficult to predict as they are driven by a complex array of internal and external influences. To minimise unpredictability and ensure compliance with energy saving goals it is possible to design highly autonomous systems which eradicate the need for human intervention completely or use constraints to prescribe actions [6]. However, by taking the decision making capability away from the user to prevent 'unsustainable' actions we separate cause and effect. Without feedback on cause and effect users may be less likely to learn from, and adapt, their behaviour accordingly. They may perceive automation as a lack of choice and this may reduce acceptance. Indeed, removing choice and reducing control may be counterproductive as providing opportunities for user control (e.g. switches, opening windows, closing blinds) can increase tolerance of indoor conditions [4, 6]. In some cases, however, users may respond positively to the automation of certain actions citing convenience and time reduction as benefits. Further investigation is needed to determine where automation of actions is acceptable and where choice is preferred.

#### 5. Conclusions

This paper has discussed a broad range of factors to be considered when designing devices or systems to enhance and promote energy reducing comfort practices.

To date, few UK studies have been identified which investigate the drivers for reducing energy consumption in low-income households. To achieve a reduction in energy consumption, design interventions must incorporate attributes which result in behavioural change; match the users' needs and expectations and fit the context of use. Participants of household energy use studies tend to have higher than average incomes and education levels [2], demonstrate some commitment towards energy management and be predisposed towards environmental issues [14]. As such, their relevance to the study of social housing tenants or those on low incomes must be evaluated and the specific drivers for energy saving in this sector examined to understand tenants' motivations, values and norms in order to select appropriate design methods to motivate behavioural change.

To this end, a series of intensive user-centred research studies of social housing tenants' energy using practices are underway, the results of which will inform

the development of design interventions for testing with UK social housing tenants.

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