GREEN CHOICES: THE INFLUENCE OF SOCIO-TECHNICAL PARAMETERS ON HOUSEHOLDER DECISION MAKING IN GREEN RETROFIT PROJECTS

Aaron Lang[1], Jacqui Glass[2], Chris Ian Goodier[2], Shamir Ghumra[1] and Richard Wilks[1]

[1] *Aggregate Industries, Bardon Hall, Markfield, Leicestershire, LE67 9PJ*

[2] *Loughborough University, Loughborough, Leicestershire, LE11 3TU*

Although the uptake of green retrofit measures (GRM) in the UK is increasing, empirical data often reveals significant shortfalls in the energy performance realised by domestic green retrofit projects. Such results pose a threat to UK emissions targets and are particularly problematic for the credibility of the government's flagship scheme: The Green Deal. The energy performance of a dwelling may be influenced by both its physical properties and the energy behaviours of its occupants and, whilst the retrofitting of GRM seeks to improve energy performance through physical alteration, the way in which users interact with these measures is likely to influence the extent of that performance. It is theorised that greater consideration for these socio-technical factors by those selecting GRM may yield more predictable energy performance in-use whilst better accommodating the needs and expectations of the occupants. A series of qualitative interviews were used to explore the decision-making processes and in-use practices of early adopters of domestic GRM. The research concludes that those currently realising exemplary energy performance demonstrate a level of technical understanding and interest which is not representative of social norms. Furthermore, acknowledging that the installation of multiple, interoperating GRM may lead to higher energy performance, it is evident that a lack of technical understanding may currently inhibit the effective operation and maintenance of such systems, regardless of users' willingness to interact with them. As such, a better understanding of the technical abilities and in-use expectations of UK householders is required to aid the development of more intuitive and intelligent green retrofit solutions. Where this could be achieved, improved predictability and superior energy performance would likely follow.

Keywords: building performance, energy, green building, refurbishment, sustainability.

INTRODUCTION

The UK is committed to an 80% reduction in CO2 emissions by 2050 (DECC 2011b). Approximately 27% of these total emissions derive from existing domestic building stock (Uttley and Shorrock 2008) of which approximately 70% may still remain in 2050 (Stafford et al, 2011). As such, refurbishment of existing dwellings attracts significant focus in current policy, most recently with the introduction of the Green Deal (DECC 2011a)

Lang A, Glass J, Goodier CI, Ghumra S and Wilks R (2013) Green choices: the influence of socio-technical parameters on householder decision making in green retrofit projects *In:* Smith, S.D and Ahiaga-Dagbui, D.D (Eds) *Procs 29th Annual ARCOM Conference,* 2-4 September 2013, Reading, UK, Association of Researchers in Construction Management, 1351-1361.

As DEFRA (2007) recognises, we can improve energy efficiency in two ways: through technological improvements, or changes in behaviour. Although the adoption of green retrofit measures (GRM) by householders may primarily be recognised as technological improvement, the way in which these are used is also consequential to potential success. Thus, success through technological improvement may always be limited by user interaction.

Taking forward the idea that these micro-level socio-technical factors could potentially restrict or even reduce energy performance, it is imperative that we understand and minimise their impact during the early planning and decision making stages of green domestic retrofit projects.

SOCIO-TECHNICAL FACTORS

There is a good understanding of the main drivers and barriers to the adoption of energy efficiency and renewable energy measures among householders (Achtnicht and Madlener 2012; Poortinga et al 2003; Jakob 2007; Caird et al 2008), yet it is not entirely clear whether adopters consider socio-technical factors when selecting GRM for their homes.

Caird et al (2008) identify that consumer adoption decisions and user behaviours are influenced by four key groups of variables: socio-economic context; communication sources; consumer variables and properties of the product or system itself. The latter group contains socio-technical factors such as functional utility and it can be seen that, setting aside socio-economic factors, homeowners favour those measures with least impact on lifestyle, i.e. with the least reliance on long term effort or behavioural change (Poortinga et al 2003). Although this suggests that adopters consider likely use-related behaviour when making purchasing decisions, it is less clear whether the measures chosen as a result do actually perform as expected. For example, where technical measures are adopted over passive or behavioural change measures, on the basis of minimum required effort, it seems pertinent to question the extent to which potential adopters consider the level of operational input or reactive behavioural change required in order to operate these measures efficiently.

The above theory identifies a general tendency towards minimum effort by society; however a qualification can be made: Commenting on earlier work by Hamrin (1979), Van Raaij and Verhallen (1983a) postulate that energy consciousness is interrelated with active involvement, whereby more energy conscious consumers achieve better savings from measures requiring their active engagement, whereas consumers with low energy consciousness are better suited to systems requiring less user interaction. This suggests that, as energy consciousness increases, householders may find it more acceptable to actively pursue increased energy performance.

AIM AND OBJECTIVES

The aim of this research was to identify whether increased acknowledgement of socio-technical factors during the decision making process could improve the energy performance realised in domestic green retrofit projects. As such, the following research questions were explored:

- Are socio-technical factors considered by householders and/or energy advisors during the decision process leading to the adoption of energy retrofit measures?

- Is there a disparity between the level of socio-technical interaction expected by the user, and that required in-use?
- Would enhanced consideration for socio-technical parameters result in the adoption of energy measures different from those currently predominating in the green retrofit market?

In answering the above, it may also be possible to theorise whether measures with lower energy saving potential could, in reality, offer superior overall performance than those with greater potential but which are chosen without regard for socio-technical factors.

RESEARCH METHOD

The study sought to investigate whether socio-technical factors are considered by householders undertaking green retrofit projects. In recognising that such projects are still essentially voluntary, an element of bias is expected. The use of judgemental sampling was therefore deemed appropriate considering both the bias and scoping nature of the research (Fellows and Liu 2008).

Qualitative interviews were undertaken on the basis that respondents were able to discuss, in detail, their decision making process from their point of view encouraging divergent, exploratory discussion where it may reveal factors deemed relevant and important to their specific decision making process (Bryman 2012). Although flexibility was required in order to expand on any specific areas of interest, semi-structuring the interview allowed the interviewer to ensure discussions stayed relevant to the area of investigation. Asking the same background questions at the outset of the interviews was also found to be a useful way of obtaining some basic demographic data for consideration.

In all but one case, interviews were conducted by telephone and recorded with the permission of respondents for accuracy and objectivity of recording responses (Fellows and Liu 2008). Interviews were typically 60 minutes in duration.

DATASET SELECTION

Initiated by the Sustainable Energy Academy, the SuperHomes network showcases over 150 green domestic retrofit projects from around the UK, offered a well-defined respondent group for data collection.

Considering time constraints and the breadth of examples available, a small group of 12 respondents were selected. The following criteria were applied to the initial data set in order to identify those projects most representative of domestic green retrofit fit in the UK:

Tenure and Type

According to the English housing survey (DCLG 2013), owner occupied properties account for 65% of the domestic stock; of which 92% are houses. Detached and semi-detached housing are the primary house type within this sector.

Property Age

Within the owner occupied stock, properties built between 1919 and 1980 predominate, accounting for approximately 60%. Although pre-1919 dwellings account for 20% of the total stock (DCLG 2013), it is thought that a quarter of these properties are either listed or within conservation areas (Boardman et al 2005). Preservation of heritage often influences building alteration decisions, i.e. through planning restriction; therefore it was considered prudent to disregard these properties for the purpose of this study.

It should be noted that hard to treat (HTT) properties (e.g. solid walled) are still well represented within the sample considering that pre-1919 properties represent less than half of such dwellings (Beaumont 2007).

Energy Efficiency

The energy efficiency and heat loss associated with new dwellings has been improving steadily over recent decades (Uttley and Shorrock 2008), but Stafford et al (2011) predict that 40% of the 2050 domestic stock will still pre-date the introduction of Part L of the building regulations.

In summarising empirical data in previous research, Stafford et al (2011) highlight that discrepancies between actual and predicted heat loss in dwellings was more pronounced in adjoined properties (terraced and semi-detached) than in detached properties. Such properties therefore appear to have a greater need for performance certainty.

Chosen Dataset

In considering the above criteria, the selected respondent group consisted of completed ‘SuperHomes’ projects on terraced, semi-detached and detached properties, of traditional construction, dated between 1919 and 1985.

In order to elicit responses representing the products currently predominating within green retrofit market, all selected respondents had employed a minimum of three GRM, consisting of both energy efficiency measures and technological measures. In line with the findings of SDC (2006), the specific energy efficiency measures considered were: Internal insulation, external insulation and cavity wall insulation. The technological measures considered were those with the highest adoption rates within the SuperHomes network: solar thermal water heating (STWH), photovoltaic panels (PV) and mechanical ventilation heat recovery (MVHR). Table 1 shows the adoption rates of these GRM within the overall sample of 153 and within the respondent group of 12.

Table 1: Adoption of Green Retrofit Measures

Green Retrofit Measures		Frequency	
		Total Dataset (n=153)	Sample Dataset (n=12)
Energy Efficiency Measures	Cavity Wall Insulation	58	10
	External Wall	42	3
	Internal Wall Insulation	73	3
Technical measures	Mechanical Ventilation Heat Recovery	41	5
	Photovoltaic Panels	99	12
	Solar Thermal Water Heating	104	12

RESULTS AND FINDINGS

Respondent Background - Technical Understanding and Ability

All interviewees were found to be from a technical background and/or highly motivated by energy efficiency and conservation. Of the 12 respondents interviewed, 9 professed to have an engineering background or specialist knowledge of the subject by way of their occupation. The remaining 3 respondents all had prior experience or knowledge of green retrofit measures.

While this trait was clearly and knowingly communicated by all respondents, the extent to which they considered this to be representative of wider society was wider ranging. In particular, when questioned more specifically on the level of on-going user input that had been required to get their homes performing to a high level, there was a tendency to assume that such behaviour was not beyond the realms of that acceptable to wider society. In fact, as conversations progressed and respondents reflected on the process leading to their current energy performance, they often became more aware of the extent to which their enthusiasm, motivation and technical ability had influenced its eventual performance.

Furthermore, 10 respondents had been actively involved in the design process and 4 had undertaken some or all of the physical works themselves. The extent of the respondents' design involvement ranged from specification of GRM to detailed design of their mechanical or electrical systems. Respondents falling into the latter category usually had subsequent practical involvement as well.

It seems apparent that those currently achieving high levels of energy performance from domestic green retrofit projects have a distinct technical understanding, ability or a combination of both, whether or not this trait is recognised by the users themselves.

Selected Measures - Solar Dominance

It is interesting to note that all respondents interviewed had installed both PV and STWH technologies and all had insulated the external walls of their property to some extent. The adoption rates for mechanical ventilation systems and heat pumps were slightly higher in the sample than for the SuperHomes network as a whole, with a little less than half of respondents having installed these particular GRM.

When questioned on the decision process leading towards installation of solar renewables, such a choice appeared almost unquestionable. In all cases, grant funding or feed-in tariffs (FITs) had had some bearing on their selection, but prior experience, the advice of installers and external advertising tended to influence decisions the most. Although not probed specifically, the early predominance of solar technologies in the GRM market also appeared to have influenced a number of respondents' decisions, reflecting the relative infancy of some current alternative GRM.

Ease of Use - Interoperating Technologies and the 'Average user'

Ease of use, or more specifically ease of optimising performance, was not a significant consideration for the majority of respondents when selecting GRM, although all had a good understanding of the behavioural characteristics required to maximise the energy performance of the systems e.g. using appliances when PV generation was high or staggering use of appliances to better match generation capacity.

10 respondents revealed that they held a particular enthusiasm for monitoring and optimising the energy performance of the project. Furthermore, a small number of respondents consciously accounted for this when selecting what were, in some cases, innovative and bespoke solutions. The challenge associated with getting the building to perform as efficiently as possible was often cited as being a driver for continued user input; it was also relevant for subsequent adjustment or alteration to the measures themselves.

It was particularly evident that the level of user input had been significantly higher where respondents adopted multiple, interoperating technologies. Such systems had often been designed and/or installed by the respondents themselves allowing homes to reach a higher level of performance by combining the different strengths of the technologies. Discussions on this topic were extensive; one particular respondent for example recognised, on reflection, that a good level of technical knowledge had been critical to the optimum performance of his home due to the nature in which various systems operate in conjunction with each other. As such, it is also plausible to suggest that lay-users would find it much more difficult to recognise and diagnose performance losses in such a system. In a traditional gas central heating system for example, where such a system fails to operate as expected, the number of possible causes and failure points is relatively small. Where the user is unable to undertake maintenance or repairs themselves, it is realistic to assume that they would instinctively call a plumber for assistance. Conversely, where a dwelling contains a number of inter-operating technologies, identification of optimum performance is much more difficult; the relative contribution of each technology may be influenced by variables such as external temperature (ASHP) or time of year (STWH) yielding a multitude of possible operating modes and performance outputs. In addition, fault finding may also be more difficult: Where performance was deemed to be unsatisfactory, at least a basic knowledge of the system as a whole would be required to diagnose the potential cause.

It follows that a user may not even know who to call for assistance where it is unclear which system element is at fault. So, where high performance is realised primarily by the installation of interoperating GRM (to account for limitations of the individual technologies in isolation), an understanding of the basic system principles would still be required to maintain such performance.

Taking this principle further, where respondents were seemingly undervaluing the influence of their technical ability on the performance of their homes, they were asked how easily a new user purchasing the property would be able to yield the same performance that they had come to realise. The majority recognised that a certain amount of knowledge transfer would in fact be required and that it would take some time to explain how the house should be operated. The implications of a new user on energy performance of a house containing GRM is beyond the scope of this paper but reveals an interesting area for further work.

Installers - The Weak Link?

A number of respondents cited difficulties in finding or working with installers/contractors from different disciplines who were familiar with how different GRM should interoperate. This was also reflected in the number of respondents who had needed to design and/or install such systems themselves and suggests a current need for multidisciplinary installers who can provide turnkey solutions incorporating a number of technologies. Another common installer issue cited was a lack of attention to detail in reference to air tightness treatments, and a clear lack of understanding of thermal performance, often evident in the over-specification of boilers.

'Show Home' versus 'Hobby Home'

There was some evidence of a relationship between motive for undertaking the project and the extent of user input cited: Where the large majority of respondents held a specific desire to design in user control and monitoring (to allow them to optimise the system) the level of on-going input and effort was considerably higher than those respondents whose motive, at least in part, was to engage society with the idea of green retrofit. Importantly, all those falling into the latter group used their projects to promote professional services in the field of domestic green retrofit and therefore showed a clear understanding of the expectations of wider society.

As such, it appears that an inherent personal interest and in energy efficiency and green technology appears to influence and facilitate the adoption of more complex solutions which are more heavily reliant on user-input. It is unclear from this study whether this level of user input is entirely necessary or whether this has been built-in, to some extent, by the user. For example, this may be the result of a lack of standardised interoperating solutions on offer in the market, or as a result of the users' inherent desire to control and optimise the system manually.

Social Expectations - Think Smart

A particularly succinct analogy developed during the interview period was that of the recent emergence of the smart phone. Those users who wanted to showcase attainable and socially acceptable projects also asserted that, whilst recognising that a user's technical understanding or ability may have a bearing on performance, it is for the market to deliver solutions which are not adversely affected by shortfalls in user knowledge – much like that of the smart phone. A small number of respondents suggested that society had come to expect intuitive products which enable them to undertake processes more efficiently without needing to invest specific effort in learning to do so.

The car was also offered as an example of offering better performance and improved efficiency without a reliance on enhanced user knowledge. Nowadays, few vehicle users expect, or are expected to, undertake maintenance themselves or even to understand which component may be causing reduced performance in order to resolve it; this is the job of the engine management system which recognises and communicates to the user when attention is required. If this principle was taken forward, one would imagine a building management system which monitored and optimised building performance based on how the building was being used and which was able to communicate to the user when performance was compromised, either as a result of user behaviour or due maintenance and repair.

It should be recognised that some users may also reject systems which prohibit detailed control and customisation. Such users are well represented by the majority of the respondents questioned as part of this study, but may not necessarily be broadly represented in society.

DISCUSSION

This section aims to address the research questions posed at the outset of this exploratory study:

Q1: Were socio-technical factors considered by homeowners and/or energy advisors during the decision process leading to the adoption of GRM?

Responses to questions regarding ongoing user input and ease of use fell into two distinct categories. While a large majority of users accepted or even preferred measures requiring ongoing input and/or behavioural change, a small minority of respondents set out to demonstrate socially acceptable environmental building practise which did not represent a significant lifestyle change. As such, only the decision processes of the latter group appeared to consider ease of use or level of input required. It can be noted however, that these individuals demonstrated a detailed appreciation for the effects user behaviour on energy performance and for the use-related expectations of wider society as described by Portinga et al (2003). As such, it is not possible to conclude whether users without such knowledge would identify such factors as being important to the success of their project.

It is also noteworthy that very few respondents sought the professional advice; seemingly as their own expertise was often deemed to be greater than those able to offer such a service. Half did seek or consider the advice of installers and manufacturers despite the majority of respondents expressing dissatisfaction with the level of knowledge held by installers; especially with regards to interoperating technologies.

Q2: Was there a disparity between the level of socio-technical interaction expected by the user, and that required in-use?

The level of user interaction with GRM was, in the large majority of cases, notably higher at the outset of the project whilst systems were being optimised than in subsequent periods where the user felt satisfied with performance. As previously identified, respondents generally held a modest view of the level of initial ongoing effort required and were evidently content with such involvement as a result of a general interest in energy saving and building performance. Those who felt input was minimal, confessed that significant effort had been required to get the building operating in such a manner and that a good level of technical understanding had lead them towards that point.

It is likely that the relative expertise of the respondent group in question influenced the level of user input applied. The responses suggest that better understanding led to better acknowledgement of relative potential performance which, in turn, led to increased socio-technical interaction. This process would repeat until either maximum performance was achieved or maximum acceptable level of input is reached. It is suggested that, for SuperHomes respondents, the latter limit is likely to be beyond that acceptable to wider society (i.e. Poortinga et al 2003), perhaps going some way to explain why performance among the SuperHomes projects was generally high. Of course, where a user's level of technical understanding is limited, user input could be expected to plateau, perhaps as early as one cycle into this process, on the assumption that performance is maximised.

Q3: Would enhanced consideration for socio-technical parameters result in the adoption of energy measures different from those currently predominating in the green retrofit market?

It is suggested above that energy consciousness and technical understanding have a bearing on the amount of user input both acceptable to, and ultimately undertaken by, the user. As a result, where energy performance is reliant on user input, these social factors should be explored during the decision making stage. It is reasonable to assume however that at least a basic level of technical understanding would be required even to assess the likely operational and maintenance requirements of a new technology.

Two responses to this are suggested: That professional advice needs to encompass an assessment of energy consciousness and technical understanding at the decision making stage; and that the market needs to work to develop solutions which reduce the level of user knowledge or input required to operate buildings efficiently.

CONCLUSIONS

The paper sought to identify whether the influence of socio-technical factors needs to be better addressed during the decision making stages of green retrofit projects. Qualitative data gathered from interviews with 12 early adopters of green retrofit measures showed a clear interrelationship between technological understanding and interest, and level of user-input applied in-use. It was also identified that such input had clearly been influential on the performance realised, especially where multiple, interoperating technologies were employed. Within the responses gathered, ongoing effort was rarely considered to be unacceptable, except where an appreciation for wider social preference is held.

We acknowledge an inherent bias in the high levels of technical literacy of our sample, but maintain that this research has elicited valuable new insights into the role of socio-technical factors in green domestic retrofit projects.

Further supporting research is required to investigate understanding of, and consideration for, socio-technical factors by occupants who better represent social norms. Where a reliance on user-input and technical knowledge is found to be unacceptable or unrealistic within wider society, it is crucial that industry moves towards providing solutions which better address this.

ACKNOWLEDGEMENTS

This work is part of a collaborative Engineering Doctorate between Aggregate Industries and the CICE at the School of Civil and Building Engineering at Loughborough University, funded by EPSRC. The authors would also like to acknowledge the support of the SuperHomes network in the production of this paper.

REFERENCES

Achtnicht, M and Madlener, R (2012) Factors influencing German house owners' preferences on energy retrofits. FCN Working Paper.

Barr, S, Gilg, A W and Ford, N (2005) The household energy gap: examining the divide between habitual-and purchase-related conservation behaviours. "Energy Policy", 33(11), 1425-1444.

Bartiaux, F, Vekemans, G, Gram-Hanssen, K, Maes, D, Cantaert, M, Spies, B and Jensen, O M (2006) Socio-technical factors influencing residential energy consumption. SEREC: Final report.

Beaumont, A (2007) Hard to treat homes in England, W07–housing regeneration and maintenance. Sustainable Urban Areas International conference, 25th–28th June 2007, Rotterdam.

Boardman, B, Darby, S, Killip, G, Hinnells, M, Jardine, C N, Palmer, J, Sinden, G, Lane, K, Layberry, R and Wright, A (2005) "40% House". Environmental Change Institute, University of Oxford.

Bryman, A (2012) "Social research methods". 4ed. Oxford: Oxford University Press

Caird, S, Roy, R and Herring, H (2008) Improving the energy performance of UK households: Results from surveys of consumer adoption and use of low-and zero-carbon technologies. "Energy Efficiency", 1(2), 149-166.

DECC (2011a) The Green Deal: A summary of the Government’s proposals. Department of Energy and Climate Change. London.

DECC (2011b) "The Carbon Plan: Delivering our low carbon future". Department of Energy and Climate Change. London.

DCLG (2013) "English Housing Survey: Headline Report 2011-12". Department for Communities and Local Government. London.

DEFRA (2007) "UK Energy Efficiency Action Plan 2007". Department for Environment, Food and Rural Affairs. London.

Dowson, M, Poole, A, Harrison, D and Susman, G (2012) Domestic UK retrofit challenge: Barriers, incentives and current performance leading into the Green Deal, "Energy Policy", 50, 294-305.

Fellows, R F and Liu, A M (2008) "Research methods for construction". 3ed. Oxford: Wiley-Blackwell.

Haas, R, Auer, H and Biermayr, P (1998) The impact of consumer behavior on residential energy demand for space heating, "Energy and Buildings", 27(2), 195-205.

Hamrin, J (1979) Energy-saving homes: don't bet on technology alone. "Psychology Today", 12(11)

Hitchcock, G (1993) An integrated framework for energy use and behaviour in the domestic sector. "Energy and Buildings", 20(2), 151-157.

Jakob, M (2007) "The drivers of and barriers to energy efficiency in renovation decisions of single-family home-owners". Center for Energy Policy and Economics, Zurich.

Milne, G and Boardman, B (2000) Making cold homes warmer: the effect of energy efficiency improvements in low-income homes. "Energy Policy", 28(6–7), 411-424.

Palmborg, C (1986) Social habits and energy consumption in single-family homes. "Energy", 11(7), 643-650.

Poortinga, W, Steg, L, Vlek, C and Wiersma, G (2003) Household preferences for energy-saving measures: A conjoint analysis. "Journal of Economic Psychology", 24(1), 49-64.

Stafford, A, Gorse, C and Shao, L (2011) "The Retrofit Challenge: Delivering Low Carbon Buildings". The Centre for Low Carbon Solutions. York.

SDC (2006) "Stock take: delivering improvements in existing housing". Sustainable Development Commission. London.

Utley, J and Shorrock, L (2008) "Domestic energy fact file 2008". Building Research Establishment. Watford.

Van Raaij, W F and Verhallen, T M M (1983a) A behavioral model of residential energy use. "Journal of Economic Psychology", 3(1), 39-63.

Van Raaij, W F and Verhallen, T M M (1983b) Patterns of residential energy behavior. "Journal of Economic Psychology", 4(1–2), 85-106.