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Co-designing the next generation of home energy management systems with lead-users

Andrew D. Peacock [a,*], Joel Chaney [a], Kristin Goldbach [b], Guy Walker [a], Paul Tuohy [c], Salvador Santonja [d], David Todoli [d], Edward H. Owens [a]

[a] The School of Energy, Geoscience, Infrastructure and Society, Heriot–Watt University, Edinburgh EH14 4AS, United Kingdom
[b] User Behaviour and Field Trials, Division Electrical Energy Systems EES, Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany
[c] Energy Systems Research Unit, Mechanical and Aerospace Engineering, University of Strathclyde, Glasgow, G1 1XJ, United Kingdom
[d] ITI – Instituto Tecnológico de Informática, Ciudad Politécnica de la Innovación – UPV, Camino de Vera, s/n. Ed / Bldg. 8G. Acc. B – Nivel 4, 46022 Valencia, Spain

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ABSTRACT

Home energy management systems are widely promoted as essential components of future low carbon economies. It is argued in this paper that assumptions surrounding their deployment, and the methods used to design them, emerge from discredited models of people and energy. This offers an explanation for why their field trial performance is so inconsistent. A first of a kind field trial is reported. Three eco communities took part in a comprehensive participatory design exercise as lead users. The challenge was to help users synchronise their energy use behaviours with the availability of locally generated renewable energy sources. To meet this aim, a set of highly novel Home Energy Management interfaces were co-designed and tested. Not only were the designs radically different to the norm, but they also yielded sustained user engagement over a six-month follow-up period. It is argued that user-centred design holds the key to unlocking the energy saving potential of new domestic technologies, and this study represents a bold step in that direction.

1. Introduction

1.1. Background and context

Reducing greenhouse gas emissions is a defining global issue. It is becoming increasingly apparent that targeted reductions will only be met if behavioural factors associated with energy use are better understood. The EU has set ambitious goals for reducing its greenhouse gas emissions, with reductions of between 80 and 95% by 2050 targeted (EU, 2011). This is mirrored by policy initiatives in most member states. The UK Government, for example, has legislated for a reduction of no less than 80% by 2050 in its 2008 Climate Change Bill (DECC, 2015a). Scenario analysis has been conducted to explore the major technical, social and economic changes required to meet these targets and one transition consistently emphasised is the human factor (Ekins et al., 2013; Foxon, 2013). The issue cannot be understated: for these emissions targets to be met, it is imperative that residential energy consumers play a more active role in the operation of the energy network. This is very likely to occur through greater acceptance of smart technology whereby appliances and heating systems are remotely controlled to benefit energy network management. In tandem, householders will be actively encouraged to change their pattern of energy use, facilitated by improved quality and relevance of information regarding their energy consumption and through the introduction of incentivised tariff schemes (Peacock and Owens, 2014). New methods of communicating to households about how they are interacting with the surrounding energy network will have to emerge.

The Orchestration of Renewable Integrated Generation in Neighbourhoods (ORIGIN) project, of which this research forms a part, explored how the increasingly active role required of the householder might become manifest. This role includes actuated, informational and incentivised methods of modifying patterns of

* Corresponding author.
E-mail addresses: a.d.peacock@hw.ac.uk (A.D. Peacock), j.chaney@hw.ac.uk (J. Chaney), Kristin.Goldbach@ise.fraunhofer.de (K. Goldbach), paul.tuohy@strath.ac.uk (P. Tuohy), ssantonja@iti.es (S. Santonja), e.h.owens@hw.ac.uk (E.H. Owens).

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consumption. The project is highly novel in that it involves three eco-communities; the Findhorn Foundation in Northern Scotland, the Damanhur Community in Northern Italy and the Tamera Biosphere in Southern Portugal. These communities represent a sample of highly engaged energy users whose insights could help drive out user-centred design solutions for all. This paper describes the process and outcomes of a participatory design process that sought to understand how information should be devised and communicated to individuals in those communities in order to encourage greater proportions of energy to be consumed from locally deployed renewable generation systems. The effectiveness of the developed informational systems was then assessed by examining the user experience coupled with usage statistics in each community.

1.2. Communicating information about energy use to households

Information on energy usage, for the majority of domestic consumers, is invisible on three levels:

i. The method of delivering energy to the home is invisible. It arrives unseen through wires and pipes which themselves are concealed in the building fabric. Consumers do not see the actual energy, or indeed the consequences of its consumption, just the indirect outputs some of which are counterintuitive. For example, some low power devices will consume more energy because they are left on all the time, or require some form of information infrastructure (like the internet or the cloud) which also consume power.

ii. The services to which energy consumption is directed are often habitual in nature, rooted in unquestioned social practices and routines (Strengers, 2011; Gram-Hanssen, 2008; Shove and Walker, 2007). These include matters such as cleanliness and conventions around clothes or dishwashing, for example. Social practices such as these make it difficult for consumers to establish linkages between their (unquestioned) activity and their actual consumption.

iii. Finally, over half of UK dwellings purchase their electricity via an automated monthly transaction between the householder's bank and their electricity retailer (DECC, 2015b). This further removes the direct link between behaviours and consumption.

As a result of these three features, householders can be unaware that a commodity has been delivered; unaware that they have used it; and unaware that they have purchased it. Home energy monitoring (HEM) systems have been promoted over the last two decades in part to overcome these invisibility issues. In policy terms HEM systems are seen as a key enabler in the transition towards active electricity consumers (Stern, 2007). Under the provisions of the EU Third Energy Package, member states are required to prepare a timescale for the deployment of intelligent metering systems, comprising some form of HEM implementation (European Commission, 2014). In the UK, for instance, intelligent metering will be fitted to all dwellings by 2020 (a process underway at the time of writing) and their deployment is anticipated to result in a 8.1TWh (1.8%) reduction in total household energy consumption (DECC, 2014). While a certain common-sense engineering logic is understandable - after all, if consumers are given explicit information why wouldn't they change their behaviour? - the evidence-base is far more uncertain. A wide range of studies have examined the efficacy of providing energy feedback and other information to consumers and the resulting changes in their behaviour. Some of these have been extremely ambitious and large-scale in nature. Faruqui et al. (2010), for example, reports on 12 energy feedback trials of varying duration, motivation, participant demographics, hardware and software configuration, conducted in the US by utility companies over the space of 22 years from 1989 to 2011. The average savings reported by each program ranged from 0% to 18%. This is far more modest than is often anticipated. Equally ambitious studies such as Darby (2006), Fischer (2008), and the work of Ehrhardt-Martinez et al. (2010) which reviewed pilot trials going back as far as 1977, reveal mixed findings. Energy savings were found to range from 0% (i.e. zero change in energy-use behaviour despite the often substantial investment in HEM technology) to a maximum of 32%. This level of uncertainty from controlled field trials is indicative of an unstable technology and a sociotechnical system which is not yet fully understood. This becomes even more manifest when the longitudinal effects are examined (Faruqui et al., 2010). The majority of trials only monitor householder responses for relatively short periods of time (less than 4 months). In a 15 month pilot trial in the Netherlands approximately 40% of participants were no longer interacting with their HEMS at the conclusion of the study (Van Dam et al., 2010). A UK trial found that consumer engagement could be extended by developing interactive usage strategies, such as the weekly input of data from the gas meter (Burchell et al., 2014). Despite this 30% of users had disengaged after 12 months. Not unsurprisingly, participants who had become disengaged provided negative feedback for the displays they had been provided (Darby, 2006). Research consistently shows that HEMS displays are not well designed (e.g. Wallenborn et al., 2011) and that users are frequently excluded from the design process. Karjalainen (2011) stresses the point that a “one-size fits all” strategy cannot be justified in the selection of HEMS design concepts, a point reinforced by Hargreaves et al. (2010) who observed that a participant's style of engagement with HEMS was gender and age specific. In a Norwegian study, differences between various types of households in their interactions with in-home displays were detected based on their level of affluence and their previous interaction with household energy data (Westskog et al., 2015). Fischer (2008) and Stromback et al. (2011) both identify a wide range of other HEM characteristics that play a role in their effectiveness. The challenges, then, are both significant and clear. Common to the majority of these previous HEMS studies is an underlying theory or model of human behaviour that this paper seeks to explore more fully.

1.3. The information deficit model

Why is there a sometimes significant gap between what should be common sense and the practical realities of domestic energy consumption? Why do domestic energy users not behave in ways that engineering logic would suggest is rational? The answer appears to lie in the assumptions contained in the Information-Deficit Model (IDM: Hargreaves et al., 2010). This assumes that the householder, once in receipt of the ‘correct information’, will make rational, economic decisions about energy consumption based on their individual attitudes and beliefs. Despite this model running counter to over forty years of research in decision making and cognitive biases (e.g. Kahneman, 2011), and the model itself widely debunked (e.g. Strengers, 2011; Hargreaves et al., 2010; Gram-Hanssen, 2008), most HEMS research still relies on the assumption that if the ‘correct’ information is ‘made visible’ then users will respond in ways that are predictable and desirable. In order to advance the research agenda a stronger focus on user-centred design is required but the challenges involved in doing this are themselves significant (Pruitt and Adlin, 2010). A conventional and widespread approach to gaining an understanding of users is by collecting quantitative and qualitative data using a range of methodologies that may include surveys, focus groups, and semi-