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Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors

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ABSTRACT

This paper explores how UK householders interacted with feedback on their domestic energy consumption in a field trial of real-time displays or smart energy monitors. After examining relevant bodies of literature on the effects of energy feedback on consumption behaviour, and on the complex role of energy and appliances within household moral economies, the paper draws on qualitative evidence from interviews with 15 UK householders trialling smart energy monitors of differing levels of sophistication. It focuses specifically on householder motivations for acquiring the monitors, how the monitors have been used, how feedback has changed consumption behaviour, and the limitations to further behavioural change the householders experienced. The paper concludes by identifying significant implications for future research and policy in this area.

1. Introduction

In December 2009, the UK Department for Energy and Climate Change (DECC) announced its intention to roll-out 'smart meters', accompanied by free standing real-time displays, to all UK householders by 2020. As well as paving the way to a 'smarter' grid able to handle large amounts of distributed generation and improved demand management, this decision is justified by the assertion that: "These meters will provide consumers with real-time information on their electricity use to help them control consumption, save money and reduce emissions" (DECC, 2009, 7). Previous studies on the provision of feedback to energy consumers support this assertion, suggesting it can help to realise savings of between 5% and 15% depending on the quality and type of feedback provided (Burgess and Nye, 2008; Darby, 2006; Wilhite and Ling, 1995), but little is known about the processes through which these savings are achieved. Katzev and Johnson's (1987) observation that "our understanding of *how* feedback does or does not work remains unexplored or untested" (in Darby, 2006, 7, emphasis in original) still largely applies.

This paper represents one of the very first attempts to explore qualitatively how UK householders interact with real-time displays or 'smart energy monitors' (see also Kidd and Williams 2008; Anderson and White 2009a, 2009b). Drawing on interviews with 15 householders taking part in a 'Visible Energy Trial' (VET) in Eastern England, it sheds much needed light on how feedback from displays may be translated into action. At the same time, it also reveals how such a process can be thwarted by household dynamics often unrelated to energy use.

The next section explores published research on feedback in domestic energy use. Section 3 introduces the devices and methodologies used in the VET. Section 4 explores the qualitative findings from the trial focusing on the motivations of participants, how they used the monitoring devices, what behavioural changes this led to, and what limitations they experienced. Finally, Section 5 draws together key implications for further research and policy.

2. Making energy visible through feedback

Burgess and Nye (2008) argue that energy is 'doubly invisible' to householders. First, although *conceptualised* as a commodity, a social necessity or a strategic material (Sheldrick and Macgill, 1998), electricity in particular is an invisible and abstract force entering the household via often hidden wires. Second, most energy consuming behaviours are part of inconspicuous routines and habits (Shove, 2003) making it difficult for people to connect specific behaviours to the energy they consume. Despite the efforts of many householders to read their bills and meters (Kempton and Layne, 1994), in the absence of more transparent cues, energy should be understood as invisible to most average consumers.

Given these observations, a great deal of research and practical experimentation has attempted to make energy visible to householders through the provision of various kinds of feedback. This has included providing more informative bills (Wilhite and Ling, 1995), putting energy labels on domestic appliances (Boardman,

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2004); providing in-depth energy advice via leaflets, websites and face-to-face (Abrahamse et al., 2007; Brandon and Lewis, 1999; Darby 2003) and, most recently, through a range of in-home real time displays and monitors (Anderson and White, 2009a, 2009b; Mountain, 2006; OFGEM, 2009; Parker et al., 2008; Ueno et al., 2005; Wood and Newborough, 2003, 2007). Notably, these studies reveal the importance and success of providing feedback that is clear, immediate and user-specific (Darby, 2001), resulting in savings of between 5% and 15% (Darby, 2006).

The central assumption underpinning the majority of these studies is that the provision of feedback on energy consumption will raise awareness and thereby encourage individuals to make the rational decision to cut their consumption, to reduce costs and/or carbon emissions. This 'information-deficit' model is expressed clearly by Wilhite and Ling:

> Increased feedback→Increase in awareness or knowledge→Changes in energy-use behaviour→Decrease in consumption (Wilhite and Ling, 1995, 150).

The appropriate policy response to such a model is straightforward: filling the 'information vacuum' (Wilhite and Ling, 1995) with appropriate data, such as that provided by smart meters and visual displays.

This cause–effect model is widespread in the area of pro-environmental behaviour change debate, and empirical evidence provides some support for it. However, more sociologically and anthropologically grounded research suggests it neglects important dynamics of household practices that are critical to whether, and how, feedback might be used (e.g. Aune, 2007; Gram-Hanssen, 2004; Lutzenhiser, 1993; Shove et al., 1998). These studies suggest that whilst feedback is both necessary and valuable, it is not always sufficient to bring about changes in behaviour as it fails to acknowledge broader social and cultural influences on household energy use. Crucially, ethnographic research has observed differences of up to 300% in overall energy consumption between otherwise closely comparable households (Lutzenhiser, 1993; Gram-Hanssen, 2004), leading to calls for research and policy to address:

> the larger issue of the importance of the people in the home, and the social aspects of their energy use, as a determinant of the level of energy consumption. (Wilhite and Ling, 1995, 154)

The social and cultural practices of households, and their associated energy use, are influenced by a number of factors which may have no direct link with either energy or the environment. Factors include the 'cultural services' energy provides such as different meanings and practices attached to ideas of the 'cosiness' of homes achieved through lighting and space heating (Wilhite et al., 1996); the gendered ways in which men and women use appliances and, by implication, consume energy (Livingstone, 1992) which means that interventions to change domestic energy use may also produce unequal gender-specific impacts (Carlsson-Kanyama and Lindén, 2007; Cowan, 1983); and the vital role that specific appliances and associated energy consumption play in home-making (Aune, 2007).

A key aim in this literature is to understand the 'domestication' of technologies within the 'moral economies' of households (Lie and Sørensen, 1996; Silverstone and Hirsch, 1992). The concept of 'moral economy' recognises that different households, even if they are demographically and technically comparable, have different histories and social practices through which they have developed agreed norms and values, habits and routines which are normally unquestioned. Rather than being a neutral form of information provision, therefore, feedback on energy use acquires meaning through the discursive, interpretive lens of each household's cultural practices. This is a social process of questioning and re-negotiating pre-existing and well-established household values and habits; as with other examples of how formal or official information is decoded in the private sphere, there is no guarantee in this cultural circuit that the meanings intended by the communicator are those understood by the recipients (see Burgess, 1990; Burgess et al., 1998; Carvalho and Burgess, 2005). Opening the 'black box' of household practices (Darby, 2003) to better understand how feedback on energy consumption is interpreted, negotiated and acted upon (or not) in the everyday lives of householders requires a qualitative research strategy such as that outlined next.

3. Methodology: researching the visible energy trial

In 2006, the University of East Anglia (UEA) won a £3Million grant from the Higher Education Innovation Fund for a programme called Carbon Connections, to build research and development partnerships between private sector companies and academics to promote innovations in technologies and/or behaviour changes to reduce carbon emissions. The VET is a collaboration, part-funded by Carbon Connections, between a small entrepreneurial company developing a range of visual display monitors (Green Energy Options [GEO]), an academic consultancy (SYS Consulting Ltd. [SYSCo]) based in UEA, which specialises in data mining, British Gas who part-funded an extension of the trial into low-income households and the authors of this paper. Throughout 2008–2009, 275 households from across eastern England were recruited to trial three different smart energy monitors of varying levels of complexity (see Fig. 1).

The *Solo* is the simplest of the monitors and offers a monochromatic display providing a 'speedometer' to indicate instantaneous levels of electricity use; a 'milometer' which indicates the amount of electricity used each day expressed in kilowatt hours, pounds sterling or carbon dioxide emissions; and a 'fuel tank' enabling householders to set a daily budget which indicates whether this is being met or exceeded by displaying a tick or a cross symbol. The *Duet* has the same functionality as the *Solo* on its left-hand screen, but also includes a second screen which monitors boiler and radiator usage (this contains icons to show householders when the boiler or radiators are on, and also gives a percentage reading to indicate how much of the time – either over a 24-hour period or over the last 15 minutes the boiler and radiators have been operating) and up to 6 individual appliances. The appliances themselves must be plugged-in via a 'PlugBug' device, which transmits consumption data to the *Duet* unit.

The *Trio* has a full colour display with a very wide range of monitoring options. Whilst the *Solo* and *Duet* are designed for self-installation involving simply clipping-on a transmitter to the electricity meter and, in the case of the *Duet*, to the boiler as well, the *Trio* demands professional installation by an electrician and a computer specialist as it involves a more extensive transmission

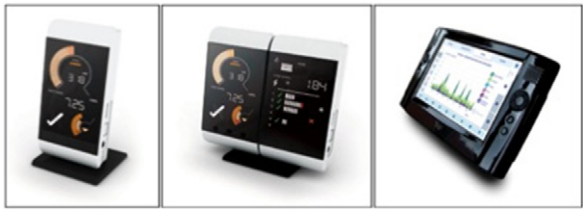

Fig. 1. GEO's smart energy monitors (showing from left to right: Solo, Duet, Trio).

system involving the household Wi-Fi system. Once installed it monitors heating, hot water usage (using the same system as the *Duet*), all electrical circuits in the home and up to 100 individual appliances (using PlugBugs). It can then display this information graphically, allowing householders to investigate their consumption patterns in more detail. For example, the *Trio* can display the consumption of a range of appliances over 24-hour or monthly periods, expressed in kilowatt hours, pounds sterling or carbon dioxide emissions. It should be noted that the display shown in Fig. 1 was still in development during the trial. Trial households were therefore provided with a small *netbook* personal computer.

Duet and *Trio* users were recruited in various ways including newspaper and internet advertisements, and at energy events and fairs. They were offered the monitors at a significantly discounted rate to secure participation: £75 for the *Duet* (later reduced to £50 to recruit further participants) and £250 for the *Trio* (later reduced to £150). The *Solo* was targeted specifically at low-income and elderly householders who were offered the device free of charge (funded by British Gas) and were recruited via local authorities and housing associations. In addition, a control group was recruited who had the *Trio* installed in their home free of charge, but were given no interactive display. The control groups were offered a full report on their domestic energy consumption at the end of the trial to help secure their participation. In total, 275 households were recruited with 75 households trialling the Solo, 75 trialling the Duet, 76 trialling the Trio and 49 in the control group.

In the trial, real-time data on energy use are being collected over a one-year period on which quarterly analyses will be performed. At the time of writing, however, quantitative results are not yet available. We do intend to follow this paper with a publication focussing on these quantitative outcomes. Nonetheless, alongside these quantitative analyses, we recruited 15 households through a stratified random sampling procedure to take part in semi-structured interviews with us. Four interviewees were chosen from each of the *Solo, Duet* and *Trio* groups, and three interviewees from the control group. Summary details of all interviewees are provided in Table 1.

The interviews lasted between 30 and 60 minutes. Six were conducted face-to-face either in the participants' home or workplace, and nine were conducted by telephone. Participants were asked to comment on what motivated them to take part in the trial; how their household had used the device; whether or not the device had changed their energy awareness or behaviour; and if they had any suggestions to help improve the device. The interviews were digitally recorded and transcribed verbatim. A grounded theory approach (Strauss and Corbin, 1997; Charmaz, 2006) was then used to analyse the transcripts and identify themes common across different households and devices. The findings of this analysis are presented in the next section.

4. Findings: interacting with smart energy monitors

This section will be divided into four subsections focusing, respectively, on the reasons interviewees gave for taking part in the trial; the ways in which the devices were used in their households; how they felt the devices had affected their energy consumption behaviour and the limitations they experienced that inhibited further use of the monitors.

4.1. Motivations for participating in the trial

Interviewees described four distinct motivations for taking part in the trial: financial, environmental, information gathering, and technological. In most cases, there was more than one reason and interviewees often volunteered that other household members were interested in the devices for different reasons (see Section 4.2). Not surprisingly, the reasons people gave for participating in the trial were critical in shaping what they expected from the monitors, how they used them and how they evaluated their effectiveness.

Financial considerations were uppermost in people's minds, especially among *Solo* users who had often been told the device would help them save money. Potential disappointment arose because participants were expecting to see large rather than small savings; several commented that advice to switch off lights or reduce standby consumption only 'saved pennies' where they "wanted to save pounds or even tens of pounds really" (T1, p. 2). Interviewees also expressed frustration that rising energy prices had prevented the behavioural changes they were making from translating into savings.

Table 1
Summary of Interviewees.

ID[a]	Group	Gender	No. of household occupants	Ages of permanent occupants	Household income (thousands £)	Household type	Ownership	Year house built	Months using the monitor
S1	Solo	M	2	61, 57	20–30	Bungalow	Housing association	Pre-1964	3
S2	Solo	F	2–4	60, 59	0–10	Semi-detached	Housing association	Pre-1964	1
S3	Solo	M	2	73, 71	20–30	Detached	Owner	Pre-1964	2
S4	Solo	M	2	61	10–20	Bungalow	Housing association	1965–2001	3
D1	Duet	M	4	37, 35, 8, 5	50+	Semi-detached	Owner	Pre-1964	6
D2	Duet	M	5	49, 48, 21, 19, 16	50+	Detached	Owner	1965–2001	4
D3	Duet	M	2	60, 46	30–50	Detached	Owner	1998	7
D4	Duet	M	4	41, 39, 6, 3	50+	Terraced	Owner	1890	7
T1	Trio	F	2	57, 44	50+	Detached	Owner	1965–2001	4
T2	Trio	M	4	36, 36, 6, 2	50+	Semi-detached	Owner	1965–2001	12
T3	Trio	M	1	29	30–50	Terraced	Owner	Pre-1964	9
T4	Trio	M	1–4	37	0–10	Terraced	Rental	2007	7
C1	Control	M	2	45, 44	30–50	Detached	Owner	1965–2001	12
C2	Control	F	2	62, 61	20–30	Detached	Owner	1965–2001	5
C3	Control	M	2–8	54, 40	50+	Detached	Owner	Pre-1964	6

[a] Throughout this paper, this unique identifier will be used to label quotations drawn from the interviews.

The second most commonly expressed motivation was environmental.

> The cost isn't too much of a problem 'cos we just pay it and that's what it is. But the environmental aspect of it – yeah, it is definitely one of the major considerations. (T2, p. 1)

The actions taken by this group of participants differed little from others with different reasons for taking part; however, the environmentally motivated interviewees were the only group of participants for whom energy saving behaviour appeared to 'spill-over' beyond the domestic setting (see Section 4.3). For example, many of those who expressed an environmental motivation said they had also tried to drive or fly less, had bought smaller cars, or had attempted to encourage their friends or family to cut emissions themselves.

A third motivation was a desire to gain more information about household energy consumption. Although not exclusively, this motivation was particularly apparent amongst the *Trio* users. For these people, participation in the trial was merely the next step in a longer journey of collecting information and monitoring their domestic energy consumption. Several interviewees already took regular meter readings and analysed them to provide detailed breakdowns of consumption. Several had already got basic, real-time display devices in their homes; in this sense taking part in the trial represented a kind of upgrade. This group of participants was often critical of the amount of information the devices provided and the manner in which it was displayed. For example, several wanted the devices to be more interactive, enabling the user to extract whatever information s/he desired.

Finally, a fourth motivation stemmed from interest in the technology itself, either for professional reasons or because it represented 'another gadget'. This group of participants appeared particularly concerned by the aesthetics of the monitors, often praising the *Solo* and *Duet* for their appearance and their use of coloured graphics. In contrast, the *Trio,* in its trial form as a small netbook PC, was widely criticised on these grounds. This response suggests that, in addition to their utility, the monitors themselves may in some cases be treated as commodities in their own right. This raises further questions about how well the monitors fit into existing household aesthetics and home-making practices (Aune, 2007). There are also serious issues in terms of the extent and regularity with which some householders may wish to upgrade their monitors' functionality and appearance. It is entirely possible that consumers will demand visual display monitor upgrades with all the product life-cycle implications that would entail.

4.2. Using the monitors: who, what, when and where?

When asked which features of the monitors had been useful, interviewees commented in various ways about the unhelpfulness of absolute measures of electricity consumed. One participant argued that the 'milometer', which displays daily consumption, showed figures that were too small to provoke any action:

> I guess that's 21p so far today - but that number really isn't big enough. I think it needs to be a bigger number to actually, you know, worry people. (D1, p. 22)

However, this interviewee also commented that the monthly or annual usage forecasts, based on an extrapolation of instantaneous demand and which therefore shift very rapidly, became enormous when the kettle or tumble drier was being used, were unrealistically large and therefore equally unhelpful. This occurred regardless of whether users had opted to view their consumption in terms of kilowatt hours, carbon dioxide emissions or money. Kilowatt hours and carbon dioxide emissions were both dismissed as being 'meaningless':

> A kilowatt hour to most people is an abstract figure, isn't it? Whereas pounds and pence, you know what you're spending. (D3, p. 5)
>
> I guess that's kilograms of carbon but I can't relate to that. I don't know what that means… it just looks like a number to me. (D1, p. 22)

Money was the metric of choice for most interviewees but, even so, several expressed dissatisfaction because the figures displayed were inaccurate. This was usually because the interviewee did not know the costs and had not programmed their own tariff details into the monitor, or because they were unaware of how to programme the devices to cope with dual rates.

Whilst there was apparently little interest in feedback on absolute measures of consumption, interviewees did find the 'fuel tank' symbols on the monitors engaging (cf. Anderson and White, 2009a, 2009b). Several *Solo* and *Duet* users said they looked at the monitors regularly to see if the tick or the cross symbol (indicating whether or not the household is on target to meet a self-selected budget) was being shown:

> [The monitor] actually shows a tick on the unit if you're in credit on the day. So we're looking at that, you know, at least every day or several times a day. If you get a cross that means you've used your credit up. (S4, p. 9–10)

As this quotation illustrates, several interviewees used familiar financial metaphors, such as being 'in credit' or 'in the red or the black', as an interpretive framework for the feedback the monitors provided. Whilst this does suggest that the monitors were being used effectively and were helping to promote energy-saving, the potential stress such symbols might place on low-income users and the fuel poor, as they can, quite literally, watch their money being spent, should not be underestimated. One interviewee – a member of the control group but who took regular meter readings and carefully monitored his electricity use, a situation heightened during participation in the trial – expressed this potential source of anxiety in a dramatic metaphor, referring to his wife:

> She could kind of feel the money seeping out every time she had the boiler on. And to be honest beating herself up over it, you know. 'I can't have it on because I'm wasting money, but I'm cold'. (C3, p. 4)

A second common way in which interviewees used the devices was to learn about how much electricity was being used by specific appliances. For *Duet* and *Trio* users, appliance-specific monitoring was built into the visual display through the PlugBug devices. *Solo* users, on the other hand, explained how they had used the 'speedometer' dial as a means of calculating the additional load created by, for instance, turning on the kettle or tumble drier.

> To pick them [my computers] out as individual segments of our electricity use was quite good. (D4, p. 12)
>
> I've been interested in how it monitors the appliances, that's what I've found most interesting… you should be able to monitor everything all the time. (T1, p. 2)

As these quotations suggest, whilst not especially concerned about the total volume of consumption, interviewees were very interested in how 'greedy' particular domestic appliances were. Several commented on their sudden realisation that the kettle, the tumble dryer, or an old fridge-freezer used significant amounts of energy. The crucial issue in these cases, as one interviewee

described it, was the monitor's ability to make energy use 'relational' (T4, p. 11). Comparisons between the energy consumption of specific domestic appliances made sense in a way that kilowatt hours or CO_2 emissions could not.

A key concern with visual display monitors is that after an initial period of intense interest, their usage will fall off to almost nothing. This tendency was evident to a certain extent in our interviewees' self-reports. All of the devices provoked great interest when first acquired:

> When I first got it I was a bit obsessed with it! It was a new gadget and I'd constantly be telling people about it… I was probably a bit of a bore. (T1, p. 2)

All interviewees, apart from those in the control group, commented that they had played with the device at first to learn what it could do and what difference they could make to their consumption patterns. After this initial period, however, a difference emerges between *Solo* and *Duet* users on the one hand, and *Trio* users on the other. The former all reported their initial phase of engagement had given way to less frequent, but still repeated and regular usage.

> I probably used it more when we first got it… [but then] you develop habits to switch things off and keep the lights off – and then you don't need to look at it so much. (D1, p. 13)

In the case of the *Trio*, however, interviewees commented that after their initial interest they consulted the monitor only rarely now. Two major reasons were given to explain this. The first related to where the monitors were situated in the home. *Solo* and *Duet* users talked at length of the need for the device to be placed where it can be seen and used regularly,

> rather than out-of-sight out-of-mind, it needs to be in a position where you can't miss it. (S1, p. 24)
>
> We stuck it in the hall. I think the biggest mistake you could probably make is to stick it somewhere where it wouldn't get seen…. It keeps it front of the mind. (D2, p. 10)

For most households, this meant positioning the monitors in the kitchen, hallway or lounge where they were in the 'corner of your eye' (D1, p. 13). The ability to move the monitors around so they could be optimally sited for the household was, therefore, seen as critical to their effective use.

All three visual energy display monitors in this study can be placed anywhere in the home, however, so this reason alone does not explain why usage of the *Trio* dropped off more severely. Here, the second reason becomes significant – discussed in various ways relating to the appearance, design or aesthetics of the device. Whilst visual appearance of the devices was a key motivation for only a few interviewees (see Section 4.1), many interviewees praised the *Solo* and *Duet* monitors for their colourful displays, clear and comprehensible graphics, and general appearance. As the following quotation illustrates, the design features also helped to capture and retain householders' attention:

> This one is actually backlit with colours. So its more striking and you feel like you've got to do something about the problem that is presented for you. (S1, p. 11)

On this issue, however, the *Trio* monitor performed less well. *Trio* owners in the study expressed disappointment at the appearance of the netbook PC; they had hoped to receive the touch screen display shown in Fig. 1 but technical issues with production had prevented this from happening. Crucially, the relative unsightliness of the prototype *Trio* monitors led to them being placed out of view. As the following quotation shows, this was often the result of negotiations between household members over what looked 'neat and tidy', and the extent to which the *Trio* prototype blended into the aesthetic standards of the home:

> It was on top of the TV for the first two to three months I guess – maybe a little bit longer. Then [my wife] decided we'd have a re-organise so then it gets put down onto a lower shelf at the front. Then it was opened up – and then she's slowly closed the lid… Then she puts it at the back and you don't see anything – and all of a sudden, it's out of the way. (T2, p. 6)

Two of the four *Trio* interviewees said they still used it regularly; in both cases, a high level of IT competence had allowed them to configure the device so they could access their feedback from their own personal computers rather than relying on the netbook distributed as part of the trial.

In short, irrespective of the level of feedback the monitors offered, the relationship between their aesthetics and their location within the household appeared to be central to their usage. One user referred to this as the need to build the monitors into 'the fabric of the home' (T1, p. 6). One consequence of being able to design the monitors into the home context emerges from interviews with some of the *Solo* and *Duet* users. When first asked, several replied that they did not really use the monitor at all:

> Well we haven't really thought about it really – it's no different from when we didn't have it, you know. (S2, p. 6)

When questioned more deeply, however, it became apparent that the interviewees had, in fact, used them a great deal and could talk eloquently about how they did so. One potential explanation for this initial hesitance is that several people argued they had developed new habits around their use of the devices and so, no longer needed to check the monitor. Although further research is necessary to fully determine the long-term effects of such devices, if the devices can indeed be designed and/or customised to fit into 'the fabric of the household', then new, long-term habits have the potential to emerge around them.

All 12 interviewees in the study with a display, explained how it was used differently by different members of the household. In most cases there appeared to be a single, dominant user of the monitor—usually the man. Throughout all the interviews, it was clear that all three monitors appealed most strongly to men, as one interviewee commented, without any obvious ironical intent:

> D3: I must admit it's mainly blokes [who've shown an interest in it].
>
> I: Why do you think that is?
>
> D3: Oh, we just like flashing lights and fiddling with knobs and things, don't we? (D3, p. 5)

Given the devices were designed around the concept of a car dashboard, the gender-specific appeal may be intentional. It did, however, appear to militate against female engagement with the monitors, with many of the men interviewed declaring that their female partners either could not understand, or were not interested in the monitors:

> My wife's not particularly interested in it. (D4, p. 9)
>
> I've shown it to my Dad who would like it, who would be monitoring it 24/7 – which is why my Mum doesn't like it…. If he had that information, my Mum…wouldn't dare put the television on and watch it, you know – [he'd be saying] 'it costs 2p to watch that TV programme'. (T4, p. 11–12)

This gender bias was not true in all cases however; several interviewees did mention that different household members

were interested in the monitors for quite different reasons. For example:

> I: It sounds actually like everyone has used the device?
> D2: Everyone but my eldest son who really couldn't care but he's a guitarist. I mean he really is, and he's a 21 year old. To be fair, my wife and daughter are the most conscientious. My daughter for the school reasons, that she's still at secondary school and she is the most environmental. My wife for cost reasons, me for both, and my two sons, who are 19 and 21 – I think it just nags them to turn the lights out. (D2, p. 8–9)

The *Solo* and *Duet* monitors were thought to be good for young children as the colours and the dials, and particularly the tick and the cross symbols, were easy to understand. Two interviewees said the devices had been valuable for school projects, and suggested that 'pester power' had some effect in encouraging the whole household to pay more attention to the monitor. As the quotation above illustrates, older children were generally seen as harder to engage. In this specific example however, the value of any energy savings realised were being factored into the older children's housekeeping payments and this, it appeared, had been critical in encouraging them to join in.

Some families in the trial reported holding regular and cooperative discussions about how best to save energy. More commonly, however, the devices were used by a single household member and had led to more difficult and contested household discussions (see Section 4.4). Given the strength of intra-household resistance to such monitoring devices, having only one household member engaged with the monitors and promoting their use may be insufficient to bring about significant and lasting changes to household practices.

4.3. Effects on behaviour

When asked whether or not the monitors had influenced their behaviour, all interviewees reported some changes and, regardless of the kind of monitor being used, three distinct types of behavioural response were mentioned: 'using it hot', making considered decisions based on the feedback provided and 'spill-over' to other lifestyle areas. These will be addressed in turn.

The first, and most commonly reported, of these was described by one interviewee as 'using it hot' (T1, p. 3). Here, whenever the monitors were perceived as giving a high reading, householders would immediately react by going around the house and switching things off. Whilst this appears a simple, reactive behaviour, interviewees noted several factors which made it possible. First, it required prior identification of a baseline of domestic energy use the householder was comfortable with. Several interviewees said the monitors had made them aware of how much energy was required just to keep things ticking over:

> It is a bit of an eye-opener just to see what – you know – the electricity that you use when you're doing nothing. (D3, p. 2)

Some interviewees referred to this as a 'natural' baseline about which little could be done, and against which 'unnatural' levels of consumption could be identified:

> Sometimes you see things that are unnatural, that was different to yesterday, so I'll go round and investigate and stuff like that. (D4, p. 18)

Only after the baseline had been established were interviewees able to react to the information the monitors were providing. People talked about this process as bringing energy consumption to the 'front of mind' or as a 'focusing of the mind' (D4, p. 22). The monitors did not necessarily offer individuals *new* awareness or insight into their energy consumption, as this already existed. Instead, they merely provided a visual prompt or trigger for behavioural responses:

> The device hasn't changed our awareness in that respect because we've always been aware of it…. It's a visual cue that if you haven't done something… it's just focusing I think, focusing the mind. (D4, p. 22)

One interviewee referred to this as the 'nag factor' (D2, p. 14). It explains the importance of locating the monitor where it would be seen routinely, and the need for the device to look good (see Section 4.2).

The second kind of behavioural change mentioned by interviewees was a more considered, rational response and involved planning the household members' daily routines and purchases in order to cut energy consumption. In a few cases, interviewees spoke of holding regular 'analysis talks' (D2, p. 9) during which prior consumption levels were scrutinized and decisions were made about how consumption might be reduced. This took several forms. Most commonly, householders used the monitors to identify 'greedy' appliances, and then either disposed of them, or began using them differently. A second response was to develop future plans to improve efficiency and thus reduce the 'natural' baseline level of consumption. Almost all interviewees suggested that using the monitors had made them realise the value of ensuring any newly purchased appliances were as energy efficient as possible. Further, the monitors appeared to have prompted a great deal of interest in various forms of micro-generation such as solar thermal or photo-voltaics and small wind turbines.

Third, although much less common, interviewees reported using feedback from the monitors in order to plan new routines or change lifestyle practices as a means of cutting domestic energy consumption. As the following quotations illustrate, some suggested the monitors encouraged them to 'think ahead' and to 're-prioritize' certain aspects of their everyday routines in order to reduce consumption.

> 'I'll tell you what, we'll do the washing tomorrow – you know – we'll just have sandwiches tomorrow'. So in that respect we're thinking ahead if you like. (S1, p. 20)

> I am so aware of how much I'm using that I think to myself well do I need to? Do I need to put my light on right now? Can I still sit here in the dark and work by candlelight? Do I need to watch *Eastenders*[1] tonight, you know? Sometimes it gives me the motivation to get on with other things as opposed to just sit down and maybe relax. (T4, p. 20)

Given the policy interest in smart meters and real-time displays as enablers of load shifting and more active demand management, this kind of response is encouraging. As mentioned, however, this kind of response was rare, even among the early adopters in this sample. A more common response was to suggest that such changes were impossible (see Section 4.4).

Finally, the least common behavioural effect of the monitors was to motivate changes in consumption either in other lifestyle areas, or to prompt interviewees to encourage other people to reduce consumption. This type of response represents a form of 'spill-over' (Thøgersen and Ölander, 2003). There were relatively few examples of this in the interviews and the examples given were very specific to interviewees whose primary motivation for taking part in the trial was to cut their carbon emissions. The monitors encouraged interviewees to consider the climate change

[1] Eastenders is a long-running British soap opera.

impacts of other lifestyle practices, and particularly transport. As the following quotation suggests, however, in these cases there was frustration at the difficulty of understanding what impact cuts to domestic energy consumption had in comparison to changes in other practices:

> One thing these devices haven't told us is how to put our energy usage in the context of other things that we do like driving, flying, using water, using gas. (D1, p. 17)

The second form of spill-over among this sample emerged from a financial motivation, as interviewees encouraged close friends and family to cut consumption and thus reduce their expenditure. These discussions were confined to close social relations and not with work colleagues for example. Interviewees were quick to distance themselves from accusations that they were 'preaching' to others and, in most cases where this form of spill-over was mentioned, there was a sense of resignation that such appeals fell on deaf ears.

As this sub-section has shown, all of the monitors appeared to have a noticeable effect on behaviour. Quantitative results from the trial are yet to be calculated but, given the kinds of behavioural effects reported, it would be difficult to imagine that these will exceed the 5–15% savings found in previous studies (Darby, 2006). Indeed, as the next section will show, as often as they spoke of positive behavioural changes resulting from the monitors, interviewees commented on difficulties they confronted.

4.4. Limits to change

Throughout the interviews, participants mentioned numerous issues that limited their ability either to change behaviour at all, or to change it still further. As (Shove, 2010) observes, it would be unwise to characterise these limitations as 'barriers' to change because, as will be seen, in many cases they represented core and occasionally cherished aspects of domestic practices. We will highlight four categories of limitation common to interviewees regardless of which device they were using.

First, many interviewees commented that certain appliances, however 'greedy', were necessities that could not be discarded. Such necessities ranged from kettles to fridges to tumble driers and fish-tanks. Each household had a different list. Further, several interviewees mentioned that they, or other household members, suffered from medical conditions that demanded the house be heated to a certain level, for instance. Throughout, there was a sense interviewees felt they simply did not have control over certain aspects of their energy consumption. In some cases this apparent lack of control, compounded by the monitors regular and visible reminders of how much electricity was being used and how much it was costing, was seen to generate anxiety among interviewees that they were spending too much money or harming the environment.

The second limitation is related to the first but, instead of feeling certain appliances or activities to be a necessity, use was seen as justifiable and reasonable. Several interviewees, for example, mentioned that there was only so much they felt they should be expected to do, after which the message from the monitor would be unwelcome. This sentiment was encapsulated by many interviewees in the phrase 'life is for living':

> There are some things you just can't change. So, as I say, I have my fish-tank and the fish need a pump, and I cook so I can't really change that. I mean, I think that life is for living and I don't want to become obsessive about it or like Scrooge or anything. I want to enjoy living and working in my house. (T1, p. 3)

Here, interviewees emphasised the importance of a comfortable, warm and well-lit home. Again, exactly what this comprised varied enormously between participants with computers, televisions, bread-makers and Venetian lamps among other things being seen as non-negotiable.

Another aspect of the non-negotiability of certain lifestyle practices relates to particular temporal rhythms of the household. Some interviewees argued they could do nothing about the 'natural' peaks and troughs of energy consumption that occurred in the mornings, evenings, and at weekends. Further, most felt that it was unreasonable to expect such natural rhythms to change:

> For me, I go home and I've got a few things – like cooking – that I need to do – like watching the football – and I'm going to do that regardless. (T3, p. 15)

These comments illustrate some of the challenges faced by those who suggest smarter meters might encourage load shifting. When asked about this directly, all interviewees said they would require significant financial incentives before they would even consider changing the times of certain practices, and many commented that they had little control over when things occurred in any case.

The third limitation mentioned by interviewees related to family negotiations about consumption provoked by the monitors. In some cases, all the members of the household held 'analysis talks' to identify how energy savings might be made. More commonly, however, interviewees reported disputes between household members over particular issues:

> Well we have told them, you know, that [using the computer] puts the electric up – but what can you tell a 24 year old? (S2, p. 5)
> We have a family difference – my wife leaves them [lights] on and I switch them off. (S3, p. 2)

One of Carlsson-Kanyama and Lindén's (2007, p. 2170) participants refers to a dispute over the length of time spent under the shower as a 'war' between household members and, although the rhetoric was not so strong here, a few interviewees did note that the monitors had caused arguments.

> It's hard with this family because the wife is just not interested at all. Her reasons for this is 'just another gadget'. That's what she sees it as – and also for me to check what she's doing with the kettle…
> I had a lot of fun to start off with. It almost caused her to move out but, you know – she threatened me… some nasty language basically [*laughs*]. (T2, p. 11)

Although this is a relatively light-hearted example, the potential for monitors to allow new forms of surveillance between household members and feed into broader disputes is very clear. This kind of intra-household conflict must not be ignored in studies which evaluate the effectiveness of smart energy monitors and real-time displays. It is likely to be a significant drag on willingness to implement changes in energy consumption practices, as earlier evidence from an evaluation of the *Ecoteams* behaviour-change programme indicated (Nye and Burgess, 2008).

Finally, interviewees reported finding the broader social and policy context unsupportive. Several interviewees were frustrated because information they required to help decide whether purchasing a new appliance would ultimately save money or reduce carbon emissions was unavailable.

> Government policies get things totally wrong. They like to tell you how things are energy efficient. They've got this wonderful A–G scale, everything has got an energy marker. It doesn't

> mean a squid to me. I bought a television…okay it says energy efficient A – what does that actually mean in financial terms? How much electricity is that television using? Why doesn't it tell you? … If I don't know how much it's using, I can't work out how much it's going cost me to run. (T4, p. 4)

For interviewees who had educated themselves about their own consumption patterns, the wider market and policy environment did not seem to promote further intelligence. Many described choice situations for which they could find no ready answers. For example, does a low-wattage but slow-boiling kettle use more electricity than a high-wattage, fast-boiling one? Others wanted to know more about how much energy other households in their area consumed in order that they could benchmark or judge their own consumption patterns. Many felt they were 'doing their bit' but were being poorly supported by industry and government (cf. Hobson, 2001).

Interviewees strongly criticised appliance manufacturers for making devices that were difficult to switch off completely; housing associations and local authorities for planning policies which made it difficult to install solar panels, heat pumps or small wind turbines; housing developers for not automatically installing efficiency and generation measures in new homes; and they criticised the government and politicians for failing to match rhetoric with action on energy conservation and climate change issues. Many interviewees reported feeling as if they were on their own in attempting to save energy and reduce emissions. This sense of a lack of institutional support was used by some participants as a justification for not doing more:

> I think I'm probably much like everybody else thinking that, you know, it's one house and if we do change something it won't make a vast amount of difference – so we don't bother. (D3, p. 2)
>
> When you think of what we're doing, we're only tinkering at the edges really. (S3, p. 12)

Whilst these sentiments are routinely captured in quantitative and qualitative studies of public engagement with energy and environmental issues, it should be remembered that these interviewees, as with the other 260 participants in the trial, could be characterised as 'early adopters' of an innovation. If feelings of futility and pointlessness are being expressed by these folk, it is probable there will be major challenges ahead in persuading the wider population actively to use smart energy monitors as a means of reducing their electricity use and CO_2 emissions.

5. Discussion and conclusions

This paper represents one of the first qualitative field studies to be carried out with households who are learning to live with a visual energy display. Several direct policy implications are immediately apparent: that the monitors need to look good to fit in with the wider household, that the information they provide needs to be clear, transparent and flexible (i.e. presentable in a variety of formats and perhaps customisable) in order that it can be easily related to everyday practices and contextualised, that efforts should be made to address whole households rather than simply individual householders, and that the wider policy and business context should be seen as supportive of householders efforts (also see Kidd and Williams, 2008, Anderson and White, 2009a, 2009b). Nonetheless, whilst a simple functionalist and linear model of individual and rational decision-making resulting from the provision of feedback may be appealing to policy-makers, our qualitative evidence suggests that no such simple cause–effect relationship exists. The sample is small (15 households, of whom 12 had a display) but is representative of the full sample of 275 households in the trial. Our findings show how the monitors are domesticated into the physical domain, social relations and cultural practices of each household. Context is fundamental to understanding the extent to which change effects will be negotiated and realised (cf. Nye and Hargreaves, 2010). The evidence, taken from an experimental trial of an innovative technology, was dependent on the contingencies of the case – technological and production challenges, the commercial requirement that the devices were purchased, sensitivity over IPR of the streamed data, etc. Despite these caveats, we believe this field study raises a number of important issues. What is needed is a much larger study which combines qualitative and ethnographic research with quantitative measures of energy use to explore the range of life settings and contexts in which smart energy monitors are being used, and over significantly longer time periods. Our findings highlight four issues which could be the focus for further research and policy evaluation.

First, the extent to which households might be willing or able to engage in so-called load-shifting behaviours is a major preoccupation of engineers and others concerned with the expansion of renewable energy. If the wind fails to blow, would households be willing to go to bed in the dark? Forego cooked breakfast and coffee? Not watch *Eastenders*? What would it take to persuade them they could or should do such things? We cannot provide answers to such questions but we can point to the strong resistance to such ideas from our early adopter households—households already engaged and interested in learning more about their energy consumption.

Second, what do the visual energy display devices mean to their owners; to what extent are they attractive gizmos suitable for public display in the home, to what extent are they machines to help strategise about reducing energy consumption? The study demonstrates that form in these cases seems to trump function. The aesthetic appearance of the devices was central to the ways in which they were appropriated into 'the fabric' of different households. If the device did not look good enough it was hidden away and lost its power to communicate.

Third, far from being a neutral technology, the findings suggest that there are gender, and age-specific styles of engagement with the devices and what they are communicating. Men in households have typically taken responsibility for managing the physical, infrastructural and large financial commitments whilst women have jurisdiction over the furnishings, fittings, domestic routines and childcare (cf. Carlsson-Kanyama and Lindén, 2007). Whose energy use is 'legitimate', whose is not; how décor works to create a 'homely' home; how reductions in electricity use are to be made, and by whom, are in no sense trivial questions. They sit at the centre of the complex, dynamic negotiations through which households manage their social interactions and their joint project of living together (reasonably) harmoniously. Smart energy monitors can lead to greater co-operation and greater conflict among the members of the household. One lesson from the trial is that domestic energy consumption is a social and collective rather than individualised process. Future research should perhaps focus more on the household and less on the individual energy consumer, as the key unit of analysis. This might point to a strategy which focuses not on educating individuals about their energy consumption, but on fostering cooperative and energy-saving household dynamics.

Finally, our findings confirm that the illuminative properties of smart energy monitors extend beyond patterns of household energy consumption to shed light on complex relationships between people, the built environment and systems of provision and consumption. Deeper engagement with smart energy

monitors can promote feelings either of empowerment or disempowerment among householders. In some cases reported here, they appeared to have a positive effect, giving participants an increased sense of control and empowering them to take stronger action to reduce their own energy consumption, to discuss such matters with their family and friends, and to seek further information, advice and assistance from housing associations, appliance retailers and local authorities. The monitors appear to have had a positive effect on the surrounding context, making energy saving (and its financial and environmental benefits) appear easier to achieve, more desirable and, crucially, a normal aspect of using energy in everyday life. In other cases, however, the monitors appeared to make environmental and financial challenges seem larger and even more insurmountable, even among these 'early adopters' of the innovation. Here, the additional information the devices offered seemed to create a sense of fatalism, despondency, anxiety and even guilt among interviewees that what they could do was futile in the face of huge social, political and environmental problems. Smart energy monitors, it would appear, are only as good as the household, social and political contexts in which they are used. Ensuring that these contexts are supportive of changes in domestic energy consumption patterns seems vital if smart energy monitors are to realise their potential.

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