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OPENING THE BLACK BOX OF THE HOUSEHOLD: UNDERSTANDING HOW HOUSEHOLDERS INTERACT WITH FEEDBACK FROM SMART ENERGY MONITORS

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ABSTRACT

Current models of the role of energy feedback in helping to reduce energy use, assume it fills an information deficit in individual energy consumers' knowledge and thus encourages them, rationally, to reduce their consumption levels either to save money or the environment. Based on 15 semi-structured interviews with participants trialling a range of smart energy monitors with real-time displays in the 'Visible Energy Trial' conducted in Eastern England throughout 2008-9, this paper seeks to develop these models in two parallel, but potentially complementary, conceptual directions. First, building on the key finding from the interviews that the monitors in the trial were interpreted and used in very different and often unique ways in differently households, the paper explores ideas about the domestication of technologies within household moral economies as offering a more thorough explanation of the processes through which smart energy monitors come to be used (or not) in specific households. Second, based on the key finding that the monitors were in fact used by whole households collectively, rather than by individual energy consumers alone, the paper explores ideas about communities of practice as offering potentially helpful ways of understanding the social learning and negotiation processes provoked by energy feedback.

Keywords: Smart meters, energy feedback, domestication, moral economies, communities of practice, household energy use.

3S strands: sustainable consumption; sustainability transitions; participation and engagement

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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. With the smart meter roll-out projected to cost over £11bn to install and operate (National Audit Office 2011), it is therefore imperative that further research is conducted to understand its potential implications.

This paper is based on qualitative data collected from semi-structured interviews with 15 householders participating in a 'Visible Energy Trial' in Eastern England. The aim of the trial was to explore how householders actually use real-time displays, or smart energy monitors, and the feedback on energy consumption they provide. It thus sought to open what Darby (2003) terms the 'black box' of the household. Full analysis of the interviews is available in Hargreaves (2010) and Hargreaves *et al* (2010 in press). By contrast, this intentionally exploratory paper is based on two of the key findings of the interviews: i) that smart energy monitors are not neutral, unproblematic devices used in similar and easily predictable ways by all households, and ii) that the feedback such monitors provide is not read-off and acted upon by individuals, but is rather collectively interpreted, negotiated and acted upon (or not) by whole households. Building on these findings, this paper seeks to extend conventional understandings of energy feedback along two distinct but potentially complementary conceptual lines. First, in relation to understandings of the 'domestication' of technologies into household 'moral economies' (Silverstone *et al* 1992) which have not, so far, been applied to smart energy monitors and yet which provide crucial insights into how such technologies are actually used. Second, in relation to the concept of 'communities of practice' (Lave and Wenger 1991; Wenger 1998) which is helpful for understanding the situated and collective nature of learning and practice.

The next section outlines the existing literature on energy feedback, before section 3 provides details of the devices, participants and methodologies involved in the Visible Energy Trial. Sections 4.1 and 4.2 explore empirical findings from the interviews in relation to ideas about domestication and communities of practice respectively, before section 5, finally, briefly explores the potential linkages between these parallel bodies of theory and their implications for further research and policy.

2. ENERGY FEEDBACK STUDIES: OPENING OR CLOSING THE BLACK BOX?

A central problem in attempts to encourage householders to reflect upon and reduce their energy use is that energy, and particularly electricity, can be conceptualised as 'doubly invisible' (Burgess and Nye 2008). It is invisible first, because of its physical properties and the fact that it is often brought into households through hidden pipes and wires. It is invisible second, because the nature of current metering and billing systems (in the UK at least) makes it very difficult for householders to make connections between their energy use and specific energy using household appliances or practices.

This problem has led to a great deal of work that seeks to make energy visible to households through the provision of various forms of feedback such as providing more informative bills (Wilhite and Ling 1995), putting energy labels on domestic appliances (Boardman 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 2009; Mountain 2006; OFGEM 2009; Parker *et al* 2008; Ueno 2005; Wood and Newborough 2003, 2007). These studies have shown that, depending on the nature and type of feedback provided, average savings of between 5 and 15% of overall energy use can be realised (Darby 2006).

Such studies have tended to rest on the assumption that feedback on energy use fills an 'information deficit' among individual householders and that, learning from the new information different forms of feedback provide, individuals will rationally reduce their consumption levels to save either money or emissions. Wilhite and Ling (1995) express this linear and rationalist model very clearly:

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

Whilst savings of 5 to 15% are encouraging, studies of domestic energy use developed within sociology and anthropology, and based on less individualist and rationalist assumptions, argue that such linear portrayals neglect vitally important household dynamics that not only account for far more than 15% of use, but are also critical in attempting to understand how households will interpret and use any feedback they are given. Gram-Hanssen (2004) for example, observed differences in overall levels of energy consumption of up to 300% between otherwise very similar households (see also Lutzenhiser 1993).

These kinds of findings demand that research looks beyond narrow, linear models, and instead starts to explore what is actually going on within households. Instead of asking how they can improve forms of feedback so as to deliver savings of greater than 15% more consistently, researchers and policy makers must instead start to enquire into the nature of the household dynamics that give rise to these enormous variations in levels of consumption. Based on 15 interviews with householders taking part in the Visible Energy Trial, the rest of this paper seeks, speculatively, to begin this challenge by exploring two distinct yet potentially complementary, bodies of theory.

First, ideas about the 'domestication' of technologies into household moral economies (Silverstone *et al* 1992) recognise that technologies are not fixed, stable or immutable entities. Instead, they are understood to acquire specific meanings and forms of use as they are tamed or domesticated into particular household situations and as they, in turn, influence pre-existing household dynamics. The concept of 'moral economy', further, 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.

Second, the concept of communities of practice (Wenger 1998) emphasises that learning is neither an individual nor entirely rational process. It shows how the knowledge required to get things done is highly situational and contingent, rather than being a-contextual and universally applicable as is often assumed. Rather than being possessed by individuals, knowledge is in fact distributed throughout members of particular localised groups, or communities of practice.

Based on the findings of the interviews, these two concepts are advanced as providing potentially helpful ways of conceptualising everyday patterns of energy use and, thus, of understanding the impact of any kind of feedback provided. First, the next section introduces the Visible Energy Trial in more detail.

3. METHODOLOGY: THE VISIBLE ENERGY TRIAL

The Visible Energy Trial is a collaboration, part-funded by Carbon Connections (www.carbon-connections.org), between a small entrepreneurial company developing a range of visual display monitors (Green Energy Options [GEO] - www.greenenergyoptions.co.uk), an academic consultancy (SYS Consulting Ltd. [SYSCo] - www.sys-consulting.co.uk) based at 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 figure 1).

Figure 1: GEO's Smart energy monitors (showing from left to right: Solo, Duet, Trio)

These 275 participants were then divided into four groups. Three of these groups (the solo, the duet and the trio) were given a working, interactive display in their household, whilst the fourth group had an advanced monitoring system installed but no interactive display. The fourth group thus represents the experimental control group. Details of the devices being used in the trial are as follows:

The Solo (n=75): The Solo device is designed around a car dashboard and offers: a monochromatic display providing a 'speedometer' with information on current levels of electricity usage; daily usage up to the present moment (expressed in kWh, carbon dioxide emissions and sterling); and a 'fuel tank' which enables householders to set a daily budget and which indicates whether this is being met or exceeded by displaying a tick or a cross symbol. The Solo also comes with an SD card enabling users to upload their data to GEO's 'MyEnergy' website which provides more detailed graphical information. In the trial, the Solo was administered to elderly and low-income households.

The Duet (n=75): The Duet device is more advanced than the Solo. The left-hand screen has the same functionality as the Solo. It thus displays a 'speedometer' of current and daily usage, and a 'fuel tank'. In addition, on the right hand screen, the Duet monitors boiler usage and up to 6 different appliances (appliances are monitored separately using 'Plugbugs' which transmit levels of consumption to the Duet unit, and of which 3 are delivered with the device). An SD card is also provided with the device for use on the MyEnergy website.

The Trio (n=76): The Trio has a full colour display with a very wide range of monitoring options. It monitors heating, hot water usage, all electrical circuits in the home, and up to 100 appliances (using Plugbugs – of which 6 are delivered with the device). Information can then be displayed graphically to investigate energy consumption patterns in more detail. For example displaying appliance usage over 24 hour or monthly periods and in kWh, CO_2 and sterling units. It should be noted, however, that during the trial itself participants were provided with a small PC laptop and not the device displayed in Figure 1.

The Control (n=49): The experimental control group had had the Trio device installed in their home, however they did not received the display unit. To secure their participation they were offered a report into their energy use patterns at the end of the trial.

Alongside the qualitative interviews reported on in this paper, the Trial involved collecting real-time data on all participants energy use as well as conducting quarterly online surveys of all participants to explore their attitudes towards and usage of the devices. At present, however, these other forms of data collection are ongoing. For the qualitative interviews, we recruited 15 households using a stratified random sampling procedure. Four interviewees were chosen from each of the *Solo, Duet* and *Trio* groups, and three interviewees were chosen from the control group. Summary details of all interviewees are provided in Table 1 (below).

The interviews lasted between 30 and 60 minutes. Six were conducted face-to-face with the interviewer visiting the participant's home or workplace, and nine were conducted over the phone. During the interviews, participants were asked to comment on the following themes:

- How they had got involved in the trial and their motivations for doing so.
- How they had used and interacted with the device.
- If the device had affected their energy awareness or behaviour, and in what ways.
- Any recommendations to help improve the device.

The interviews were then transcribed verbatim and analysed using a grounded theory approach (Charmaz 2006) to identify the dominant themes in each of these categories.

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

Table 1: Summary of Interviewees

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

4. RESULTS AND DISCUSSION: DOMESTICATING SMART ENERGY MONITORS IN HOUSEHOLD COMMUNITIES OF PRACTICE

Whilst a full analysis of the interview data is available in Hargreaves (2010) and in Hargreaves *et al* (2010 in press), this exploratory paper focuses on further explicating two of the interview study's key findings. First, section 4.1 will explore the finding that neither the monitors nor the feedback they provided were treated as unproblematic or neutral devices by householders. In each case, pre-existing household dynamics and practices were critical to how the devices and feedback were used and interpreted. Ideas about the domestication of technologies appear potentially helpful here. Second, section 4.2 will further develop the key finding that, despite the individualistic assumptions of conventional energy feedback studies (see section 2), domestic energy consumption is, in fact, a fundamentally social and collective process. The households in our study negotiated and interpreted the feedback provided by the devices collectively. Such findings expose the limits of individualistic understandings of learning as exemplified by conventional feedback studies. Accordingly, the concept of communities of practice is explored here because it offers a theory of learning as locally situated and socially distributed.

4.1 Domesticating Smart Energy Monitors

In general, there have been rather few studies of how technologies become incorporated into household practices and routines or, in turn, how such practices and routines are influenced by such technologies (Lie and Sørensen 1996). A key concept emerging from the few studies that have explored this process – and often with regards to the use of information and communication (ICT) technologies (e.g. Silverstone and Hirsch 1992) – is that of 'domestication'. "Domestication may be seen as the process through which an artefact becomes associated with practices, meanings, people, and other artefacts in the construction of intersecting large and small networks" (Sørensen 2004, 8). The point, here, is that the domestic contexts of use into which technologies are introduced are not blank canvasses. They have pre-existing routines, practices identities and values that technologies, if they are to be accepted, must align with. At the same time, the technologies themselves are not fixed. What they mean, what properties they are attributed, what they are capable of doing and how useful they are, are not inherent properties of the technologies themselves, but must be constructed and negotiated as they settle into different contexts of use. Silverstone *et al* (1992) understand these contexts of use as 'moral economies':

> "The household is a moral *economy* because it is both an economic unit, which is involved, through the productive and consumptive activities of its members, in the public economy, and at the same time it is a complex economic unit in its own terms (Pahl 1990). The household is a *moral* economy because the economic activities of its members within the household and in the wider world of work, leisure and shopping are defined and informed by a set of cognitions, evaluations and aesthetics, which are themselves defined and informed by the histories, biographies and politics of the household and its members. These are expressed in the specific and various cosmologies and rituals that define, or fail to define, the household's integrity as a social and cultural unit." (Silverstone *et al* 1992, 18)

Each household thus has a unique moral economy and, crucially, these are so embedded in, and reinforced by, household rituals and routines that they normally escape conscious attention. Rather than studying the quality of the feedback provided by smart energy

monitors, the challenge of trying to understand how smart energy monitors succeed or fail, is thus to consider the ways they interact in complex and non-linear ways with existing moral economies within households.

Vitally, studies of domestication show that this process is not one-way but reciprocal and dynamic. Just as technologies mutate depending on their relationships with existing moral economies, so too are these moral economies altered by the introduction of new technologies which may introduce new meanings, values, habits, practices and identities to the household.

Throughout the interviews, there were numerous examples of how: i) use of the monitors was shaped by existing household dynamics; ii) the monitors influenced existing moral economies, and iii) there were limits to this process of mutual influence. This sub-section will address each in turn.

First, the devices' aesthetics, their form rather than their function (as is usually the focus of feedback studies) proved critical to their usage. As noted in section 3, above, the Trio participants were, initially, provided with a small laptop device rather than the monitor shown in figure 1. In all cases, this had led to Trio users placing the device out of sight, as the following quotation illustrates:

> "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 reorganise so then it gets put down onto a lower shelf at the front…then she closed the lid, she does that a couple of times. 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, p6)

By contrast, users of the Solo and Duet devices often praised the appearance of their devices and particularly their colour displays as being both eye-catching and particularly engaging for children:

> "I mean the kids look at it, certainly when it first came in they were interested in all the pretty lights and stuff like that." (D4, p8)

Although often ignored in feedback studies, the aesthetics of smart energy monitors, as much as the accuracy, quality and frequency of the feedback they provide, appeared to be crucial to whether or not they were used at all.

Second, interviewees repeatedly stressed how vital it was that the devices were well positioned in the home so as to 'fit in' with existing household routines and patterns which, as the following quotations show, varied enormously:

> "We are quite prolific TV watchers and it was yeah, it was probably the most obvious place to put it. I mean if we come into the lounge we can see it from there, if we're sitting down there" (D4, p11)

> "I think siting it in the kitchen was probably a very good idea to do because it's the sort of place where you're in the kitchen a lot and you tend to sort of stand there while you're making a cup of tea or something and it's somewhere where you can see it and I think if it was anywhere else in the house I probably wouldn't be sort of button pressing and playing with it as much as where it is now. So I think that's probably a positive. I think if it was somewhere else, in the hallway or something like that, I probably perhaps wouldn't have made so much attention to it." (D3, p8)

> "The unit sits in the hall by the front door now so you can't miss it. We have a house with a central hall everyone has to come through so you absolutely can't miss it." (D2, p5)

There is, then, no ideal or optimal location for the devices. This must be carefully learnt and may change over time. In one case, for example, a Trio user had initially positioned the device in her kitchen where she used it regularly but, after it suffered a technical fault and she was forced to move it upstairs into her study, she had lost interest in it and stopped using it almost altogether.

These two simple examples – of the devices aesthetics and of their location in the home – demonstrate that existing household dynamics are vital to how, and even to whether or not, the devices are used. In the words of one interviewee, the devices must fit in with the 'fabric of the home' (T1, p6).

At the same time as the devices had to fit in with this household fabric, however, the interviews were also filled with examples of how the devices had stretched, torn, unpicked or re-stitched this fabric in new ways. First, and most obviously, the feedback provided by the monitors passed new kinds of judgement on other household devices. Quite suddenly, previously unquestioned household devices came to be seen as inefficient.

> "…like the tumble drier, it's quite powerful too, I didn't realise." (S3, p4)

> "…because we had the meter; we could see that when that come on how much that's used and what have you, so we decided to get rid of the fridge-freezer." (S4, p2)

As the second quotation shows, in many cases the monitors had encouraged householders to 'get rid' of inefficient appliances such as kettles, fridge-freezers, and incandescent light bulbs or to try and reduce their usage of other greedy appliances such as ovens and tumble driers. The devices thus introduced a new form of judgement into existing household moral economies based around levels of economic or environmental efficiency. Accordingly, although within certain limits, households re-domesticated other appliances or even de-domesticated them and disposed of them.

As well as altering the meanings and use of other household technologies, several interviews spoke of how the devices had changed their social dynamics. In the case of one family with a Duet device, for example, after initially struggling to get their teenage sons to save energy, the family had begun to use the devices to calculate how much money they were saving by using less energy and incorporated this into their sons' weekly housekeeping payments. The introduction of this economic incentive, the interviewee argued, had been remarkably effective.

In other cases, interviewees spoke of how the devices had brought energy consumption to the front of their minds when they were in the home and had made them re-evaluate all of their household routines. For some, this had led to the formation of new, energy-related identities such as, as the following quotations suggest, that of the 'energy bore':

> "In fact my wife has become a real energy bore now because she's, why's that meter so high, and it's got to the stage she can now spot when the outside light comes on." (D2, p5)

> "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 and every visitor to the house, friends and family and I'd be telling them all the things it could do and then their eyes would glaze over, so I was probably a bit of a bore." (T1, p2)

The devices thus seemed capable of re-moralising household moral economies, casting new judgements on existing household appliances, giving rise to new kinds of relationship between householders, and even supporting the development of new energy-related identities.

Whilst all of the examples so far have shown how the devices were either shaped by or themselves shaped household dynamics, it is also important to stress that there were limits to this process in many cases. For example, in some instances, rather than being successfully re-moralised by the energy monitor, existing household appliances fought back and led to the monitors' new judgements of them being resisted or rejected.

> "I think it's really important to get the balance right between the sort of big brother and monitoring things and also just allowing people to enjoy their lives and their homes. I mean I have some really lovely lamps in my lounge that I got from Venice and I refuse to be beaten down on this, I want to enjoy them and don't want to use them less or sit there looking at horrible light. Because you see all this stuff in the media that makes you feel guilty about things, but I think life is for living." (T1, p4)

In other cases, interviewees (and these were typically men – see table 1) complained that other householders, especially their wives or their children, simply refused to take action to save energy. Although they differed between different households, there thus appeared to be distinct limits to the flexibility of existing moral economies. Processes of domestication and re-domestication appear to be far from smooth.

In summary, the concepts of domestication and moral economies appear useful in attempting to understand how smart energy monitors and the feedback they provide are likely to be used by households, and are certainly worthy of further empirical attention. In particular, the analysis presented here suggests that further attention should be paid to the ways in which whole suites of technologies are inter-related and how smart energy monitors effect a kind of re-domestication process. Further, and of particular relevance to policy makers in this area, attempts might be made to classify the different kinds of moral economies that exist and thus to try and understand the full range of different kinds of interactions and relationships that smart energy monitors are likely to encounter. Whilst such classifications will themselves have effects on the moral economies they classify, to provide an example, Gram-Hanssen (2004) identifies two distinct kinds of moral economy in relation to energy use. First, household moral economies with a 'saving attitude', and second, those that are more profligate, expressing the sort of 'life is for living' attitude expressed by some in this study. Finally, further research needs to be done to explore the processes of learning and change in moral economies. Where do the limits of change lie? To what extent is radical change possible or can moral economies only change incrementally? How are these processes negotiated? Here, and as the next section will show, the concept of communities of practice might be especially helpful.

4.2 Communities Of Practice

The concept of *communities of practice* (Lave and Wenger 1991; Wenger 1998) was developed largely in professional contexts, such as educational institutions and corporations (see for example Brown and Duguid 1991; Hodkinson and Hodkinson 2004; Lindkvist 2005; Handley *et al* 2006; Roberts 2006). It recognises the fundamentally social nature of learning, exploring how people coordinate themselves to jointly negotiate and perform particular practices. It shows that getting things done does not rest on single individuals learning what to do in isolation, and mechanically performing it. Instead, the performance of practice rests on sets of informal associations and tacit understandings amongst groups of colleagues, friends, family members etc. These *communities* of practice thus represent networks of situated and distributed cognition (Lave and Wenger 1991) vital for the collective accomplishment of practices.

Wenger (1998) suggests that all communities of practice share three core elements:

1. *Joint enterprise:* All members share the same aims.

2. *Mutual engagement:* Members work together to perform a practice. Such cooperation can take three forms – *engagement* involves actual performance, *imagination* involves thinking about and planning around the practice, and *alignment* involves bringing the practice into line with other associated practices.

3. *Shared repertoire:* Over time, communities of practice develop a set of shared understandings, perspectives, routines, artefacts, turns of phrase, stories etc., that help them perform their practice and hold them together as a community.

These features form gradually and continually as different individuals are socialised to become members of communities, and as communities of practice learn and develop accordingly. As individuals weave different trajectories in and through communities of practice – from peripheral participants to core members in many different communities simultaneously - the communities themselves learn and develop, and their practices change. Wenger (2000) casts this collective learning process as one of dynamic tension between understandings of *competence* and levels of *experience*. When we're newcomers to a group, we want to belong and in order to do that we try to demonstrate the competence that core group members exhibit. In this view, forms of competence pull experience. Sometimes it can be the other way round however, we may, for example have an experience that opens our eyes to a new ways of seeing the world. On returning to our communities of practice, we try and communicate this to our peers – in the process we are trying to change their definition of what counts as competence. Here, experience is seen to pull competence.

As part of this tension between competence and experience, boundary encounters between different communities of practice seen as a crucial mechanism of learning. As communities of practice conflict or cooperate with each other, they develop new experience and may change their understandings of competence. Similarly, as individuals carry their experience of other communities around with them, they too can play a part in renegotiating what counts as competent performance of the practice. Material artefacts in the form of 'boundary objects' that cross between communities enabling them to communicate with one another can also generate forms of learning.

Although developed in organisational contexts such as schools and businesses, similar processes of social and collective learning and practice were discussed by many of our

interviewees, indicating that the communities of practice concept might also be applicable to households. In particular, the ways in which interviewees discussed the kinds of household cooperation and conflict provoked by the monitors relate clearly to Wenger's (2000) notions of competence and experience.

In several cases, interviewees spoke of how they had worked together with other household members to learn from the meter and make changes to their energy usage. For example:

> "I mention it to everyone on Monday morning that we used an awful lot yesterday and we sort of discuss what could have caused it and stuff like that." (D4, p13)

Other interviewees also mentioned holding family meetings and 'analysis talks' to work out what they've been using and what action they might take. In these examples the meters – acting as a kind of boundary object – are introducing new definitions of competence to the household setting. By helping them to re-assess their daily routines according to the energy they consume, the monitors serve to challenge existing forms of competence and thus encourage householders to bring their everyday experiences into line with the new definition.

In many other cases, however, interviewees discussed the forms of conflict that the monitors had given rise to. For example, conflicts over switching lights on and off, over how much the kettle or tumble drier should be filled, over ovens or games consoles being left on, and over how warm rooms should be. In these examples, the new definitions of competence being introduced by the monitors were being resisted and even sometimes rejected in the light of existing and well-established household experiences. In many cases these negotiations and arguments are ongoing, and it might be expected that the household member with the most power or influence - whether that is the person who pays the bills or the person who defines, for example, what a warm and well-lit home actually means – will eventually prevail. It might well be expected, however, that such forms of conflict could also lead to a hardening or retrenchment of existing routines in direct opposition to the monitors (*cf*. Hobson 2002).

Wenger's (2000) understanding of the dynamic tension between competence and experience thus appears helpful in understanding the collective learning and negotiation processes prompted by the monitors, and it certainly exceeds the explanatory power of individualistic understandings of learning from feedback. The concept of boundary encounters also appears useful, as many interviewees discussed ways in which they had either been influenced by or had attempted to influence members of communities of practice beyond their household. Several interviewees discussed how having children doing 'environmental projects' at school had been vital either in first deciding to participate in the trial, or in encouraging the household to use the device more regularly and more thoughtfully. In this instance, boundary encounters with communities of practice beyond the home introduce new forms of experience that challenge existing household definitions of competence.

In other cases, interviewees told how they had enthusiastically discussed the monitor with close friends and other family members and attempted to get them to adopt new understandings of competence in relation to energy use. In particular, emphasis was placed on the challenges involved in encouraging the 'younger generation' to adopt these new forms of competence, given that they were such wasteful and profligate consumers in other aspects of their lives. For example:

> "I don't want to sound rude about it, but it's the younger generation isn't it, you know…they want everything and they want everything now sort of thing. Perhaps when they get a bit older they'll start thinking about well saving for a rainy day sort of thing. Does that sound like I'm a bit of dinosaur or something?" (S1, p26)

These kinds of boundary encounter are valuable as they further extend the nature of the collective learning that the devices promote. Here, such processes are seen to extend way beyond individuals, and beyond single households even. They are seen to have potential implications throughout whole communities of communities of practice as new forms of experience and competence reverberate through interviewees' existing social networks.

Finally, whilst the concept of communities of practice has been criticised for, amongst other things, emphasising incremental change and being unable to conceptualise radical transformations in communities (e.g. Roberts 2006), this conservatism appears appropriate to many of the interviewees in this study. As noted above, many of the households had rejected the monitors' uncompromising judgements on their behaviour, proclaiming instead that 'life is for living' which, arguably, is closer to the current *joint enterprise* of most household communities of practice than the joint enterprise of energy saving the smart energy monitors seek to introduce. Further, others suggested that no matter how much energy certain practices or appliances used, they either refused to change their behaviour, or felt that they could not do so for various reasons.

> "If we have too much power, the electric, like the television, the computers, everything, then we get a cross saying we've got too much… we're using too much…and it's difficult to get the tick because you need things on, you know, you want to use the things. So I don't really know what to say about that." (S2, p3)

> "There are some things you just can't change. So, as I say, I have my fishtank 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, p3)

As with household moral economies, these quotations show that there may be limits to the extent of change feedback on energy consumption can provoke. Whilst incremental shifts in behaviour and the elimination of inefficiencies and waste might be possible, it seems as if something more than the introduction of an energy monitor is required to challenge unsustainable social conventions about what constitutes a normal and comfortable home (Strengers 2008; Shove 2003).

In summary, the concept of communities of practice appears to offer a useful way of understanding the social and collective learning processes prompted by energy feedback. By implication, policy makers and those looking to roll out smart meters more widely, might look for further opportunities to promote and support these processes of social learning and reflection within communities of practice, rather than focussing their efforts on educating individuals in a social vacuum. At the same time, however, the communities of practice concept suggests there might be serious limits to the kinds of change that smart energy monitors appear able to bring about. The point, here, is that existing household communities of practice are extremely strong and appear quite resistant to change. Arguably, the *joint enterprise* of existing household communities of practice is in fact one of rising levels of energy consumption. The new kinds of judgement and understandings of competence introduced by the smart energy monitors thus appear not only quite radical,

going against the grain of existing and household routines and practices, but also and more importantly, quite weak.

Further research should seek to examine the power relationships involved when existing communities of practice learn and change, the forms of conflict these processes provoke, as well as exploring how more radical forms of change that challenge unsustainable social conventions might be brought about. Finally, the analysis presented here suggests that the concept of communities of practice itself might be usefully extended by paying greater attention to material artefacts. Wenger (1998) discusses objects as 'reified' forms of participation, seeing them as rather passive static forms that embody the particular norms and conventions of the communities they are used within. By contrast, the analysis presented here shows smart energy monitors to be dynamic entities that actively bring about forms of learning and change within households. The concept of domestication, with its attention to the micro-scale co-production of technology and society in household moral economies, might therefore help further populate communities of practice with the 'missing masses' (Latour 1992) of new, material members.

5. CONCLUSIONS

Based on 15 semi-structured interviews with participants in the Visible Energy Trial in Eastern England, this paper has sought to explore two conceptual extensions to existing and conventional understandings of the use of energy feedback and smart energy monitors by householders. First, ideas about domestication have been explored which contest visions of smart energy monitors as fixed and stable entities, and also contest understandings of households as blank canvasses into which such devices are unproblematically introduced. These ideas suggest that research and policy attention should shift away from attempts to understand the cognitive processes through which individuals learn from feedback on their energy consumption and instead begin to explore the complex interactions and relationships at play when smart energy monitors are introduced into specific household moral economies. This demands a more qualitative and even ethnographic approach to advance understanding of these household dynamics and of how they change over time. Attempts might also be made, however, to classify different or common kinds of household moral economy as a means of understanding the range of ways in which smart energy monitors might be used, and also of developing means of improving the effectiveness of their domestication into household routines and practices.

Second, ideas about communities of practice have been put forward as helping to understand how learning processes and the performance of household practices are fundamentally social and collective processes. These ideas sensitise analysts to the particular processes through which feedback from smart energy monitors is encountered, made sense of and ultimately acted upon (or not) by householders. By implication, rather than solely seeking to improve the nature of the feedback provided, policy makers might also look for ways to support the social learning and negotiation processes that occur between householders when smart energy monitors are used.

In developing these two exploratory themes, this paper has also suggested that understandings of domestication processes might usefully profit from the mechanisms of social learning and change developed in analyses of communities of practice. Further, ideas about communities of practice might benefit from the serious attention given to material artefacts by theories of the domestication of technologies. Realising such cross-fertilisation

would demand extensive further empirical and theoretical work, but holds out the possibility of an exciting future research and policy agenda on the use and effectiveness of smart energy monitors specifically, and more generally on the social knowledges and practices behind energy use in everyday life.

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