'Energy monitoring as a practice: Investigating use of the iMeasure online energy feedback tool'

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Abstract

Energy feedback is a prominent feature of policy initiatives aimed at reducing domestic energy consumption. However little research has been conducted on the phenomenon of energy monitoring itself, with most studies looking at whether, and how, feedback impacts on energy conservation. This paper aims to address that gap from a practice theory perspective. In particular we: set out the difference between energy feedback and energy monitoring; define the practice of energy monitoring; and investigate the rationale and qualitative experiences of those performing energy monitoring. An online energy feedback tool ('iMeasure') was the basis of the case study. A netnographic analysis of online discussion about the tool informed complementary in-depth interviews with ten current/former iMeasure users. We found energy monitoring to be a distinct practice that focuses on measuring and identifying energy use trends and requires specific know-how to perform. However, its connections to other household practices were weak and, for those who did perform monitoring, there was no guarantee that this practice would reorganise other practices to induce household energy saving. In fact, monitoring often followed decisions to make energy-related changes, rather than prompting them. We conclude that policy expectations need to be reframed in terms of how energy monitoring tools are used.

Keywords

1. Introduction

1.1. Feedback provision: A behavioural attempt to reduce domestic energy demand?

Energy use in buildings represents a major component of global emissions (19%) (IPCC, 2014), and in the UK 17% of emissions are attributed to residential building energy demand (DECC, 2014a). Quantitative energy feedback – when information on levels of energy consumption are reported back to the consumer – is commonly advocated as an effective means to reduce energy consumption in buildings. For example, this is a key part of the European Union's framing for its target to roll out intelligent metering systems to 80% of EU consumers by 2020 (Directive 2009/72/EC). This new energy monitoring infrastructure will apparently create 'an unprecedented new platform for innovation in energy data' (DECC, 2015a, p. 1), with implications for day-to-day energy use.

The UK Government is setting even higher ambitions to roll out smart meters to *all* UK homes and small businesses by 2020. As part of this, the last 13 months' worth of electricity and gas use data will be available at 30-minute intervals, via a Data and Communication Company (DCC) (DECC, 2015b, 2012a). Alongside this longer-term data, every household/business will be offered a free In-Home Display (IHD) (DECC, 2013, 2012b). IHDs primarily provide real-time feedback on the amount of energy (usually electricity, but sometimes dual fuel) being used at that very moment in a building, and the implications in terms of cost and carbon emissions (more recently, some IHDs are also able to provide historical feedback charts). A central rationale behind this programme is that this 'will enable people to understand their energy use and maximise opportunities for energy saving' (HM Government, 2011, p. 38–39). In particular, the UK Government has advocated adding in the IHDs component to the roll-out of smart meters because IHDs will 'let [households] have more control over their energy use and help them save energy and money' (HM Government, 2015). Furthermore,

a UK Government impact assessment report explicitly noted that a central benefit of the smart meter programme will be energy savings, although they did conservatively estimate electricity and gas (non-pre-payment meters) savings at 2.8% and 2% respectively, due to 'existing uncertainty on the precise level of energy savings' (DECC, 2014b, p.47).

All energy feedback initiatives assume that people are 'rational' decision-makers and that, on the basis of available information, they will weigh up the costs and benefits and take particular actions in order to maximise their own personal utility. They share an assumption that by providing information on building energy usage, and its implications, people will be empowered to save energy. Implicitly this intervention approach assumes a linear behavioural process: from provision of feedback, to engagement with that feedback (i.e. energy monitoring), to improved knowledge about levels of energy consumption, to actions by the individual household aimed at delivering energy savings, cost savings and/or environmental benefits. There is also increasing popularity for feeding back more 'invisible' aspects of energy that go beyond kWhs (e.g. heat loss), as part of encouraging behaviour change to reduce energy use (e.g. Goodhew et al., 2015).

1.2. Energy feedback research

Traditionally energy feedback research has been conducted on the basis of a similarly rational behavioural perspective to that underpinning the aforementioned policies, as highlighted by Wilhite and Ling (1995). Herein, the most commonly addressed barrier is an assumed information deficit amongst the public which many – including Burgess et al. (1998) and Owens (2000) – have argued as being hugely inappropriate. But despite such critiques, the behavioural perspective still persists. For example, it has been suggested (e.g. by Bahaj and James, 2007) that if only accurate information was accessible on how to live 'correctly' in low-energy housing, people's awareness would increase and they would act as intended, i.e. reduce their domestic energy demand. More recently, with greater

emphasis being given to people's attitudes, beliefs and/or values (e.g. Dennis et al., 1990; Fischer, 2008; He et al., 2010; Webb et al., 2013), it is increasingly assumed that when people are presented with information they are more likely to change from behaviours deemed inappropriate if they are able to take action in accordance with those attitudes, beliefs and/or values (i.e. if options exist which do not conflict with these). Using a similar point of departure, there are also studies (away from energy) that explore the impact of an individual's mental construction of goal monitoring upon actions that lead towards goal attainment (Harkin et al., 2016). This has all spun out of a research agenda focussing on factors which might make an individual more or less likely to undertake a particular activity (e.g. Ajzen, 1991). Thus, fundamentally, all these approaches still assume that action is driven through individual choice.

In critique of these dominant approaches, a growing number of (primarily sociological) feedback-related studies are focussing more on the internalised and dynamic nature of social and cultural context within which digital feedback technologies operate (e.g. Pink et al., 2013; Wallenborn et al., 2011). Many of these, at least in part, draw on insights from the theories of practice literature (e.g. Buchanan et al., 2015, 2014; Burchell et al., 2014; Ellegård and Palm, 2011; Hargreaves et al., 2013, 2010; Strengers, 2011). According to Shove *et al.* (2012), a practice consists of three interconnected elements: materials (tangible items needed to perform a practice, such as technologies); meanings (social significance of performing a practice); and competences (skills, knowledges and understandings required to perform a practice). It is important, however, to note that other conceptualisations of practice exist, and there are different propositions for what a practice could be said to consist of (e.g. Gram-Hanssen, 2010, Reckwitz, 2002). Nevertheless, despite variation, theories of practice do share a focus on socially shaped 'blocks' of routinised behaviours that have evolved through being performed in space and over time (i.e. practices) and which constitute people's everyday lives (Reckwitz, 2002). Moreover, most would now acknowledge that materiality is a 'core programmatic point' (Røpke, 2009, p.2492) of theories of practice. Essentially, this whole

theoretical approach distinctly contrasts with dominant rational understandings of behaviour change, in that both sociotechnical stability and change are regarded as being culturally, institutionally and infrastructurally mediated (Shove, 2010).

Many studies have employed theories of practice to consider how, in the context of domestic energy demand reduction initiatives, the provision of energy-related feedback leads to (or fails to prompt) the reorganisation of everyday domestic energy-consuming practices, such as cooking, cleaning, or showering (e.g. Hargreaves et al., 2010; Strengers, 2011). Whilst we also do this, we go further by looking at energy monitoring as a practice in and of itself.

All of this is not to imply that theories of practice represent a theory of everything. Theories provide us with points of departure that pose certain questions and thereby produce certain answers and, as such, inevitably overlook other sets of issues that alternative theories would focus our attention towards. It is in this vein that we also pull on complementary sociotechnical theories in this paper, in much the same way as others have done previously. For instance, 'domestication' theories (Silverstone *et al.*, 1992) can help shed light on how households come together in making technologies part of their home; such an approach was adopted by Hargreaves *et al.* (2010; 2012). We similarly adopt Strengers' (2011) implicit position that sociotechnical systems, and the associated infrastructures and technologies, are mediating how energy-consuming practices are organised in the day-to-day (Van Vliet et al., 2005).

1.3. Positioning energy monitoring in the context of different forms of feedback

A small, but growing, part of the theories of practice literature is considering the variety of feedback mechanisms that are in play in day-to-day life. For example, Strengers (2013) puts forward 'sensation', 'social' and 'material' feedbacks. Much of this work directly confronts overly simplistic

assumptions regarding the everyday impact of energy feedback (Foulds et al., 2014). Indeed, people

are continually checking that a practice is being performed in accordance with the rules of doing it

'right'. This fits well with Orlikowski's (2002, p. 249) assertion that people are 'purposive and

reflexive, continually and routinely monitoring the ongoing flow of action – their own and that of

others – and the social and physical contexts in which their activities are constituted'. Thus,

monitoring is *always* part of performing and organising practice, because the human

knowledgeability it provides is 'inherent within the ability to 'go on' within the routines of social life'

(Giddens, 1984, p. 4).

However, these more implicit forms of energy feedbacks and monitoring are not our focus in this

paper. Instead, we focus on the quantitative monitoring of energy use and its associated trends (e.g.

daily fluctuations, seasonal changes). We appreciate that this sort of energy monitoring has a long

history that has not involved dedicated energy feedback tools (e.g. monitoring the wood pile or coal

store; c.f. Jalas and Rinkinen, 2016), but here we explicitly focus on the emerging context of digital

technologies and how they have led to a specific type of monitoring activity. Finally, whilst we

discuss energy monitoring in the context of household energy consumption, it can include forms of

energy use outside the home or buildings, such as car petrol usage (which several of our

interviewees also monitor).

1.4. Proposed knowledge gaps

In relation to research on energy monitoring and its effects, we note two specific knowledge gaps.

Firstly, as far as we are aware, energy monitoring as a distinct practice in its own right has not yet

been explored. Much research has overlooked if, and how, householders become actively engaged

in measuring and identifying energy trends associated with domestic life (i.e. performing

'monitoring') and with what effects. Instead dominant approaches concentrate on interpreting the

outcomes of energy monitoring activities. For instance, whilst the very relevant work of Burchell *et al*. (2014, 2016a; 2016b) did indeed focus on the routes to engagement via energy monitoring (specifically, through community action and contextualising feedback for different households), this was done with respect to better understanding the outcomes of energy monitoring on the organisation of various other energy-consuming practices in the home. As such, their conclusions mainly concerned the ways in which feedback provision could be tweaked, and accompanied with more appropriate organisational processes, so as to achieve behaviour change and hence energy use reductions in the home. We therefore argue that a more distinct focus on energy monitoring as a practice could lend insight into why energy feedback tools do not always deliver the level of energy savings expected. It could also highlight reasons why householders participate in energy monitoring, potentially enabling redesigns of feedback tools and household energy interventions more broadly.

Secondly, there has been an overwhelming focus on quantitative energy use feedback (in kWh, £ or $kgCO_2$) and, particularly in recent years, on IHDs and real-time feedback (e.g. Alahmad et al., 2012; Buchanan et al., 2015, 2014; Faruqui et al., 2010; Hargreaves et al., 2013, 2010; McKerracher and Torriti, 2013; Wood and Newborough, 2007). But in exploring quantitative energy feedback, there has been relatively little research on non-automated energy feedback, which can require personal input of data. Few studies have considered how people engage with (non-automated) longitudinal feedback, which enables comparisons of energy demand over time to be made and identification of patterns, although one such example would be the Smart Communities project (Burchell *et al*., 2014, 2016a; 2016b). Therefore, whilst energy monitoring as a practice and coordinated entity in itself has received little attention within the theories of practice literature, this particular sort of practice-as-performance (voluntary engagement with longitudinal data) also warrants further empirical investigation. Indeed, the performance of energy monitoring (and its horizontal connections to other domestic practices) by householders voluntarily participating in long-term domestic energy

monitoring initiatives will differ from householders who have, for instance, had feedback

technologies imposed upon them as part of a temporary or incentivised trial or study.

1.5. Research aim and article structure

To appraise the potentially transformative process of energy feedback provision, this research aims

to investigate how householders interact with, and (may) become actively engaged in, monitoring

their domestic energy consumption over the long-term, and how this reconfigures energy-related

household practices (if at all). We appraise energy monitoring as a household practice in its own

right and, using a case study research design, examine an online longitudinal energy feedback tool

that explicitly markets itself as being for 'energy monitoring' (iMeasure). This householders-focussed

study also sits alongside another professionals-focussed study that uses the same case study (Foulds

et al., 2017).

We begin this paper by outlining our iMeasure case study and methods. Our findings and discussion

then defines energy monitoring and how it relates to energy feedback and energy saving. Whilst

slightly unconventional to define the paper's main subject in the findings and discussion section, we

do so because it was formulated through analysis, on the basis of the evidence we collected. We

then specifically discuss: competences of energy monitoring; different ways energy monitoring is

performed; energy monitoring as an individual endeavour; and how energy monitoring relates to

other household practices. We finish by outlining implications for policy.

2. Methodology

2.1. Case study background: iMeasure

iMeasure[1] is an online energy feedback tool created in 2006 by the University of Oxford's

Environmental Change Institute. Its purpose is to feedback domestic energy consumption trends

(kWh; £; $kgCO_2$) to interested householders. By inputting household meter readings (for grid

electricity and/or gas) into the online platform, the tool provides the householder with longitudinal

(weekly/monthly/annual) trends. At the time of the interviews, householders were also able to

participate in an online community of fellow iMeasure householders to discuss challenges, insights

and outcomes associated with using the feedback tool (although few did).

The iMeasure case study is particularly interesting because of the significant (voluntary) ongoing

commitment of households required to generate detailed energy feedback (e.g. manually inputting

weekly meter readings). This is opposed to automatic data collection (e.g. as for IHDs) or one-off

events (e.g. as for carbon calculators). Householders have to be adequately engaged to sign up to

iMeasure and sustain this commitment. iMeasure householders have not had a feedback tool

imposed on them via a (often time-limited/incentivised) study or policy initiative. This means that

iMeasure, and the particular sample of household practitioners interviewed, are representative of a

very small proportion of society that is engaged in domestic energy monitoring. In terms of

appraising the feedback tool, it could be argued that if feedback does not deliver energy savings for

these households, then it is even less likely to do so for others.

2.2. Methods

This investigation adopted a qualitative approach that primarily included: (1) a netnography

analysing online website content, iMeasure HQ-to-user emails, and social media discussion; and (2)

semi-structured interviews with a sample of iMeasure householders. These are discussed in turn.

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[1] Formerly located at imeasure.org.uk, but now rebranded under the Pilio brand and found at
http://www.piliogroup.com/home-monitoring/.

With the relatively recent emergence of online discursive communities, netnography has emerged as a new methodological approach increasingly used in social science research (for more details, see Kozinets, 2010), which has origins in marketing and advertising research (e.g. Kozinets, 2006; Xun and Reynolds, 2010). It is 'an interpretive method devised specifically to investigate the consumer behaviour of cultures and communities present on the internet' (Kozinets, 1998, p. 366). Netnography was undertaken at the start of the project to: (1) provide insight into assumptions underpinning the design of the iMeasure tool; (2) explore the doing of energy monitoring, including the extent to which the interviewees could talk (to each other) about practices; and (3) inform the design of semi-structured qualitative interviews with sample iMeasure householders (later discussed). We acknowledge that there are some limitations to using netnography, including it pulling the researcher towards explicitly stated textual data as opposed to more tacit, experiential and unspoken forms of data. In addition, since it is a relatively new method, there are fewer established conventions for systematic data collection and analysis.

Our netnographic approach involved compiling textual data from the internet (referenced as L), covering the period 2 November 2009 to 28 March 2014. Data collection and analysis specifically included: iMeasure's website content, including webpages in the user account (approximately 8% of netnographic dataset); iMeasure weekly HQ-to-user emails (31%); user exchanges on the iMeasure Twitter, Facebook and LinkedIn feeds (29%); and other online discussions of iMeasure in blogs, forums, and reviews (these included the web forums: Make Wealth History; Green Living; Money Saving Expert; Superhomes; and Navitron Renewable Energy and Sustainability) (32%). Note that there was very little repetition of content across these various sources. Employing netnography as a methodological tool in this way forms a markedly different approach to most research on the impact and use of online feedback tools. Those studies tend to involve user questionnaires and/or interviews (e.g. Foster et al., 2011; Froehlich et al., 2009; Kuniavsky, 2003; Petersen et al., 2007), and thereby may overlook how relationships are established and how understandings and practical

insights are shared as part of an online community. As such, our work builds on emerging work that uses online ethnography to better understand energy-consuming practices in the home (e.g. Royston, 2014).

In April 2013, a questionnaire was sent out via email to 2,778 iMeasure householders identified as those who had logged into their iMeasure account over the preceding 15 months. A response rate of 20.6% (571 householders) resulted. Of these respondents, there was an unrepresentative (in relation to the general UK population) dominance of: males (75.0%); owner-occupied tenure (87.8%); ages between 40 and 69 years (73.9%); and educated individuals holding at least an undergraduate degree (72.4%). Whilst such figures reflect the iMeasure monitoring user-base, inevitably only certain kinds of people may be willing to do a survey on this topic, and hence these figures should be treated indicatively. In addition to socio-demographic characteristics, the questionnaire collected data on reasons for using iMeasure, frequency of use and features used, and experience of iMeasure in comparison to IHDs. The questionnaire crucially provided a means to recruit iMeasure householders for semi-structured interviews (64% of questionnaire respondents were willing to be contacted about these), as well as informing the lines of questioning in those interviews.

Ten interviews were conducted in June and July 2014, with an average duration of 55 minutes (range: 39-115mins). Informed by the netnography and the questionnaire, the interviews had a relatively open frame, with questions focusing on: how they came to and currently do use iMeasure; how iMeasure forms part of other energy monitoring activities and domestic everyday life; how iMeasure has (or has not) changed established household practices; and whether, and if so how, they interact as part of the online iMeasure community and culture. These interviews were as interactive as possible, with interviewees logging into their iMeasure online account to provide further prompts for discussion (c.f. Millen, 2000; Vermeeren et al., 2010).

In selecting a sample (n=10) from all those who volunteered for an interview, we endeavoured to achieve a mix of different frequencies of use because we were interested in different ways in which the feedback tool may have been used: every week (5 households); most weeks (3); every few months (1); and no longer using iMeasure (1). Inevitably, it was more difficult to recruit interviewees that were using iMeasure less frequently and/or not at all. Whilst frequency of use was a primary concern, we were also mindful of achieving as even as possible spread of gender; household type, property size, and year of registration on iMeasure. Nevertheless, our constructivist philosophy meant that we were not searching for one perfect representative sample, from which context-free generalizable results could be found. The interviews focussed on two UK cities demonstrating significant iMeasure use: Oxford (where iMeasure was developed) and Cambridge (where the tool has been significantly promoted by a local community group). Throughout this paper, household interview quotations are referenced by codes (A-J).

During data collection and analysis, the researchers maintained a written reflective account of their thoughts and ideas (referenced as K). All of these qualitative data were subjected to a process of constructionist thematic coding (Braun and Clarke, 2006), on the basis of the issues prioritised by each of the research questions. The researchers came together before the final round of coding as part of eliminating, combining, subdividing and ultimately prioritising various themes and sub-themes, before then the final emergent themes were identified. Finally, we do note that the relatively small number of interviews (n=10) may have influenced the extent to which certain themes may have emerged during the analysis of interview data.

3. Findings and discussion: Energy monitoring as a practice?

This section discusses five key findings. The first two are predominantly related to the entity of energy monitoring, and specifically concern: (1) a proposed definition of energy monitoring, as a practice and (2) the competences of energy monitoring. The second two broadly move the discussion towards the performance of energy monitoring, and specifically concern: (1) differences in performance and (2) how energy monitoring tends to be an individual endeavour. The section finishes with discussion of how energy monitoring connects to other household practices and energy saving.

3.1. Defining the practice of energy monitoring

We define energy monitoring as a set of routinised behaviours that involves attempts to improve one's understanding of (typically one's own) energy use patterns and drivers. It occurs over time, hence multiple data points are needed. Energy monitoring can also either be on a real-time (e.g. IHDs) or historic (e.g. yearly or seasonal comparisons) basis and across different levels of aggregation (e.g. whole-building or circuit-level).

Energy monitoring necessarily involves both measuring and identifying:

- *Measuring* is the first step in monitoring: "if you don't measure it [energy demand], you can't monitor it" (F). This can either be undertaken through choosing a specification (e.g. units, scales, frequency of collection, etc.) for recording one's own energy use, or (more commonly) via a measurement technology/tool that one may have chosen which essentially decides upon this specification and then measures one's energy use accordingly. In this latter example, many of the skills associated with monitoring may be transferred to non-human actors.

- *Identifying* begins with the observation of the measurements collected, followed by a subsequent cross-checking and comparative analysis (which may vary considerably in depth and approach) that often culminates in the identification of reasons behind trends or differences in use (e.g. winter versus summer consumption; 'normal' living versus periods when away on holiday). As one interviewee noted, "I can go back on the history of it, and compare say last year's with this year's [energy use]" (H). We argue that identifying, where various measurements are brought together for a wider analytical purpose, is the key distinguisher between Darby *et al*.'s (2015, p.8-9) 'information approach' (e.g. IHDs used as spot-checkers for power demand at one moment in time) and 'monitoring approach' (e.g. IHDs used to understand energy use trends over time).

The process of both measuring and identifying facilitates learning about (what influences changes and stability in) energy use, which is what energy monitoring is really about. Whilst we appreciate that the performance of every practice involves the gaining of competences as part of constantly re-adjusting performances, we are referring here to the cognitive learning associated with better understanding energy use trends and their underlying drivers:

"The process of measuring and recording my energy usage, and graphing it, has just helped me understand [my energy consumption. In particular, to not just] …have a rough feeling about it, but to have quite a good feeling." (B)

The objectives underlying measuring and identifying embody, in Schatzki's terms, 'teleoaffective structures', as a characteristic property of energy monitoring. Teleoaffective structures represent 'a range of acceptable or correct ends, acceptable or correct tasks to carry out for these ends, acceptable or correct beliefs (etc.) given which specific tasks are carried out for the sake of these ends, and even acceptable or correct emotions out of which to do so' (Schatzki, 2001, p.52-53). For

instance, the focus on learning pulls on normative understandings of there being "value in data" (C) and what can be achieved through evidence gathering. It is exactly this that meant that this "hobby" (G; H) was "an intellectual interest" (G) too, whereby some took particular pleasure in being able to understand "the science and the maths behind it, which would confuse most people, including myself sometimes!" (I).

In attaining this better understanding, it is inevitable that the householders do also develop competences that make them more proficient in doing energy monitoring. Indeed it may actually be that proficiency of monitoring more generally becomes transferable to other aspects of one's everyday life, thereby leading to householders becoming:

"Someone who spends most of his life sort of measuring things and controlling things." (G)

Perhaps this positions energy monitoring as being one smaller component of monitoring more broadly, which could be conceptualised as a 'dispersed practice' that occurs within and across different domains, in a similar way to 'explaining, questioning, reporting, examining and imagining' (Schatzki, 1996, p. 91). In this way, monitoring would span different fields and sub-domains, unlike Schatzki's alternative classification of an 'integrative practice', for instance, which is 'found in and constitutive of particular domains of social life' (e.g. cooking) (Schatzki, 1996, p. 98). This aside, it was certainly clear that most interviewees explicitly talked about themselves as being 'energy monitors', for which they displayed a real passion and proficiency. Indeed, during our netnography, we noted how clear it was that householders took "pride in [their] monitoring and measurement prowess" (K). We speculate that the householders' involvement in manual data entry reinforced this identity.

In briefly reflecting upon why we opted for the term 'energy monitoring' we note that (1) we opted against 'energy management' as this has tended to either be used interchangeably with energy saving (e.g. Carbon Trust, 2012, 2007), or be in association with energy management systems that in part relate to control of energy-consuming technologies (e.g. Clarke et al., 2002; Klein et al., 2012), and (2) we felt that 'energy accounting' predominantly relates to the processing and analysing of data, rather than active collection and entry of that data too. Further, the terms 'energy feedback' and 'energy monitoring' are commonly conflated and used interchangeably. Indeed, IHDs are often colloquially called 'energy monitors' (e.g. Buchanan et al., 2014; Hargreaves et al., 2013, 2010; Wallenborn et al., 2011; Which?, 2015). However it is important to make clear how our definition of energy monitoring implicitly differs from energy feedback. Energy feedback (as a source of information) can be provided to householders, but energy monitoring involves the householder directly engaging with the delivered energy feedback in some way, either in its production or its interpretation. In addition, by separating out measuring and identifying, and by making clear that each has a different purpose, we emphasise that the behavioural assumption of measurement (via feedback) guaranteeing a degree of interpretation is inappropriate.

3.2. Competences of energy monitoring

Whilst our data does show energy monitoring to have its own distinct elements of practice (Shove *et al*., 2012) – including meanings (e.g. demonstrating intelligence, geeky-ness, technophilia, being a good householder/provider, relaxation and enjoyment, etc.) and materials (e.g. energy, heating systems, computers, iMeasure servers, etc.) – we give particular focus here to the competences required to do energy monitoring. We do this because knowledges emerged, particularly from the interviews, as a prominent theme. The doing of energy monitoring (which, of course, requires its own set of competences) was usually undertaken with the purpose of attaining new knowledges of some kind, as has been previously discussed. One common example was how energy monitoring was

providing an improved understanding of "the pattern of our lives over time" (B) and how that was related to changes in domestic energy use. Indeed, the interviewees tended to interweave discussion about the skills required to do energy monitoring and the skills that came from energy monitoring, most likely because the latter would soon become the former (e.g. as part of them seeking an 'improved' performance).

In considering the competences required for energy monitoring, we certainly acknowledge that materials and algorithms (e.g. feedback tools) can hold many of the competences, nevertheless we focus our attention here on some of the competences held by human actors. For instance, the householder still first and foremost has to have an understanding of how to operate the tool (assuming the tool is not totally automated) in order to perform the energy monitoring practice.

But such is the sophistication and capabilities of the iMeasure tool that some householders were barely able to use it. For example, despite being considerably confused – to the extent that he struggled to simply input his meter readings into iMeasure each week – one householder had been devotedly collecting meter readings every week for six years. Indeed this particular householder spent the majority of the interview asking the interviewer an array of detailed questions about how exactly the iMeasure tool worked and what each of the analysis outputs actually showed:

> "I don't really understand the analysis. I just keep the records… At the moment iMeasure doesn't really help me very much." (A)

> "I want you to take me through these boxes because they don't mean much to me. There is this very curious thing which I have had explained to me, and I still can't understand. And I don't understand this [other] thing [either]." (A)

Most of the above has implicitly focussed on monitoring's *measuring*-related knowledges, but if we move towards the *identifying*-related knowledges, we can see that different sort of competences are required: instead of knowing how to collect data and operate the iMeasure tool, one now needs to know how to interpret the analysis that the tool throws back to you, as part of identifying energy use trends. For example, discussion of this in the interviews tended to centre around iMeasure's capability to ensure energy use analysis adequately used degree day data as part of weather compensation[2].

In enhancing one's ability to better understand energy use, it was clear that different reference points existed for comparisons. That is, what exactly householders were seeking to identify, and for what purpose, varied. Examples included considering the trend-related impact of either energy efficiency improvements or actions that conserved energy:

> "For me at least it is about analysis. And, as I say, when you change something in the house and that has an effect. You know for example if I was to go and finish off the insulation in the bathroom, I would be very interested to go and look at the data set again and see how I have reduced my energy consumption further." (G)

> "To have a tweak [to my heating system controls] and [from the iMeasure analysis then] know what I have done and know whether it has done it right or made it worse." (F)

It is in these contexts that we note the importance of practical forms of knowledge regarding *how* to do something ('know-how') in order to both undertake energy monitoring itself, and potentially take energy saving actions as a result. This type of knowledge, which often must be based on practical experience, can be very much taken for granted within the rolling out of feedback or energy saving

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[2] A degree day is a unit for measuring the difference between outdoor temperatures and the target indoor temperature, and thus is commonly used to account for weather-related differences in heating fuel consumption.

initiatives, with the focus more traditionally being on providing intellectual knowledge ('know-what') (Burchell et al., 2015; Royston, 2014). However, we found that simply using the iMeasure tool requires a degree of know-how which many may not possess (e.g. regarding meters, computers, iMeasure software, or even linear regressions).

3.3. Different practice performances of energy monitoring

Despite being willing to be interviewed on their iMeasure experiences, not all the householders were using iMeasure. Indeed we deliberately selected one interviewee who was not using iMeasure anymore. Furthermore, those that were using iMeasure to perform energy monitoring did so to different extents and in different ways.

At the simplest level, many of those still using iMeasure on a fairly infrequent basis were mainly using it as an online data "store" (B; C; J) for their meter readings and, as such, did not fully (or sometimes even at all) embrace its analytic capabilities. For these householders, iMeasure often acted as a "reliable way for storing" (L) energy data that tended to be associated with home management and being economical, for example, negotiating the best contract with one's energy supplier:

> "So, when I am in discussion with my energy providers or checking their prices or looking at my direct
>
> debits or whatever, I am kind of more in control and have more understanding of what is going on." (B)

This also surfaced in the netnography, mainly through an online discussion about whether there was "a way to include the standing charge" (L) in the monitoring units of iMeasure. We argue that such examples do still represent energy monitoring because iMeasure was serving to provide a better understanding of householders' energy use trends, albeit those trends were at a higher level of

aggregation and with longer time intervals employed. These examples also illustrate that, whilst the householders are very much talking about and focusing on energy, it is sometimes the cost of energy that they are monitoring – sometimes as a proxy, other times as the main unit of analysis.

In addition, energy monitoring can also involve other (often tailor-made) monitoring materials that may be used instead of, or as well as, a digital energy feedback tool. Both the netnography and household interviews found many iMeasure householders maintained other (e.g. offline) records of their energy use, most typically via personalised excel spreadsheets, although some preferred paper records. This extra data had, for some, been supplied by additional monitoring equipment they had installed in their homes, enabling extra analysis (including disaggregation) that was beyond the scope of iMeasure. We would suggest though that these additional means of data collection align with the sample's willingness to manually collect data. In addition, we found online discussions that involved iMeasure householders challenging the calculations and assumptions of iMeasure itself, and their comments were usually justified through these additional data collection and analyses. This also emphasises the range of householder experiences in the context of energy monitoring, in that some enthusiasts went considerably further than others in the pursuit of furthering their understanding.

Comparing the use of iMeasure solely as a data store for negotiating energy contracts, to the use of iMeasure as a starting point from which other more advanced monitoring materials are used, emphasises how it is possible in a social sense to distinguish between 'better' or 'worse' performers of energy monitoring (e.g. on the basis of materials used, expertise, experience, regularity of performance). Finally, we note that it was certainly evident that the online forums facilitated comparisons between those that were more able to (and had a track record in) effectively monitor their energy use.

3.4. Solitary performance: Energy monitoring as an individual endeavour?

One particular householder's weekly habitual routine of reading his meters and trying to input it online was very much an individual endeavour. It was not something that he spoke to his partner about, nor indeed anyone else, which was especially surprising given that he had first been encouraged to join iMeasure through one of his local community group's meetings (yet never discussed it with those at his community group). This was not a rarity, with other householders similarly suggesting that it could be seen by others as a boring activity. The householders 'confessed' that they were "ubergeeks" (L) or "knit-your-own-sandal and save-the-planet types" (L), and argued that it was only those sorts of 'Resource Man' (Strengers, 2013) characters who would be interested in iMeasure, which interestingly reiterates a very particular set of meanings associated with energy monitoring. Consequently, they believed that no-one else in their household would want to hear about it:

> "She [my daughter] doesn't give a toss and neither does her husband." (F)

> "A lot of people wouldn't care to get started on doing what I do [i.e. energy monitoring]." (H)

Since energy monitoring was usually an individual endeavour, any knowledge acquired by householders from the feedback was usually kept to themselves. Consequently, there were very few conversations, arguments or negotiations that took place; this differs to other studies that found their respective energy feedback technologies to cause conflict to some degree (e.g. Hargreaves *et al*., 2010; Burchell *et al*., 2014). Whatever the reasons for this, the fact that iMeasure results were not usually discussed within households has implications more generally for energy-consuming domestic practices which are certainly *not* individual endeavours (e.g. cooking family meals; hosting guests; joint decisions over which temperatures are too warm/cold). Thus, the likelihood of energy

monitoring (re-)shaping how a household manages its energy use may be diminished if feedback

platforms seek to engage individual householders, as opposed to households or communities. It

should be noted though that our netnography did find that online forums provided a (digital) space

for like-minded individuals to connect with one another, and thus they were facilitating more direct

interaction with other energy monitors. However, it is questionable as to how many iMeasure

householders benefited from these online communities; none of the interviewees participated in

them. Moreover, there is no evidence that discussions between energy monitors would actually

impact on energy saving; we know from the rest of the study that there is not a linear correlation

here. Indeed, almost all our interviewees were completely disinterested in comparing their feedback

to others, which is certainly different to the suggestion made by one of Burchell *et al*.'s (2016a,

p.184) interviewees that comparative feedback could be the 'real glory' of energy feedback

initiatives – perhaps such a difference could be embedded in the fact that the Burchell *et al*.

feedback study focused on *community action*. Relatedly, it was interesting to note that their

participants seemed pleased to be part of a wider community of interest even if they never actually

engaged with anyone else on the subject.

In light of all this, our data would suggest that there was a lack of sociality of energy monitoring as a

practice, with it being a fairly solitary pursuit. This certainly poses questions about how theories of

practice seek to deal with practices that seem to be performed by individuals in relative isolation,

albeit in the inevitable context of the wider infrastructural and socio-cultural influences. The concept

of 'moral economies' (Silverstone *et al*., 1992) is potentially useful here as each household has its

own respective histories – and thus trajectories and configurations of practice – within which

designated household members have their own normalised and agreed upon roles, which have been

habitually reinforced over time due to repeated performance.

3.5. Inter-practice connections and boundaries: how energy monitoring relates to energy saving and other household practices

It is important to firstly reiterate that we see energy monitoring and energy saving as distinct from each other; the clear implication being that a practice which involves improving one's knowledge on a given subject can be separate from practice(s) that involves action on the same given subject. Thus, energy monitoring and energy saving can be performed without the other being performed (i.e. you need not always be monitoring to save energy, and vice versa).

The interviews revealed that many householders undertook measures to reduce their energy consumption with a primary purpose being so that they could monitor the energy-related consequences (e.g. the installation of a new energy efficiency technology, or changes to their water heating control settings). Therefore, for many, this was not first and foremost about saving energy, but about improving their understanding through a process of 'tinkering' (Knorr-Cetina, 1979, p.347) as part of monitoring, whereby they tested out and continually improved their technical knowledge (e.g. of which energy efficiency technologies or water heating control settings are best). Herein, the householders' experiences supported Burchell *et al*.'s findings that feedback-inspired changes to the way householders live involve 'a time-consuming and lengthy process' (2016a, p.185) that often constitutes 'hard work' (2016b, p.4). Thus, changes to how one used energy sometimes came about because of a desire to see, and better understand, the effect of such changes. It also seemed that such changes were much more in line with smaller, less radical changes (tinkering), as opposed to fundamental overhauls. This does not fit within proposed definitions of energy saving, as these attempts to lower energy consumption are actually related to gaining energy-related learnings. Therefore, this is primarily an extension of energy monitoring because changes are mainly being made so that they can be monitored. Indeed, this complements our previous discussion of the normativized learning objectives (as teleoaffective structures) in sub-section 3.1. In addition, it is

important to note that seeking energy savings in this way is markedly different from being motivated to save energy purely to save money, which is often assumed by policy.

Saying this, there were also a few direct examples of people trying to reduce their energy use because of, or facilitated through, the feedback garnered from energy monitoring. Since the energy feedback sometimes led to energy saving endeavours, some iMeasure householders were keen for iMeasure to get the "credit" (E) it deserved. For example, some used the degree days analysis in iMeasure to identify and then seek to reduce building heat loss, and one even frequently used it as a tool for weekly target setting. However, the householders commonly talked about there being a limit to what they were willing to do, and there were aspects of their everyday lives that they assigned as a non-negotiable 'need' (e.g. thermal comfort):

> "Whilst I am anxious not to overuse, I am also not going to sit and freeze if I can afford to pay for it. I will put on another jumper rather than switch the heating controls up but, as I say, the heating will be on." (D)

It was this non-negotiability, which has also been discussed by Strengers (2011), that was a common reason for a breakdown between energy monitoring and energy saving. Indeed, for most of the energy saving enthusiasts (frontrunners) that we interviewed, the act of registering for iMeasure followed (rather than preceded) them re-negotiating how they performed energy saving practices. For example, some householders only sought to monitor their energy use after they had re-programmed their heating and boiler controls, or agreed with the rest of their family that everyone would wear slippers and jumpers in winter. The netnography also found online discussions around the question: "had there been any changes in consumption" (L) after investing in insulation or other energy saving technologies? In this way, monitoring tools such as iMeasure could be regarded as a means for supporting people who have *already decided* to make changes, as opposed to inspiring

people to make changes in the first place – this was also the finding of Gram-Hanssen and Christensen (2012) in the context of carbon calculator feedback. Consequently, they were not in a position to or even aiming to reduce their consumption any further.

We argue that energy saving is not a practice in and of itself, mainly because energy is used to facilitate the performance of a practice; as Warde (2005, p. 137) states, consumption is 'a moment in almost every practice'. Therefore energy saving is simply a manifestation of one particular way of organising and performing other (energy consuming) practices. Since energy monitoring's links to other energy-consuming everyday practices are weak, monitoring itself usually did not directly lead to changes in everyday life (e.g. regarding temporal changes; taking up of other, such as DIY, practices; reduced consumption).

Although some interviewed householders – who profess themselves as being energy "geeks" (F; G) – did actively seek to reduce their energy usage, when they actually talked about how they did this, they tended to talk about it in terms of their everyday life and its relevant practices:

> "[We] run our washing machine on 40°C or 30°C if we can. And we don't fill the kettle with a lot more water than we need. So it is all those things that you might kind of think of as just ordinary." (B)

Since discussion of energy saving always switched to how other practical everyday doings may have changed, it suggests that these actions are not part of a distinct energy saving practice, but instead form a part of other practices that happen to consume energy. And it is the changes that are made to those practices – that in turn have their own histories and context – which determine energy consumption (and whether any energy reductions are achieved). As one householder commented, his household's environmental concerns were shaping how "we run our lives" (B). Energy saving is thus dependent on the configuration of energy-consuming practices and, in particular, how much

weight is given (consciously or not) to images that align with energy saving within each practice's 'meanings' element (e.g. environmentalism, sustainability, frugality). Whilst these vary across individuals, a practice's social organisation ensures relative consistency.

It is thus unsurprising that whilst many of the sampled householders saw themselves as being 'monitors' of energy, they did not seem to regard themselves as 'managers' (or 'savers') of energy in the same way. The latter was not a practice that they saw linked to an identity, even if they had made large changes to save energy. Instead, they were much more comfortable in talking about how they were energy conscious in their daily household activities.

4. Conclusion and policy implications

The aim of this study is to investigate the phenomenon of energy monitoring, as part of which we employed an online energy feedback tool that focuses on longitudinal energy consumption trends ('iMeasure') as a case study. We have found that energy monitoring should be recognised as a practice in and of itself, which involves measuring and identifying energy use trends. We have also found that of those performing energy monitoring in earnest, there was no guarantee that it would result in them actively seeking to reduce their energy consumption (although there were certainly, more complex, links to energy saving activities). For our study, energy monitoring was quite often the ends, rather than the means. Going further, in thinking more about the inter-relationships between practices, it would interesting to reflect more on the potentially unusual nature of energy monitoring in comparison to the organisation of other practices.

Among various socio-technically co-ordinated commonalities, this study has also demonstrated clear variations in how individuals perform energy monitoring, including: the deemed 'quality' of performance (e.g. 'novice' performance of bill reading, vs. 'expert' performance of analysing

additionally collected data); the extent, type and means of learning that takes place (e.g. regarding amount, vs. timing, vs. influences of energy use); the units of analysis used that still maintain a sole focus on energy use (e.g. kWh, vs. £); the frequencies of performance (e.g. weekly analysis, vs. weekly uploading of data but analysis only occurring when energy contract needs renewal); and the role of automation (e.g. technologies that measure energy use, vs. manual reading of meters).

We wish to emphasise six policy implications. First, it is vital that policies and policymakers distinguish between energy feedback and energy monitoring. Language matters as it is a core constituent of how the problem is being defined. Using the terms interchangeably is likely to cloud the intended purpose of relevant policies and, as such, may well mean that the implementation and end-user experience of these policies is confused. Second, energy monitoring also needs to be better distinguished from the active management of one's own energy consumption. Indeed, many policy measures may do well at recruiting more energy monitors and/or in making energy monitors better at monitoring their energy use, but that will not necessarily translate into energy saving action. This point is critical in re-framing the individualistic expectations of existing and future energy feedback interventions. Third, an opportunity exists for more energy monitors to be recruited post-energy saving. This links to how the search for a better understanding of household energy use (change), through the gathering of energy feedback information for energy monitoring, was found to often be initially driven by other activities, such as those aimed at energy saving. This recommendation is thus reminiscent of some marketing techniques that focus on the moment of purchase. Fourth, energy feedback interventions may recruit more energy monitors if they target households, rather than individual householders. Otherwise, they are not sufficiently aligning with the social dynamics that underpin how practices are organised in the home. Fifth, monitoring is not an activity that is solely attributed to understanding energy use patterns. Policies need to do more to account for the fact that monitoring straddles multiple applications, quantitative-qualitative divides, sites, and hence policy areas beyond the home (e.g. work, transport). Sixth, it is vital that a policy's measures of

success (e.g. of uptake) sufficiently recognise variation in the appropriation of energy feedback tools. It was clear that the tool was used in a variety of ways, all of which still amounted to energy monitoring.

Considering that energy monitoring is bound to its associated materials, it is also important to reflect upon possible changes that may arise as part of the transition to the smart energy grid, which includes the domestic smart energy meter. Consequently, there are various unanswered questions for the future evolution of energy monitoring, such as: how will householders be afforded access (and in what format) to these energy data? Will it result in the recruitment of millions more energy monitors across Europe, or will it just 'improve' the performance of those already monitoring energy? What else could anonymised versions of energy data be used for (aside from feedback) by government and industry? For instance, could the monitoring infrastructure facilitate a higher-level form of ('big data') energy monitoring at the societal/aggregated scale? Whatever the answers, it is certainly true that these new (smart) infrastructures could significantly change the organisation of energy monitoring – but it looks unlikely that these changes alone will actually contribute to a reduction in energy consumption.

5. Acknowledgements

6. References

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