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Apportioning energy consumption in the workplace: a review of issues in using metering data to motivate staff to save energy

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The UK government has set ambitious targets to reduce carbon emissions, and lowering energy demand within workplaces is important to help meet these. With the rollout of smart metres and the availability of more fine-grained energy monitoring equipment for the workplace, it is increasingly possible to disaggregate collective energy consumption and *apportion* this among building users. This article presents an interdisciplinary perspective on the rationale and feasibility of different approaches to apportionment to motivate staff to reduce energy consumption. Our review indicates greatest potential for energy saving when consumption is apportioned to small to medium-sized groups, rather than individuals or entire buildings, particularly when they represent existing communities to which staff members strongly identify. We highlight the complexity of technical, psychological, social and organisational factors that not only inspire, but also often confound, efforts to innovate in this area.

Keywords: energy monitoring; smart meter; non-domestic; BMS; data; behaviour change

Introduction

Amongst sectors reviewed by the Intergovernmental Panel on Climate Change (IPCC), emissions from constructing and operating buildings have the most significant potential for reduction by 2020 (Levine et al. 2007), with buildings being responsible for 32% of total global final energy use (IPCC 2014). *Non-residential buildings* are a major culprit; across Europe, electricity consumption in non-residential buildings has increased by 74% over the last 20 years (BPIE 2011). This is likely to continue to increase in non-OECD countries (IPCC 2014). There has been a

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corresponding increase in guidelines and regulations aimed at improving energy efficiency in the workplace.[1,2]

In response, attempts to reduce workplace energy use have included building service management (Fong, Hanby, and Chow 2006), intelligent manufacturing (Dietmair and Verl 2009) and paperless office systems (Sellen and Harper 2003). However, the use of office equipment and lighting regularly accounts for more than half of overall consumption in commercial buildings (Murakami et al. 2006) and so user behaviour can have an important impact (IPCC 2007). Indeed research has demonstrated that people's behaviour can account for large variations in energy consumption across buildings with similar characteristics (Schipper, Bartlett, and Hawk 1989).

A building user's energy consumption is a socio-technical system – a function of workplace systems, equipment and culture – which can be altered through interventions. Emerging technologies and understanding make it increasingly possible to deliver specific feedback – where energy consumption data are *apportioned* to particular occupants, or to spaces and systems, to encourage efficiency and conservation. Research into intervention techniques of this type has burgeoned in recent years (e.g. Froehlich, Findlater, and Landay 2010; DECC 2012; Yun et al. 2013); however, defining best practice around effective workplace interventions remains a largely unanswered challenge (Pierce and Paulos 2012). These reviews note in particular that evidence of the social and psychological impact of workplace interventions is sparse. Studies have echoed the need to explore this impact; for example, Katzeff et al. (2013) demonstrate, through deployment of technology probes in different workplaces, that the goals of such deployments often clash with entrenched organisational attitudes and productivity motives, highlighting a need to align technical with social research on this topic.

This review integrates social and technical literatures relevant to energy monitoring in the workplace, demonstrating where existing knowledge can feed into emerging workplace systems and policy. Importantly, while apportioned energy consumption is becoming increasingly technically feasible, the organisation must be sensitive to the potential for monitoring to alter staff's behaviour and work practices.

Energy monitoring technologies

There is a diverse range of monitoring technologies currently installed in non-residential buildings both in the UK (our focus here) and elsewhere. Figure 1 illustrates this range and links the various technologies discussed in this section to the different levels of granularity to which consumption might be apportioned.

At the building level, non-residential buildings are commonly fitted with self-contained 'fiscal' utility metres, which can be considered the most basic form of monitoring. These do not provide owners or occupiers with the means to extract and analyse aggregate data (Lehrer and Vasudev 2010). More advanced building-level metres can be found in larger workplaces: in the UK, metres that provide half-hourly automated metre readings (AMR) are mandatory in buildings larger than 1000 m^2 (RIBA 2010) or with peak consumption routinely exceeding 100 kWh (Elexon 2001). However – in line with many other EU countries – smart metres (which not only offer different functionalities from AMR metres, but also produce regular, e.g. half-hourly, readings) are now installed in the UK as the primary building-level energy metre in new commercial buildings, regardless of size or consumption (Carbon Trust 2011). Both AMR and smart metre data provide a basis for comparative and historical analysis of energy consumption and costs (BBP 2011).

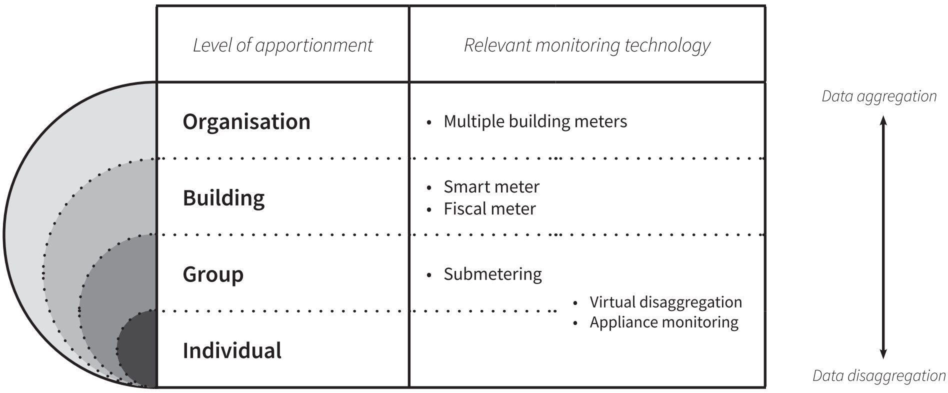

Figure 1. Energy monitoring technologies applicable to various levels of apportionment.

Ongoing national roll-outs of smart metres will generate data on energy consumption that may drive a range of new ‘eco-feedback’ services (Froehlich, Findlater, and Landay 2010), including digital displays and mobile applications that allow consumers to reflect on their consumption. To date, research has focused on their impact in the residential context. Within the residential sector, the potential for reductions in electricity consumption as a result of feeding back aggregate (house-level) energy profiles from smart metres to occupants has been up to 15% (Darby 2006; Ofgem 2011). It is logical to consider how such results might be applied to the workplace, but fundamental differences mean that they may not be so. Notably, if energy feedback is directed at employees (rather than energy managers), their effect on energy use might not be as large, given that employees do not directly incur costs (Foster et al. 2012). Furthermore, employees tend to have less control over the energy that is used in the workplace (Jain et al. 2013), and responsibilities are shared, with individual contributions to energy use harder to distinguish than in the residential context (BPIE 2011). However, motivations to save energy beyond costs can be considered; for example, environmental imperatives (Spence et al. 2014) and other contextual aspects of the workplace such as social sharing and comparisons (Froehlich 2009) could also serve to encourage and promote sustainable actions (e.g. Cialdini 2003).

Disaggregating energy consumption

Numerous technological options are available for organisations to disaggregate and pinpoint the causes of energy consumption within a building (i.e. to the ‘group’ or ‘individual’ levels in Figure 1 and Table 1). Sub-metering is regularly encouraged at a national policy level (e.g. Part L of UK building regulations[3]). In buildings where circuits map logically to rooms, groups of staff or sets of appliances, sub-metering can help building owners link their energy consumption to actionable optimisations (NSTC 2011). Currently, the potential to sub-metre and make use of these data is not fully tapped in many countries: sub-metering of energy consumption in commercial buildings has been a required element of UK building regulations since 2002 (RIBA 2010), but is often implemented without an overall strategy or a means to bring the data together for analysis (Jones 2012).

In larger workplaces, building energy management systems (BEMS) are frequently commissioned to gather data from sub-metres and simplify the task of evaluating the energy performance

Table 1. Psychological and social mechanisms resulting from disaggregation of energy consumption.

	Level of apportionment	
	Group	Individual
Positive factors	• Group identification and dynamics • Descriptive norms • Greater levels of instrumentality	• Highly personalised feedback • Descriptive norms • Lateral control • Easier identification of energy-consuming actions • Instrumentality
Negative factors	Freeriding and conflict	• Marginalisation ('black sheep' effect) • Privacy concerns

of the buildings. A sophisticated BEMS may comprise tens or hundreds of real-time energy monitoring and control points, particularly when monitoring is implemented at the individual appliance level. This sophistication can give unique insights: previous reviews of workplace energy conservation (e.g. DECC 2012) have highlighted the potential for organisations to use disaggregated consumption data to understand the end use of energy, revealing (a) opportunities to more closely align workplace infrastructures with actual staff need (e.g. tightly matching heating provision with occupancy), and (b) opportunities for sustainable behaviour change. In the UK initiatives such as government-funded End Use Energy Demand centres[4] and TEDDINET[5] are beginning to explore this potential.

Virtual disaggregation

Although energy sensors in workplaces are proliferating, it is also recognised that poorly planned integration of many different sensors in a BEMS can lead to overwhelming complexity (BBP 2011) and the need to employ technically skilled systems managers (DECC 2012). In response, research into energy systems and ubiquitous computing has considered how to 'virtually' disaggregate energy consumption data *without* installing complex energy sensing hardware. Non-intrusive load monitoring techniques allow aggregate consumption to be algorithmically deconstructed into profiles of characteristic appliances and users (Ruzzelli et al. 2010), including approaches that identify office appliances (Schoofs et al. 2010). Experiments to identify unique energy-consuming events by non-invasive monitoring of noise on electrical circuits also have promising results (Patel et al. 2007). However, this research is currently far from being able to distinguish the majority of appliances – and more importantly *users* – in complex workplaces.

An alternative to deconstructing an energy profile is to monitor a related phenomenon and correlate this with energy consumption. Researchers have noted that infrastructures for detecting occupancy already exist in many workplaces; that occupancy is a correlate for energy consumption (Dodier et al. 2006) and that this information could be used to roughly disaggregate consumption (Hay and Rice 2009). Rice, Hay, and Ryder-Cook (2010) demonstrated that their approach allowed long-term electricity consumption predictions for sets of appliances, users and heating, ventilation and air conditioning (HVAC), which were within 10% of the true value. Other researchers have demonstrated how network logs in workplaces can be used to align energy consumption with floors or rooms of a building (Christensen et al. 2014), and how data from motion sensors in automated lighting might be used as a proxy for room-level energy consumption (Milenkovic and Amft 2013).

It is also possible to track individual occupants, thus enabling the approximate apportionment of *personal* consumption. Research into context-aware power management considers how tracking systems, for example, through triangulation of wireless devices (Harris and Cahill 2007), can reveal who is using energy (Harle and Hopper 2008). Technical solutions for tracking occupants are a tempting solution, particularly as such solutions can be far cheaper than installing a complex new energy monitoring system; however, this research largely ignores the impact that energy apportionment might have on staff. Colley, Bedwell, and Rodden (2013) explore reactions of staff to apportionment based on personal tracking, and suggest that current approaches tend to underplay the highly social nature of workplace energy consumption and may potentially demotivate staff.

In line with advancements in computing – the adoption of increasingly complex monitoring systems is likely to continue. Importantly however, the specific mechanisms by which the process of apportionment might motivate staff, or otherwise change their behaviour, are not specified or well understood. Knowing the level of granularity at which apportionment provides the greatest opportunities for conservation is important both to channel technical research towards the most cost-effective solutions, and to inform workplace energy policy.

Apportioning consumption to occupants

Application of social psychology insights to non-domestic energy behaviours remains sparse (DECC 2012), despite this literature offering the potential building blocks for organisations to create measures that involve their staff more actively in workplace energy conservation. Research has shown that strategies that include specific feedback based on energy data are particularly effective (IEA 2007; Bin 2012). Data that allow energy consumption to be apportioned to occupants are unique in enabling the operation of psychological and social mechanisms that have been shown to influence behaviour, particularly self-efficacy and instrumentality (the feeling that your actions make a difference: Locke and Latham 2002), and cooperation and social control (Leygue et al. 2014). We explore these mechanisms – summarised in Table 1 – in more depth here, considering the motivational and social effects of the different possible levels of disaggregation of energy data.

Monitoring and apportionment of energy consumption enable the setting of goals for reduced consumption, which can have an important motivational effect on individuals and groups (Davis 1995; White, MacDonnell, and Dahl 2011). Goal setting promotes action by directing people's attention and effort towards the goal; through energising people to try to achieve the goal; through encouraging persistence in behaviours that work towards the goal and by making salient and encouraging the discovery of new goal-relevant information and strategies (Locke and Latham 2002). Crucially, if data are available to apportion energy consumption among staff, goals may be *specific*. Specific goals reduce ambiguity around what individuals are being asked to do (Locke et al. 1989) and are more efficient in creating new habits (Holland, Aarts, and Langendam 2006). Therefore, setting people concrete energy-saving goals (e.g. to try and reduce their weekly electricity use by 5%) is likely to be much more effective than simply asking people to try their best to save energy (Gollwitzer and Sheeran 2006). Moreover, energy data enable the provision of feedback, helping people understand how they are proceeding towards a goal, and combining goals and feedback is more effective than goals alone (Bandura and Cervone

1983; Houwelingen and Raaij 1989). This research implies that the most effective way to reduce energy use in the workplace is to adopt explicit energy goals within company strategy and to make associated energy data available to individual employees in some form (e.g. public display and personalised feedback). Indeed this combination of intervention has resulted in reductions of 5–12% of energy use in households (Van Houwelingen and Van Raaij 1989; Abrahamse et al. 2007).

Making apportionment visible may also allow occupants to compare their consumption to that of others. Workplaces tend to consist of many more people than in residential situations, and the implications for apportioning to different configurations of building users are complex. As such, we reach an important distinction: between the mechanisms at play when energy consumption can be apportioned to *individuals* – requiring a finer degree of disaggregation in monitoring – or to *groups* of individuals.

Apportioning to individuals

A key benefit of being able to divide up consumption and apportion it to individuals is the ability to engage the individuals with tailored feedback. Social and behavioural research suggests that the provision of personalised information is useful in promoting behaviour change (Abrahamse et al. 2005; Abraham and Michie 2008), demonstrating that messages increase in effectiveness as they become more personally specific (Locke and Latham 1990).

The creation of individual feedback means that this may be revealed and become public – either through design or by accident – and thus provide a means of comparison. Peer effects are often sought when pursuing behavioural change (discussed later), and research shows that people are more likely to undertake sustainable behaviour when encouraged by peers and when this behaviour is visible to peers (Cialdini 2003). Having knowledge of other people's behaviours works as 'descriptive norms' to the group, and people will be inclined to follow these norms and act similarly (Cialdini, Kallgren, and Reno 1991; Cialdini 2003; Thogersen 2006). Descriptive norms are different to injunctive norms, which are perceptions of what other people think you ought to do rather than knowledge of what other people actually do themselves (Cialdini 2003). Note that neither of these necessarily encourages sustainability. With regard to descriptive norms, if in fact it is observed that others tend to consume more, then people may actually increase their usage as a result (Brandon and Lewis 1999; Fischer 2008), known as a 'boomerang effect'. Similarly, a culture may prevail where employees do not desire to save energy, for example, seeing environmental goals as counterproductive to other goals, and in these cases injunctive norms may discourage energy conservation.

Data sharing may result in forms of lateral control and peer scrutiny (Brivot and Gendron 2011) that provoke animosity between individuals (Ellway 2013). In fact it may be difficult to marry apportionment to individuals with working environments where the fundamental unit is the team and therefore energy use of devices and systems is collective (Sewell 1998). On one hand, social identity theory (Tajfel 1974) suggests that individuals perceived to be behaving differently from the rest of the team may be marginalised (Hogg 2006) – as they threaten the integrity of the group's norms (Hogg, Fielding, and Darley 2005). Revealing the consumption of individuals may therefore contribute to this 'black sheep effect' (Marques and Paez 1994), which has been observed within groups in organisations and could lead to organisational defections (Bown and Abrams 2003). In addition, apportionment of consumption that an individual believes is unfair, or the setting of goals for individual consumption that are unachievable in comparison to others', may result in the perception of procedural injustice (Konovsky and Cropanzano 1991). Perceived injustice may then result in a resistance from the individual, possibly resulting in reduced efforts (Tucker 1993; Ambrose, Seabright, and Schminke 2002), undermining others' efforts or possibly even vandalism of equipment (Laabs 1999).

Apportioning to groups

Apportioning energy consumption to groups, rather than individuals, may have some advantages, particularly in terms of group dynamics and motivations and in terms of increased instrumentality achieved in aggregate. People grouped together, even by arbitrary means, are likely to identify with that group and act to enhance the group's image (Tajfel 1970). Simple organisation of a workforce by geographic space could therefore introduce an additional reason, group identity and norms, for individuals to change their energy behaviour. The simplest form of sub-metering, that is, the monitoring of electrical circuits, is technically and financially trivial and fairly easily provides the means to monitor a number of co-located groups of individuals.

Grouping by association vs. community

Spatial location in a workplace often relates to team membership, but does not always. While arbitrary groups (e.g. as spatially divided by sub-metering) are subject to social effects, grouping people by organisational or entrenched social relationships (i.e. into 'teams' or friendship groups) increases levels of social identity felt by members (Hamilton and Sherman 1996) and group dynamics observed. Within more cohesive groups, centrality, in-group affect and in-group ties tend to be stronger (Cameron 2004); they are therefore more likely to work together and less likely to loaf or freeride (Williams, Sarau, and Bourgeois 1993). Group members may be more likely here to also take positive social actions, for example, campaigning for more sustainable procedures or purchases (Sturmer and Simon 2004), assuming that environmental goals are significantly valued by the group.

Apportioning consumption to pre-existing communities may therefore hold even stronger potential for motivating changes in consuming behaviours than spatial apportionment. However, there are significant practical constraints on our ability to apportion to communities in the workplace. Work trends currently are towards 'frictionless,' 'nomadic' architecture (Bean and Hamilton 2006), such as hot-desking (Hirst 2011), flexible open plan layouts and ubiquitous, mobile technologies (Ciolfi and Bannon 2005). The structures of social communities also change over time as the group's members and configuration change (Levine and Moreland 1994). These mean that individuals are highly mobile, and that community members are often not co-located. If individuals are transient, the consumption of particular sub-metered spaces no longer acts as a direct proxy for the consumption of those teams; instead, a greater reliance on the 'virtual disaggregation' approaches discussed earlier in this review – approaches that allow individuals to be tracked – may be required.

Impact and instrumentality

Research on decision-making has demonstrated that the scale presented in feedback can have an influence through the salience that it achieves (Taylor and Thompson 1980). We know that the form of energy feedback can have a significant impact on people's perceptions and resulting behaviour, but research here has primarily focused on metrics, for example, meaning and context provided by different units of measurement (Abrahamse et al. 2005; Karjalainen 2011; Spence et al. 2014). There is little applied evidence in this field of the impact of aggregating amounts presented in feedback. Energy feedback often focuses on individual actions and related small costs/savings, which may dishearten individuals given that they see their actions only having a relatively minor impact (Spence et al. 2014). Observing the larger scale consumption apportioned to a group – and the more significant impact of a collective energy goal – may increase perceived instrumentality, a significant factor in promoting energy-saving behaviour (Locke and Latham 2002; Spence et al. 2011).

Freeriding and sanctions

Although the apportionment of energy consumption to groups offers the potential to motivate, basing group goals on collective consumption may also absolve individuals from direct accountability for their energy use. Team rather than individual apportionment is therefore likely to be less stressful for individuals involved (Aiello and Kolb 1995), yet also provides the opportunity for individuals to freeride, that is, rely on others' efforts to reach a common goal (Karau and Williams 1993) or to use more than an equal ('fair') share (Dawes 1980; Fehr and Fischbacher 2003).

Freeriding tends to be more common in larger groups and when individual behaviour is more anonymous (Hamburger, Guyer, and Fox 1975). In line with this, cooperation within the group may be increased by making mechanisms available to identify freeriders (Haley and Fessler 2005) and implementing sanctions (social, e.g. gossip, or institutional, e.g. fines) to prevent further freeriding (Fehr, Fischbacher, and Gächter 2002). The injustice of freeriding encourages anger and confrontation (Carver and Harmon-Jones 2009), and there is potential for unjustified scapegoating when there is no specific evidence of individual consumption. Organisational sanctions tend to be preferred by group members (Guala 2012); however, without individual monitoring, these may be difficult to operationalise. There is actually some evidence that retaining a degree of ambiguity – not revealing exactly who has consumed what proportion of a resource – may result in increased fear (of whether one might be over-consuming) or guilt (of potentially over-consuming) and lead to reduced consumption overall through compensating behaviour (Elgaaied 2012; Leygue et al. 2014). However, the impact of this was found to be minor, and deliberate attempts to instil uncertainty may clash with more traditional organisational values of teamwork.

Optimum group size is as yet unknown in this context. Literature on group performance highlights optimal group sizes of around five people (Hare 1981), but it is notable that this is for specific task-orientated activities; when idea generation is required, larger group sizes tend to be more beneficial (Dennis and Valacich 1993; Valacich, Dennis, and Connolly 1994). Optimum group sizes for energy monitoring is likely to be dependent on factors including social and organisational aspects, for example, if there is a clear goal and a tangible reward (Karau and Williams 1993), whether there is potential for being creative in achieving efficiency gains, and contextual aspects, for example, environmental layout and mutual visibility (Chidambaram and Tung 2005).

Policy and organisational control

Monitoring of energy consumption must be considered within the context of organisational control, for 'seeing something is the first step to controlling it' (Espeland and Stevens 2008). There is a history of characterising this context through Foucault's (1975) metaphor of the panopticon, in which the subjects are aware of the potential for being observed at any time, and so assumes that they are (e.g. Preston 1989). From this perspective, energy monitoring and apportionment are a means through which management can ensure the compliance of workers. This has clear positive consequences: as discussed, individuals tend to prefer sanctions on group goals that are enforced at the organisational level and this assures individuals that they will not be acting in isolation. Efforts to reduce the independence of staff can have unintended consequences, however: we have also already highlighted contexts in which lateral control may be exerted (surveillance among staff, the black sheep effect or scapegoating), and where control can also reverse direction in the form of resistance rather than compliance (Scott 1990). Organisational implications are that monitoring is best implemented within a framework that makes assumptions transparent, offers benefits to those involved and communicates these benefits clearly. However, if these benefits include rewards – financial or professional (e.g. the integration of energy use in performance reviews) – for employees who save a certain amount of energy, it is important that the manner of apportionment is perceived to be legitimate lest the rewards be interpreted as being distributionally unjust (Vardi and Weitz 2003, 125).

Monitoring may also impact actual work processes. This may be intentional: energy data may form part of an audit process in which practices are ‘dis-assembled and reconfigured’ to increase efficiency (Hargreaves 2011). On the other hand, monitored tasks – or some parameters of them – may come to be accorded greater attention by the employee (Larson and Callahan 1990). This may have positive consequences in that efficiency behaviour becomes intentional and habitual, but could also lead to outcomes where energy behaviour is simply shifted (Bevan and Hood 2006); for example, monitoring printing costs could result in greater use of electronic screens as alternatives, potentially increasing energy demand, and/or creating new less productive working practices (Sellen and Harper 2003). More deliberate rebound effects might also occur, where people, after saving energy in one instance, feel more entitled to reduce their efforts in energy savings in another setting (Greening, Greene, and Difiglio 2000).

Personal privacy

Monitoring technologies, as ‘embedded systems’, have tendencies towards both pervasiveness and invisibility (Moran and Vallejo 2013). This heightens the risks of unexpected social and behavioural effects and reinforces the need for real-world deployments.

Responses to monitoring systems are theorised to be determined by the individual’s personal boundaries, the individual’s general attitude towards compliance and resistance and the agency that individuals have to mitigate any negative aspects of monitoring (Ball and Margulis 2011). These individual dispositions and circumstances will interact with contextual elements of how the monitoring is implemented to determine likely reactions. Importantly, meanings given to the monitoring system by organisational dynamics and by the act of monitoring, and the nature of the managerial support given to the system (Ball and Margulis 2011) will influence individuals’ likelihood to respond positively or negatively.

Notably, it is recognised that a ‘privacy paradox’ exists (Norberg, Horne, and Horne 2007), by which individuals’ stated unwillingness to share personal information contrasts with willingness to do so in practice. From this, Bolderdijk, Steg, and Postmes (2013) argue that privacy concerns are dependent on the individual’s motivations; monitoring may not necessarily raise privacy concerns and is likely to be accepted where the subject of it believes it comes with a neutral or positive personal benefit–cost ratio. Particular forms of monitoring (e.g. presence detection) may transgress public–private boundaries in such an invasive manner, however, that they are liable to provoke negative reactions regardless of how they are implemented (Zweig and Webster 2002).

Discussion and conclusions

It is becoming increasingly possible to collect fine-grained energy data in the workplace, where improving efficiency has significant potential to reduce global carbon emissions. Our review has integrated insights from both technical and social science literature, identifying key research areas that provide evidence of the value in leveraging these data for behaviour change. Our review shows that *disaggregation of energy data is increasingly possible* and that *apportionment of energy to groups that are spatially organised is preferable*, rather than to transient communities or individuals, given both technical and motivational considerations. It is clear that successful workplace energy policies will be *well integrated within, and coherent with, wider organisational policies*. In particular, setting *clear specific goals* around energy use is likely to be effective, and more so if *specific feedback* on these goals is provided.

Complex issues relating to where energy data can, and should, be apportioned at an individual or group level remain. With regard to individual apportionment, there may be motivational benefits of personalised feedback, however revealing that individual feedback could lead to negative social phenomena based on perceptions of injustice. Group apportionment of energy data also has potential for motivating staff, through increased salience and greater perceptions of instrumentality. Additionally, group identity may encourage collaboration and competitiveness. These benefits may be particularly significant if pre-existing communities can be defined and apportioned to, but technical solutions to tracking membership of such groups are complex.

We challenge researchers to make technical solutions for virtual disaggregation a reality, while considering their *social and ethical implications*. We have shown that personal devices may be useful tools to provide approximations of occupancy and apportion consumption without the need to deploy complex energy monitoring infrastructure, but ask whether these approaches are privacy-preserving. New solutions may ask questions of the typical top-down approach to monitoring: might groups be motivated to monitor themselves? We have shown that room occupancy and network use can be easily monitored, and correlate with energy use. What other workplace practices already leave digital traces that might be combined with energy consumption data to enable apportionment? Given the literature reviewed in this article, we highlight a need to build on literature around the impact of surveillance in the workplace to explore 'in the wild' implementations of energy apportionment systems.

We raise challenges for research around the *motivational and social processes* surrounding engaging workplace staff with energy data. Indeed, basic research relating to what might motivate individuals to save energy in the workplace, and whether specific rewards here may be useful, is currently an open question. Previous research has highlighted a potential conflict between environmental and financial values (Maio et al. 2009; Corner, Markowitz, and Pidgeon 2014), indicating that company policy and communications on these issues could undermine each other; however, this remains to be empirically tested in this domain. The social processes that are theorised to operate around the implementation of both individual and collective monitoring and goals, for example, the utility of energy goals and feedback, require field testing in this domain and are likely to interact with the specific institutional context.

To conclude, this review has integrated key insights from a range of disciplinary perspectives in considering the challenge of utilising energy data, via apportionment, to motivate behaviour change in the workplace. In particular, we propose that organisational motivations for and implementation of monitoring need to be clear and aligned with the organisational culture. The apportionment of energy is likely to have utility in motivating conservation behaviour, and group-level apportionment by spatial location currently appears the most fruitful direction. Importantly, while apportioned energy consumption has motivational benefits, the organisation must be sensitive to the potential for monitoring to transform its staff's work practices.

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Notes

1. http://www.breeam.org
2. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:001:0065:0071:EN:PDF
3. http://www.planningportal.gov.uk/buildingregulations/approveddocuments/partl/
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Nick Banks (CSE) is a Senior Development Manager, and has a Ph.D. in the Sociology of Energy Use from Oxford University's Environmental Change Institute and has conducted numerous projects examining human responses to technological and behavioural interventions in the energy field, most recently exploring potential design for a new fuel economy label for passenger vehicles. Although he specialises in social research, he has also worked in a range of other areas including delivery of energy and environmental audits and carbon footprinting of organisations, life cycle assessments, implementation of energy and environmental management systems (ISO 14001), energy modelling and mapping projects, statistical analysis and general strategy and policy work.

Alexa Spence is a Lecturer in Psychology at Horizon. Alexa has considerable experience and expertise in researching public perceptions and behaviour relating to both energy and food choices. Notably, she was the first to develop implicit measures to examine perceptions of GM food and demonstrate their predictive value (beyond explicit measures) for related food choices and has led high-impact survey and experimental work in examining public perceptions of energy and the promotion of sustainable behaviour. She currently leads the energy team at Horizon, is the PI of the C-tech BuildTEDDI project and is well integrated into energy research in the UK, being involved in TEDDINET, UKERC and the Midlands Energy Consortium. She has held funding awards from a variety of organisations including UK research councils (ESRC, EPSRC and NERC), UKERC, the British Psychology Society (BPS) and EON, totalling a value of ~£3.3 m, which have developed Alexa's experience of managing people. Whilst still early career, she has achieved 25 peer-reviewed publications in journals such as Nature Climate Change and Appetite, which are well cited and won a Lloyds TSB prize for Risk Research (Behavioural Risk) in 2011. Alexa speaks at conferences regularly and is increasingly invited to give talks internationally.

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