Exploring energy monitoring in the wild

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ABSTRACT
The introduction of smart-meters and in-home displays to monitor and provide feedback on energy consumption is imminent, and such interventions are currently a focus of research. In this paper, we identify two key concepts in relation to such interventions – that personal energy consumption occurs in a social frame of reference, and that personal responsibility for energy consumption does not start and end in the home. We then outline two on-going studies designed to explore these concepts, both involving the deployment of novel technologies "in the wild".

1. INTRODUCTION
The Climate Change Act 2008 commits the UK to an 80% reduction in the emission of certain gases by 2050 (compared to 1990 levels) [4]. Interventions that "help consumers to better manage their energy use" [5] are expected to be an important component of fulfilling this commitment. In the medium-term, this might include the wide-scale deployment of smart-meters, which are integrated into the home [5], which provide consumers with real-time information about energy use, and which may also allow a more proactive and efficient energy infrastructure to be developed. In the short-term, after-market energy meters, which monitor household electricity consumption through clamps attached to power cables and present data to consumers through in-home displays (IHDs), are being incentivized. However, studies have failed to provide substantial evidence for the impact of interventions. For example, in one UK-wide study, coupling a smart-meter with an IHD reduced demand by only 3% [2].

More broadly, the identification of principles to consider when designing domestic interventions targeting energy conservation behaviours is a subject of research for environmental psychology and HCI [1,6]. A recent review by Froehlich [7], for example, identifies *feedback frequency*, *representing and mediating information*, *enabling comparisons* and *sustaining potential benefits* [7]. In this work, we identify two novel and relevant concepts – that *energy consumption occurs in a social frame of reference*, and that *personal responsibility for consumption does not start and end within the home*. We then provide an overview of two ongoing field trials which have been structured around these concepts, and which are taking place over the coming months. By deploying interventions into people's homes and personal mobile devices, we aim to better understand how such technologies can fit effectively in an everyday context, and to contribute to the design of effective interventions in the future.

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2. CONCEPTS

2.1 Personal energy consumption occurs in a social frame of reference
Individuals understand their everyday practices with regards to social norms, using appropriate frames of reference to contextualize their behaviour. Interventions such as those in the Tidy Street project seek to play on relationships within local communities, to encourage households to look outwards and consider their home's consumption with respect to that of their neighbours [3]. Such interventions treat the household as the unit to be motivated with respect to others, rather than seeking to encourage individual responsibility within the household.

In contrast, interventions such as Flo [8] aim to encourage each individual *within* a household to become more responsible for their personal consumption by allowing individuals to compare their consumption to that of others within the home. In reality, within all shared homes there are established and often unspoken practices and understandings that surround energy: members of a household will assume roles with different degrees of responsibility and accountability, often with a nominated bill-payer taking sole responsibility. Interventions encouraging greater *personal* responsibility among all members of the household are likely to upset this arrangement, particularly when interventions introduce accountability where previously there was none. We do not believe that there has been adequate research into the effects that such interventions may have on the relationships within the home: without *capitalizing* on the dynamics within a home it is unlikely that interventions which risk upsetting established practices will be accepted.

2.2 Personal responsibility for consumption does not start and end within the home
Current IHDs and research deployments focus heavily on consumption in the home. This has the potential to lead people into considering demand reduction purely as a domestic responsibility when it is in fact the case that a 'nine to five' office worker spends a large proportion of their day consuming energy away from the home. A smaller body of work has focused on energy consumption by staff in the workplace, e.g. [9], and there is the possibility that encouraging behaviour change in one environment will cause behavioural spill-over into other environments, yet we suggest that more research needs to be carried out to assess the value in actively encouraging individuals to reflect on their consumption across the boundaries of different environments. This research will need to consider the different relationships between an individual and energy in different environments, e.g. the greater or lesser degree of responsibility for energy use at work vs. at home, and whether interventions should seek to level or be sympathetic to these differences.

3. INTERVENTION DESIGN

To investigate issues around these concepts we are carrying out two studies – *living with energy monitoring* and *personal energy monitoring*. The interventions on which the studies are based make use of a combination of existing techniques such as energy saving tips, comparisons and the ability to drill down into the data. However, rather than the maximisation of behavioural change, our focus in these studies is on the exploration of the everyday practices that surround energy monitoring.

3.1 Living with energy monitoring

Twenty households were recruited to take part in an eight-week-long study of how they experience living with energy monitoring in their homes. To study a variety of households, seven families, six couples, four singles and three shared households were recruited living mostly in houses (18) as opposed to flats (2). We installed a monitoring infrastructure in their homes consisting of commercially available electricity measuring clamp[*], in-home display and a small form factor computer that connects to the participants' broadband router and transmits electricity readings to our server. After one week of baseline data collection, a welcome letter was sent to the households introducing the interventions.

The study employed the following four interventions drawing on motivation techniques used in behavioural psychology [7], namely *feedback, comparison* or *benchmarking,* and *information*. An off-the-shelf IHD that shows consumption in (near) real-time lets us explore questions of the utility and perception of such devices providing feedback. A bespoke web application was built that allows logged-in participants to view and interact with representations of their real-time and historic electricity use, and estimates of cost and carbon emissions. In addition, they may compare themselves to their 'neighbours', i.e. anonymous representations of the other participants in the study. Each home also tweets once a day about its occupants' electricity consumption, and gives energy saving tips if consumption was higher than on the previous day. This is to provide an alternative, succinct and textual representation of a day's consumption, and to provide existing Twitter users with a means to integrate home monitoring into their everyday information consumption practices (i.e. by 'following' the home's tweets). Finally, participants receive a daily text message informing them of the cost of yesterday's electricity use and how they compare to the average. SMS was used as a push-notification to remind people of their electricity consumption to assess its effectiveness as a technique to incite and sustain ecologically responsible behaviour.

3.2 Personal energy monitoring

The concept of personal energy monitoring seeks to investigate what a user might make of their *day-long energy footprint,* by combining data from location-aware mobile technologies, domestic energy monitoring systems, workplace building management systems and publicly available energy consumption figures. With energy consumption becoming exposed by the 'internet of things', the opportunity arises to move away from seeing energy consumption as *environment*-centric practice (energy consumed in places in which we are personally billed for consumption) and towards seeing it as a *person*-centric practice.

Six participants were invited to take part in the study. In order to engage with the study, participants were equipped with a mobile application that reports their location to a cloud-based infrastructure. The infrastructure translates the participants' location data into diary entries, keeping track of the time that they have spent in various buildings throughout the day.

Within the scope of the study, participants occupy three categories of space; the home space – where a consumer of energy relates to consumption in the most direct manner, the work space – in which there exists complicated mixture of personal, communal and non-attributable energy consumption, and the unmonitored space – where there is no consumption information available. After a week of carrying the mobile application and being 'tracked', users are given access to a web application that combines their location diaries with energy consumption data to represent to them their day-long energy footprint. The representation allows them to compare their consumption and time spent across the three categories of space. Interaction with the web application will be logged. Two focus groups will be held with the participants in order to discover the degree to which it has altered their perspective on energy consumption. During the focus group, particular attention will be paid to the level of control users feel they have over the energy consumption in the three categories of space and how this compares to the amount of consumption.

4. CONCLUSIONS

We have elaborated on the need for the inclusion of social context in energy consumption and the need to go beyond the spatial boundaries of energy feedback technologies. The two intervention-based studies to explore these issues are currently in progress. Findings from this work will inform requirements for the design of technologies that will be more attuned to people's everyday practices, and thus more engaging and motivational, inspiring energy demand reduction.

5. REFERENCES

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[*] In this study we focus on *electricity* as a proxy for energy, due to a lack of readily available off-the-shelf gas or water monitoring equipment.