Take It Personally: Personal Accountability and Energy Consumption in Domestic Households

Yukang Guo
Computer Science
Swansea University
Swansea, SA2 8PP, UK
y.guo@swansea.ac.uk

Matt Jones
Computer Science
Swansea University
Swansea, SA2 8PP, UK
always@acm.org

Benjamin Cowan
School of Computer Science
University of Birmingham
Birmingham, B15 2TT, UK
b.r.cowen@cs.bham.ac.uk

Russell Beale
School of Computer Science
University of Birmingham
Birmingham, B15 2TT, UK
R.Beale@cs.bham.ac.uk

CHI 2013 Extended Abstracts, April 27–May 2, 2013, Paris, France.
ACM 978-1-4503-1952-2/13/04.

Abstract
We explore the overlooked area of personal energy consumption in the context of a shared domestic household. We discuss the potential benefits of such an approach. We report the results of a lab study and field trial with four households using a personal energy monitoring system. We describe the results of the studies and discuss how such previously hidden information might raise awareness of individual energy consumption and the benefits and problems this entails.

Author Keywords
Energy consumption; mobiles; wearable computing.

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces.

Introduction
In 2010, the domestic sector accounted for 36.2% of the UK's total electricity consumption [4]. Driven by external stakeholders, such as the government and utility companies, and researchers in areas such as Ubicomp and HCI, commercial consumer devices and research prototypes that measure and give feedback on electricity consumption are widely available. Most of

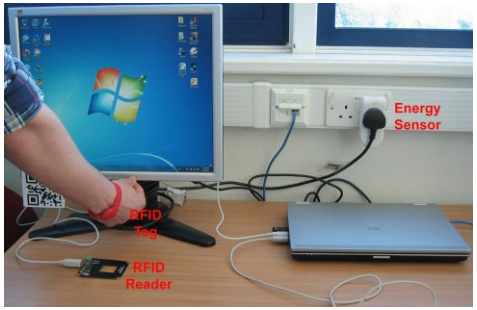

Figure 1. Probe One

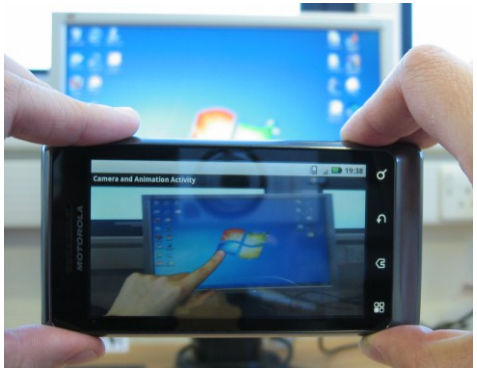

Figure 2. Visualisation application

these devices and systems, however, only sense electricity consumption at either appliance or household level. While in 2010/2011, 70.9% of English households contained more than one person [3], most existing work focuses on tracking and visualising appliance, household and wider community energy consumption. However personal energy consumption in shared domestic households has been overlooked.

In 2008, Hopper et al. envisaged the Personal Energy Meter (PEM) which collects individuals' daily energy footprints, including travel, heating, water and transportation of food consumed etc. and provides breakdown information of the energy consumption of individuals' activities. This concept has the potential to help individuals to identify alternatives to their current activities but was not implemented [7].
Methods and tools have since explored personal energy consumption in workplaces. Hay et al. explored apportioning electricity consumption for workers on flexible time [6]. In another study, a mobile application was developed to provide estimations of personal electricity consumption in a research laboratory and gave users the ability to operate specific appliances [8]. These systems simply apportioned a static fraction of the appliance energy consumption to all potential users. No method of accurately estimating personal consumption of fine-grained shared appliances has been established yet.

Moving to domestic households, individualised energy use tracking systems are neither widely available nor easily accessible due to the high cost of the hardware, the effort to maintain and the extra energy needed to deploy them. However, there has been interest in tracking other forms of resource in a household. For example, Chetty et al. designed tools to help domestic households to manage their internet bandwidth [1], and determine the cause of their internet slow-downs [2].

To investigate whether personal energy consumption information will raise people's awareness and change their energy use, we designed two lightweight prototype systems to demonstrate how the personal energy consumption problem might be addressed.

Probe One – the "Hands On" Visualiser

Two electrical devices, a floor lamp and a LCD monitor, were plugged into electrical outlets via AlertMe SmartPlugs[1]. Personal operations of the appliances (i.e. switching them on or off) were tracked using PhidgetRFIDs[2]. A PhidgetRFID reader was placed near the switch of each device, and the user was asked to wear an RFID tag in the form of a bracelet. When the user operated the device, their identity was recorded and the device energy consumption was logged from the plug (See Figure 1). For the purpose of data acquisition, PhidgetRFID readers are connected via USB to a computer. To visualise personal appliance operation history, a mobile application was developed on an Android smartphone. The mobile application is illustrated in Figure 2: holding the mobile up to a QR code on the device displays the hands of the users who turn the device on (image bright) and off (image dull as in Figure 2).

[1] www.alertme.com

[2] www.phidgets.com

We conducted a lab study with 12 participants from multiple-occupant households (6 females and 6 males, aged from 19 to 61, 4 participants were students and 8 were university staff). Participants took part in the study in pairs and were introduced to the concept and basic use of the system they would be using. Their hands were photographed for use with the mobile phone visualisation. Following this introduction, the pair of participants was asked to complete a predefined ten-step device operation task, each step involving the switching on/off of one of the two electrical appliances while wearing the bracelet shaped RFID tags.

Upon finishing the device operation task, both participants began using the smartphone application to expose the energy consumption history of the individual devices. No description or guidance about the purpose of the phone application was given. Following the completion of using the phone application, a semi-structured interview was conducted to gather opinions and experiences. At the end of the session, each participant was rewarded with a £10 gift voucher as an honorarium for participation.

The preliminary study indicated that the overall scheme is viable in terms of tracking accuracy. There were concerns over wearing a tag with several participants suggesting the tag should be integrated to some existing accessories, e.g. a watch or jewellery. In terms of visualisation, participants suggested they would favour additional details such as the costs of running an appliance and the duration that a device has been left on. The differences in benefits such a tracking system might bring for families and shared households became apparent. Our "family" participants were more interested in the value of the system in playfully educating; whilst the "shared household" participants reflected on a desire for more appropriate sharing of bills.

Participants in both groups noted that while one person may turn on a device, several others might benefit from the action (e.g. in watching the TV together). The energy consumed in this action, they suggested, should be shared amongst the users.

Probe Two – Field Deployment

Taking the findings from the Probe One study, we developed a second prototype (as shown in Figure 3) for a field deployment. In this system, users wore an RFID bracelet as before. When they entered the room (the living room) that the system was deployed, they were asked to touch a "check-in" box (to indicate they

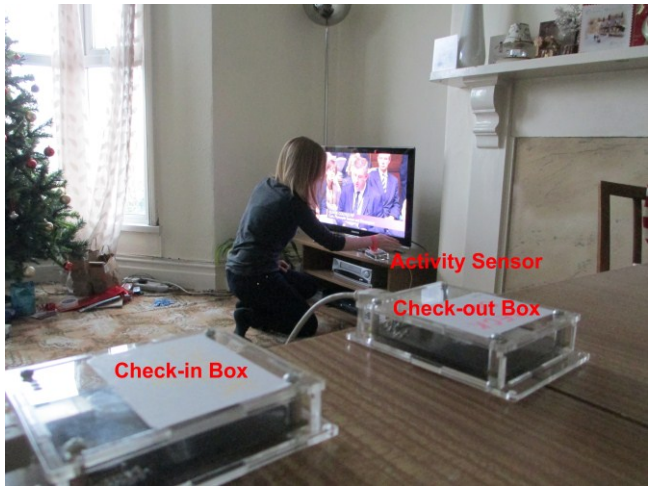

Figure 3. Prototype Two

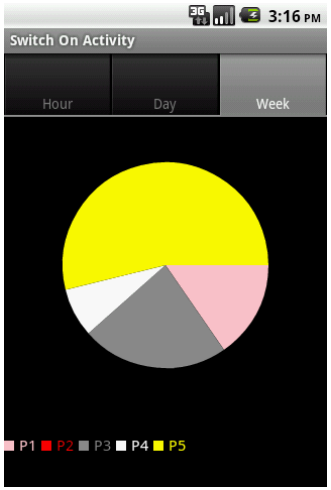

Figure 4. Switch on information

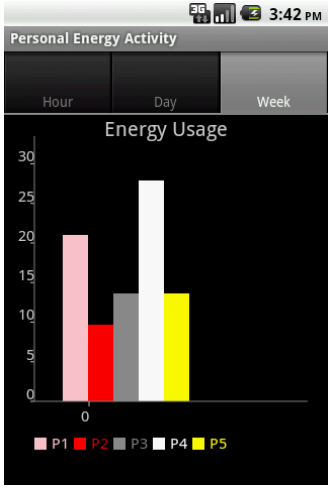

Figure 5. Personal energy consumption information

had entered the area). When they left the room, they touched the "check-out" box. One appliance in the room (the TV) was connected to an energy monitor along with an activity sensor as in Probe One. In this way, we could track who turned the device on and off as before. The energy being used by the device was assigned to all users who were checked into the room, regardless of who had turned it on.

Another mobile application for individuals to visualise personal energy consumption was built. Participants could see, for each person in the house: the proportion of the counts of switching on (shown in Figure 4) and switching off the monitored device; and energy consumption (shown in Figure 5). To provide historical energy consumption information, device operation data and personal consumption data for the last hour, day and week were shown in separate tabs on the application.

Field Trial

We recruited four UK shared households to participate in a two week field trial from November 2011 to January 2012. Each participant was compensated with a £25 voucher for the entire field trial. Households were 4-6 people in size and mainly students and in total 21 adults between the ages of 21 to 27 years participated. In terms of the utility bill payment method, the households recruited for this study can be divided into two types: University-managed households and self-managed households. The utility bills of University-managed households were deducted as a fixed amount each month, and towards the end of the contract year, the actual consumption would be calculated and the outstanding amount would be refunded to each housemate. No actual bill would be available for the housemates to view until the end of the rental contract (normally 12 months). Self-managed households dealt their energy bills with utility companies directly. They would get the energy bills every 3 months.

During the study period, every household was visited by the researcher a minimum of twice, with visits lasting between 30 minutes to one hour. In the first visit, a semi-structured interview was conducted in order to understand participants' current energy consumption habits. The prototype system was installed and demonstrated to participants. In the second visit, which was approximately two weeks after the installation, we interviewed members of the households to collect their feedback on the system, and their perception of energy consumption. Interviews were video-taped; field notes and photos of interesting phenomenon were observed and recorded.

Findings

In this section, we present results addressing two questions that drove our investigation: (1) What was a participant's perception and attitude towards his/her personal energy consumption before the system was introduced? ; and, (2) In what ways might an in-home personal energy consumption system affect individual energy use and awareness?

Perception and Attitude

Before introducing our prototype, most of our participants had very little prior knowledge about their personal energy consumption, and rarely thought about their energy consumption. There are several major contributing factors to this issue including a lack of information and relatively low costs of utility bills due to the sharing mechanism.

In self-managed households, participants, (apart from those who dealt with utility bills), did not know the exact cost of their monthly energy bills. In University-managed households, while none of them knew the actual amount of energy they were using, most participants knew the fixed amount of utility bills that were charged from them each month, as that was listed in their rental contract. Most of the time, the unawareness of energy consumption was due to the lack of information. Therefore, compared to those from University-managed households, participants from self-managed households were more conscious about their energy consumption and tried to maintain more energy efficient behaviour, such as wearing more clothes at home while keeping the temperature of central heating down. In University-managed households, some participants simply ignored their energy consumption or did not adopt any energy conservation activities. Because they thought the money they paid to the management body was not a fair reflection of their usage (even though the offset would be refunded towards the end of the rental year) and they didn't have control over this issue.

Prototype Engagement and Behaviour Change
Based on database logs, the prototype was running in each household for 11 days on average, with a mean of 44 device operational activities (switch TV on/off). Meanwhile, a mean of 70 check-in/check-out activities were recorded for each household.

16 of the TV on/off activities were not sensed by the bracelet monitoring box placed next to the TV. There are three possible reasons for this. First, the participant did not use the RFID watch while he/she conducted the operational activity, either by forgetting or from avoidance. Second the participant used the RFID watch, but because of the inadequate RFID reader range and the gesture of an individual user our system did not detect the corresponding event. Finally due to the network connection drops caused by ISPs, our system might not have managed to collect the data.

The activity tracking system of our prototype required participants to wear their assigned watches while presenting at the monitored areas and use the register points when the relevant activities occurred. Before the deployment we thought use overhead might cause users to stop using the system. However, many participants said they liked this part of the prototype as it was a tangible reminder of energy awareness.

Most participants agreed that their awareness of appliance usage had been raised. For most participants, instead of reducing appliance usage, energy wasting behaviours, such as leaving TV on while no one was in the room, were cut back. Some participants extended similar behaviours to other devices around the household.

Data Sharing and Household Dynamics
The prototype had the effect of revealing a view of the household that was not previously available, showing individuals' daily appliance use in the house. This information was not only available to individuals, but also available to all housemates. Therefore, participants became more aware of who was using and not using energy. In interviews, participants noted that with such a system energy saving behaviours could be prompted due to mixed feelings of guilt, responsibility and visibility to others in the house.

Conclusion

We have presented two probes designed to explore how members of shared households might better understand their energy consumption. Providing awareness of individual energy consuming activities was seen a beneficial by our lab and field participants helping them to think how they could act together.

The studies also indicate that different household types and contexts (e.g. how the bill is calculated and shared) can affect the value and perception of such systems.

Our intention in creating these probes was not to take the first steps towards a complex energy and individual tracking system. Rather, we wished to understand the value in giving people in a shared space a better sense of their personal impact on energy consumption.

In our ongoing work we are building prototypes that give users a greater ownership of the "energy issue" in their shared homes, allowing them to personalise, make sense of and be challenged by energy data on an individual level.

Acknowledgements

This work is funded by EPSRC grants EP/I00064X/1. We thank our colleagues on the Taking on The Teenagers team for their input to this research.

References

[1] Chetty, M., Banks, R., Harper, R., Regan, T., Sellen, A., Gkantsidis, C., Karagiannis, T., and Key, P. Who's hogging the bandwidth: the consequences of revealing the invisible in the home. In Proc. of CHI (2010), 659-668.

[2] Chetty, M., Haslem, D., Baird, A., Ofoha, U., Sumner,B., and Grinter, R. Why is my internet slow?: Making network speeds visible. In Proc. of CHI (2011), 1889-1898.

[3] DCLG. English housing survey headline report 2010-2011. Tech. rep., February 2012.

[4] DECC. UK energy in brief, 2011.

[5] Fishkin, K. P., Philipose, M., and Rea, A. Hands-on rfid: Wireless wearables for detecting use of objects. In Proc. of ISWC (2005), 38-43.

[6] Hay, S., and Rice, A. The case for apportionment. In Proc. of BuildSys (2009), 13-18.

[7] Hopper, A., and Rice, A. Computing for the future of the planet. R. Soc. Lond. Philos. Trans. Ser. A Math. Phys. Eng. Sci. 366, 1881 (2008), 3685-3697.

[8] Hsu, J., Mohan, P., Jiang, X., Ortiz, J., Shankar, S., Dawson-Haggerty, S., and Culler, D. Hbci: human-building-computer interaction. In Proc. of BuildSys (2010), 55-60.