The Pulse of Tidy Street: Measuring and Publicly Displaying Domestic Electricity Consumption

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Abstract. We give an overview of a domestic energy monitoring project which we are currently setting up in Brighton, UK, that will study the effect that publicly displaying a household's electricity consumption has on their energy usage. We describe our approach to designing: i) a low cost and low energy electricity monitoring system; and ii) effective displays of domestic electricity use that indicate both current and longer term consumption and how this relates to the street average.

Key words: public displays, domestic energy monitoring, social norms, low energy systems

1 Introduction

In the CHANGE project, we are interested in changing people's everyday habits with respect to environmental concerns, such as reducing an individual, group or organization's carbon footprint. We are exploring how persuasive techniques can encourage, enable or enforce people to change their everyday habits. Our goal is to promote 'proactive' and 'provocative' interactions with the environment. We use off-the-shelf devices that allow for flexible forms of ambient and contextual information to be displayed. Our focus is on the point of situated decision-making, where the aim is to provide information at key locations where it can nudge or nag.

Extensive research, summarised in three review papers [1, 3, 4], has shown that domestic energy usage can be reduced by providing households with feedback on their consumption. However, there are outstanding questions about the properties that make feedback effective. Studies do suggest that the frequency of direct feedback appears to be positively correlated with saving behaviour, with continuous or daily feedback giving higher saving results than monthly feedback [3, 9]. This favours the use of technology-enabled interfaces that can provide regular and/or real time feedback versus paper based billing supplements.

The type of representation used is influential. For example, if it is too obvious and explicit it may be perceived as too personal, blunt or 'in your face', resulting in people objecting to it. An alternative approach is to provide simple representations that are more anonymous but striking and whose function is to lure people's attention. In so doing it can make them think about the different choices available to them, encourage reflection and even promote public debate about what is represented and how it affects them. However, if a representation is too abstract and implicit, it may be attributed other meanings, such as simply being an art piece, resulting in people ignoring it. The ideal may be somewhere in between. However what makes an effective display and where and how those displays are best embedded in the environment are still open questions.

We are currently setting up a domestic energy monitoring project in Brighton, UK, which is motivated by a number of research questions: What effect would publicly displaying a household's electricity consumption have on their energy usage? For example, if several houses in a street used their front windows to display how much energy they had consumed over the previous week and whether this was above or below the neighbourhood average, would the domestic energy consumption in an area go down? Would a public display of a household's real-time energy usage be more effective at reducing energy consumption than displays that showed longer term usage? In a study by Schultz and colleagues [8], households were shown how their energy consumption compared to their neighbourhood average. This research clearly illustrates the power of social norms to affect domestic energy usage: households above the average tended to decrease their consumption but those using less electricity than average tended to increase their consumption. The study found that this 'boomerang effect' could be counteracted by providing households with an emoticon along with the numerical information about their energy usage: households using less energy than average continued to do so if they received a smiley icon; households using more than average decreased their consumption more if they were given a sad icon. In contrast to the Schultz study, where each household's energy consumption was kept private, we want to explore how a households energy consumption is affected when they display their electricity usage in their front window so that it is visible to their neighbours and passersby. We aim to display both the average and real-time electricity consumption data for each household: people walking down the street will be able to see pulsing displays that indicate how much electricity each household is currently using. Just as measuring a person's pulse is a simple but effective measure of their health, the public displays we are building will make visible the 'energetic pulse' of each household and give a public indication of their 'environmental health'.

1.1 Tidy Street, Brighton

We are currently setting up a long term study in Tidy Street, a residential road in the centre of Brighton, UK [5] that will investigate the feasibility of publicly displaying household's domestic energy usage and its effect on energy consumption. There are just under fifty terraced houses in the street, all built in the 1840s, as well as several boutique shops at both ends. Most of the houses are the same three storey design (basement, ground and first floor) and dimensions, although a small number have an additional second floor. Besides the similarity of the houses, there are four other reasons why we chose this street for our study. First, there is a strong sense of community and the residents organise communal activities. For example, there is an annual street party where the road is closed off, artificial turf is laid down so the children can play and residents have a picnic and put on musical performances. Second, some of the residents have previously used their front windows for public displays. In 2006, twenty households in the street participated in an art project where their front windows effectively became light boxes that displayed large scale family photos chosen in collaboration with the artist, Lisa Creagh [2]. Third, the street is close the bustling centre of Brighton and the project will be visible to many passersby, as well as the residents. Fourth, we know a family who live in the street who are very keen to participate in an energy monitoring study and have agreed to publicly display their energy usage in their front window. This family have lived in their house for over twenty years so they know many of their neighbours and have agreed to help us recruit other participants. Initially, we are hoping that between five and ten households will take part in the project.

2 Design Challenges

There are two main design challenges that we have to address:

- building a low energy system to measure a households electricity usage;
- effectively displaying the electricity consumption data.

2.1 Measuring Domestic Electricity Usage

We are currently developing an unobtrusive, reliable, low energy consumption system that will measure the total electricity usage in a household and send these data to a website via a wireless router. We use a light sensor to record the impulse flashes from a domestic digital electricity meter. This is connected to an Atmega 168 microprocessor, commonly used in Arduino microcontrollers. We remove it from the Arduino board in order to run it at a lower voltage (3.3V rather than 9V). To reduce energy consumption further, the microprocessor remains in a hibernation state until awoken by the detection of a light flash, when it in turn wakes up an XBee series 1 wireless radio which signals an XBee wireless receiver that 1 Wh of electricity has been consumed. Both the microprocessor and radio then return to standby mode. The receiver XBee is connected to the serial port of an Asus WL-520gU wireless router which sends the data to an aggregating website. We use this router as it is both a low energy (5W) and low cost device (£45) in comparison to a laptop or desktop computer and the firmware can be configured to use OpenWrt, a flexible open source Linux distribution for embedded systems.

If we assume an average electricity consumption of 5200 kWh per year [6], then the sensor system will detect 100,000 impulses per week. Given that it takes under 5ms to signal an impulse event to the wireless router at a transmission rate of 9,600 baud, there will be less than 9 minutes total transmission time each week. An XBee uses 45 mA when transmitting, so under 7 mAh per week of energy will be used by the radio module per week for signalling the detected impulses. When in sleep mode the XBee consumes 0.1 mA, or around 17 mAh per week. The Atmega uses 20 mA when awake and if we allow 20ms for the processor to wakeup, communicate with the XBee transmitter and then power down, it will consume around 11mAh of energy per week to signal impulses. In sleep mode the Ardunio uses 0.05 mA or 8.4 mAh per week. The total energy usage per week for the electricity usage measurement system placed in a house with average electricity consumption is therefore less than 45 mAh, meaning that a rechargable 3.7 V 2000 mAh battery will last for over a month before it needs to be replaced. The microprocessor will track and signal the battery level daily.

2.2 Displaying Domestic Electricity Usage

We aim to display the electricity consumption data to three different groups. First, privately to each household; second, publicly to neighbours and passersby in the street; and third, to other interested parties via the internet. Our first participant family are keen to see detailed information about their electricity consumption on a website that only they can access. In consultation with the participants we will also explore what data from the project can be made available publicly on the internet to other interested parties. It is very important that the residents of Tidy Street are involved in the design process and that they are happy with the way that their electricity consumption is publicly displayed in their front windows. We are actively exploring different ways of publicly displaying the energy consumption data and addressing the following key questions:

- what form should the display take: abstract colours; numbers; or something more figurative, for example, emoticons?
- do we incorporate the history of a household's electricity consumption into the public display? For example, if a household's current usage is above the street average but has significantly reduced over the last month, then we would want to display this fact, as well as how they relate to the street average, in order not to demotivate them.
- how often will the visualization be updated (in real-time, daily, weekly or some other frequency)?
- how do we ensure that non-residents walking down Tidy Street will be able to understand what the public displays mean?

2.3 Electroluminescent (EL) Wire Displays

EL wire is a thin (2-8mm diameter), flexible, plastic covered material that can be twisted into intricate shapes. When connected to a battery it shines extremely brightly and is sometimes known as cold neon as it does not heat up but has the intensity of a neon display. It consumes very little energy (< 5 mA/m) and can be pulsed and faded in real-time by a microcontroller. It also comes in a wide range of colours and it is relatively cheap at around £5/m. In close consultation with each household we aim to create individual displays that they find meaningful and aesthetically appealing. It is important that each household can shape what form their window display will take. If the displays were uniform then there would be a danger of a 'big brother' aesthetic. Second, people naturally like to use their front windows to display their individuality. Third, by encouraging households to create displays that they like, we hope to increase their engagement with the project and the impact it has on their electricity consumption.

2.4 Designing EL Wire Window Displays

Although we want households to determine the look of their display, we will have to impose some creative and technological constraints so that the displays are affordable, consume minimal energy and are understandable to neighbours and passersby. Here is a possible design for a display that will allow households some creative freedom while still being practical to implement. The display will consist of two main parts: a border (which could be rectangular, circular or some other irregular but connected shape); and two central elements inside the border (words, patterns, numbers, or figures). We will constrain all designs in the street to use the same colours, for example, red and green, which are associated, respectively, with dangerous and environmentally friendly activities. Each border shape will be repeated in the two colours: one green and one red. One of the central elements will be red and the other green. We can then control the display so that we can indicate the following information: the history of electricity consumption by the household and whether it has increased or decreased over the course of the project; the current energy consumption of the household relative to the street; and the current energy consumption or energy pulse. For example, the border could represent historical electricity consumption, green indicating that the household has reduced their usage, red indicating that it has increased or stayed the same. If a household's electricity consumption over the last week is currently average or below average relative to the street, then the green central element will be lit; otherwise the red central element will be lit. Finally, the households current energy usage can be signaled by pulsing the currently lit central element. Given that even at peak consumption times 1 wH of electricity is consumed every few minutes, it will probably be necessary to increase the frequency that the display changes to make the 'pulse' engaging. For example, average electricity consumption could be signaled by a 1 or 2 Hz pulse which will be noticed by people walking down the street. We plan to place EL signs in the shops at the end of the street that provide a legend to the displays so that they can be understood by passersby.

2.5 Minimising the Energy Consumption of the Display

Although EL wire uses very little power, we would like the display system to be driven by non-grid electricity. We are going to investigate using solar power to supplement rechargeable batteries. The real-time pulse will be controlled using an XBee radio connected to an Atmega 168 microcontroller, in a similar circuit to the one described in Section 2.1. We would also like to provide householders with a hand crank, similar to those used on wind up torches, that will enable them to charge up the display system. LEDs will indicate to the participants whether the display unit has sufficient electricity stored in its rechargeable batteries or not. As well as reducing the frequency with which the display batteries have to be changed, it will enable us to investigate whether there is any correlation between the amount of time households spend hand charging the system, a measure of their engagement with the project and energy consumption issues, and the way their electricity usage changes during the course of the project. For example, do households that keep the display charged show a greater decrease in electricity consumption over the duration of the project than participants who require more battery changes?

3 Summary

We have given an overview of a domestic energy monitoring project which we are currently setting up in Brighton, UK, that will study the effect that publicly displaying a household's electricity consumption has on their energy usage. We have described our approach to designing: i) a low energy consumption electricity monitoring system; and ii) effective displays that represent both current and longer term consumption and how this relates to the street average.

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