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# Experiencing a Home Energy Management System: Finding Opportunities for Design

Bingxin Ni, <sup>1</sup>Abdullah Al Mahmud, and David V Keyson

Department of Industrial Design, Delft University of Technology, The Netherlands

<sup>1</sup>School of Design, Swinburne University of Technology, Australia

Nibingxin1117@gmail.com, aalmahmud@swin.edu.au, d.v.keyson@tudelft.nl

**Abstract.** This paper reports a study, which examines how people experience a Home Energy Management System (HEM). We conducted a probe study with six families in China for two weeks. From our study, we found that people had difficulty in understanding energy data, which were shown as graphs. Families with teenage children showed more interest in using the Home-Energy Management System. Overall, all the participants were fascinated by the remote monitoring and controlling of the appliances offered by the probe. Based on the findings, opportunities for designing HEMs for the target groups are discussed.

**Keywords:** Smart home control system; home energy management system; Chinese context; user experience

## 1 Introduction

Home Energy Management Systems (HEMs)/eco-feedback systems are defined as intermediary devices installed at home that can visualize, monitor and/or manage domestic gas and/or electricity consumption [1]. The end-goals of HEMs are to help homeowners to conserve energy, reduce cost of energy bills and improve comfort [3]. It is a fact that residential energy consumption has been increasing each year in China due to the rapid urbanization [1, 2, 4]. There exist a gap between an awareness of energy-conservation and behaviors, because it is difficult for users to link their various activities and develop a coherent, comprehensible, and concise cognitive frame of what energy conservation could mean in one's everyday life [2]. HEMs offer a worthy solution by providing timely feedback of daily energy usage. It is evident that some studies and experiments of implementing HEMS into people's life have been conducted in western countries [1, 8]. Several Chinese companies have already stepped into this field and have started developing solutions. However, it is not known how HEMs can be applied to existing Chinese families, which arouses great curiosity for further exploration.

## 2. Experiencing the Plugwise HEMS package

To discover how people would feel using a home energy management system, user experiments were conducted in Chengdu, China. We used the Plugwise package [7] to assist participants to monitor in-home energy usage and take control of it. The Plugwise package contains four basic components such as one or more Circles, Circle+, USB Stick and Source Home Software. The Circle is plugged in between an appliance and the socket. It measures energy consumption of the connected appliances and can switch it on and off, and send the measured energy consumption data to the Plugwise software via Zigbee wireless network. The Circle+ has the same functionalities as a Circle, but also serves as the network coordinator to control and organize the network. The USB Stick is the connection between the Plugwise Source Home Software, the installed plugs (Circles) and other Plugwise products. After being connected to the USB port of the computer, the Stick receives data from and transmits commands to the installed Plugwise modules. Source Home is the Plugwise software for visualizing energy data and controlling appliances. Ten upper-middle class families responded to volunteer the experiments. However, four families did not install the Plugwise program (three families felt uninterested and bothered to install it, and one family was leaving for a vacation and found no time to experience the Plugwise package). Hence, in total, six families used the Plugwise package for two weeks.

### 2.1 Procedure

On the first day, the Plugwise PC program was installed by the first author. Later on, participants were asked to choose several household appliances to be connected with the Circles to measure electricity consumption (see Fig. 1). After the program was ready and all the hardware were well connected, the interface was shown to the participants with an explanation of each item. Then sensitizing cards were left to participants to fill in. People were asked to first explore the program and then answer a few questions, which would reflect their experience with the Plugwise system. Finally, they needed to fill out the task cards after each time they checked energy usage data. On the day when the Plugwise package was picked up after the study period, the participants completed an evaluation form and participated in short interview sessions. The sensitizing card consists of three parts: 1) collect first time user experience, 2) task card to understand why participant would like to use the probe, what kind of data they are concerned about and what is their emotion, and 3) an evaluation form, to get an overall opinion of the system. The interview data were analysed thematically.



Fig. 1. Circle+ is connected to a television; circles is connected to a desktop and to a refrigerator (left to right)

## 2.2 Results

Test participants cared more about high-energy consumption appliances. They always chose what they thought were high energy consuming, such as television, water kettle, laptop and refrigerator. However, they did not choose air conditioners because it was not the right time to use them. They appreciated that it was easy to use the Plugwise hardware but some participants thought it was troublesome to install the plugs for the first time. Furthermore, they felt it was quite like magic that with just a small device, they could track energy consumption of their household products in a simple way. However, since it was only a test for a shorter period, participants did not feel a strong involvement with the system.

Families with teenage children showed more interest in HEMs. From the sensitizing booklet, some feedback were received, such as when asked what emotional feeling they might have when they checked energy information on the Plugwise dashboard. Participants reported that it was interesting to receive energy feedback. Participants had questions about energy consumption such as how much electricity it would consume if the computer was on for the whole night? How much electricity it would consume for one light and how much they could save? These detailed information were present however, participants did not know how to switch between different views in the Plugwise dashboard.

The energy feedback data were understandable, but they could not evoke a sense of caring of the participants because the data were found meaningless to them. Two of the participants mentioned that the reasons for causing the changes were not clear to them, which made them feel frustrated after seeing the graphs. Participants were not interested in seeing the numbers and information provided on the interface. They reported that the data in kWh and graphs are generally understandable but quite meaningless to them. "I know what this means, but I need energy forecast. Since I still have to consume this amount even I know its energy usage, I am not sure this system will make a difference on my family." (One person from family #5). "Those data are not hard to understand, but according to my knowledge, I cannot understand why the curve is shaped like this? I want to know the reason caused the changing which I cannot find in the program." (One person from family #1)

Participants were very interested in the turn on/off the appliance function provided by the Plugwise HEM package. Participants were quite surprised by remote control function when it was shown to them and later when they interacted with it. One participant even asked to set a schedule for their television because sometimes they fell asleep and left the TV on for a whole night.

## 3. Discussion and Design Implications

For some families, the program could only be installed on a desktop computer, which they used very often. Hence, it was not convenient to check the energy data

now and then, which was the limitation of the Plugwise HEMS package. They treated the Plugwise system as a test rather than their own property, so they did not pay much attention and did not truly experience it, either. At this phase, by using the system, it is important to help users to cultivate their awareness of in-home energy management. Making energy more transparent to people proved to be a key insight for changing consumers' attitude and behaviour towards saving energy [6, 8]. Although it is argued that money is not a good stimulus to rise people's attention in the long run, it is still of great necessity in the early development phase when people start to experience any HEMS. Another remarkable finding was that participants were more attracted to the remote control of household appliances rather than the home energy management system. The reason was that the remote controlling of appliances at home provided them direct advantages when compared with the home energy management system. This also verifies that if users could be offered some benefits, they could pay more attention to HEMS. Besides cost-effectiveness it is an influential aspect to consider when designing HEMS for the target group. From the study, it has been revealed that the target groups are positive to accept the notion of controlling home appliances remotely, which can be considered part of HEMS. Therefore, it is assumed that integrating HEMS with smart home control system could be a good idea for the target group. Another key design issue is the visualization of the energy data, which should be more meaningful to the users and help users to get engaged. Though our study period was quite short and the Plugwise package had several limitations, it was helpful to gather valuable feedback, which provided directions for designing an adapted Home Energy Management System (HEMS) for the target group.

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