Behavioural Change for Efficient Usage of Electricity at Homes

Engin KAPKIN
Eskisehir Technical University
ekapkin@eskisehir.edu.tr

Sharon JOINES
North Carolina State University
sharon_joines@ncsu.edu
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Abstract: Electricity is not visible or tangible yet always available in our houses. The only way users can keep track of electricity consumption is to look at meters or monthly bills. Energy-monitoring systems promise to help users understand their consumption by visualizing and displaying the consumption data in a meaningful way. However, they are not successful in changing users’ behaviours and sustaining their intentions. The current paper presents a suggestion to promote behavioural change by adapting Diffusion of Innovation (DOI) Theory to stratify the target user groups and apply user-centred design approach when developing a prototype of conceptual electricity monitoring system. Initially, users’ awareness and knowledge levels were measured by a questionnaire identifying and stratifying the target groups who were interested in saving energy in their homes. For one of these groups who are ready to act on an opinion, users’ electricity usage behaviour and their intentions were captured and detailed through interviews. The resulting information was used to develop a series of criteria to design a conceptual electricity monitoring system. The study proposes a case in which DOI stratification of target users may have a potential for behavioural change.

Keywords: behavioural change; product design; diffusion of innovation; design process; electricity monitoring

1 Introduction

It is obvious that electricity is intertwined with daily-life. It keeps houses warm or cold, it helps to cook and keep food safe, and it runs almost every appliance that makes life easier. Its efficiency and reliability increase the users’ dependence upon it every day. According to the records of US Department of Energy (2009), most of the residential houses in USA, which account for 24 percent of total energy consumption, use electricity as their main energy source. The Department of Energy records also forecast that the demand as well as the cost of the electricity will increase more than any other energy sources after 2020, and will continue to rise through 2030. Therefore, American energy policy focuses on increasing efficiency, not just decreasing energy consumption (Diamond et al., 2001). European countries, on the other hand, aim to reduce energy consumption by 20% in the year 2020 (Kulkarni et al., 2014). These projections establish two main questions: how residential users should be able to learn to use electricity efficiently,
and how they should be able to control their electricity consumption. Technologies that allow users to monitor their electricity consumption attract users’ attention; however, their interest on these devices decreases over the time of usage (Anderson & White, 2009; Kulkarni et al., 2014). Also, the presentation of information is not sufficient enough for users to change their behaviour toward energy consumption in houses. They require a motivation for change (Darby, 2006; Roth & Brodrick, 2008). It appears that models assuming economical advantage and favourable attitudes toward energy conservation are not enough for users to change behaviour (Costanzo et al., 1986).

Nevertheless, apart from one exceptional study (Darley, 1978) that discusses reactions of users to these systems, the awareness and willingness of users to act on efficient electricity consumption in their homes remain unclear.

Electricity is not visible or tangible and is always available in our houses. The only way users can keep track of electricity consumption is to look at their meters or their monthly bills. However, users generally might not know where the meter is, and those who check the meters cannot associate the numbers on the meter with their consumption. Moreover, the bill can be automatically paid through their bank account or their monthly rent might cover their utility expenditures (Wiggins et al., 2009). The electricity should be measured first in order for users to manage their consumption (Ambati, 2013). To do so, energy-monitoring systems appear to be promising to help users understand their consumption by visualizing and displaying the consumption data in a meaningful way. According to Anderson and White (2009), these systems provide real-time feedback in both cost and kilowatt format, showing daily, weekly, and monthly consumption and are supported by social networking. However, their study reveals that existing solutions lack actionable information, and fail to encourage behavioural change and maintain users’ interest. Furthermore, the existing solutions in the market generally provide information about the overall consumption for the house, and fail to focus on specific user types (Wiggins et al., 2009; Kapkin, 2010). The recent solutions such as Nest, Hive, Brilliant control, and iHome either focus on the specific control of a certain system, such as heating or lighting, or provides only a wireless control over the devices at home. The current paper evolved as a part of corresponding authors’ master thesis (Kapkın, 2010), and is encouraged by several conceptual studies holding scenario-based methodological approaches that suggest building prototypes and collecting user feedback (Ludvigsson, 2005; Backlund et al., 2006; Mazé & Redström, 2008). However, these studies have limitations due to the strategies when stratifying and targeting users. The current paper represents a user-centred design approach to the topic and illustrates a case study that adapts Rogers’ (1995) Diffusion of Innovation (DOI) Theory in order to stratify and identify a potential target user group of a conceptual electricity monitoring system. Initially, users’ awareness and knowledge levels were measured in order to identify the target user group interested in saving energy in their homes. Afterwards, users’ residential electricity usage behaviour and their intentions on efficient usage of electricity at their homes were captured. The resulting information led to a set of criteria that was then used to design a conceptual electricity monitoring system. The goal of this paper is to share our design process to reinforce residential users’ awareness about efficient energy usage in residential houses.

2 Diffusion of Innovation Theory

There are many tools and methods focusing on identifying target user groups for a product. To do so, this paper investigates implementation of Diffusion of Innovation (DOI) Theory in early design process. According to Rogers (1995, p. 55), innovation is “an idea, practice, or object that is perceived as new by an individual or other unit of adaption.” DOI theory suggests that users in a social system have different time sequences of adaptation to an innovation; therefore, they can be classified (into groups) according to when they first begin to interact with an innovative product or service (Rogers, 1995). The goal of the theory is to develop marketing strategies for the future new product. It is a predictive theory that supports decision makers when they introduce a new product to market (Li, 2011). Rogers (1995, p. 106) describes “the process through which a user passes from first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adapt or reject, to implementation of the new idea, and to confirmation of this decision.” The theory has been subject to many studies in different fields. Al-Jabri and Sohail (2012) looked at users’ adaption processes of mobile banking use. Alkhaeef et al. (2009) studied physicians’ adaption of electronic detailing information systems in pharmaceutical companies. Studies have investigated educators’ adaptation to technologies in the teaching environment (Brahier, 2006; Gonzalez, 2014). The theory received attention from the field of medical technologies (Lee, 2004; Trelease, 2006; Gonzalez, 2014) to the adaption of local food by chefs and restaurants (Inwood et al., 2009), and innovation adaptation levels of design firms (Panuwatwanich et al., 2009; Panuwatwanich & Stewart, 2012). DOI has also been utilized by the studies investigating energy conservations. Darley and Beniger (1981) suggest that energy conservation behaviour is an instance of decision of the adapting of an innovation. They introduce and evaluate eight dimensions of energy conservation behaviour: cost of these systems, effect of perceived saving when using these systems, certain saving, compatibility of values between users’ expectations and what these products offer, whether a system or product requires life-pattern change, trialability of these systems, dissatisfaction of the existing situation in which users do not have control over
their consumption, and efforts and skills that require to install these systems. A study proposed that perceived compatibility and advantages that these systems offer are significant predictors of intention to adapt energy conservation behaviour (Völlink et al., 2002).

DOI theory has five major characteristics of an innovation that influence users’ diffusion process: relative advantage of innovation refers to perceived value of the innovation; compatibility of an innovation refers to value that fulfils users’ needs, values and personal experiences; complexity refers to the difficulty in understanding and using an innovation; trialability refers to the temporary interaction between user and innovation; and observability refers to the apparent benefits of the innovation to others (Rogers, 1995). Moreover, the pace of users’ adaptation depends on many macro and micro factors that can be categorized into four areas (Leung & Wei, 1999) that are adapter-related personality traits, socio-economic influences, interpersonal channels and mass media use, and perceived attributes of an innovation. Similarly, Trelease (2006) highlights the importance of communication channels by which users share messages about an innovation; time at which a user decides to adapt to a certain innovation; and social system in which the innovation is introduced and exists. The theory suggests that users’ decisions on whether to adapt or reject an innovation begins first with awareness. The characteristics of innovation drive users’ attitudes towards innovation and generate perceptions. Depending on the match between users’ perception and expectations, users decide on whether to adapt or reject an innovation. Afterwards, users utilize and confirm this decision (Lee, 2004).

The categorization of users might be driven by users’ knowledge and attitudes towards technology, products, services or social norms influencing their adoption level of innovative products (Rogers, 1995). Innovators are not only the consumers of new ideas but also the developers. They are able to understand and apply complexity and they like to experience the new. Early Adopters are the first adaptors. They are the ones companies like to interact with during the product development and design process. Their opinions are used to validate assumptions of the product development team. Early Majority are the users who have a general awareness but rarely have a strong interest in a new product. Rogers (1995) suggests they provide interconnectedness in the social system. Users, who are sceptical and careful about new products, comprise the late majority. They require time to adapt to a new product or innovation. Laggards are the most suspicious among all the users. They generally rely on their previous experiences and are resistant to a change. Rogers (1995) recommends removing uncertainty around the products and services helping these last two groups of people to feel safe in order for them to adapt. The DOI approach was adjusted to fit the goals of the current paper. Rather than measuring their adaptation to an innovation, it was important to identify users’ knowledge and awareness level. Therefore, the names of the categories that DOI suggests were adapted to terms that were meaningful for the study, although the logic was kept the same. Thus, the category groups were named:

1. Ready to advocate publicly (Innovators)
2. Ready to act on an opinion (Early Adopters)
3. Ready to hold an opinion (Early Majority)
4. Ready to know (Late Majority)
5. Not ready to know (Laggards)

3 Research Procedures

The brief methodological framework of the study is presented in Figure 1. First, an in-depth literature was reviewed to define and emphasize the electricity consumption in residential houses in USA. In addition, a market review helped to identify the opportunities for the current and near-future market. An online questionnaire was conducted to measure users’ awareness and knowledge on their residential electricity consumption. The results of the questionnaire guided screening the users, and identifying the target user group. Participants that were in the target user group supported the second phase of the study where they filled another questionnaire, and contributed to a semi-structured interview. All the results were then summarized to define the design criteria for a prototype of a conceptual energy monitoring system (CEMS). After the prototype was developed, feedback from the participants in the target user group were obtained to evaluate the success of the CEMS using an online questionnaire-based prototyping tool.

3.1 Market Review

The goal of the market review is to identify the general features of existing home energy monitoring systems currently on the market. First of all, the list of the product and service suppliers was compiled. A total of 32 products were investigated based on their general features and specifications. The information for each home energy monitor was prepared from the information on vendor’s web site. Afterwards, these services and products were categorized according to their commonalities. The first group included stand-alone products that do not use the Internet. They are
generally attached to a meter and present the consumption wirelessly on their screen. They display the total electricity consumption of the house or a specific socket. They do not use any network infrastructure. The second group of stand-alone products used complex network systems and the Internet. Not only do they display the total consumption but also keep track of the history online, allowing users to take control of the electricity at home. Some examples can communicate with each socket and prepare a report that the user can access online. Although they generally use mobile devices and the computer as their interface, few companies offer an additional screen.

The last group included monitoring services that offer only Internet solutions. They offer two main services; one allows users to enter their billing information, and the other collects information from stand-alone products, providing history of usage at home and around the neighbourhood. There was a categorical opportunity to position a new product solution in the existing market. There was a lesser number of products in the market offering a modular approach to users. There were just a few products that could be positioned in between stand-alone products and Internet-based products. Such a line of products could have a great opportunity to bring modular solutions that offer stand-alone services as well as optional Internet services. Figure 2 illustrates the possible market position of a product line in terms of categorization and computerization. There was a market opportunity in modular products that use either the Internet or their own connectivity, or both.

![Figure 1. Methodological framework of the study](image)

![Figure 2. Potential market positioning for this study.](image)

**3.2 Stratifying Potential Users via DOI Approach**

An online questionnaire was designed to measure individuals’ awareness and knowledge about their electricity consumption in order to stratify and identify the target groups (see Appendices, DOI Target User Questionnaire). Initially, 217 individuals participated to the online questionnaire, mostly from North Carolina but also from Georgia, Washington, California and New York. Only 191 participants completed all the questions (122 females, 69 males; age range from 18-55, average age ~35; 97 participants had graduate education, 55 had a bachelor’s degree and 39 had high school or equivalent level education). Descriptive statistics and frequency of occurrences were conducted for each item in the questionnaire. Approximately half of the participants (96 of the 191) held an opinion but they had not acted according to their opinions on the topic of electricity consumption (ready to hold an opinion). DOI theory
suggests that these users might need tools to act towards their opinions to save energy at home. Thirty-five participants had already taken an action to use electricity more efficiently, and they were positioned to save energy in their homes (ready to act on an opinion). DOI suggests that this group of people most likely allocate time and invest money on products or a service monitoring electricity usage at home. Users in this group might not need help or tools since they somehow already manage their energy consumption. Consequently, the current study focused on these two groups (the 96 that held an opinion and those 35 that are ready to act) for the further investigation (see Figure 3). These two user groups may not necessarily need guidance on the topic and it can be assumed that they most likely did not need a device to monitor their consumption since they already have their own tools and methods. Fifty-two participants had little idea about their electricity consumption and they might not really pay attention to their consumptions, and do not tend to save energy in their homes (ready to know). Among all, only six participants were revealed not to really be aware of their energy consumption at all (not ready to know). Users in these last two groups could not be considered as current potential customers until they were more motivated and until the obstacles they faced were eliminated. Once users step up to holding an opinion and seeking guidance, they may eventually become potential customers. Finally, there were only two participants who had high awareness and knowledge about the topic. These users advocated support for others, and were also not currently considered as customers.

The online questionnaire results indicate that a service or product, which supplies meaningful feedback on electricity consumption, has potential interest for the majority of the participants, particularly for the users who are ready to hold an opinion (n=96), and who act on their opinions (n=35). When these two groups were specifically explored, a higher proportion of females was observed (81 females and 50 males). The age within these two groups varied from 18 to 55 years. There were 72 participants with graduate degrees, 37 participants with Bachelor's degrees and 22 participants with high school or equivalent education. Participants in these two groups typically reported having less than $100,000 annual income. These results corresponded to those seen in previous studies (Ehrhardt-Martínez et al., 2010) associating energy saving at home with the level of education, income and age.

The results of online questionnaire that measures users' awareness and knowledge on electricity consumption at home. The case study focused on users who are under ready to hold an opinion and ready to act on an opinion. If the Y Axis of the graphic is considered as time the results are match with Roger’s idealized curve of diffusion of innovation over time (the light grey curve).

3.3 Electricity Consumption Behaviours of the Target Users

After the screening process, participants who were categorized under ready to hold an opinion and ready to act on an opinion were asked to participate in the second phase of the study which comprised two substages. In the first phase, participants were asked to fill an online questionnaire (see Appendices, Questionnaire on Habits), which addressed participants’ home type, family type, reasoning behind saving energy, how they are informed about their electricity consumption, and what their preferences are in terms of feedback types and communication. Items in the questionnaire were informed by Rogers (1995) and Leung and Wei (1999). In the second phase, semi-structured interviews were held with five participants within these groups in order to collect in-depth insights (see Appendices, Interview Protocol).

3.3.1 Questionnaire on the Behaviour of Target Users

Twelve participants from both groups (users who hold and act on an opinion) supported this phase and shared insights. Descriptive statistics and frequency of occurrences were calculated. 8% of the participants lived in mobile houses, 58% lived in a house and 33% live in an apartment. Only 7% lived alone, while 13% of the participants shared their house with their partner or a roommate. 20% of the participants lived with three people, 27% lived with four people, and 33% lived with five people in their residence.
Only 17% of the participants reported that it was hard to learn about their electricity consumption. The rest of them reported that they could learn easily through their billing. However, 60% of them stated that monthly feedback is not an effective way to learn. 20% of them stated that their bill was paid by other parties, and they were not aware of how much they use, and the rest of the participants (20%) stated that they have automatic bill pay; therefore, they were not aware of their usage. All of the participants were informed about their electricity consumption monthly. However, only 17% of them wanted to be informed monthly. The majority of the participants, 41% percent of them, preferred to be informed weekly. 17% of them preferred either daily information or real-time feedback, while only 8% percent of the participants preferred to learn about their consumption hourly. 79% of the participants received conventional paper-bill and 21% of the participants received e-mail billing about their electricity consumption. However, 72% of the participants wanted to be informed via e-mail, and the rest of the participants wanted to receive their billing via other communication tools, such as SMS text message (8%), mail (8%) or real-time (8%). Only 8% of the users wanted to share their consumption with the public.

Based on the responses to the questionnaire, participants were more motivated by saving money (92%) than reducing their environmental impact (75%). None of them stated that competition with others on saving electricity would affect their motivation. The majority of the participants (67%) were willing to buy an electricity monitoring system to be able to control on their consumption. However, 75% of the participants wanted to be notified at a specific level of consumption. Only 8% of them wanted control over the consumption of each electrical socket, while 33% only wanted to track the general consumption. 58% of the participants wanted to keep track of some of the sockets in their home. This preference supports the idea of having a modular system in their house, which would allow users to control over general consumption as well as the consumption of specific sockets.

Half of the participants preferred a mounted stable energy monitoring system, whereas 25% of them wanted the product to be portable, and 25% preferred combination of mounted and portable systems. Participants were asked to choose from five different display types identifying the one they felt more comfortable to read (see Figure 4). 75% of the participants responded that the first display was clear to read; the third display was chosen by 25% of the participants. The second display was preferred by 17%, and the last display was preferred by only 8% of the participants. None of the participants preferred the fourth display. In terms of feedback preferences, 82% of the participants thought that visual warnings, such as flashlights and red light, attract attention and are helpful. 55% of the participants preferred auditory feedback. Some of those who preferred auditory feedback noted that sound sometimes bothers them and that is why they would turn off the system. 9% of the participants thought that tactile feedback, such as vibration, heat change, movement and surface chance, could be helpful. The room utilization of the homes varied among the participants; however, most of the participants indicated that they spend most of their time in the kitchen, living room and bedroom.

![Figure 4. Display types that users were asked to provide feedback.](image)

### 3.3.2 Semi-Structured Interview with Target Users

Five participants who responded to the questionnaire agreed to participate in a semi-structured interview. Among these five participants, four of them were female and one was male. Each interview took approximately 15 minutes, and due to the locations of the participants, two of the interviews were face-to-face, two were on-phone, and one of them was online. There were five key themes specifically coded: communication preferences, room utilization, habits (strategies) to save energy at home, their motivation to save energy at home, their thoughts on an ideal energy monitoring system. Habits, behaviours, motivations and concepts that were frequently observed during the interviews are summarized in Table 1.

When considering communication mechanisms inside the house, white boards in the kitchen, posts-its and SMS seemed to be the most preferred medium among all participants. Participants mostly utilized the kitchen and living room in their houses. They considered first switching off the light bulbs, second preventing phantom load, and last adjusting the thermostat in order to save energy at home. When they were asked about placement of a conceptual electricity monitoring system, they pointed out a preference for both a table-top and mobile, or a wall-mounted system. They associated this device mostly with a wall clock or a thermostat. Their expectations from the device varied. A major expected function of the device appeared to be a reminder. It was expected that the device would
present usage, remind occupants to switch off the lights, adjust the thermostat and identify peek points for using certain appliances. Control seemed to be the second important function that this device should have. Users perceived this device as a central point in which they could be first notified, and then remotely control the status of lights or sockets. Education/Instructiveness seemed to be a surprising function that was revealed during the interviews. Surprisingly, the main motivation that drives to save energy at home appears to educate and teach their children on the importance of saving energy at home, and become an environmentally aware and conscious person, so that it becomes a part of the family culture.

<table>
<thead>
<tr>
<th>Communication preferences</th>
<th>Room utilization</th>
<th>Habits</th>
<th>Motivation</th>
<th>ideal energy monitoring system</th>
</tr>
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<tbody>
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<td>Reminder</td>
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<td>Adjustable</td>
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<td>Education</td>
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<td>Peek Point Reminder</td>
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**Summary**

Participant thinks that energy monitoring system can be look like table, under AC thermometer. Participant wants post-its in order to leave message to other members of the family. Participant calls in order to leave message to other members of the family. Participant uses Facebook in order to leave message to other members of the family. Participant pays attention to control over air conditioner. Participant pays attention to use energy star products. Participant wants portable monitoring system which can be placed on kitchen table. Participant thinks that energy monitoring system can look like GPS. Participant thinks that energy monitoring system can look like wall clock.

**4 Building the Design Criteria**

Results indicate that according to target users, the conceptual energy monitoring system (CEMS) should be placed where people leave notes for the other members of the family. The system should be able to send text messages to the users about notifications and warnings. CEMS should be placed in either the kitchen or living room. Users want to see this device mounted on the wall, under the AC thermometer, or on the kitchen table or counter. Consequently, CEMS should present the meaningful information in both vertical and horizontal positions. Users want to gain the
ability to control the lights, sockets, and AC. They think that CEMS may look like wall clock or thermometer. CEMS should give an opportunity to remind the peak points where the electricity is expensive and should allow users to compare their usage with other people. Displaying numbers in kilowatt does not always make sense for the target users; therefore, CEMS should present information at least in both kilowatts and money spent, it should allow users to adjust their electricity usage. More importantly, CEMS should create scenarios in which parents train their children about how to use the electricity efficiently at home. Gamifying and engagement while offering children-safe interactions appear to be key design elements for the CEMS.

5 The Design and Evaluation of the Conceptual Energy Monitoring System

The prototype of the CEMS was designed after several iterations in order to incorporate the target users’ expectations, habits and behaviours. A main hub device, light bulb, socket, magnet modules, and room module were generated with a graphic interface (see Figure 5).

![Figure 5. Family of product of CEMS branded as ICO](image)

The main module can only measure the total consumption of the house when working in standalone mode without connecting to other modules. It shows weekly, daily, current and estimated monthly cost of the total electricity consumption. Main device has an online interface where real-time feedback can be watched, comparisons to neighbourhood and friends can be seen, historical usage is kept, and tips and tricks to save energy are shared. Each icon on the main device’s interface activates a specific module. Home icon helps users to switch measurements of room modules; light bulb, socket and appliance icons indicate corresponding modules. Users have ability to set and target a weekly consumption (budget). Depending on the consumption level, interface illuminates colours around the main device (green indicates efficient consumption, red indicates over consumption, yellow refers to warnings). Main device also provides awarding alerts -if the consumption did not reach the target budget by the end of the week, the device illuminates and projects images such as stars and flowers to its surroundings. This function may have the potential to engage parents and children to use the energy efficiently. They may set a target usage and follow the strategies that the device offers to save energy, and when the goal is achieved, the main device may celebrate their success.

Light module measures the consumption of a specific light bulb. The light module has a motion sensor functionality slightly different than regular sensor -if there is somebody in a room and the light is on, it does function normal. However, if there is nobody in a room and the light is still on, main device gives red warning. Users may remotely switch on/off the light via mobile device or using the main device. If there is no one in the room for a certain time period then the module turns the light off. Similar to the light module, socket module calculates the consumption on a specific socket. It also has motion sensors which function similar to the light module’s motion detection. Magnet modules measure the consumption of several different household appliances such as washing machine, dryer, kitchen fan, oven and microwave. A magnet module should be put on a corresponding appliance. When the appliance is on, it vibrates, and the magnet senses that it is on. It sends information to the main device for it to calculate the consumption. When electricity cost is peaked, magnets illuminate red warning. Users prefer either to turn on the appliance knowing that electricity is expensive or postpone using it. An optional room module communicates with other modules in the room, and shows the current consumption of the room. Room module allows users to target a weekly budget for a room. It also gives warnings and awards according to the user’s consumption rate.

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Prototype Testing and Evaluation

A scenario-based approach was held to evaluate the CEMS prototype. A digital working prototype was created on an online prototyping platform. Thirteen participants from the target user group interacted with each and every function of the main device and its modules as if they were installed to their home. They were asked to set a weekly target consumption, turn on a light, observe the phantom load on a socket, and experience how the motion detection functions. They were able to fail or succeed over their targeted consumption and receive warnings and awards (see Figure).

![Figure 6. Screenshot from the online prototype. The image presents the scenario which illustrates the motion detection functionality of the light module and its interaction with the main device.](image)

After experiencing the device, they were asked to evaluate each of the functions and/or the scenarios according to their desirability (I would like to see this device in my home), usability/complexity (It is easy to use, it gives meaningful information, or it is difficult to understand), and usefulness/compatibility (It gets my attention, it impacts my behaviour, it fulfils my needs) in three questions in which 0 indicates the lowest, and 100 indicates the highest score. Also, participants were asked to provide additional comments on the value and relative advantage of the concept (Sanders, 1992; Rogers, 1995; Jordan, 2000). Descriptive statistics were calculated, and average scores were presented in Figure 7. The CEMS was found to be useful by 77%, usable by 83%, and desirable by 81% of the target users.

![Figure 7. Results of prototyping test](image)

Based on the information gained from the feedback, there were opportunities for improvement. Awarding should be emphasized as much as warnings; also, users should be able to turn off the award signs and warnings. Modules should be small, and should fit the decoration of the house; and they should be offered separately from the main package. The oven magnet module scenario was not found realistic since even though it consumes more or it is peak time, the oven will be used regardless of cost. CEMS was found promising to increase engagement between parents and children. Participants were able generate several game scenarios around CEMS (see Figure 8).
6 Conclusion

This paper presents a case study utilizing Roger’s Diffusion of Innovation (DOI) Theory when identifying target user groups during the design research phase of the development process. Results were promising providing insightful and surprising suggestions introduced by the target users. The stratification using DOI theory was found to have potential applications for promoting behavioural change, user-centred design approach and gamification. Also, such an approach provided applicational advantages such as users not being challenging to work with, since they were ready to learn about the topic, seek guidance, and share what they already knew. Although the study has promising results, there are limitations. Firstly, the prototype was fully functioning yet it was a digital prototype. Also, sustaining and maintaining users’ interest in the product and using energy efficiently at home appears to be uncertain. Cases when the users gain the habits and therefore do not need the device anymore should also be further investigated (this might occur in an instance when user’s awareness and knowledge level move from ready to act on an opinion to ready to advocate publicity). It should also be kept in mind that users who have different levels of awareness but live in the same house may need different types of feedback.

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References


**About the Authors**

**Engin Kapkin** received his master’s and PhD degrees in Industrial Design from NC State University as a Fulbright Scholar. He worked at local craft centres, T-Design office, DXLab Design-USA and interned at Ford-Turkey, and IDEO-CA. He currently works at Eskişehir Technical University where he pursues projects on human centred design, human factors, user experience design, and the interaction between product form and meanings it evokes.

**Sharon Joines** received her bachelor’s, master’s and PhD in Industrial Engineering degrees from NC State University. Sharon is a researcher, ergonomist and design educator, teaching courses in human centred design and ergonomics. Her interests reside in universal design, applied product and process research, innovation and the effect of aging on fatigue development and work. Her research focuses on quantifying the interaction between individuals, products, and their environment.
Appendices

DOI Target User Questionnaire

Questionnaire on Electricity Consumption of U.S. Residential Houses
Researcher Engin Kapkin, Graduate student at NCSU Industrial Design Program
NC State University, College of Design Leazar Hall (214), Raleigh, NC.
ekapkin@ncsu.edu / 919 749 1207

Overview
The purpose of my final project is to investigate user-friendly and on-time feedback to inform users about their electricity consumption. That is how power consumption could be represented in order to reinforce residential users’ awareness about efficient energy usage in U.S. residential houses. Capturing the users’ electricity usage awareness and behavior is focus of this questionnaire. This questionnaire will take approximately 2 minutes. Thank you for your participation.

Q1. What is your gender?
[ ] Male  [ ] Female

Q2. What is your current age?
[ ] 18-24  [ ] 25-34  [ ] 35-44  [ ] 45-54  [ ] 55 - older

Q3. What is the highest degree or level of school you have completed?
[ ] High School or equivalent  [ ] Bachelor’s Degree  [ ] Graduate Degree

Q4. What is your combined annual household income?
[ ] less than $20,000  [ ] $21000 - $50,000  [ ] $51,000 - $100,000  [ ] $101,000 and upper

Q5. Do you know where the electricity meter is in your home?
[ ] Yes  [ ] No

Q6. Can you remember how much money your household spent on electricity last month?
[ ] Yes  [ ] No

Q7. Can you remember the amount of electricity that your household used last month?
[ ] Yes  [ ] No

Q8. Are you interested in observing your household’s electricity consumption?
[ ] Yes  [ ] No

Q9. Are you familiar with the terms Watt (W) and Kilowatt-hours (Kw/h)?
[ ] Yes  [ ] No

Q10. Do you generally unplug the power cord after you use an appliance?
[ ] Yes  [ ] No

Q11. Have you ever turned off the electricity in your home before going on extended vacation?
[ ] Yes  [ ] No

Q12. Do you have a renewable energy source in your home?
[ ] Yes  [ ] No

Q13. Does the energy efficiency rating of a product affect your decision to purchase?
[ ] Yes  [ ] No

Q14. Are you familiar with this logo?
[ ] Yes  [ ] No

Q15. Do you mostly use energy efficient light bulbs in your home?
[ ] Yes  [ ] No

Q16. Do you have an energy monitoring system in your home?
[ ] Yes  [ ] No

Q17. Have you ever changed your behavior to save electricity in your home?
[ ] Yes  [ ] No

Q18. Do you know how you can save electricity in your home systematically?
[ ] Yes  [ ] No

Q19. Do you believe there is an environmental impact related to individual’s electricity consumption?
[ ] Yes  [ ] No
Q20. Are you familiar with the term "phantom power"?
- Yes
- No

Q21. Do you know how much you pay for electricity per hour?
- Yes
- No

Q22. Do you know what part of the day electricity is least expensive?
- Yes
- No

Q23. Do you think that reading an electricity meter can support your reduction in consumption?
- Yes
- No

Q24. Do you read your electricity meter?
- Yes
- No

Q25. Do you know how to read your electricity meter?
- Yes
- No

Q26. What kind of light bulbs do you mostly use in your house?
- I do not know
- Incandescent bulbs
- Compact fluorescent lamps
- Fluorescent
- LED Light
- Other

Q27. Estimate the percent of electricity that you think is consumed by the following appliances.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>%5</th>
<th>%10</th>
<th>%15</th>
<th>%20</th>
<th>%25</th>
<th>%30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning</td>
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<td>Computing</td>
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<td>Cooking</td>
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<tr>
<td>Lighting</td>
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<tr>
<td>Refrigeration</td>
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<td>Space cooling</td>
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<tr>
<td>Space heating</td>
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<tr>
<td>Water heating</td>
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</tr>
</tbody>
</table>

Q28. Thank you for your participation. Please leave your e-mail to be informed about the results or if you want to be a part of my project. If you are not willing to be contacted, leave this blank.
Questionnaire on Habits

Electricity Consumption Habits of the Target Users: Questionnaire

Researcher: Engin Kapkin, Graduate student at NCSU Industrial Design Program
NC State University, College of Design Leazar Hall (214), Raleigh, NC.
ekapkin@ncsu.edu / 919 749 1207

Overview
The purpose of this study is to investigate user-friendly and on-time feedback to inform users about their electricity consumption. In this sense, the question is how power consumption should be represented in order to reinforce residential users’ awareness about efficient energy usage in U.S. residential houses. Capturing the users’ electricity usage behavior and preferences are base of this interview. This questionnaire will take approximately 2 minutes. Thank you for your participation.

Q1 - What kind of home do you mostly live in?
☐ House  ☐ Apartment  ☐ Mobile Home

Q2 - How many people are there in your household? _____

Q3 - How often are you informed about your electricity consumption?
☐ Hourly  ☐ Daily  ☐ Weekly  ☐ Monthly

Q4 - How often would you like to be informed about your electricity consumption?
☐ Real-time  ☐ Hourly  ☐ Daily  ☐ Weekly  ☐ Monthly

Q5 - How are you informed about your electricity consumption?
☐ I do not know  ☐ Mail  ☐ E-mail  ☐ Sms (Text message)  ☐ Phone call  ☐ Real-time feedback  ☐ Other

Q6 - How would you like to be informed about your electricity consumption?
☐ Mail  ☐ E-mail  ☐ Sms (Text message)  ☐ Phone call  ☐ Real-time feedback  ☐ Other

Q7 - What would motivate you to save electricity in your home?
☐ Saving money  ☐ Environmental Impact  ☐ Competition with others  ☐ Other

Q8 - Do you think it is hard to learn about your electricity consumption?
☐ Yes  ☐ No

Q9 - What are the obstacles for you in learning how much energy you consume in a month?
☐ My parents pay my bills  ☐ My partner pays utilities  ☐ My rent includes utilities
☐ I share my room with other people  ☐ My bank pays bills automatically  ☐ Other

Q10 - Would you be willing to buy an electricity monitoring system to reduce the consumption?
☐ Yes  ☐ No

Q11 - Would you like a notification at a specific level of energy consumption?
☐ Yes  ☐ No

Q12 - Would you like to control the electricity consumption of each sockets?
☐ Yes  ☐ No  ☐ Some of them

Q13 - Would you like to share how much energy you consume and how much you save with the public (Internet, social networking, etc.)?
☐ Yes  ☐ No

Q14 - Do you want your energy monitoring system to be portable?
☐ Yes  ☐ No  ☐ In some cases

Q15 - Which type of display do you think make more sense to you? Which one you can read more clearly?

Q16 - What kind of feedback would affect you electricity consumption habits? And what kinds of feedback bother you?
Visual warnings (red lights, flashing lights, etc.) ____________________________
Auditory warnings (phone rings, radio, warning sounds etc.) ____________________________
Tactile warnings (vibrations, heat change, movement, surface chance etc.) ____________________________

Q17 - Where do you spend most of your time in your home? ____________________________
Interview Protocol

Electricity Consumption Habits of the Target Users

Researcher
Engin Kapkin, Graduate student at NCSU Industrial Design Program
NC State University, College of Design Leazar Hall (214), Raleigh, NC.
ekapkin@ncsu.edu / 919 749 1207

Overview
The purpose of this study is to investigate user-friendly and on-time feedback to inform users about their electricity consumption. In this sense, the question is how power consumption should be represented in order to reinforce residential users’ awareness about efficient energy usage in U.S. residential houses. Capturing the users’ electricity usage behavior and preferences are base of this interview. My goal is to create better process and solution for designing meaningful feedback of electricity usage.

Interview Number
Name of the Interviewee
Date / Time
Place

Research Subject
Electricity Consumption of U.S. Residential Users
Recording
Audio Recorder, Digital Camera
Time Period
Approximately 15min.

Introduce yourself and Ask permission to remind recording.

☐ Interviewee is agree to record this interview
☐ Interviewee is NOT agree to record this interview
☐ Interviewee is agree to participate further study

This interview will try to identify your communication preferences in your home. Because the device that I will design, has to supply correct communication so that it can help to control on electricity consumption. Remind the questionnaire.

Questions
1. Do you leave messages for your family or for roommates before you leave the house? In other words, what kind of in-house communication styles you prefer to use? On table, board, refrigerator etc.
2. Where do you leave those messages?
3. How do you check the weather?
4. Have you ever tried to save energy in your home? What kinds of behavior changes observe during this period of time?
5. Do you have any future plans to save energy in your house? What do you to for it?
6. Where do you spend most of your time in your home?
7. Would you consider using electricity-monitoring systems, such as smart meters or screens to have control over your electricity consumption?
8. What kind of functions would you expect from this kind of device?
9. If you had an electricity monitoring system in your house, where would you like to place it so that you can see it?
10. Where would you like to put this device in your home? Do you want it to be installed somewhere or do you want it to be portable?
11. When you think of monitoring systems or things providing you reminders, what type of products come to your mind?
12. Do you have any questions for me?

Thank you for participating. Your assistance is highly appreciated. Invite them to my presentation. Ask if they are interested in.

Ending time of Interview