Identifying User Preferences for Visualisation of Household Energy Consumption

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ABSTRACT
Domestic electricity consumption accounts for up to one third of a country's yearly energy consumption. Home automation and energy feedback are likely to impact energy efficiency by: informing the energy consumers about their current energy consumption; suggesting more energy efficient behaviours; and actively changing/ modifying user actions automatically or manually for reducing energy wastage. However, the design criteria for designing effective visualisation of the household energy consumption remain unclear. It is likely that the design criteria would be more effective the requirements are provided by the energy consumers themselves. Hence, a user-centred survey is designed to identify and understand both the functional and non-functional design requirements which would help in developing an effective, easy-to-understand visualization which would be more likely to be used and promote behavioural changes.

Categories and Subject Descriptors
D.2.2 **[Design Tools and Techniques]:** User Interfaces --- visualization
D.2.6 **[Programming Environments]:** Interactive Environments

General Terms
Design, Human Factors

Keywords
Energy Consumption, Visualization, Energy monitoring, energy feedback, online survey, Questionnaire

1. INTRODUCTION
The need to visualise, analyse and understand energy consumption in relation to household energy patterns plays a vital role in energy reduction [1]. A home which is automated to inform the users about energy consumption would be a better example of that. An automated feedback must be easier to read, more likely to be used and also promote behavioural changes [2], which must start reflecting on the users' energy use. To be easily read and more likely to be used, it is highly important that the design must be user-centred [3].

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The user-centred software design could be useful in obtaining the design decisions or design criteria (i.e., functional and non-functional requirements) by means of an online questionnaire/ survey and the focus group. This article concentrates on the online questionnaire to obtain the design criteria for visualising household energy consumption.

The goal of this survey is to understand the design criteria needed to design visualisation for increasing awareness (energy feedback or energy monitoring) of electricity consumption by household electricity users. We asked the users to fill out a survey by responding to a set of carefully designed questions, aiming at:

(a) Understanding the suitable platform for developing the software application for visualising household energy consumption, e.g., software application suitable for mobile phones, laptops, tablets, etc.

(b) Understanding the user-preferred-metrics to be used for visualising the household energy feedback, e.g., feedback with kWh and price (in $) as metrics.

(c) Understanding the primary reasons to save energy, thereby improving the visualisation to achieve the same.

(d) Identifying the need for the smart electricity tips and understanding the most suitable medium for conveying the notifications.

The paper is organized as follows: Section 2 details the related work in this research. Section 3 illustrates the survey method followed by results and discussion in section 4 and 5 respectively. Section 6 describes the conclusion and future work.

2. RELATED WORKS
Household energy consumption and the corresponding user behaviours are being researched by several researchers worldwide with the aim of understanding the energy patterns and to encourage more energy-efficient behaviours [4]. Energy monitoring is a human-related task which needs user centred approaches to be tackled [5].

One of the earliest works in this field is a 2004 survey [6], which was used to assess the users' preferences for energy feedback and had improved information about household energy consumption. Another study [7] was conducted to understand consumer awareness of energy consumption at home and to determine the requirements for visualising household energy consumption. Dario et.al. [2] conducted a user survey to understand what feedback is felt by users easier to understand, more likely to be used and more effective in promoting the behaviour changes. The survey identified that the clear real-time electricity feedback results in maximum energy savings.

Although several studies concentrated on user-centred survey, very few study concentrated on identifying both the functional

and non-functional requirements of the visualisation software to be developed. This survey is designed to identify the requirements (i.e., design criteria), which would help the software developers in developing an effective software, so that it is easier to understand, more likely to be used and would help the users to promote beneficial behavioural changes.

3. SURVEY METHOD

3.1 Objective

The main objective of this web based anonymous survey is to identify the design criteria for visualising the household electricity consumption. The category of design criteria to be elicited by the online survey are: (a) preferred device to view visualisation, (b) preferred software platform, (c) preferred type of visualisation, (d) preferred metrics for visualisation, (e) preferred medium to receive the tips/notifications, etc. This online survey would help in designing an effective and efficient software application for New Zealand domestic electricity consumers.

3.2 Participants

The participants for the survey were invited through Facebook event. Out of these, 73 people (aged above 18 years) participated in the survey, resulting in a response rate of 9.64%. The survey had been open to public during Sep – Nov 2014.

3.3 Design, Materials and Procedure

The online survey was created using a free online tool, *eSurv*[1]. The survey contained 18 closed questions and 2 open ended questions. The questions posted were related to demographical information, visualisation currently used by the participant and visualisation expected to be used by the participant.

4. RESULTS

The results are expressed under three main categories. They are (a) Demographical information, (b) Existing visualisation, and (c) Preferred visualisation.

4.1 Participants' Demographical Information

As mentioned above, there are 73 participants who responded to the online survey, out of which, 53.42% (39 participants) are male and the remaining 46.58% are female. The majority of the responding people are between the ages 21 and 29 (61.54%), completed post-graduation (50.68%), spending most of the time at work (58.9%), living in homes with more than five rooms (31.51%), and with 2-3 people in a household (46.58%).

4.2 Existing Visualisation

The technical details include the visualisations that are currently used by the participants to view their household electricity consumption. The first question asked the participants to list the devices that they use mostly for viewing internet. The majority voted for Laptop (39.73%), followed by mobile phone (26.03%). A significant number of votes were also received by the personal computers (24.66%).

The next question asked was about the current way of accessing the electricity bill. More votes were received by the option, "No bill, as house owner pays the bill" (49.32%). This means that the participants are in shared accommodation or in hostels. The interesting thing is that only 2.74% (2 people) said that they use the smartphone application provided by their service provider. The others have said that they use paper bill delivered in post (12.33%), e-mail bill (13.7%), and view bill in electricity provider's website (12.33%).

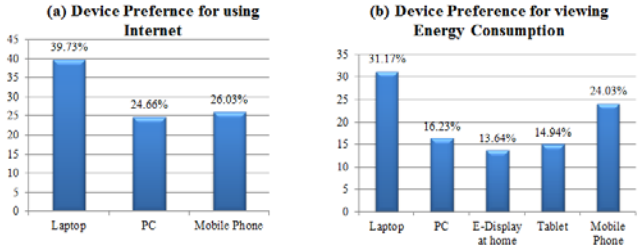

Figure 1 (a) Device preference for using internet, (b) Device preference for viewing Energy Consumption

One of the important parameters needed to design the software are the information that a person read from the bill. The popular one is overall bill amount (25.56%), followed by the electricity usage in kWh (21.05%). There were a significant amount of votes for bill duration (18.05%), monthly electricity consumption comparison (13.53%), and price per kWh unit (11.28%). Some of the participants also put their eye on daily fixed charge (6.02%) and electricity meter reading (4.51%).

Above all, 77.14% of participants said that they either attempted or attempting to save energy in some way. The major reasons behind saving the electricity is either to save money (53.66%) or to save the environment (45.12%), which is very clear from the following quotes.

Resources like coal mine and other minerals are non-renewable, and it is meaningful to save power and resources.

- *Respondent ID: 10692385*

My electricity charges are included in the rent so I just make sure that my usage is not exceeding the amount allocated in the rent so that I do not need to pay extra.

- *Respondent ID: 10692457*

It's not good to waste energy. And it also reduces household bills.

- *Respondent ID: 10695622*

Save the energy to protect the Earth

- *Respondent ID: 10718922*

Ensuring power for future generations and preserving the natural resources like coal, atomic energy etc., which are depletable resources.

- *Respondent ID: 10714742*

4.3 Preferred Type of Visualisation

The participants also had been enquired for the preferred way of visualising the electricity consumption, which would help with the future design and development of a visualization tool.

A significant parameter for the designers to design/develop the visualisation is to decide the platform (e.g. Windows, Android, iOS, etc.) in which the software needs to be developed. So, the participants were asked to opt for the devices that they prefer to view the electricity consumption. The greatest support has been given to laptop (31.17%) followed by mobile phone (24.03%), personal computer (16.23%), tablet/iPad (14.94%), and electronic display in kitchen (13.64%). Hence, it can be concluded that the software should support multiple platforms.

It is also quite important to understand how often the users like to get feedback on energy consumption. Most of the participants preferred once-in-a-month feedback (30.88%) over once-in-a-

[1] https://esurv.org

week feedback (27.94%), real-time feedback (16.18%), once-in-a-day feedback (10.29%), and once-in-an-hour feedback (2.94%). Few of the participants (2.94%) responded that they do not need any feedback, with the reason being the one below.

I have an idea of which devices consume a lot of energy, so I don't need a specific overview. I know how to save more energy. I would start with double glassing and insulation.... Also I have switches on sockets so I don't have too many devices sitting around on standby.

- *Respondent ID: 10693154*

The participants are asked about the metrics or units that they prefer for viewing their electricity consumption. The popular ones were kWh (34.68%) and price in dollars (33.87%), followed by kW (13.71%), number of trees equivalent to energy consumed (9.68%), and CO_2 emission (8.06%). And, the most preferred medium to receive the smart electricity conservation tips are E-mail alerts (39.71%), software application (27.94%) followed by text message alerts (25%). There are participants who did not prefer to receive any notifications.

I don't want more notification in my life.

- *Respondent ID: 10693154*

I don't need it. I've never wasted energy. It's money for me.

- *Respondent ID: 10711705*

Please no extra spam.

- *Respondent ID: 10714580*

It is quite important to understand what motivates the users to save energy. Out of 73 participants, only 68 responded to this question. The majority of high ratings were received by 'rewards and incentives' (542 points – 79.7%) as the best motivating factor for conserving household electricity. The next highest rating was received by 'disaggregated electricity data', i.e., energy consumed by each appliance (515 points – 75.7%), followed by 'general electricity saving tips' (470 points – 69.11%), 'archived data' or historical electricity data (428 points – 62.94%), and 'comparison with friends, peers, neighbours, etc.' (396 points – 58.23%).

The software application that is to be developed would be based on user centred design. To accomplish this, the users were asked about the electricity information (apart from the ones available today in-practice) that they would like to visualise/view to conserve electricity. The responses help in bringing the software to the next level. The participants recommended for disaggregated electricity information, highest and lowest peaks of energy consumption per day, separation between space heating and other appliance, etc.

The highest and lowest peaks of electricity consumption everyday

- *Respondent ID: 10706064*

Classify the energy used by each electric device

- *Respondent ID: 10712588*

Fluctuations of voltage if at all any noticeable changes prevail.

- *Respondent ID: 10707869*

Some kind of separation between house heating consumption and other consumption. I think the most things which increase my bill are heaters in the winter.

- *Respondent ID: 10727387*

One of the participants mentioned that he/she does not need to be notified or informed about the household energy consumption.

None, if I don't save enough energy, it is because I am lazy but not because I am uninformed

- *Respondent ID: 10693154*

5. DISCUSSION

The questionnaire has identified that most of the participants (approximately 77%) expressed that they have attempted to save energy. There were different ways in which people had been trying to reduce their energy consumption through a normal paper bill to the latest software application. There are several advantages with respect to the software application over the other forms of feedback. They are (a) the feedback is immediate and updated, (b) different dimensions of the feedback could be provided, and (c) the users are highly informed through notifications. But, not many people use the software application (2.74%). So, the development of software application would be highly useful in conserving household electricity.

5.1 Functional Design Decisions

The main advantage of software application is to have multiple dimension of information about household electricity consumption. From the questionnaire results, the highly motivating parameter to conserve energy is rewards and incentives (79.7%) and so this is one of the important information to be visualised in the software. The visualisation would also include disaggregated electricity consumption (75.7%), electricity saving tips (69.11%), and archived data of household electricity consumption (62.94%).

With respect to the disaggregated electricity consumption, the questionnaire recommends to separate the space heating from other electrical devices. Also, a comparison of the archived electricity information is worth adding to motivate the users. The preferred medium of sending the electricity saving tips can better be personalised by the users themselves as the questionnaire response is inconclusive to choose one. The preferred medium are (a) text message alerts (25%), (b) E-mail alerts (39.71%), and (c) software application notification. Also, there would be an option to disable the notifications as some participants recommended.

The next functional design decision is to select the appropriate metrics to visualise the electricity consumption. The highly preferred metrics are kWh (34.68%) and price in dollars (33.87%). As like the electricity tips, the users can also choose the preferred metrics during signup.

The next design decision is the frequency of the electricity feedback. From the questionnaire results, it can be observed that the maximum response was received by once-in-a-month feedback (30.88%) and once-in-a-week feedback (27.94%). Hence, the users can choose one between them.

Around 77.14% of the participants said that they are attempting to save energy and the major motivation or reason behind saving electricity is to save money (53.66%).

5.2 Non-functional Design Decisions

Through the online questionnaire, it is important to understand the non-functional design decisions for the to-be-developed software. The first step is to understand the platform in which the software is to be developed. Through the questionnaire, we understand that people use different devices such as laptop (39.73%), personal computer (24.66%), mobile phone (26.03%), tablet (5.48%), etc. to view internet. Since, the percentage margin is very less, it is

quite important to make sure that the users can use the software in different platforms. So it is good to employ the first non-functional design decision, *cross-functionality*. The cross-functionality is a way of developing software, so that it could be used in multiple device platforms.

Some of the other basic non-functional design decisions are *extensibility* (the ability to extend or add features to the software application), *security* (the ability of the software to secure the users' electricity data), *reliability* (the ability of the system to perform under specific conditions for specific period of time), etc. would also be achieved in developing the software for visualisation.

5.3 Limitation of this questionnaire

The questionnaire was limited to participants living in New Zealand. Also, the sample is very low because of the low response rate.

6. CONCLUSION

This paper presented the results of a web-based questionnaire with the main goal of understanding the functional and the non-functional design requirements to design a software application for household electricity consumption. The results show that more respondents are interested in once-in-a-month feedback. The respondents use a variety of devices to access internet, which concludes that the software to be developed should support multiple platforms such as mobile, laptop, tablet, etc. which suggests our visualization should be accessible on multiple devices and platforms. The most preferred feedback metrics are kWh and price (in $). Hence, the users should be able to personalise their settings.

The smart electricity tip is one of the major elements in reducing the household energy consumption. The respondents replied that the major medium for conveying the tips could be either text message alerts or email alerts. This could also be personalised with software settings. As the major reason behind saving electricity for users is saving money and saving environment, all the electricity tips should motivate the users either based on monetary benefits or based on environmental benefits. In addition to all of these, people recommended the following non-functional requirements: security, and reliability. From the development perspective, extensibility should also be considered.

Although the response rate and the sample are low, the response can be used as the initial step for developing the software. This user-centred design would also be supported by the literature review evidence.

FUTURE WORK

To support the literature and the user-centred web questionnaire, the next step in the process is the user centred visualisation design, i.e., obtaining the users' opinion about visualising the electricity consumption by means of a focus group. The focus group would help in selecting the preferred designs for visualisation from a pre-designed set of options. The focus group would last for a couple of hours with around 20 participants in each group. The focus group design is iterative and incremental to achieve the maximum results.

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