User interface design for changing energy end-users behavior

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Abstract: In order to reduce Carbon emission from buildings, a number of technical approaches and end-users policy can be adopted. It was reported that providing energy end-users with accurate and regular information can give rise to energy reduction by 4-20 %. User interfaces plays a significant role in the energy feedback system. In this paper, a design guideline of the user interface for the energy feedback system was proposed and discussed on the applicability with examples.

Key words: Energy feedback, User interface, Design Guideline.

1. Introduction

Greenhouse gas reduction is a global issue in setting up energy policy nowadays[1]. About 25% of total energy consumption is associated with buildings [2]. While technical approaches to reducing energy use in buildings requires substantial investment, energy feedback is a cost-effective measure to achieve energy reduction[3]. There are a number of devices invented for the implementation of the energy feedback measures in which user interfaces play significant role in terms of sustainable energy awareness and motivation. In this paper, a design guideline is proposed on the basis of the review of the effects of various contents and design examples.

2. Effect of energy feedback

In Europe and North America, studies on the energy feedback effect have been made since the late 70's[4][5]. Darby [6] reported a literature review of energy feedback methods in which she categorized the energy feedback types into Direct feedback and Indirect feedback. In the Direct feedback, end-users can always receive real-time energy information on real time via display devices (e.g. PC, Web) while in the Indirect feedback, end-users are informed via processed information regularly (e.g. bills). As can be seen in Table 1, energy saving ratios are various from 4 % to 20 % when adopting direct and indirect feedback systems. These differences are possibly incurred by contents of information and the way of delivery.

Table 1. Effect of energy feedback

Energy saving (%)	0-4	5-9	10-14	15-19	20 of peak	20-	Un known
Direct Feedback	2	8	7	1		3	
Indirect Feedback	3	-	6	1	3		
1987-2000	4	6	5	1	1	3	1
1975-2000	6	9	13	3	1	3	3

A study in Norway reported that the issue of energy bills for years made about 10% reduction through changing energy use pattern[7]. In the case of issuing energy bills more frequently and containing more motivating information such as comparison data with the previous year, the energy saving ratio improved up to 12%. A Canadian study in 2006[8] showed that when end-users are informed instantly on energy use (i.e. electricity) and indoor environment condition(e.g. temperature, CO_2) using a portable monitoring device, the maximum energy reduction rate reached to 16.7 %.

A field study in England in 1999 [9] demonstrated how the information contents affected the energy saving effect. In the study, 120 households were selected and divided into 6 groups. Each group was provided with different contents of information as follows.

Group 1 comparison of energy use against other similar houses.
Group 2: comparison between current and last season's energy use.
Group 3: comparison of energy cost
Group 4: educational program on environment awareness
Group 5: provided information on energy saving technologies
Group 6: provided with a software program to check energy data on demand.

After 9 months field experiment, the group 6 turned up the best in terms of energy reduction rate and was followed by group 1 and group 2. Although the field study was restricted in terms of the period (i.e. less than one year), the number of sample (i.e. 120 households) and area (city of Bath), it gave an insight into the significance of the format and contents of the information delivered to end-users. Therefore, it is required to develop more effective ways to make end-users proactive in energy saving. In this paper, we suggest an on-line energy feedback system and discuss on the design guide line for the user interface of the on-line energy feedback system.

3. On-line Energy Feedback System.

Figure 1 illustrates the schematic diagram of the generic on-line energy feedback system consisting of sensor clients, a server system and display devices. The sensor client is a set of devices which measure energy consumption (e.g. electricity, gas, water etc) and environment information (e.g. temperature, humidity, CO_2 etc). The measured data from the sensor client are sent to the server system which manages the database and transforms the data to informative contents with energy analysis algorithm if necessary. The informative contents

are delivered to energy end-users via display devices. Although display devices play a key role as a human interface, the data processing part in the server system is crucial since it defines the data format and contents that improve energy consciousness of end-users and lead to behavioral changes eventually.

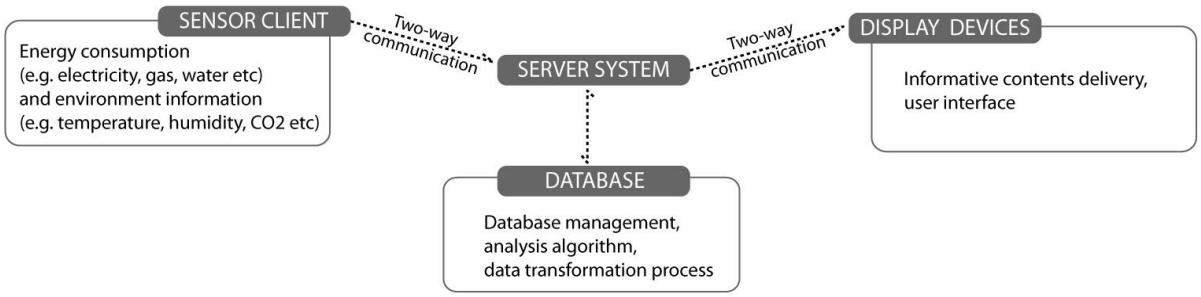

Figure.1 Schematic diagram of on-line energy feedback system.

4. Design guideline of user interface.

4.1 Explicitness

Figure 2 shows examples of the conventional electricity meter that indicates the total energy use. The information provided by the conventional energy meter makes little sense to end-users in terms of improving energy awareness. In order for end-users to get engaged in energy saving actions, more explicit information is required through which they should be able to appreciate status of individual energy demand devices, identify energy use patterns and set up appropriate energy saving strategy. Meanwhile, Figure 3 gives a good example of the appliance level monitoring interface[10] which displays the energy use information of individual energy consuming devices. By providing elaborated consumption data, end-users can spot the problematic appliances. The information should be displayed with a specific message in clear and concise manner. Redundant and abstract information can hardly lead end-users to any specific action.

Figure.2 Conventional power meter

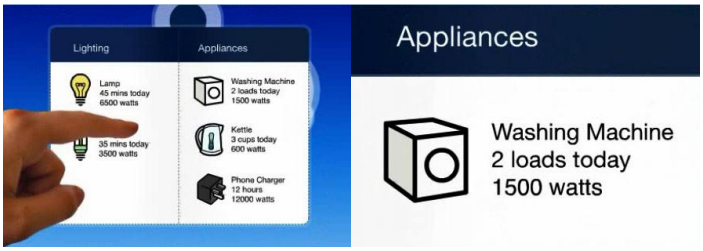

Figure.3 Energy monitoring of home appliances [10]

4.2 Simultaneity

According to the literature review of field studies on energy feedback, the direct feedback is generally more effective. The status of energy feedback systems should be delivered to end-users on real time. End users should be able to react against the alert from the monitoring system. A number of products are already available implementing the real time energy monitoring and display. The Home Energy Hub shown in Figure 4 indicates current energy use of each appliance[11]. Wattson equipment in Figure 5 is equipped with a more dramatic

device which displays current status of energy use in number and color. The device indicates the level of energy use with colors and brightness of light which change in the event of energy use level.

Figure.4 The Home Energy Hub[11]

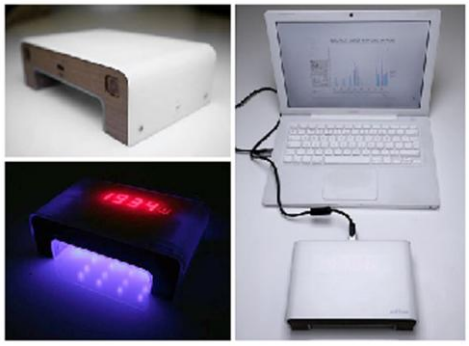

Figure.5 Wattson (Japan)[12]

4.3 Harmony with human living context

The form of information delivery is also an important aspect in making energy feedback effect sustainable. The display devices should be harmonized with indoor context. Characterization of energy use pattern will help to attract occupancies attention. An example of characterization of energy use pattern is the Flower Pod Energy Monitoring Device designed by Doug Gunzelaman [13]. This flowerpot look-like device displays a flower in the device which bloom or fade away according to the energy use pattern. This kind of entertaining effect could make end-users more friendly interact with energy consuming devices.

Figure.6 Flower Pod Energy Monitoring Device[13]

4.4 Motivation

Motivation induces human action and makes the behavior keep on. It is also defined that it leads them to show good attitude continuously [14]. To motivate users, we should understand human desire and feeling and focus on the process of informational. Abraham. H. Maslow, who is an American psychologist, classify 5 human desires to pyramid shape and said that people pursuit high level desire after satisfying lower level desire step by step in the Hierarchy of Needs [15]. By the theory, we can know that the users should satisfy their indoor circumstance in order that they are induced to do the reasonable behavior to save the energy.

Figure.7 represents a wide screen display device that can show the energy information entirely in their house [16]. That device show the energy produce consumption and additional information at home and can control various indication signatures according to each person so can be familiar with the users. Also, that helps them to

recognize and respond to shown information by the visual Metapo icons expressing the information that they want to know.

Figure.7 Energy mirror [16]

Figure.8 is the software to serve Carbon footprint that be proportional to the energy use amount according to person transportation, moving path and space using the GPS of the smart cell-phone [17]. The software doesn't give the users much information that is too many to understand by comparing hierarchical information. Specially, that emphasizes the energy consumption cost, so follows that energy saving behavior of them becomes habitual. Also, the software has easily approachable merit because that is installed in the cell-phone.

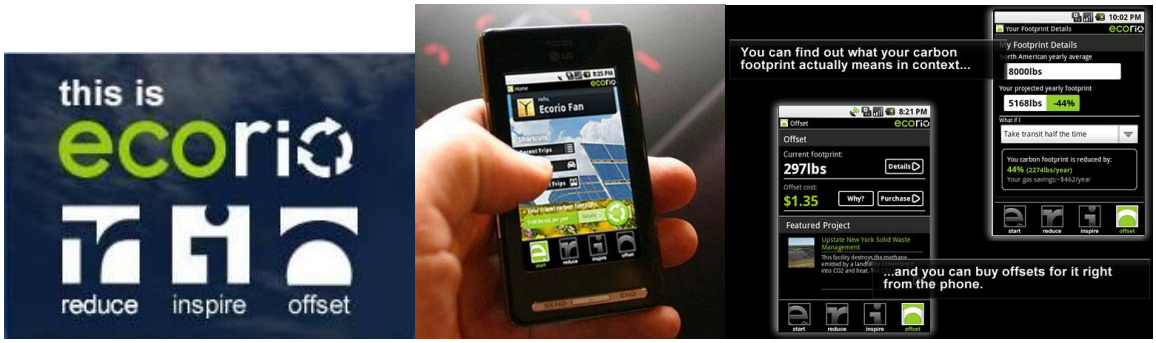

Figure.8 ecorio [17]

People should be attracted by the compensation to be gotten through the behaviors to have a mind to do such a specific action [18]. It is expected that the motivation is more effective, if the government supports incentive programs.

5. Conclusion

There are a number of devices invented for the implementation of the energy feedback measures. User interfaces play significant role in terms of sustainable energy awareness and motivation. To make energy feedback measure more effective, user interfaces should be designed with explicit strategy. The design guideline proposed in this paper is an initiative of further systematic researches for the future. Multidisciplinary approach involving psychologists, energy engineers, policy makers and designers is required to develop effective energy saving policy engaging end-users.

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