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**Article**

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# Real-time Feedback on Consumer's Behavior: Literature Review

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**ABSTRACT**

Effective energy management can provide an important tool to reduce energy consumption, which is crucial in the fight to protect natural resources and to have a clean environment. Reducing energy consumption can be achieved by reducing energy waste in residential building. Waste in energy can be a result of using energy wasting appliances as well as reckless human behavior such as not turning off unwanted electrical appliances or operating air conditioners or heaters at unnecessary temperature settings, just to name a few. This paper reviews a couple of studies which was conducted on the use of real-time feedback technology to improve energy consumption behavior and habits. The methodologies used will be described along with the results of each study. A list of challenges and limitations of such studies will be explained. The review should give guidance and recommendations on how to conduct a study on the use of real-time feedback technology. Using these recommendations, a study on the topic was conducted by one of the authors in the Kingdom of Bahrain. The results of the study are briefly described in the paper.

**Keywords:** Real-time Feedback, Consumer's Behavior, Energy Management
**JEL Classifications:** Q43, Q47, Q53

## 1. INTRODUCTION

As per the International Organization for Standardization (ISO), "Using energy efficiently helps organizations save money as well as helping to conserve resources and tackle climate change" (ISO 50001, 2017). A popular standard from the International Organization for Standardization, ISO-50001 calls for the efficient use of energy by means of effective Energy Management Systems (EnMS). Although the model is originally designed for organizations, the concept can be applied to residential sector as-well. According to a research by Williams and Matthews, (2007), residential users waste 41% of the power supplied to them. This wastage can be a result of inefficient devices being used at residential level as well as inefficient usage behaviors such as not turning off unwanted lights, operating air conditioners or heaters at unnecessary temperature levels and keeping unused appliances plugged in. The residential users in the USA are responsible for more than 20% of the annual $CO_2$ emissions as per the US Environmental Protection Agency (Karlin et al., 2015). These emissions are forecasted to be increasing at an average of 0.3% per year until the year 2035 (Alahmad et al., 2012). The main culprits for these emissions are the power and transportation sectors (Karlin et al., 2015; Alahmad et al., 2012). According to a research by Alahmad et al., (2012) 60% of the energy consumed in the USA is in the electricity sector.

While efforts are being made on going green and switching towards renewable sources, it has been found to be of grave importance to study methods of reducing the consumption and wastage in the first place. Residential energy conservation is one of the most effective ways of reducing energy emissions and shows potential of saving 25% of energy costs resulting in $300 billion gross savings through years 2009-2020 (Karlin et al., 2015). This shows that these energy associated concerns not only affect the environment but have a strong economic effect as well. At a lower level, it has been observed that in the UK, keeping appliances on

stand-by like televisions or laptops and not disconnecting them from power source causes an additional cost of 50-86 GBP per year on each household (Zimmerman et al., 2012). These figures may look small, but considering the fact that these values are only for a single household, the cumulative effect of them is extremely significant both economically as well as environmentally.

Many studies related to energy consumption behavior have been published in the literature (Alahmad et al., 2012; Gardner et al., 2002; Oltra et al., 2013; Houde et al., 2013). These studies identified some approaches relevant to the topic of energy management and conservation and discussed some of the challenges in the implementation of these approaches. The literature reviewed in the following section hence proves that effective energy management is extremely important at a residential level to reduce energy waste. Recent studies and technological advances along with growing trend/awareness of the importance of "Data Driven Decision Making" has shown a great potential for feedback technologies in this domain.

## 2. FEEDBACK AND ENERGY MANAGEMENT

Since the 1970s, the impact of feedback of energy consumption on the behavior of the consumers has been under investigation (Gardner et al., 2002). "According to the theory of feedback, effective feedback devices let people teach themselves how to save energy, promote self-efficacy and reinforcement and result in energy conservation" (Oltra et al., 2013). In the 70s, with the technology available at that time, a reduction of 10% was observed in the energy waste by employing feedback technologies (Oltra et al., 2013). But the recent advancements in technology and the availability of real-time feedback has reported up to 20% decline in energy consumption at the residential level (Houde et al., 2013). In comparison to just educating people on energy wastage and its environmental implications, this method is viewed to be a more effective way of cutting down energy consumption. This is due to the fact that it provides the real-time feedback to the consumers of their energy habits, giving them an opportunity to educate themselves on the usage and make energy saving decisions on the go.

A qualitative study was conducted in Barcelona, Spain by the Barcelona Energy Agency back in 2011 in context to the European Union (EU) PACHELBEL Project (Oltra et al., 2013). PACHELBEL is an acronym for "Policy addressing climate change and learning about consumer behavior and everyday life" (Centro et al., 2013). This project focuses on taking public behaviors and habits into consideration while making policies. The study was based more on a qualitative model comprising of 17 individuals divided into two groups. Group 1 consisted of volunteers whereas Group 2 comprised of people recruited randomly (snowball approach was used as well). Group 1 was provided with feedback devices for a week and after that focus groups were called to discuss various methods/approaches that can be used to conserve energy usage and discuss the progress. Whereas, Group 2 was a part of these focus groups but was not provided with a feedback device until after the focus groups were dismantled. After the dismantling of the focus groups, Group 2 was given a feedback device and interviewed after 3 weeks to study the effect. The main data collection techniques used were focus groups, diaries and interviews in this research. The results of the research were quite positive in gaining energy savings and reducing energy wastage. The sample achieved a good level of awareness on the energy consumptions of various appliances and applied this knowledge effectively to showcase energy savings. They reduced the use of devices or certain settings on devices that consumed extra energy and felt that they reached a level of saturation where further savings were not possible due to "necessities." On the other hand a few people showed lower level of engagements (especially from Group 2) based on lower motivation levels to save energy. Others did not find the devices easy to use as well as found them to be missing relevant information. They complained that the device only showed kWh values, with which they were not aware and it was nothing more than a number going up and down to them. They would have been more motivated and engaged in the experiment if they better understood the values or if a unit that means something to them was used (e.g., the dollar amount of energy usage). In summary, real-time feedback showcased positive results but the level of engagement seemed to vary with motivation levels.

Another study intended to observe the impact of real-time feedback technologies in reducing electricity wastage by means of experimentation (Houde et al., 2013). Google partnered with Houde et al. in the study that took place from February, 2010 till October, 2010. Google employees from various locations around the USA voluntarily took part in the study. By the end, the number of volunteers that registered for the study were 1743 of which only 1065 were selected/met the requirements. Out of these only 752 volunteers were provided feedback technology straightaway whereas the rest of 313 were utilized as a control group and were provided feedback only after 3 months. The participants of the research were required to install the hardware necessary for the research on their own and were provided with a web-interface by Google called the Google Power meter to showcase their usage. This was a very powerful dashboard that provided functionalities like forecasts, comparisons, budget trackers, email notifications and daily reports etc. The values were updated on the dashboard every 10 min. Initially, the reduction in electricity wastage was very high but gradually people lost excitement and the change could only be seen for morning and evening times. The average reduction observed was 5.7% which is lesser than previous studies. But the researchers here claim that the lower reduction levels are due to the better research design and is therefore more accurate. People were not chosen on the basis of bias and the sample-set was extremely large compared to other researches in the same domain hence providing more realistic results. Another reason can be the lack of motivation due to less or no price sensitivity as the entire sample-set is the households from Google and Google as a company is known to pay handsomely to its employees. Also, the 10 min lag can sometimes be annoying and demotivate the user who has to wait a certain period of time to know the result of his/her step.

A similar study was sponsored by the Institute of Electrical and Electronics Engineers (IEEE) Industrial Electronics Society in

partnership of Omaha Public Power District (Alahmad et al., 2012). The study was carried out in many phases throughout the years 2008-2010. The paper with findings on the related topic was published in 2011. The paper focused on reducing the electricity wastage in the city of Omaha by providing real-time feedback to the consumers. Additionally, it also compared three main devices for their effectiveness in reaching this end-goal. Two variants of Aztech In-Home displays and the Blue Line Power Cost Monitor was provided to 151 of Omaha's customers and the change in behaviors as well as usage was studied through surveys and consumption analysis. These devices were chosen out of many other similar devices based on their credibility. After 30 days, a comparison was made which showed less or almost no affect for the households that used Aztech displays. Whereas, the blue line power cost monitor (PCM) resulted in a 12% savings. This was because of the fast refresh rate of the Power Cost Monitor that would display changes in <15 s. On the other hand, Aztech required more than 2-5 min at times which was frustrating for the research participants.

In Eastern England, a qualitative study was conducted to find out the motivations people have behind purchasing the real-time cost feedback devices for electricity consumption and their interactions with such devices. The research concluded that mostly people are motivated by one or more of the four (Hargreaves et al., 2010).

a. Financial motivations
b. Environmental motivations
c. Informational motivations
d. Technological motivations.

Financial motivations topped the list as mostly people wanted to save money by means of being more aware of their usage (situational awareness). Following financial motivations in the list was the environmental motivation as people less sensitive to finances believed they had to pay the bills anyway and that was not going to stop them from living in comfort, but if it had an environmental impact they would need to rethink the way they do things. Thirdly, people purchased these devices based on the need for more information about their usage. It can be mere curiosity as well as the desire to save more money, environmental impacts or just to test out new technology. This motivation was not chosen exclusively and came in as a combination with one of the other 3 listed. Lastly, people purchased these devices to add to their list of gadgets. These were technology enthusiasts who get easily excited by technology. The usage and behaviors of response also differed from people to people. Some were really interested in the beginning with this new piece of technology where as they lost interest later. Genders played a role as well men seemed to be more excited by it while on the contrary women were not equally excited (Hargreaves et al., 2010).

## 3. CHALLENGES

Analysis of the above studies shows that each model had a certain drawback. These drawbacks would include inability of the devices to update data in a reasonable time. Lags of up to 10 min were observed, which can in turn demotivate people who are not so patient. This brings us to our second drawback that was observed; the lack of motivation affected the results as well. Some customers might get excited in the beginning of the experiment, but loose interest as time goes by. In this case, high electricity prices can be a source of motivation. Finally, the inability of people to understand the concept of Watts affected the studies adversely as well. Therefore, Real-time feedback should be provided to customers in terms of monetary value and not just in Watts.

Furthermore, research results of studies in this domain have shown a lot of variability not just between them but within the same research studies as well (Vine et al., 2013). Studies without control factors showed a higher average saving of 10% but the variability was observed from 55% savings to 8% more consumption rather than savings (Delmas et al., 2013). On the other hand, studies employing control factors showed a lower average of just 2% saving but at the same time the variability was within the range of 5% saving to 5% more consumption. (Delmas et al., 2013). Such results could be attributed to the tendency of people to behave differently when being monitored (called Hawthorne effect) as well as self-bias shown in the selection of sample by the researchers. This effect poses a big challenge as it can't be identified directly or easily (Buchanan et al., 2014). In contrast, a study published by the support of University of California in the year 2015 conducted a meta-analysis of 42 of the prominent studies in this domain (Karlin et al., 2015). Hawthorne Effect and biasedness which are feared as challenges were two out of six characteristics studied and they showed no significant effect on the effectiveness of the experiments conducted in these studies (Karlin et al., 2015). Interestingly, it was observed that even the usage of energy for identical households is not similar and can vary by as much as 260% (Karlin et al., 2015; Parker et al., 1996). Thus, the consumption of any two similar houses cannot be compared against each other as behaviors have a huge impact on energy usage (Karlin et al., 2015).

The feedback technologies used were also compared and it was found that computers were the most effective means producing more significant results. Computers provide more customizability and updates to keep the audience from losing interest in the technology as feared in the threats (Karlin et al., 2015).

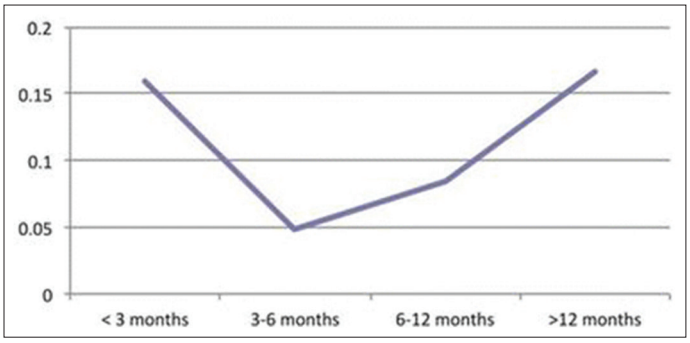
Human factor is another threat to the research as it has been observed that the success of the real time feedback approach is highly dependent on keeping research participants motivated and interested (Buchanan et al., 2014). Duration of the study was another challenge posed to the research. People tend to show interest in new gadgets but lose that interest overtime. Pereira et al. (2012) conducted research in this domain and discovered 60% less interaction with the feedback displays after 4 weeks. On the other hand, Dam et al. (2010) discovered the savings that were seen 4 months after a similar experiment seemed to drop when studied after a period of 15 months. This lose in interest can also be explained under the Wilhite and Ling's "Fallback Effect" – if technology does not provide something new or extra overtime, people tend to get over it (Wilhite and Ling, 1995). UK government conducted a survey in this domain and found out that 1 in 5 people did not even pay attention to these displays. This is not just because of losing interest; it also has to do with the motivation to save

energy (Buchanan et al., 2014). Another study (Karlin et al., 2015) investigated the duration of a study and its effect on participant interest. It was observed that research participants loose interest when studies last <3months, but a gain in interest was observed for long-term studies (i.e., more than a year) as shown in Figure 1 (Karlin et al., 2015).

## 4. REAL-TIME FEEDBACK TECHNOLOGY IN ENERGY MANAGEMENT IN THE KINGDOM OF BAHRAIN

Little research has been conducted in the Kingdom of Bahrain to study the effect of real-time feedback technology on energy consumption and consumer behavior. Keeping in mind the environmental and economic impacts of energy wastage, the Electricity and Water Authority of Bahrain (EWA) has started awareness campaigns to reduce electricity usage. Due to the hot climate conditions, air conditioners are the main culprits of electricity usage in Bahrain which consume 60-70% of the energy during summer. The second and third culprits are lighting and refrigerators respectively. On the other hand, while some countries provide some sort of feedback through smart-meters (not necessarily real-time feedback), Bahrain still lacks that technology. The implementation of real-time feedback technology to achieve an effective energy management will be a completely new concept in the Bahraini market. Nabeel (Nabeel, 2017) carried out an experiment to investigate the effect of real-time feedback technology on energy consumer's behavior in residential buildings in Bahrain. The experiment was conducted by installing feedback devices in 5 different houses. In the first 20 days, the houses were only educated on electricity saving practices recommended by EWA and were not given access to feedback displays that showed total real-time consumption in KWh besides monetary value. This was done to monitor their regular usage from the same device to ensure accuracy. In the second phase of the experiment, they were provided access to the feedback displays. Daily consumption of the 5 houses for the 40 days of the experiment was recorded and analyzed. Additionally, interviews were conducted with the families at the termination of the experiment to understand the unquantifiable aspects of the study. The participants felt motivated by the real-time cost feedback provided by the device and re-evaluated their energy usage behaviors accordingly. The research study reported an overall reduction of 12% in the electricity consumption with a variation from 3.9% to 25.7%, thus providing a successful solution to the wastage problem faced by EWA. The houses motivated by financial and environmental concerns reported the highest reductions. Whereas, the houses motivated by technological and informational interests reported a lower reduction in electricity consumption.

**Figure 1:** "Feedback duration (x-axis) as moderator of feedback effectiveness (y-axis)" (Karlin et al., 2015)




## 5. CONCLUSIONS

This paper reviewed published literature on the effectiveness of real-time feedback technology in creating a change in the behavior of energy consumers. Different studies concluded that the technology helps in reducing energy waste with varying magnitude depending on factors such as participant interest and displayed information. The different research methodologies and the challenges faced by researchers in this field were explained in an effort to provide researchers with a list of recommended best practices when conducting research in this field. The paper then briefly described an experiment which was conducted in the Kingdom of Bahrain using the knowledge gained by this review.

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