Energy@home: Energy Monitoring in Everyday Life

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Abstract. Goal of the research is to assess evaluations of the innovative smart monitoring system Energy@home for domestic electricity consumption. Aim of the Energy@home system is to provide householders with a persuasive tool that allows to manage energy consumption more efficiently. A combination of persuasive communication strategies such as graphical real-time and historical feedbacks to encourage competitiveness against "similar" households are provided to users through domestic user-friendly interfaces and combined with personalized energy saving prompts sent via newsletters. The Energy@home system was tested on 52 users selected all over Italy. From the qualitative standpoint, the system was evaluated easy to use and useful from 95% of trial users. The average system evaluation on a 1-to-10 scale was 7.8. From the quantitative standpoint, the Energy@home system motivated domestic consumer to save more than 9% in the electricity bill and emerged as an effective tool in reducing stand-by consumption on average above 15%.

Keywords: Energy, User Experience, Persuasive Stimuli, User Interface, Changing behavior.

1 Introduction

Moving towards a model to understand household behaviour, the human decision to behave in a certain way is driven by a wide range of internal and external factors [1]. Specifically, in the area of domestic energy consumption, there is a need to take into account the physical, social and cultural factors that influence and/or constrain a user's choices and behaviours, such as age, gender, social class, income, geographical position and political differences, aside from information provision and economic incentives [2]. Achieving energy conservation is a double challenge, partly technical and partly human. Thus, disciplines such as sociology, social psychology, anthropology and building physics are increasingly relevant to understand findings into behavioural patterns of energy consumption in households.

To address the human side of energy efficiency, theories of persuasive communication and attitude change must be coupled together with available home automation technologies displaying energy information, with the aim of educating, motivating, incentivizing and persuading domestic user towards energy saving behaviours.

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The goal of this study is to assess and provide evaluations of the innovative smart monitoring system Energy@home for domestic electricity consumption. The aim of the Energy@home system is to provide householders with a persuasive tool that improves awareness of energy behaviour in their homes and allows them to manage their energy consumption more efficiently. A combination of persuasive communication strategies such as graphical real-time and historical feedbacks and comparison tools to encourage competitiveness against "similar" households are provided to users through domestic user-friendly interfaces and combined with personalized energy saving prompts sent via web-newsletters.Besides, qualitative techniques to collect data from users during the Energy@home trial are applied, such as questionnaires and focus groups, with the aim to gather information on occupant behaviour related to electricity energy use in homes.

2 Problem Statement

Although significant improvements in energy efficiency have been achieved in home appliances and lighting, this alone is not enough: the electricity consumption in the average EU-25 household has been increasing by about 2% per year during the last 10 years [3]. Moreover, occupant behaviour at home can enormously vary on the base of different energy related behavioral patterns: accordingly, Andersen in 2012 [4] demonstrated that energy consumption in almost identical dwelling might increase up to three times. Interestingly, results of several studies [5, 6, 7, 8, 9, 10, 11] underlined that the energy saving potential by improving occupant behaviour is on the average about 15%.

The concept of displaying energy consumption to domestic consumers in order to promote energy saving behaviours has been suggested since the 1980s [12, 13, 14]. Existing real-time energy monitoring tools allow users to visualize and to manage more efficiently their electric energy loads at home.

Field studies on environmental behaviour [15, 16, 17, 18] conceptualized persuasive strategies, pointing out that energy consumer may be influenced by antecedent (general) and consequence (feedback) information. Antecedent strategies announce the availability of positive or negative consequences through information, prompts, demonstration and commitments. Consequence strategies provide rewards and feedback, following particular energy behavior that has been observed and monitored.

From the literature concerning feedback information, there is still little clarity on how best to achieve energy-saving potential in dwellings. A study conducted by Harkins and Lowe [19] gave evidence to the fact that if users are given a goal to reach, they feel a sense of satisfaction of achievement from reaching that goal. Moreover, it is believed that there is a social driver at work in the presentation of energy use in comparative fashion. Van Houwelingen and Van Raaij [20] stated that if users are shown how much energy they are using compared to others, they may well get satisfaction from knowing they are doing better than others. If households learn they use more energy than other similar households, it is assumed they will be motivated to reduce consumption and possibly more so than those other households.

Regarding the feedback display's form, it is important to examine how the type of unit of power used to convey energy consumption influences the consumer. Hayes and Cone [21] emphasized that using the kWh as display unit would be the most obvious choice among technicians for identifying electricity energy use. Moreover, people may not understand the relevance of the amount of energy they are using to the effect it has on environment or economy. For this reason, home energy saving potential must be communicate to end users also in terms of economic and environmental impacts.

3 Energy@home System

The Energy@home project envisions a communication web platform that provides users with information on their household consumption by means the direct visualization of the energy loads on smart appliances displays, smart phones or personal computers. The system is based upon graphical user/friendly interface, information exchange and persuasive feedback information related to energy usage, energy consumption and energy tariffs in the home area network. The system's general architecture of the Energy@home system is reported in figure 1.

Two parallel energy efficiency strategies are tested with the aim of reducing domestic electric loads. The "human-sided" strategy focuses on potentialities in influencing the occupants' use of domestic equipment through information and feedbacks (web based graphical user interface). The "machine-sided" strategy focuses on the automatic management and shifting of domestic energy loads.

Fig. 1. Energy@home system

4 Energy@home Trial

In 2013 Telecom Italia managed a trial with 52 households to test the Energy@home system both from a technological (system efficiency) and user-experience (system usability) point of view. Among the selected trial sample, 20 households installed a photovoltaic meter, 9 households have 4.5 and 6 kW contractual power meters and 23 households have 3 kW contractual power meter. Trial users were dislocated in different Italian regions and differed for house typology (condo vs. detached house) and family members (from two to six households). They were also different for the propensity to save energy.

Telecom Italia managed the trial in collaboration with Enel Distribuzione and Indesit Company, all founding members of the Energy@home Association (Energy@home: http://www.energy-home.it/). Every participant of the Energy@home trial installed (by himself or through a specialized technician) the Energy@home kit including: a smart gateway, 5 smart plugs, a smart info (turning into “smart” the traditional electrical meter) and a zigbee washing machine (see fig. 2). A web based app allowed every user to access his/her energy data directly at home or remotely (office, another home, mobility…) and to see household breakdown consumption as a function of Watt (stand-by power), kWh (appliances’ consumption details, historical consumption data, overload warnings, etc.) or Euros (spending forecast). Trial users had also access to a web-platform community connecting people involved in the trial. Scope of the web-community was to allow users to compare peer consumption data or to ask for suggestions or technical support.

Fig. 2. Energy@home kit devices

The trial was managed in order to test the system both from a technical and user experience point of view.

During the trial we collected both qualitative and quantitative data. Quantitative data are related to log files that indicate the “click number” on different visualization options of the system like energy cost, energy consumption, appliance details, number of access to the system, and data sent from every device in terms of watt and watt/hour. Quantitative data are also related to statistical data about changes in user behaviour after specific “persuasive stimuli” we sent them through 8 newsletters every 15 days of system use.

Fig. 3 shows the 8 the persuasive stimuli sent through newsletters to the participants. The participants were grouped in 10-12 people and newsletters were sent in different periods to different groups of users.

8 newsletters: everyone was sent with test and "graphical position" of user in comparison with others							
Prompts on energy consumption with reference to family type	Prompts on stand-by energy consumption	Suggestion of actions to reduce stand-by energy consumption	Prompts on refrigerator energy consumption	Which is the most energy consuming appliance?	Prompts on smart washing machine energy consumption (Part I)	Prompts on smart washing machine energy consumption (Part II)	Visualization of changes in energy consumption load

Fig. 3. Persuasive stimuli in newsletters

Qualitative data concerns a direct daily communication channel settled with trial users. Trial users communicate with the experimenter team (comments, problems, questions, suggestions…) through email. Persuasive stimuli were sent by email and qualitative users' responses were collected and associated to direct observation of behavior changes. These information were analyzed to highlight social and contextual drivers in home energy uses as well as correlations with statistical quantitative data to explain behavioral changes. Furthermore, users information were collected through an online forum (directly accessible from graphical user interface), focus groups and online questionnaires. Two questionnaires were distributed. The first one gathered detailed information about the sample of trail users in order to correlate household typology to their consumption data. The second one was sent after about one year of Energy@home system usage. It collected data related to system usage, habits, satisfied needs and unsatisfactory experiences related to the Energy@home system and it took about 20 minutes to be filled in. Most of the items had multiple-choice answers, moreover some open questions were inserted in order to better identify user opinions on perceived system benefits and possible optimizations of system usage in the real context of use.

Two focus groups were settled in order to gather information related to the users' satisfaction, to find confirmation to the evidences of the questionnaire as well as to evaluate new concepts about energy management, evolution and business model. Finally strengthens and weaknesses of the system were highlighted and the voice of the users were used as a guide to next improvements.

5 Main Results

5.1 Qualitative Analysis: Focus Groups, Questionnaires and Spontaneous Feedback

Data were collected through emails, newsletters' feedbacks, forum, focus group and questionnaires. Data from different sources are consistent and complement each other:

more than 70% of the sample responded to the questionnaire (39 users among 56) and about 75% of the sample sent at least one feedback or suggestion during the trial. Besides, a first focus group (8 trial users with 3kw meter) was managed to test the satisfactory level of the system usage as well as to deepen the questionnaire findings.

Main qualitative results of the trial are summarized, selected from the questionnaire's results.

In a scale from 1 to 10, the average respondents' vote of the system is 7.8. Trial users considered the system "innovative" and "effective" in its energy saving potential. 56% of the users interacted with the system every day; 77% of the users looked at graphical interface at least one day/week (33% 2-3 times/week; 13% everyday).

The system is considered easy to use and useful from 95% of interviewed people. Moreover, trial users would be pleased to keep system at home after the trial (88%) and they would suggest the system usage to their friends (74%). Above 34% of the sample would pay the system about 2 euros/month or a corresponding percentage between 10-25% of the economical saving obtained by the system usage (31%); just 13% of the interviewed wouldn't pay for the system usage.

Three main perceived strengths of the Energy@home system are:

- Consumer awareness regarding stand-by consumption.
- Reduction of wasteful behavior.
- Ease of use

Some weaknesses have emerged too:

- Smart plugs are too bulky
- Inadequate number of smart plugs
- Technical problems of various types (reported by individuals, not always significant for the entire group).

Focus groups were useful to confirm questionnaires data and overall to deepen knowledge related to users' motivations, drivers in energy saving behaviors, customers' needs and suggestions about the system.

5.2 Persuasive Stimuli

Results of the research demonstrate that:

- The Energy@home system motivates users to change their behavior and generated a savings of more than 9% [Fig. 4].

Results in figure 4 show the amount of energy saving after 8 months of system usage where each month is compared with the same month of the previous year: about 77% of the users (10 over 13) achieved energy savings after installing the Energy@home system in their homes, on average 9% of savings were measured corresponding to 5.6 TWh[1]. Significantly, the "best case" user managed to lower its electricity energy consumption up to -40%.

[1] Analysis performed for a basis of 61.3 TWh of annual domestic electricity consumption in Italy (AEEG, 2013).

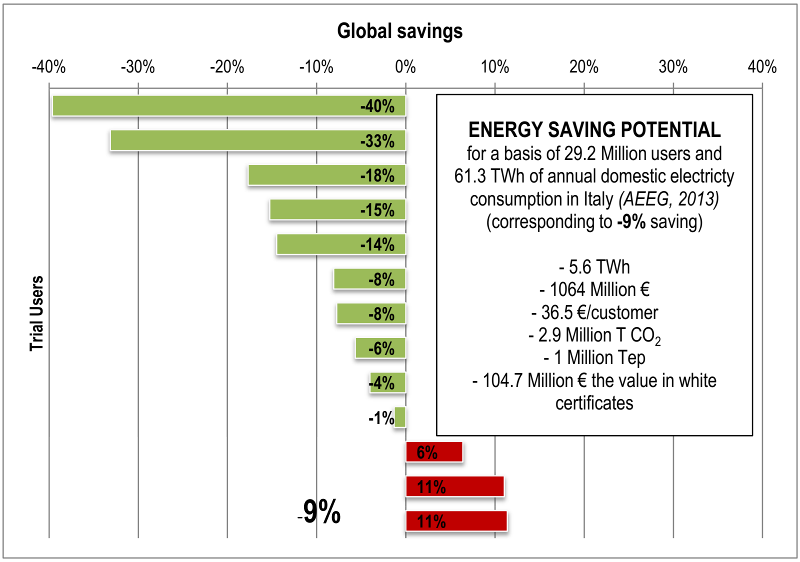

Fig. 4. Global energy saving achieved during the trial testing phase of the Energy@home system

In the Italian context, assuming that energy saving would be achieved by 29.2 million Italian electricity domestic consumers,[2] in one year a total amount of 1064 Million € can be saved, equivalent to 35.6 € saved in the electricity bill from every Italian family. This saving corresponds to avoiding the emission of 2.9 Million tons of CO_2 and a value of the corresponding white certificates of 104.7 Million Euro, i.e. 3.6 €/customer.

- The Energy@home system is an effective tool to reduce the contractual power.

Analysis of the energy loads of trail users having contractual powers of more than 3 kW were performed in order to understand the percentage of time of effective need of 4.5 kW or 6 kW. This study highlights that only one over 8 trail users exploited the potentiality of the contractual power they paid for. All these users can lower their contractual power and go back to the 3 kW contract with an economic saving in their energy bill of more than 180 €/year.

The Energy@home system is an effective tool to motivate users to reduce the stand-by consumption on average above 15% [Fig. 5].

Analysis of the standby power was performed on data related to 10 trail users of the Energy@home system. The stand-by consumption of each trial home was assumed as the minimum electrical consumption recorded over the 24 hours with a 2 minutes acquisition step. These values were then aggregated into a daily mean of stand-by consumption, for each of the 10 trail users. Results highlight that the standby was on the average above 66 W.

[2] (AEEG, 2013).

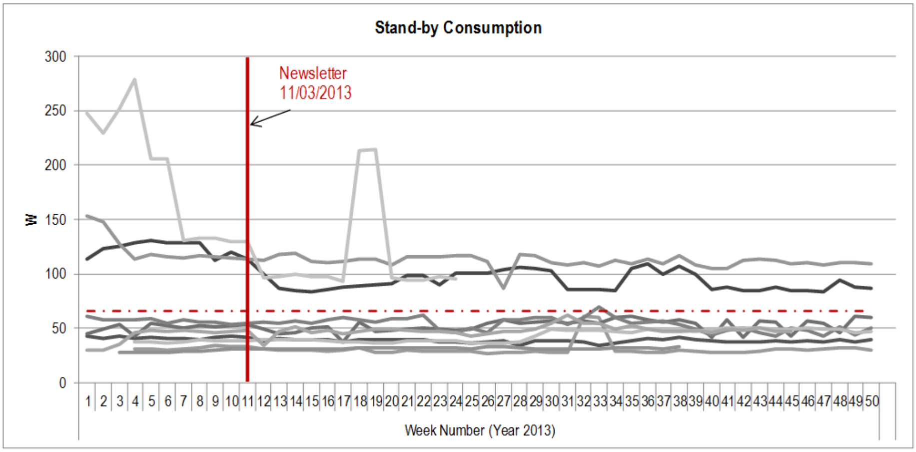

Fig. 5. Standby energy consumption in 10 trial homes. Effect of the newsletter on the stand-by consumption

- A newsletter was sent to these 10 selected trail users on the 11th week of monitoring (11/3/2013), providing suggestions on how to reduce the stand-by consumption in their homes. Significantly, it emerged that educating users in reducing the stand-by power of their appliances results in the greatest energy savings at home. The effectiveness of this communication is summarized here:
  - 6 over 10 trial users reduced the home stand-by consumption, after receiving the newsletter.
  - Trial users reduced on average their stand-by power of -15% (11.5 W).
  - The "best practice" user managed to reduce the stand-by power of -40% (80 W) corresponding to an annual energy saving of above 125 €.
  - Thanks to the decrease in stand-by power, the "best practice" user managed to reduce up to 23% of his/her domestic electricity consumption.
- The Energy@home system is an effective tool to motivate users in shifting their consumption in the off-peak time ranges on the average of 5%. Based on national regulation, economic tariff of domestic electricity energy varies based on three hourly categories:
  - F1: from Monday to Friday 8 – 19 (peak hours)
  - F2: from Monday to Friday 9 – 8 (off-peak hours)
  - F3: Weekends and Holidays (off-peak hours)

Energy consumption for 18 selected trail users was organized into three hourly categories, corresponding to the two-hour tariff applied by Enel Servizio Elettrico (electricity supplier). For each trail user, the consumption recorded during peak hours (F1 tariff) was compared to the consumption recorded during off-peak hours (F2 ad F3).

Results show that electricity consumption of trail users using the Energy@home kit moved from peak to off-peak tariff consumption on average of 5% with respect to the same months of 2012.

6 Conclusions and Next Steps

The Energy@home system is an effective tool in reducing electricity energy consumption at home on the average among 9%. Results demonstrate that more than 77% of the testing-users achieved energy savings, after installing the Energy@home system in their homes. “Best-case” trial user managed to lower his/her electricity energy consumption up to -40%. Significantly, whether this energy saving would be achieved by 29.2 million Italian electrical domestic consumers, in one year a total amount of 1064 Million € can be saved, equivalent to 35.6 € saved in the electricity bill from every Italian family. This saving corresponds to avoiding the emission of 2.9 Million tons of CO_2 and a value of the corresponding white certificates of 104.7 Million Euro, i.e. 3.6 €/customer. Qualitative responses from users indicate that the system is effective and easy to use and “helps” users to reduce consumptions and electrical costs in everyday life. Most important, people perceived their changes in consumption behavior.

Further improvements are needed to enhance system reliability and effectiveness. A goal for future control devices in dwelling is to became a cost-effective tool able to raise user awareness regarding energy uses in homes and hence to guide users towards more energy savings behaviors.

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