

## **Technologies to improve energy conservation in households:**

### **The users' perspective**

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#### **Introduction**

Improving energy conservation by changing the habits of residential consumers is the goal of BeAware, a EU funded project running from 2008 to 2011 (EU FP7/ICT-2007.6.3, project n. 224557). Simply put, the main strategy in the project consists of providing the users with a feedback of the electricity consumption. This project distinguishes itself from other similar attempts to several respects: by adopting a pervasive, digital feedback system; by tailoring the feedback to the consumer; by using social communication tools to connect the tested households; and - especially – by putting great emphasis on understanding the users' habits and motivations. In fact, a serious weakness of the attempts at improving electricity conservation through feedback provision is often a poor commitment to making the feedback usable and understandable.

BeAware takes into serious account this aspect and includes the study of usage practices since the early stage of the system development, with the purpose of

making the resulting prototype easy and even enjoyable to be used, and then more effective. The present contribution describes the system developed in the project, called EnergyLife, starting from the users' requirements and ending with the research and evaluation plan.

## **Requirements**

The identification of the requirements started with a series of interviews with people who are assumed to possess wide experience in increasing energy awareness because of their position, work and commitment. The interviews were integrated with a literature review of more than 70 scientific articles that report the results of interventions to reduce energy consumption by way of various feedback systems. The review allowed to single out the characteristics of the interventions that proved more effective and that are worth being implemented.

A total of nine Finnish and Italian stakeholders were interviewed according to a common protocol; stakeholders include prominent activists of environmentalist associations, members of governmental agencies, and house appliance producers. The interviews revealed the stakeholders' idea of the consumers' energy conservation practices. According to them, consumers' knowledge barely consists of the bill they pay. Details, such as the amount of kW/h spent or the cost of a kW/h, escape regular consumers. In addition, people lack some basic knowledge of the proper use of an electric device (e.g. meaning of power class), or embrace wrong beliefs (e.g. switching on and off fluorescent bulbs any time they leave a room for a short while). Besides direct energy use, consumers lack information about the long-term impact of their behaviors, about the energy production process (e.g. energy re-use, when the energy generated by one appliance is used to feed another one) and

about invisible consumption (e.g. devices in stand-by state). Their perception of the consumed energy can be based on superficial, misleading cues (e.g. usage time).

Since the interviewees share these concerns coherently, then an intervention to increase consumers' awareness seemed like a necessary companion to the feedback system planned in the project. Increasing their awareness would mean to facilitate the acquisition of the necessary knowledge about electricity conservation practices of everyday home devices; this would allow consumers to interpret the feedback appropriately and to adopt effective countermeasures to improve energy conservation. In fact, any feedback must rely on a clear comprehension of the goal to be pursued (goal setting, e.g. McCalley & Midden, 200; Becker, 1978; McCalley, 2006) and of the way to achieve it (task-motivation level and corrective feedback, Kluger and DeNisi, 1996). Therefore, the two synergic pillars of EnergyLife are awareness tools and consumption feedback.

Regarding the first pillar, no good ways to increase awareness seem to have been found so far: advice tips and information packages provided in several studies did not improve performance with respect to sole feedback (Ueno, Inada, Saeki, Tsuji, 2006; Hutton, Mauser, Filiatrault and Ahtola, 1986; Wood and Newborough, 2003). A different solution could rely on contextualized and tailored information, coherent with the feedback provided, yet separated from it. There are indications that tailored information is sometimes effective (Abrahamse, Steg, Vlek, Rothengatter, 2007). This solution will be attempted in EnergyLife.

Regarding feedback, it could not consist of the kind of consumption information that consumers are currently offered and often ignore. Information on kW/h is difficult by itself and is not immediately translatable into a solution to improve consumption other than generically reducing any electricity use. Instead, a feedback must be related to the conservation goal selected (McCalley & Midden, 2002; Becker, 1978; McCalley, 2006) and tailored to the household actual consumption (Abrahamse, Steg, Vlek, Rothengatter, 2007; Midden, Meter, Weenig and Zieverink,

1983). Also, feedback should be as close as possible to the users' action: the literature remarks that it is easier to affect specific behavioral intentions than general ones (Van Raaij & Verhallen, 1983; Painter, Sementik, Belk, 1983), and that the user needs to understand which actions would fill the gap between their actual state and the targeted one (Kluger and DiNisi, 1996). Therefore, BeAware will provide consumption feedback device by device, appliance by appliance. On the other hand, feedback on the general household consumption will also be provided, since it could discourage a rebound effect, where the electricity saved with one device is spent with another new devices and then the adoption of energy conservation practices would not lead to a decrease in the overall energy consumption (Dillman, Rosa, Dillman, 1983; Haas, Auer, Biermayr, 1998; Herring, 2006). Finally, the information provided by the feedback must be remembered when needed (Ilgen, Fisher & Taylor, 1979) in order to orient the prospective actor, and accessed on the same place where it is used without additional actions (e.g. such as turning off a dedicated terminal as in Ueno, Inada, Saeki, Tsuji, 2006).

All these aspects can be realized through a well designed information technology: sensors and algorithms can provide feedback on specific devices, as well as on the household; the feedback algorithm can express the information based on several parameters including the conservation goal; networks created between sensors and server can update in a quasi real time the feedback based on the usage of the single devices in the household; awareness tools can be implemented in the system and exploit the electricity measurement in order to be tailored to the household.

Regarding the type of feedback, historical feedback has proven to be more effective than comparative one, where the household consumption is compared to other ones (Midden, Meter, Weeenig, Zieverink, 1983; Schultz, Nolan, Cialdini, Goldstein, Griskevicious, 2007; Kantola, Syme, Campbell, 1984). This might be because comparative feedback relies on a term of comparison that is not relevant to

the consumer, or because the comparison generates a boomerang effect (i.e. the consumer already saves more electricity than the other ones, and then loses the motivation to further improve). The feedback must be sensitive to small savings: an interview to 20 Finnish meter loaners revealed that meters made the instantaneous energy consumption of a single appliance appear too negligible to motivate any need for energy conservation practices (Liikkanen, 2009). Another example of poorly motivating feedback - contrary to common opinion - is the monetary one: using financial saving as a motivator is not effective on the long run, since it is too much connected to low income and financial crisis (Neuman, 1986; Monnier, 1983; Pfaffenberger et al, 1983; Black, Stern and Elworth, 1985). In other words, the feedback system should appear as a nice piece of technology, serving efficiency and well-being, in order to appeal all types of households, especially those with highest saving potential. In synthesis, historical, sensitive and aesthetically attractive feedback is more likely to be effective.

In the next section we will see how this scattered input has been translated in the design of a pervasive, integrated system that gives visibility to the value of the electricity used in the house.

## **EnergyLife**

As anticipated, the system developed within BeAware, and called EnergyLife, bases its persuasive potential on two pillars, awareness tools and consumption feedback. Awareness tools are meant to increase the users' knowledge of the consequences of their electricity consumption in general and on specific devices; consumption feedback makes visible to the users their current distance from the saving goal set at the beginning. The two kinds of information together would help the users to monitor the quality of their conservation practices, and would enable



Figure 1. An example of EnergyLife mobile interface (from [www.energyawareness.eu](http://www.energyawareness.eu)).

them to know what to change in these practices to better achieve their goal, and how to do so. Both types of information are tailored to the actual consumption of single devices and of the whole household.

The resources provided to the user by EnergyLife, the data on which they rely and the modality through which they are presented constitute a whole system that pervades the household and connects the different moments of electricity life from the perspective of the user: from the consumption (sensors), to the consequences (lights dimming and mobile interface), to the information that helps to modify the consequences of consumption (advices), to

the verification that the information has been acquired (quizzes).

In order to create a coherent, familiar and attractive rationale for the use of EnergyLife, the pursuit of the saving goal follows a game-like rationale: awareness and consumption (saving) are expressed in scores; goal is divided into sub-goals connected to different levels of the game, so that the fulfillment of the objective at one level gives access to a higher level; higher levels have higher difficulty and richer functionalities; the saving activity can be discussed with other people participating to the same program; knowledge is tested through quizzes and improved through contextualized tips, all of which contribute to increase the awareness score.

Attractiveness and pleasantness are pursued also in the mobile interface of EnergyLife, which follows state-of-the-art design solutions for touch screen mobiles. Figure 1 shows an example of EnergyLife mobile interface. At the center of the screen is the carousel with the electric devices connected to the system; by rotating

each card the user can access specific saving and awareness information for that device. On the top of the screen, the game level, the overall saving feedback and the overall awareness score of the household are displayed; navigation buttons are located on the bottom of the screen. Appliances included in the carousel are chosen according to an investigation from Vattenfall and Enelsi, reporting on Finnish/Swedish/Italian electricity consumption and typical appliances.

The system does not need the user to do anything special in order to access the feedback, since it can receive it on the same mobile device s/he uses for telephone calls; or, even s/he does not want to open the mobile, a minimal feedback is anyway provided by the lights in the house, which dim at switch- on when the goal is not met.

### **Investigation plan**

The commitment to emphasize the users' practices is not limited to taking into account the requirements distilled from the results of other studies. BeAware also includes its own studies of feedback usage. The research plan covers the usability tests of the prototype on the one hand, and the investigation of the psychological processes underlying electricity consumption habits on the other hand.

*Pursuing simplicity.* To refine the interface and the feedback offered by EnergyLife, and make it simpler to be used, usability tests are performed on the first EnergyLife prototype and on existing feedback systems.

The test of EnergyLife covers four dimensions of usability, i.e. effectiveness, learnability, efficiency, and satisfaction. EnergyLife provides detailed information, but it has been found that too much information on different appliances might lead to overload and drop outs (Ueno, Inada, Saeki, Tsuji, 2006); thus, tests must ensure that the information provided and the functions displayed do not confuse the user.

More generally, computerized feedback is more effective than other methods (Brandon & Lewis, 1999), but should not require inspection of too much data and log-in procedure. The perceived accuracy and stability of a system have proven to be crucial to persuasiveness (DiMicco, Pandolfo, and Bender, 2004), and credibility (Becker, Seligman, 1978). Making sure that EnergyLife is usable facilitates the achievement of its final goal, which is not just to be adopted by the users, but to modify their habits.

A first test cycle of tests has already been completed on an early version of the system, but the process is still ongoing. The test involves checking the understandability of the different information displayed in the device and the ability to use this information to answer some questions. These questions are formulated to represent the kind of information that a user would seek in the interface to improve its awareness and energy saving. During tests, users are endowed with two cameras, a steady camera and a wearable one (Figure 2).



Figure 2. A frame from the video-recordings of the usability test; one camera shoots the participant frontally, the other is worn by the user and points at the space at which the user is looking. The two images are recorded synchronously and then analyzed.

The test of EnergyLife is accompanied by the study of existing feedback systems. One was performed on appliance meters and has been already mentioned above (Likkanen, 2009); the second deals with smart meters. The former was conducted on Finnish users, the latter involves Italian users, who have been

endowed with smart meters at no charge by one energy utility, Enel. The study involves 40 consumers who try to execute some readings of their smart meter, 20 with the help of the user manual and 20 without; the issue is whether they take advantage of the feedback provided by the meter and what are the problems they meet. The participants' performance is videorecorded. The data collection has been completed and is now under analysis; the results will allow to identify main sources of difficulties in interpreting the information on consumption, not to be replicated in EnergyLife.

*Modeling consumption habits.* The second research effort in the project is directed to better understand energy consumption habits, and to identify some influent cognitive and social processes underlying them. The results will contribute to advance the knowledge of the factors shaping the electricity consumption habits in a household. This effort benefits initially from several different methods of investigation, and leaves room in the final year of the project to the trials as the main research arena.

A first source of information is provided by a paper and pencil survey with 400 Finnish and Italian consumers, that will continue from the BeAware website, once transformed into an on-line survey in several languages. These two surveys will serve several purposes, including identifying users' weaknesses in energy conservation awareness, their definition of waste, and their opinions about electricity conservation. It will also consider the extent to which gender, education, income and household composition affect these dimensions.

A second source of information is represented by experiments aimed at studying the role of two specific components of energy conservation, namely its social desirability and the cognitive executive functions that play an important role in changing routine behaviors. The first experiment relies on the comparison between implicit and explicit data collection techniques. The explicit technique is a shortened

version of the questionnaire used in our survey, while the implicit technique is called aIAT, Autobiographical-Implicit Association Test (Sartori, Agosta, Zogmaister, Ferrara and Castiello, 2008). The analysis focuses on the inconsistencies between the data obtained with the two techniques. The data collection involves 180 participants and is now completed.

The second experiment is based on the administration of a shortened version of the energy conservation questionnaire and of the PASAT test, addressing attention, working memory and information processing. The correlation of the two measures provides a first hint of the extent to which (declared) energy conservation practices and executive functions are related.

All experiments and surveys are not conducted on a laboratory with university students, as in classic psychological studies: in order to collect valid results, participants are adults, recruited in public spaces, and paying for their own electricity bill.

A third source of information is provided by the trials. Trials represent a precious opportunity to test EnergyLife in the field, to assess its persuasiveness, and to observe the actual users' electricity consumption practices, after which the model obtained from the experiments and surveys can be refined. The trials will start after the current prototype of Energy Life is validated, and will have 16 to 20 consumers' households in North and South Europe using the system for months, since trials must run long in order to be effective (Van Raaij & Verhallen, 1983; Henryson et al., 2000; Wilhite, 1997).

## **Conclusions**

Within an articulated educational process organized in stages within a game-like metaphor, EnergyLife is meant to support electricity conservation. The system

developed within BeAware project is pervasive in the household through sensor layers, ambient and mobile interfaces; it provides the users with the necessary tools to conserve energy, namely feedback on the consumption level with respect to a target level, and tips to facilitate the achievement of the target.

The hallmark of this project is represented by the emphasis on the usage practices, both in terms of making the system usable and in terms of understanding scientifically the psychological processes underlying electricity consumption.

The project is now in its second year with the research plan fully functioning and the system undergoing a redesign and validation to be tested in the trails. More information and constant updates on the projects intermediate results and events is available from [www.energyawareness.eu](http://www.energyawareness.eu).

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