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BeAware

Boosting Energy Awareness
with Adaptive Real-time Environments

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Impact Assessment of BeAware Applications

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Executive Summary

The aim of the D6.4 is to provide a final evaluation of BeAware technologies in the light of the trials experience with households in Italy, Sweden and Finland. It presents the main findings of the project against the initial objectives:

- The efficacy of BeAware for what concerns the changes in the use of the electricity energy (efficacy for energy saving in the households).
- The impact the provided feedback has in the users' behavior, and specifically in increasing the awareness and the conservation behaviors.
- The degree of usability and acceptance of the final prototype.

Main achievements after the evaluation of the final BeAware prototypes and technologies in the second trial are:

- Information provided by EnergyLife can be turned into concrete actions to improve the awareness and change users' everyday habits.
- Feedback on devices consumptions allow the users to identify all sources of consumption in the household, the impact they have on the total consumption, and build or experiment practices for energy saving.
- The adoption of BeAware technologies stimulates the users to start discussions on energy related practices and issues, hence improving the knowledge, the sensibility and the capability of all members of the family in reducing wastes and save energy.
- The level of usability and acceptance of the final prototype was rated highly by the users themselves. This was proved to be a key aspect for the final success of BeAware, since it allowed the game-based approach of EnergyLife to be effective on keeping high the level of engagement of the users.

These and other interesting aspects discovered, are assessed according to the quantitative results of the second trial, namely the decreasing trend in the energy consumption during the trial period, but also focusing on the qualitative interpretation of the declared users' experience, the answers to the questionnaires and some anecdotes on how they were able to use the information provided by EnergyLife to change their conservation behaviors.

The comparison of the degree of usability and acceptance, between the first and the second trial, highlights the improvements made and the impact that these had on translating the concepts behind the design of EnergyLife in a more fruitful user experience. In this perspective, lesson learnt includes the importance of an application to be easily navigable and understandable by the majority of the users, with the information presented in a simple and intuitive way.

Starting from the above considerations, the project was able to identify a list of key elements for the success of "EnergyLife-like" systems, provided in this document. Thanks to the interaction with the trial participants, their answers to the questions

submitted, the discussions had with them during the research meetings and the stories they reported, the project also identified some practices for energy conservation with BeAware, these are reported as well in the document.

The evaluation of the results of the new Ambient Interface, the Watt-Lite Twist, developed and deployed for experimentation in 2 households in Sweden and Finland during the second trial, is given showing, from the end users perspective, the benefits of its use as a teaching tool for improving the knowledge of energy related concepts (kWh), and the awareness of the consumptions of the different devices.

Some areas of further improvements can be still identified after the conclusion of the two trials experience. Regarding EnergyLife interface and features, these refer especially to the content of the non-smart advices, whose utility was evaluated by users in a controversial manner, while still remaining useful to improve their knowledge and to trigger virtuous behavior, and to the community, that exposed language issues and was object of different opinions and suggestions from the users.

In general, a way for the quantitative evaluation of the effects of some external factors on the consumptions, such as lighting, but also the strong impact of electric eating components during different periods of the year, should be considered and included in future works.

1 Introduction

Main objective of BeAware trials has been to demonstrate how the proposed solutions (namely EnergyLife and Watt-Lite Twist) can help the end users to save energy and become more aware regarding the energy conservation practices, having in mind the need to develop software solutions close enough to the actual users' needs, in terms of usability and acceptance.

To this end, specific user metrics and research questions have been identified, and taken into account during the execution of the trials and the evaluation meetings with the users. Well targeted research plans have been followed, and suitable research tools have been developed and used (questionnaires and interviews, list of tasks, satisfaction surveys): these are described in details in the D6.2 (Results of BeAware First Trial) and D6.3 (Results of BeAware Second Trial) deliverables.

The experiences and stories reported by the trial participants have been of undeniable usefulness for understanding, from a qualitative point of view, of how the users were able to use EnergyLife to improve their knowledge and habits regarding energy conservation practices and, at the end, to save energy.

Section 2 of the document refers to the impact assessment of the BeAware technologies, focusing on the results of the second trial: the experience and findings from the adoption of EnergyLife, and the main outcomes of the users' experience with Watt-Lite Twist are presented. In this section, the progress made between the first and the second trial, thanks to the adoption of the refined prototype of EnergyLife starting from the outcomes of the first trial, is also highlighted and its impacts on the final findings evaluated. Lessons learnt and key elements for the success of an energy awareness system such as EnergyLife, are also presented and discussed. Thanks to the outcomes of the trials and the feedback received from the users, a description of identified best practices for energy saving with BeAware is also provided.

Section 3 describes the impacts of the deployment of BeAware equipment in real households: how the users perceived the presence of the hardware elements of BeAware, and how/if they can impact normal household activities.

Finally, Section 4 concludes the document and highlights some aspects which, after the project conclusion and the results achieved, still deserve some attention and, as a consequence, can be considered for future works and further improvements.

2 Impact assessment of BeAware technologies

From the experience acquired by carrying out two cycles of trials with real consumers, and especially during the second trial when the final software and hardware prototypes have been evaluated, the main impacts of the adoption of BeAware technologies can be summarized as follows:

- Information provided by the EnergyLife software, by means of advice, smart advice and quizzes, are perceived as effective and very useful from the user's point of view, in that they can be turned into concrete actions to improve their energy conservation practices.
- Feedback on real time and average consumptions, collected by the installed sensing system and provided through the mobile interface of EnergyLife, are of great importance as they allow consumers to see the actual effects of specific behaviors, understand what are the devices that consume more and why, identify the sources of hidden and sometimes unnecessary consumptions.
- The adoption of BeAware technologies triggers discussions on energy conservation practices between the members of the family. This provides means for good educational and comparison lesson also for younger people in the family (kids) and for those not actively involved in the use of the technology itself.
- The game-based approach of EnergyLife with level and goal based approach, helps to keep users motivated and engaged.
- Usability, as well as a user driven design, are key aspects of such systems. Issues on these aspects directly impact on the users' motivation and involvement and, as a consequence, on the persuasive efficacy that can be otherwise achieved.
- In general, users can save energy using the technologies developed in BeAware.

Starting from the analysis of the data collected during the second trial, reported in the D6.3, the above findings will be explained in more details in the following subsections, with special focus on the qualitative interpretation of the feedback provided by the users, reported spontaneously during the visits, or answering to the submitted questionnaires.

2.1 Impact of the feedback-based approach of EnergyLife: energy awareness and conservation behaviors

We start from the discussion on the efficacy of the feedback provided by EnergyLife in improving the users' awareness on energy consumptions and energy conservation practices. To this respect, the main research question was:

"Does users' knowledge of conservation practices improve thanks to EnergyLife? How is it related to conservation behavior?"

From the analysis of the data collected during the research meetings, namely from the satisfaction questionnaires, the general feeling of the users was that their awareness and knowledge of energy conservation practices improved during their participation to the trial, thus improving their capability of saving energy. They also highlighted the relationship between the use of EnergyLife, and the changes in their habits.

Further, from the comparison of the answers to the two awareness questionnaires submitted during the first and the second visit, it was found that the perception of some wasting behaviors was rated with higher levels of seriousness after several weeks from the beginning of the second trial. This demonstrates how the feedback provided by EnergyLife (advice, smart advice, quizzes), have been effective in gradually achieving this goal.

Further interesting elements that strengthen the positive assessment of EnergyLife feedback are:

- By analyzing the monthly and daily consumptions, it has been noticed that the saving trend has increased gradually during the trial, and in relation to the activation of the various features of EnergyLife (hence of the various types of feedback in the different levels).
- A decrease in the average daily consumptions has been also evident through the analysis of the devices monitored by the sensors; this demonstrates a close relationship between the feedback given for each monitored device (advice tips and quizzes but also information on real-time and average consumptions), and the actions put in practice for a more virtuous and conscious use of the devices themselves. This is particularly true for some of the monitored devices (e.g. the PC) that, apparently, have shown a higher saving potential.

When interacting with families during meetings, it was obvious that they were excited to discover, thanks to EnergyLife, things they were not aware of, and apply them immediately in their everyday life.

As an example, while answering to the second awareness questionnaire, the wife of one of the Italian households said she had always heard from her mother and her grandmother, that the use of the washing machine full-loaded was discouraged: ***"Never use the washing machine fully loaded, otherwise you will damage it"***, they recommended. As a consequence she always used the washing machine in low load while, thanks to the advice and smart advice received with BeAware, she learned that the use of the full load is a good way to save energy.

Another nice example is that during the training visit, just after setting up EnergyLife and begin checking the consumption of the monitored devices, one of the participants was impressed to discover the different standby energy consumption of the old CRT TV in the bedroom and a newer LCD TV in the living room: more than 5 Watts the first one, about 0.3 Watts the second one. His prompt reaction, thinking at the amount of energy wasted keeping 24 hour a day the old TV in standby mode, was: ***"I am going to turn off that TV immediately"***.

These events suggest that the information provided by EnergyLife can have strong persuasive effects when compared to some usual, non-optimal behaviors of users. It seems also clear that the users will hardly forget them, meaning that these findings will change their future behavior.

2.2 Energy saving with EnergyLife

Research question regarding the saving/consumption during the trial was:

"Does the actual enactment of conservation behavior increase after the adoption of EnergyLife? Consumption and saving during the trial."

The target improvement in the use of energy was tentatively set by the Consortium to 15% of the starting status before the trial. From the analysis of the data automatically collected by the system regarding electricity consumption during the second trial, reported graphically in the D6.3, it has been found that the high decrease in the energy consumption in the Northern households was affected by some external factors, making it very difficult to understand and isolate the effect of EnergyLife on those results. The effect of the adoption of EnergyLife is, on the other hand, more evident by considering only the Italian households, where data were not affected by the same factors. For this reason, the comparison between the energy consumption in the initial and final month of the second trial (January and April, 2011) in Italy, which showed a percentage of energy saved of 19%, and the decreasing trend of the daily consumption, seems to be a very promising result.

It is interesting to interpret these results in the light of what declared by the users themselves, through the answers to the questionnaires or orally, through some experiences reported. On one hand, they specifically declared that they learned a lot on how to save energy from the suggestions received through the mobile interface (advice, smart advice and quizzes). Some other meaningful findings, supported by actual experiences, are described in the following subsections.

2.2.1 Interaction between the members of the family, and educational effect towards the younger members (kids)

One important impact of EnergyLife concerns the interaction between the members of the family, and especially the fact that the participation to the trial was a way for triggering discussions related to good practices for energy conservation.

During the second research meeting (after several weeks of participation into the trial), the wife of one of the households (2 adults and 2 kids, 7 and 4 years old, in the house) observed as the fact of using EnergyLife, and talk about it at home, has modified the behaviors of all the members of the family, even the daughters. The 7 years old daughter continuously reminded her: ***"Mom, let's turn off the light if we do not need it. Why is it switched on?"*** In the same way, the discussions started thanks to the trial participation of their parents, have been the only way for them (the daughters) to understand that the

TV should not be on for the whole afternoon: ***"Why the TV is on, if we're not watching it?"*** the older sister complained with the younger sister. In other words, the mother nicely reported how the kids, not the adults, were becoming the most careful and conscious in relation to energy conservation practices.

2.2.2 Monitoring of energy consumptions and investigation of different consumption sources

The second important aspect was the possibility of a real-time verification of the energy consumptions of the whole household or specific device. This has also stimulated the curiosity to investigate other sources of consumption and to act on them when possible.

While looking at the difference between the overall household consumption and the sum of the consumptions of the monitored devices, some users were able to discover, for example, that some light bulbs were very likely having a great impact on the total consumptions and decided to buy low-energy light bulbs.

In the same way, reasoning about the knowledge of the consumption of other devices, which are normally always on, was triggered: one of the users, posted one message in the community asking for someone able to find/provide the actual instantaneous consumption of a particular model of ADSL router.

Most interested users have performed various tests (by switching off as many devices as possible) for discovering the actual consumption of some particular devices. Some of them decided, for example, to replace old power strips with new power strips with multiple switches to control the devices (i.e. turn them on/off) one by one.

Finally, more attention was observed as for the choice of new devices/appliances to buy: some of the users declared that, conversely to what usually happened before participating to the project trial, they had become more heedful to the type of technologies, and the related energy consumptions: one family asked for further advice for a new washing machine while another conducted a deliberate search to discover the different energy consumptions of a plasma TV with respect to a LCD/LED TV.

2.3 Usability and acceptance of the mobile application

In the following we discuss the important outcomes regarding the usability and acceptance of EnergyLife.

The research plan (satisfaction questionnaires submitted to the users, and video-recorded series of task), was executed in order to give answers to the following research questions:

a) ***Acceptance*****:** "*is the system well accepted and trusted by the users?*"

b) ***Usability*****:** "*is the interface usable, without problems highlighted in previous versions?*"

The above questions, and especially the one related to the usability of the system, take into account more specific user metrics, such as ease of navigation, learnability and consistency of the information provided.

As highlighted in the deliverable D6.2, during the first trial some usability issues were discovered. For this reason, a user-centered design has been adopted by modifying EnergyLife starting from those outcomes. Main weaknesses of the first prototype have been then addressed in the final prototype. It is now interesting to discuss the improvements in the usability and acceptance degree achieved during the second trial, and the impact these improvements had in the users experience with BeAware.

Specific questions aimed at assessing the perceived pleasantness of the application, as well as the detailed analysis of all specific user metrics in the area of the usability of the system, have shown positive evaluation scores for almost all the questions submitted to the users. In general a higher evaluation score with respect to the first trial was achieved. This shows that the effort spent by the consortium for identifying the areas of improvements, and for solving the weaknesses of the system in the final prototype, has reached its targets.

Table 1 below provides a summary of the evaluation given by the users during the two trials for some of the usability metrics, by specifically focusing on some key items:

	Trial 1	**Trial 2**
Learnability	Negative evaluation concerning the organization in levels	The organization of EnergyLife in levels is appreciated and considered as an added value for the learning of its functioning
Consistency	Negative evaluation concerning the regular reception of advice	The reception of advice is positively evaluated (i.e. regular reception of advice)
	Negative evaluation concerning the regular reception of quizzes	More positive evaluation concerning the reception of quizzes, although still in the lower range
User Control	Negative evaluation concerning possibility to correct unwanted operations (undo)	More positive evaluation with respect to undo functions
	Negative evaluation concerning the ability of EnergyLife to respond to the commands correctly	More positive evaluation
	Negative evaluation concerning the possibility to find old advice tips	Good evaluation of the possibility to find and read again old advice
	Negative evaluation of the capability of EnergyLife to respond to the commands quickly	More positive evaluation, even if still at the limit

Comprehensibility	Majority of the sample failed to give correct answers to the comprehension check contained in the satisfaction survey	Majority of the sample was able to give correct answers to the comprehension check contained in the satisfaction survey
Informativeness	Majority of people declared they already knew most of the advice tips provided by EnergyLife	More positive evaluation, although the general feeling remained the same (most users declared they already knew most of the provided advice tips)
	Majority of people declared that EnergyLife should provide more specific advice tips	Very similar evaluation score on specificity of advice tips
	Negative evaluation of the repetition of advice tips (considered as superfluous)	Advice tips, also repeated, are always appreciated if not too much generic

Table 1: Evaluation of some key items related to the usability metrics, during the first and second trial

Learnability

Regarding this specific metric, the organization in levels was the only item which was negatively evaluated in the first trial, mainly due to the difficult comprehension of the score calculation to pass to the next levels; this aspect was conversely appreciated, and considered as one important motivator, in the second trial, after the choice of simplifying the score calculation in the new prototype.

Consistency

The items related to the consistency of the information provided, obtained in general a better evaluation score in the second trial, especially with respect to the regularity in the reception of advice, thanks to the resolution of some bugs found in the first prototype. A similar item related to the regularity of the reception of quizzes, on the other hand, still suffered of some bugs on quizzes, discovered after some time from the beginning of the trial: since this issue was promptly solved however, it didn't affect the prosecution of the trials and the motivation of the users, that allowed to obtain the important achievements already highlighted in the previous sections.

User control

Very similar considerations done for the consistency apply to the user control in general: while still suffering of some aspects not directly related to EnergyLife itself, such as the high response times due to a low quality of the Internet connection in some of the households, the evaluation of the user control items was more positive after the resolution of some bugs. As a consequence, again, engagement has been kept high for the whole duration of the second trial, and the issues found during the first one (decrease in motivations with impacts in the results) has been overcome.

Comprehensibility

A consistent improvement has been obtained in the comprehensibility of the functioning and the various features of the new prototype: where the majority of the respondents failed during the first trial, the majority of the respondents provided correct answers in the second one.

Informativeness

The level and quality of the feedback provided was very positively rated, especially thanks to the introduction of the smart advice in the second trial: users have found the introduction of this context aware feedback as one of the most important and useful, both because of the possibility to be "alerted" concerning very specific wasting behaviors, and for the interesting, most of the times unknown, information provided, as for example the amount of CO2 emitted corresponding to a certain number of hours of computer use.

On the contrary, the trial experience, and especially the opinion provided by the users appeared to be a bit controversial about the informativeness of the non-smart advice. While almost all members of the families participating to the trial in general declared that they were always useful to remember some virtuous actions to put in place for energy conservation, and to improve their level of awareness, most of them still claimed the introduction of some more specificity. This suggests the content of the non-smart advice as one of the elements, which could be still investigated and maybe tailored to the users' profile.

The informativeness of the quizzes was always appreciated, and the possibility to compare the answers between the members of the family, as a very fruitful way to improve each member awareness and knowledge. Some of the users were occasionally a bit confused concerning the interpretation and specificity of some questions, for example, due to questions concerning the ways for saving energy with the computer, mostly related to the desktop PCs and, as a consequence, not applicable to the laptops.

2.3.1 Lesson learnt concerning usability and acceptance of the system

Main lesson learnt after the analysis of the final results, and taking into account the different achievements between the first and the second cycle of trials, is that the concepts behind a system such as EnergyLife must be organized and presented in a simple and intuitive way, in order to be understood by everyone, even people with no particular familiarity with the same concepts and/or the technology in general.

All information must also be easily accessible, and the information contained in the tips and the quizzes must be as clear as possible, and avoid misunderstandings.

It is important to provide to the users bug-free applications in order for this kind of system to be able to properly implement the needed mechanisms at the basis of the game logic. While this seems to be an obvious conclusion, it is important to emphasize the negative effects that failures may have regarding the users involvement and interest in a game and feedback based system: this was many times highlighted by the users

themselves for explaining the low level of interest they exposed during the last period of the first trial, that was also reflected in the quantitative measurements such as capability to save energy and number of accesses to the application. All issues strongly attenuated with the second trial, as reflected by the final quantitative and qualitative results.

2.3.2 The experience with the Community

One element that deserves some specific considerations from usability perspective is the community. Like all other system features it was evaluated easy to understand and use, and the last introduced concepts (i.e. the ranking between users and between households) a stimulating idea. On the other hand, the interaction with other users in the community was not as effective/useful as other EnergyLife features. This is probably due to the fact that most of the users were not able to read and write in English and thus were only able to communicate between members of same nationality.

Moreover, it seemed that not all users appreciated or had the same point of view concerning the organization of the community itself. Some of them expressed doubts for the fact that not all messages exchanged were pertinent to energy conservation practices and opinions, by suggesting the introduction of some form of controls, or a sort of "Netiquette" to be followed by the participants. Other exposed their difficulties in finding interesting topics for starting discussions with other people, suggesting the presence of a moderator or an automatic daemon in charge of "launching" specific topics with a predefined schedule.

For the above-mentioned reasons, while believing that the results concerning the ideas behind the community, and its capability to maintain high the level of interest and participation of the users, are very promising, we also consider the community aspect as one of the concepts that can still be object of further studies and improvements.

2.4 Key elements for the success of "EnergyLife-like" applications

From the trial experience, in the following we provide a list of key elements that need to be taken into consideration for the success of "EnergyLife-like" applications, applications aimed at acting on the user's degree of energy conservation awareness, and on the user's habits by keeping them motivated and active:

- In general, user driven approach to be followed during the design, by testing different scenarios and, possibly, in real contexts, such as the context of real households we tested during our trials. The contribution this can give to the success of the final product is unquantifiable.
- Easy to use, with all the information provided immediately and logically accessible, without the need to navigate too many menus.
- Easy to understand for any type of user, with the more complex concepts presented in simple ways, with the addition of help menus, and without giving

the possibility of different “interpretations”.

- Clear and well targeted suggestions, which can be directly verified and translated into concrete actions, again without the possibility to create misunderstandings.
- Particular relevance to be given to the possibility of providing context-aware feedback (actual consumptions but also e.g. smart advice), that can be directly correlated to specific actions.

2.5 Best practices for improving energy conservation with EnergyLife

Always thanks to the trial experience, and particularly thanks to the interaction with the users and their precious comments and stories, we can extract some best practices for energy conservation with EnergyLife. Actually, they are partly related to the application of the information directly provided by EnergyLife, partly based on specific situations and experiments reported by the users themselves, though always based on the knowledge gained and the possibility of experiencing with the application. They can be listed as follows:

1. Learn from advice and smart advice received, and actively follow the suggestions they provide.
2. Learn from the correct answers to the questions received, and actively follow the (indirect) suggestions they provide.
3. Discuss the tips and quizzes received/answered inside the family. The discussions triggered are a good teaching system. This has been proved to be especially useful in involving people in the household not directly using the application, even the kids. This is of great importance as all members of the households are active players in the energy consumption and conservation, and the kids are often, for obvious reasons, the main source of wasting behaviors.
4. Test each device consumption, and identify what of the monitored elements are consuming more than expected, and think about a solution: e.g. if, for different reasons, an old appliance (a Fridge, a TV) is consuming much more with respect to a newer model of the same appliance you have in your house, consider replacing it with newer model.
5. Make tests by checking and comparing the consumption of the whole household and of the monitored devices, and try to identify the elements inside the house that can affect consumptions without being evident: e.g., by switching on/off a particular lamp, one can understand if/whether it is consuming more than expected, and decide to use it in a more virtuous way or, when possible, to replace the light bulbs with low-consuming models.
6. Sometimes it could be useful to connect many different appliances to a single sensor, in order to monitor and control a system of appliances rather than a single one. In this way, one can e.g. test the actual consumption of the printer, when the PC, the monitor and the external hard disk are switched off. And

understand whether that particular appliance is consuming a lot, and if there actions to lower consumptions.

7. To ease the control of multiple appliances connected to the same power strip, consider to buy a power strip with different switch, each of them associated to a particular socket: this way you will make easy your actions to save energy, avoiding the need to unplug the appliances from its socket (for appliances that don't have the power button), every time you want to turn off it.

8. When you need to buy a new device, always check for the declared consumptions for that technology/product: this can be applied not only to fridges, washing machines, etc. (by looking at the class of energy consumption), but also to other devices.

2.6 Impact assessment from trials with Watt-Lite Twist

The elements of major interest after the execution of the Watt-Lite Twist trial in 2 households can be summarized as follows:

- Feedback provided by Watt-Lite Twist have proved to be useful for improving the users' awareness, especially for what concerns the identification of the devices consuming more in the household: for that devices participants seems to have put in place some actions/countermeasures to try to mitigate their effects on the total energy consumption.

- The educational aspect of Watt-Lite Twist, on the understanding of the concept of kWh, was met with great interest by the users, although its real usefulness depends on the level of initial knowledge of each participant.

- The above point, together with the prototype characteristics of the component, its shape and size, not exactly comfortable to use during the everyday life, suggest that, at the time being, the most interesting application is as a tool for teaching of concepts related to energy in schools.

The experience of the participants to the Watt-Lite Twist trial is explained in more details in the following subsections.

2.6.1 Feedbacks, energy awareness and conservation behavior

The first research question during the evaluation of the users experience with Watt-Lite Twist concerns the energy awareness, and specifically:

"*How do users' awareness of and attention to energy related practices relate to their use of Watt-Lite Twist, its context and use the feedback it provides?*"

The trials showed that the users' awareness and attention to energy related practices related to their use of Watt-Lite Twist in that they directed their attention to high- and low-consuming devices. They also tested previous assumptions concerning these

appliances.

Further, physical attributes have shown their efficacy in that the red color, signaling something urgent, triggered associations to fire extinguishers, while the torch like shape communicated a search message – search for kWh or energy thieves.

As Watt-Lite Twist allowed the user to move it around it supported the use wherever this was needed. Results however showed that users were quite content by letting Watt-Lite Twist stay in one place, but it had to be a central place in the house. The preferred context of use was, consequently, the centre activities of the household.

Second question is related to the capability of Watt-Lite Twist to act on the **conservation behaviors**, and specifically:

"*Does the actual enactment of conservation behavior increase after the adoption of Watt-Lite Twist? How do behavioral patterns and understanding change over time?"*

Although the trials showed that participants of the two households used in this study were already quite aware of their energy use, it has been also noticed how they both directed their attention to the tumble dryer and the large amount of kWhs it consumed when it was used. As a consequence, participants tried to save some energy by hanging their washing instead of using the tumble dryer.

2.6.2 Engagement

Another aspect evaluated during the trial of Watt-Lite Twist was the engagement of the users themselves on using Watt-Lite Twist:

"*How does Watt-Lite Twist engage and trigger reasoning within the household? Does it trigger engagement of people outside the household? In what way?"*

Two different levels of engagement have been observed, related to the possibility of making some "experiments" with Watt-Lite Twist, and the capability to trigger discussions between the members of the household and also with outsiders.

Experimentation

Watt-Lite Twist supported experimentation by allowing for the discovery of:

- The association of projected colors with specific electrical appliances.
- High- and low-consuming appliances.
- Appliances which cannot be completely switched off.

A result from the study in Sweden also showed that Watt-Lite Twist could be used for experimenting with activities during a day and thus examining the question of how long one may make 2 kWhs last if electrical appliances aren't actively used.

Communication

Watt-Lite Twist triggered communication within the household. Feedback could initiate discussions of the type of whether one should hang-dry the washing instead of using the tumble dryer. Participants also talked about the prototype and the project with colleagues at work and friends in school.

2.6.3 Comprehension of energy concepts

Allowing users to understand energy concepts is one of the main purposes of Watt-Lite Twist:

"*How does users' comprehension of energy concepts, such as kWh and Watt relate to their use of Watt-Lite Twist? How do issues of information presentation relate to users' understanding of energy consumption and how does it relate to their context of use?*"

It was noted that the contribution of Watt-Lite Twist to users' comprehension of energy concepts obviously relates to how much knowledge they have to start with. Some users already had quite an advanced understanding of the concept of kWh and Watt-Lite Twist did not appear to add much to that knowledge.

Other users were sometimes impressed with the speed with which a kWh could be "eaten" by an appliance. They also talked about Watt-Lite Twist "painting" the energy consumption on the wall by its projection.

In this perspective, the application of Watt-Lite Twist as a teaching tool for users who normally don't have much knowledge of the energy related concepts, and who need to build their awareness of energy conservation practices, seems to be the most suitable one.

3 Impact of BeAware equipment and maintenance in households

Some further considerations can be done regarding the users' acceptance of the BeAware system from the point of view of the equipment deployed. From the trial experience, we can evaluate the impact of this aspect from 2 different points of view:

- How the presence of the sensing system (Base Station, sensors) and the hardware in general in the household has been perceived.
- To what extend the need of on-site update and maintenance interventions can be accepted by the users.

Sensing equipment

From the answers to some of the questions in the satisfaction questionnaire, we can conclude that the sensing equipment, i.e. sensors and Base Station, was not considered bothersome neither with regard to space (it was not considered as an obstacle to perform normal activities), nor from the point of view of the noise: this latter aspect was, indeed, carefully considered for the selection and assembly of the Base station hardware. Further, the participants declared that, after the first period, it was as the sensing equipment was not present in the house: the design of the sensors took into considerations a sort of trade-off between the overall sizes needed to develop their functionalities, and the need to ensure an easy placement and connection to different appliances.

On-site interventions for hardware maintenance and software or configuration updates (basically on the Base station, since any other BeAware software component is managed off-line), are seen as annoying by most of the users: this suggests the need to minimize these interventions, for example ensuring the possibility of performing software updates remotely, when needed. This was experienced in the Swedish households and achieved by just doing some more network configuration work at users', i.e. by opening a set port in the household's router, and using dyndns service to assign the household's IP number to an easier-to-remember dummy web address. This came in handy for doing system updates, applying patches and also gave extra, more extensive, monitoring/maintenance capabilities, even though the BaseN wiki and the email alerting system in most cases gave enough information. It is definitely something to be recommended for applications of BeAware and similar products on the real marked, since decreasing the number of maintenance related visits, much will be gained from the users' acceptance point of view.

Watt-Lite Twist component

Both the families who have experienced Watt-Lite Twist, declared that the torch was unnecessarily large. This suggests that some improvements on the shape of the current solution could be made and, conversely to the sensing equipment, it is still too invasive to be placed on the market for daily use, while maintaining its undeniable value from the educational point of view.

4 Conclusions and areas of potential improvements

The trials experiences and the research carried out showed how the impacts of the adoption of BeAware applications in real households is very positive, matching to all the primary objectives fixed by the consortium since the beginning of the project.

It was really interesting to observe that, while the trial progressed and the users became more familiar with the application and, in the same time, different type of feedback were provided through the mobile interface, progresses were also made regarding the energy saved: this showed a very close relationship between the feedback provided and the progressive increase in the users awareness and in the conservation behavior.

One of the most important aspects was to discover, from the questionnaires and also from what the users reported orally during discussions with the research team, how they were able not only to turn the improved knowledge of energy conservation practices into concrete, everyday behaviors, but also to build on their own tricks and practices to save energy using BeAware.

The improved usability of the system in the second trial was a key factor for the achievements of the above results.

Areas of potential improvements of EnergyLife, or that anyway deserve some more studies and tests, have been identified, they are listed below:

- non-smart advice: while the quantitative results and the stories reported by the users themselves show as they were an added value with regard to improving their skills and understand how to save energy, discussions on their specificity and content have highlighted controversial interpretation, which could be object of specific studies and test in the future;
- community: in a similar way, the concepts and ideas were positively evaluated by the users (especially the ranking mechanism, considered a good motivator), but general opinions on its organization were controversial. Further, some of the users expressed specific warnings and provided specific suggestions, which can be further analyzed and considered for future refinements of this part of the application.

The impact of external factors such as lighting, or electric heating components used only in the cold periods, which were not considered for simplicity reasons and to be able to focus the effort of the research on specific and well defined aspects, should be considered in future works, by adding for example thermal corrections on the baseline calculation. This could help on isolating and better understand the impacts of the applications in the quantitative data collected.