Using a Living Lab Methodology for Developing Energy Savings Solutions

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ABSTRACT

It is becoming increasingly important to create a sustainable environment. One important step is to reduce the energy consumption. In Europe, 25% of the energy used is consumed by private households. How energy is produced and consumed in different European countries varies a lot, thus it is hard to develop general solutions based on country-specific traits. The aim of this paper is to describe an approach to cross-country development of an energy savings solution. This paper reports on the usage of a method based on collecting users needs related to their current energy consumption, the actions they can take, and the possible future solutions they want to see.

Keywords

Energy consumption, smart grid, mobile applications, end-user evaluation

INTRODUCTION

The possible impact of climate change has been a topic of scientific discussion during the last decades, but since the publication of the fourth assessment report by the Intergovernmental Panel on Climate Change of the United Nations worldwide efforts to lessen the effects of climate change have been renewed.

According to Elliot (2011) there are several issues that must be addressed within the area of sustainability including what we mean with environmental sustainability, what are main challenges, what is being done, and what needs to be done. The last issue is perhaps the most difficult. One thing that is certain is that public participation is vital. The roles for individuals and the means of motivating them to substantially change their behavior is still unclear.

One part of the work towards sustainability is to decrease energy consumption. An important factor when it comes to saving energy is human behavior, but knowing which approach that gives the most sustainable solution is difficult. A particular challenge in addressing this on a large scale across nations is the large variation of energy productions and consumption in different countries.

The objective of this paper is to describe a living lab approach to establish general requirements across several countries to information systems supporting reduced energy consumption in personal homes. These needs have then been the basis for scenarios, and further development of concrete solutions that are piloted in private homes across several of the involved countries. In this preliminary pilot, a main aspect was to evaluate to what extent the requirements gathering process was successful in capturing the most important requirements.

The paper will start with a short background on related work on energy saving solutions. Then the Living Labs methodology is presented before we introduce the project in which the study has been carried out. The results from the user participation sessions are provided followed by a discussion of different type of needs related to energy savings. The results from a pilotimplementation and evaluation of the system developed based on the requirements found are provided before we conclude the paper.

BACKGROUND AND RELATED WORK

According to Caird and Roy (2008) the energy efficiency market is dominated by a techno-centric model of innovation that assumes that consumers are rational decision makers who will adopt energy saving technologies and use them effectively as soon as they become aware of the benefits these systems have both from an environmental and an economic perspective. Caird and Roy (2008) claim that several researchers suggest that people's motivation and actions related to energy use are more complex. According to (Wunderlich et al., 2013) research has to look closer into the origins of consumers' motivations. Results from their study indicate that consumers' motivations are major direct determinants of intentions to adopt. While this finding notably holds when consumers perceive the adoption as self-determined and internalize values such as environmentalism, motivations based on external rewards and feelings of compulsion matter to a lesser extent. A comparison of users and non-users revealed important differences in motivation, in particular that extrinsic motivations tend to be more relevant for non-users than for users. In addition(Watson et al., 2010) reports that people have different lifestyles and needs.

A lot of people are unaware of alternatives to reduce their energy consumption. Consumers need information on their energy consumption so that they can change their behavior (Watson et al., 2010). The effect of feedback on energy consumption has, according to Broms et al. (2010), recently been the focus for several researchers, and its potential success is well documented (Lund and Krogstie, 2011). Already Darby (2000) concludes that the savings in energy usage in households from direct feedback ranges from 5 to 15 %. (Schleich et al., 2011) reports from a field trial in Germany and Austria related to a smart metering program savings on around 3,7 %. On the other hand there are several aspects that are still unknown, for instance, what motivates users to change their behavior on a long-term (Broms et al., 2010), what information do consumers need to increase their energy efficiency (Watson et al., 2010), or how should energy information systems be designed (Melville, 2010). Later work by Derby (2008) analyses some of the issues relating to billing, metering and attempts to change consumer behavior in the UK. It highlights the dispute over the desirability of requiring suppliers to give feedback displays to residential customers in advance of a smart metering rollout, outlining tensions between anticipated benefits to the utilities and to end-users and the environment. In (Derby, 2010) she uses the theory of affordances to understand how households have used consumption feedback, with and without smart meters. Although AMS offers possibilities for household energy management, there is little evidence to suggest it will automatically achieve a significant reduction in energy demand. Appropriate forms of interface, feedback, narrative, and support will be needed to reach all parts the population population. (Fischer, 2008) reports from an investigation in Germany that there is some indication that the most successful feedback combines the following: high frequently and over a long time, provides an appliance-specific breakdown, is presented in a clear and appealing way, and uses computerized and interactive tools. (Foster et al., 2010) highlight the opportunities from the use of social networks. A significant reduction in energy was observed under the socially enabled conditions. (Schulz et al., 2007) warn that such mechanisms should be used with care to avoid a boomerang effect.

Finally, we can mention (Stromback et al., 2011) that have collected results from a large number of pilots for smart meter usage. We notice that the varying climatic conditions in different countries might make it hard to compare these pilots i detail, although looking across countries is useful compared to the mostly national investigations reported above. Our case is in this sense on middle ground. The countries involved are all in Northern Europe with comparable climatic conditions, although they have very different patterns for energy production and consumption.

LIVING LAB METHODOLOGY

To involve users, we have used a living lab approach. According to (Følstad, 2008) the term 'Living Lab' has been used over the last 20 years for varying approaches for involving users in innovation and development. Common characteristics are:

- To provide insight into unexpected ICT (Information and communication technology) uses and new service opportunities
- To evaluate new ICT-solutions with users
- To experiment with ICT solutions in contexts familiar to users
- To conduct medium or long-term studies involving users

In our view, an important aspect of Living Labs is experimentation and also co-creation with real users in real life environments, where users together with researchers, companies and public institutions work together in the development of new solutions, new products, new services or new business models. The FormIT approach to Living Lab activities used is based on five key principles (Ståhlbröst, 2012):

1. Value: Living Lab processes should support value creation in preferably two different ways: for their partners in terms of business value and for the presumptive customer, or user, of the developed innovation in terms of user value.
2. Influence: Viewing users as active, competent partners and domain experts are vital since their involvement and influence in innovation processes is essential. Equally important is to base these innovations on the needs and desires of potential users and to realize that the users often represent a heterogeneous group.
3. Realism: One of the cornerstones of Living Labs is that its activities should be carried out in a realistic, natural, real-life setting. This is important, since people cannot experience anything independent of the experience they get from being embodied in the world.
4. Sustainability: includes economical, ecological and social aspects. In Living Labs it is defined as an approach that meets the need of the present without compromising the ability for future generations to meet their needs.
5. Openness: This principle emphasizes the importance of having an innovation process that supports a bidirectional flow of knowledge and resources between stakeholders. The idea is that multiple perspectives bring power to the development process and contribute to the achievement of rapid progress. However, to be able to cooperate and share in a multi-stakeholder milieu, different levels of openness between stakeholders seems to be a requirement.

In the project, three iterative phases following the FormIT Living Lab methodology has been applied (Ståhlbröst and Bergvall-Kåreborn, 2008). FormIT is built on three theoretical streams: Soft Systems Methodology (SSM), Appreciative Inquiry and Needfinding. From SSM we are inspired by the assumption that changes can only occur though changes in mental models (Checkland, 1990). Based on this, it is of vital importance that we need to understand both our own as well as other stakeholders worldviews and that those involved in the Living Lab processes need to be clear about their interpretations and the base on which they are made. Appreciative Inquiry (Cooperrider et al., 2005), has motivated us to start the development cycle by identifying different stakeholders' dreams and visions of how IT can improve, and support the lives of people. Needfinding and its motivation, is mainly borrowed from Patnaik and Becker (1999). The main motivators for this approach are that user needs are more long lasting than trends, hence innovation processes should build on user needs rather than specific functions or features. The first phase in FormIT focuses on needfinding and idea generation, the second on concept development and testing, and the third is the development and test of the final system.

CASE STUDY

In the first cycle and first phase needfinding was conducted through user-pool brainstorming sessions where the users told their stories and needs. We also discussed ideas, and suggestions on energy saving solutions were given. This phase also included public authorities, developers and providers of energy saving solutions. The sessions were conducted in all participating countries (Norway, Sweden, Denmark, Lithuania, Iceland), and with the best practice Living Lab methods. The user-pool suggestions (and solutions) were documented in each country and then compared and packaged into one report where future scenarios were described.

In the next phase these scenarios were elaborated further and two scenarios (Smart People and Smart Kids) were chosen among users as the most-wanted pan-national pilot set-up. The scenarios were illustrated through short cartoons in which the essence of the users' expressions were explained and put into context. The actors involved in these sessions were experts in energy saving solutions and they reflected on their involvement on the most applicable solution. The energy market actors could then apply for funding from the project to develop an energy solution pilot that was tested cross-border.

In the third iteration a pan-national beta-trial were conducted. The private businesses involved are experts in energy saving solutions and ICT and they decided on which solutions they could integrate into their own current energy saving service. The experts then proposed on how to work on development of the solution. The Living Lab partners choose two proposals for funding and the LL partners tried to initiate co-operation between companies, preferably in diff erent countries.

The co-partners then did solution development. During the solution development stage a small pre-pilot was conducted in each partner country, to give the solution providers (the private co-partners) valuable feedback on the prototypes and make sure that possible nuances are solved before the trans-national pilots were conducted across partner countries. In the trans-national pilot the different solutions that the co-partners have developed were tested in real life situations with user-groups in different partner countries. The user experience was then evaluated and documented.

It is also possible to frame work of this kind, where a need is discovered and an artifact developed and evaluated as design science research (Hevner et al., 2004). How to combine a Living Lab methodology like FormIT with design science research is described in (Krogstie, 2012). Here we focus on the use of the living lab methodology.

Needfinding

A total of nine needfinding session where held, involving a total of 61 users. The number of participants in an individual session ranged between 4 and 18. Participants competed on a price, in addition to be able to contribute in the process. As an example we describe the sessions in one country in more detail. In these two sessions, nine users interested in energy saving were invited through the local Living Lab involved in the project. It was eight men and one women age-span 25-65 years. The sessions lasted between 1-1.5 hours and they were semi-structured. For these sessions a question form and a Powerpoint presentation were developed to ensure that the same aspects were covered. The session started with a short presentation of the project and its aim, we described the process of the session and a short presentation round of all participants was done. In the next part, question areas were discussed among the participants. The question areas focused on aspects such as their energy usage today, how they use IT-tools and their perspective on energy saving. Thereafter some stimuli were shown in terms of pictures of different energy saving solutions and a film on how to save energy followed by a discussion on how they would like to save energy and services they would like to use to stimulate them to use less energy. The session ended with a slogan competition combined with a picture for a badge where the participants could win a surf pad.

In the following our analysis of the results from the focus groups are presented. We have manually clustered the results into four themes: ICT usage, Current situation, Actions, and Future solutions.

ICT Usage

The participants were all mature ICT users who use computers on a daily basis both professionally and privately. They have their mobile always available, most of them use smart phones and some of them have also use surf pads. The usage of devices also differs at home where some people carry their surf pad around to search for information. The laptop, or stationary computer, is usually in another room and is not carried around in the same way.

Current situation

Most of the participants were not very interested in energy saving on a daily basis, it is mainly during winter they keep track of their energy consumption. In the northern parts of Europe, energy is mostly used for heating the houses during winter while very little energy is used during the summer. In the city where this investigation took place, the cost for energy is rather low since the houses are heated with district heating produced from surplus gas from a large plant and electricity comes from water power. This somewhat demotivates the users from changing their energy consumption behavior since they think that they have both low prices and an environmental friendly production. Also when the users live in an apartment, the energy consumption for heating is included in the rent, hence the users state that they do not have any incentive to change their consumption behavior. In their current situation, users express a difficulty in knowing how much energy the devices in their home consume. Currently, they only know their consumption in kWh on a monthly basis.

Actions to save energy

Almost all users have changed to low energy light bulbs. However, installing these has decreased their motivation to turn the lamps off; hence it is difficult to know if they are actually lowering their consumption. Among the private house owners some have installed heat pumps and triple-glazed windows to lower their energy consumption and most of the users have installed district-heating.

The users are looking forward to the hourly measurement of their consumption mandated from 2016 since this will make it easier for them to keep track of their consumption and to acknowledge if they deviate from their normal consumption. The users also talk about solutions that are common in public buildings such as motion detectors for the light, doors that open and closes automatic and sensors that feel how much heating or cooling that is needed related to how many people there are in the building. These are all solutions the users could consider installing in their houses, but the motion detector is the most appealing if it was cheap and easy to install.

Other actions are that they have changed their dish-washers to energy graded ones, they have it a bit colder in the rooms they are not using frequently and they have isolated their houses. They also think that they could turn off their computers during night, they could take shorter showers and they could turn off all devices that have stand-by mode.

Ideas for Future Solutions

The users stated that for them it is most important to consume the right type of energy. The future climate is the most important incentive, the amount of money that can be saved is not as important. The users expressed that they would like to have a solution that showed their consumption in more detail. For instance, they want to see how much electricity their devices consume, the cost for heating hot water and how much energy that is used for heating their homes.

The users also said that they want to have an energy visualization tool on their mobile phone. They want this solution to be easy to understand both for children and adults. To increase the understanding of the consumption one approach to visualize the consumption could be to express it in monetary terms.

The users also said that they want to be able to both monitor and control their energy consumption, including to remotely turn on and off devices. They also want to have continuous feedback on their consumption and get suggestions on actions that could be taken to decrease this. Including in these solutions the users also expressed a desire to have a solution that alarms them when something is wrong.

Solutions that would motivate the users to lower their energy consumption are games. Related to that, the users said that they might consider to compete with other similar houses on energy saving. They also suggested that they could participate in a "neighborhood feud"; in this "feud" both apartments and houses could participate.

The users wanted to know which energy producer that provides green energy. For instance, they want a solution that makes it possible for them to select the energy providers they want to get their energy from. They also suggested that the government could give advantageous loans for energy investments for private persons with very low interest so that these investments would pay off faster.

Concept Design and Evaluation

Based on the needs found, a call for interest among solution providers was performed. One of the winning bids related to the use of information in the new infrastructure coordinated by the Wireless Trondheim Living Lab (Andresen et al., 2007).

The results in the project were:

- AMS for meter reading using Wi-Fi. Meters were installed in houses in two cities in two countries with different energy mix (at 6 out of 8 planned homes) and tested with users in their homes.
- An application for smart phones and web were developed and tested (6 out of 8 homes).
- The application was developed further so that power consuming devices could be controlled. This was developed and tested in lab and at 1 out of 8 homes

Normally, in an AMS-rollout, an electrician would have to visit the end user to install a new meter. To install this solution, little additional work has to be done by the electrician; the idea is that a package that enables the end user to monitor and control his usage can be almost fully installed by the end user her-/himself. In this way, the end user can get an affordable solution to control his smart home and save power and money.

The concept consists of three main "modules" as illustrated in Figure 1:

1. Using existing Wi-Fi as transport for AMS meter readings. 80 % of all households in the countries tested have Wi-Fi installed already, and the rate is expected to be similar in most of Europe within a few years.
2. Provide an app showing real-time energy consumption and other power statistics
3. Provide smart house technology enabling the user to control power devices through the mobile app.

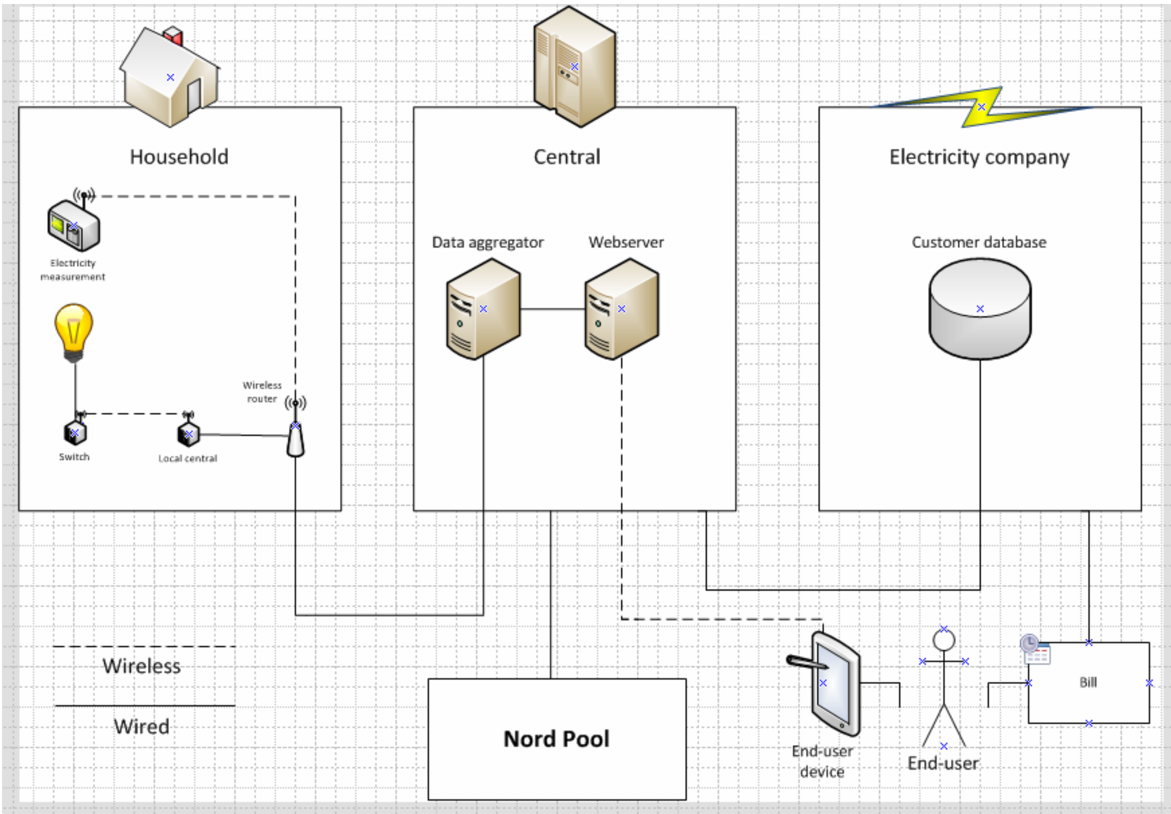

Figure 1 Architecture for AMS WiFi solution developed by Wireless Trondheim

The project was structured based on FormIt for planning iterations of user trials and feedback loops, including surveys for both pre-pilot and cross border pilot. To do measurement of different attitudes the users had different feedback mechanisms available. We performed start interviews, questionnaires underway and an end-interviews to see how they have experienced the trial. The partners included both energy providers, solution providers and technology providers in addition to the user.

The application had both visualization and control. You could also make it to run automatically based on the energy price. The main goal was to visualize the consumption and the cost as well as what consumes energy.

Project Relative to the Five Living Lab Principles

Added Value in AMS WiFi Project

In this project we tried to ensure that all partners gained from the project. For example, energy companies are probably interested in selling extra services in addition to electricity. The energy company could significantly reduced the costs for installing and running AMS, The meter company could beat competitors by offering a more cost efficient solution and the ICT company could deliver a solution for using WiFi to the power companies as well as offering an interface for providing the AMS data to the end user. Societal benefits would be that people have the opportunity to have a smart home at a low cost and thereby the possibility to save energy using his smart home. With AMS over Wi-Fi the end users is able to control certain devices in the house and see the effects immediately online using web or his smart phone.

User Involvement and Influence in AMS WiFi Project

We wanted the user involvement to be flexible, meaning that the users would use the application because it was useful. Still we have tried to do some controlled tasks both through the questionnaires and in other ways to evaluate all functions of the system. The recruitment of test users was done to be able to compare so we had a group of houses that were similar in size, type and also families living in them.

In the questionnaires we have asked about how the application altered usage and use, but also on feedback on functions. In total 15 different changes were made as a direct response to the feedback, although these where mainly minor issues related to usability and technical interoperability.

Realism in AMS WiFi Project

The providers had a lab for developing under stable condition. On the other hand putting the solution into real world environments was very useful to get early feedback. You get to see that every house is different; there are as many scenarios as there are households. You also get a first hand view of how it is to install this kind of technology and specific changes that are needed to fit the context.

Sustainability in AMS WiFi Project

The starting point in this project was that both the potential savings using Wi-Fi for AMS and the reduced power consumption will benefit society and the environment. If all expected gains can be realized, the savings for society is huge.

It is also considered positive that the users see that they will benefit from AMS. In many countries there is a debate related to that AMS by itself will not give any effects for the end users. It is expected that the end users will be negative to taking the cost of AMS while getting no gains. With the proposed concept one can show the benefits for the end user.

Openness in AMS WiFi Project

During the project there has been openness between the partners and the test users. Information has been shared freely among stakeholders. However, one drawback was that one wanted to use an open standard for communication and after a long time one acknowledged that this could not be done.

DISCUSSION AND CONCLUSION

The aim of this paper was to describe an approach to capture citizens's needs related to energy consumption in their homes across different countries. Although a number of issues were discovered on the user-interface and technical level, we found that the overall functionality discovered in the early phases was a good basis. One can identify a number of threats to validity to the reported results. Since the number of people and households involved were limited, generalizability is problematic. Specifically since the users in the focus group were recruited from people being interested in energy usage, the output might be skewed. Even if the responses from the pilots are positive, it is in any case too early to say to what extent the availability of this kind of solution will instill long-term behavioral changes or not. A challenge is also to motivate the energy companies to provide such solutions.

ACKNOWLEDGMENTS

We thank all focus group member, developers and test users for providing the basis for the results reported in this paper

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