Take a Closer Look - The Role of the User in Ubiquitous Smart Energy Systems

Marco Jahn
Fraunhofer Institute for Applied Information Technology FIT
Schloss Birlinghoven
53754 Sankt Augustin, Germany
marco.jahn@fit.fraunhofer.fe

Abstract

The core concept of many energy awareness systems is that providing feedback about energy consumption will lead to significant energy savings. Although some systems integrate other interventions (than feedback) like goal-setting, rewards, or comparison, there is no structured mapping from the findings of behavioral psychology to such systems. This raises the question if and how such interventions can contribute to change our behavior and sustain these changes in the long run. In the field of human-computer interaction (HCI) some researchers argue that common feedback-based systems are not suited for promoting long-term behavioral changes towards a more energy efficient lifestyle [5, 8]. This seems to be true, when taking into account the fact that people differ widely in their attitudes, motivations, knowledge etc. I argue that it makes sense to take into account the peculiarities of people when designing smart energy systems. Further, I present ongoing research considering the role of the user and the relevance of motivation within the context of an ubiquitous smart energy system.

Keywords

energy efficiency; ubiquitous computing; behavior change

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation: User interfaces – Evaluation/ methodology

Introduction

Advancements from the field of ubiquitous computing will open up great possibilities for the design of smart energy systems. Currently, energy efficiency is - or is becoming - a huge hype but the potential of integrating energy efficiency into ubiquitous systems is still waiting to unfold. Ubiquitous computing and the possibility to integrate information and knowledge into our everyday environments has the potential to contribute to an energy efficient lifestyle. If such an environment would be able to understand the specific goals, attitudes and motivations of its users, it could react according to these parameters.

In this paper I present ongoing research that aims at providing a link between behavioral psychology and ubiquitous computing. I argue that in order to support long-term behavioral change towards a more energy efficient lifestyle, smart energy systems need to take into account user-specific attributes, especially motivation. Changing behavior and sustaining it, is not a simple matter of providing feedback. We rather need to know about a persons motivation, knowledge and attitude beforehand, and then can think of a suitable intervention. Further, I describe our ubiquitous office system that we employ to collect user data related to energy consumption.

The Role of Interventions

Regardless of the current hype about energy awareness and efficiency, the question of how to motivate behavioral change towards energy efficient behavior, is subject to research for quite a long time now. Abrahamse et al. [1] provide an overview of 38 studies on interventions aimed at household energy conservation, many of them reaching back to the 1970s. These studies examine different interventions (e.g. goal setting, information, feedback, rewards, and combinations of these) and resulting effects on peoples' energy conservation efforts. While most of these studies resulted in energy savings reaching up to 15%, Abrahamse et al. also add that *[...] underlying determinants of energy use and energy-related behaviors have hardly been examined [...]* and that the problem of sustaining the behavior has not been tackled. Furthermore, the attitude and knowledge of people towards pro-environmentalism was not subject to most of these studies.

While Abrahamse et al. review various kind of interventions, Darby [3] focusses on the role of feedback and comes to the conclusion that direct feedback provided by some kind of monitor or display can support savings from 5-15%. But, similar to Abrahamse et al., Darby also points out that in order to establish an intrinsic motivation to save energy, additional interventions might be helpful.

The Leading Role of Feedback

Current developments in the research community as well as in the industry, have a clear tendency towards feedback-based energy awareness projects and/or tools; a bandwagon that also the big industry players did jump on. Microsoft Hohm[1] and Google Power Meter[2] both provide to the user real-time power consumption information, following the assumption that increased awareness induces behavioral change.

Research projects cover ambient hardware feedback like in [6] and [11] as well as software based systems. The eMeter system [12] connects a mobile phone with a smart meter to provide real-time feedback. Jahn et al. [10] present an energy aware smart home system that provides device-level, real-time feedback and control functionality. EnergyLife [9] combines feedback information with goal setting and aware-

[1] http://www.microsoft-hohm.com/

[2] http://www.google.com/powermeter/about/

ness tips. Both, feedback and tips are available for single devices as well as for whole households.

The Need for Personalization

While I strongly believe that providing feedback to the user is useful and can help him to change his behavior, I also think that this is just the very basis of achieving long-term behavioral changes. Abrahamse et al. [1] point out that the early studies did not take into account the users' motivations, attitudes, and knowledge. Darby [3] speaks of the environment and social factors.

If we want to support long-term behavioral change, we need to take into account that people are different; they have different goals, attitudes, motivations, levels of education etc. For someone who is completely indifferent to his energy consumption, fine-grained feedback might not be the right persuasive technique. He might rather need some information on the consequences of his behavior. The case is likely to be different with a person that devotes her whole live to sustainability.

Other researchers take a closer look at models from behavioral psychology. Froehlich [5] and He and Greenberg [7] state that feedback itself does not necessarily lead to sustained behavioral change. He and Greenberg point out that *[...] changing consumption behavior is a psychologically, socially and culturally complex problem*.

Riche [14] and He et al. [8] take a closer look at the process of behavioral change. Both consult the Transtheoretical Model of Change (TTM) [13], which describes the process of behavioral change as a hierarchy of stages to pass through. This process can roughly be described as a change of attitude and a new behavior that can replace problematic behavior. In detail the actor undergoes several stages, namely:

1. Precontemplation (Actor is uninformed and unaware, unwilling to change behavior)
2. Contemplation (Actor is aware about his problematic behavior and intends to change)
3. Preparation (Actor is planning to take action)
4. Action (Actor is changing his behavior)
5. Maintenance, Relapse, Recycling (Actor tries to sustain the new behavior)

He et al. [8] apply the TTM to energy feedback technology and provide a motivational framework describing goals (i.e. how to motivate the actor to move on to the next stage) and recommendations (i.e. how technology can help to reach a goal) on how to step up in the process of behavioral change. I believe that applying the TTM to energy feedback systems is a promising approach and that ubiquitous computing provides the appropriate base technology to develop user-centred smart energy feedback systems.

The User, the Motivation and the Ubiquitous System

With the rise of ubiquitous computing more and more smart devices, sensors, and actuators will be embedded into our every-day environments whether it be the home, the office or public spaces [15]. I believe that such environments can be exploited to motivate energy conservation (or more general, pro-environmental) behavior, in a way that takes into account the individuality of the user. Allowing a system to classify a user according to e.g. the stages defined in the TTM could contribute to developing tailored interventions, fitting a user's personal attitude.

Froehlich et al. [5] describe the gap between environmental psychology and HCI and discuss relevant issues. One question that remains open is, how to model behavioral change and stages of motivation. I argue that to foster behavioral change, as a first step it is of the utmost importance to know

the user and his current stage of motivation. Our goal is to track the user's energy-related behavior in an ubiquitous office environment and derive certain facts e.g. his current stage of energy usage, his level of knowledge or his stage of motivation according to the TTM.

As described in [10] we developed a feedback-based ubiquitous system that exploits device-level energy consumption information and makes this information available to the user via different kinds of interaction metaphors. This system is based on the Hydra middleware [4, 2]. The Hydra middleware framework supports the development of scalable, pervasive systems of networked devices. It simplifies the development of such systems by abstracting from the heterogeneity of different network communication protocols, allowing unified device access on a Web Service layer.

Currently this system is able to track energy consumption on the level of single devices using Plogg[3] wireless plugs to access consumption data. Further, we employ the Arduino[4] sensor platform to integrate more sophisticated energy-related usage tracking. Thanks to Hydra, we can easily abstract from the specifics of programming for Arduino. We can just access sensors and actuators via Web Services and thus rapidly integrate new functionality into our system. Currently integrated sensors recognize temperature, lighting and presence of people.

Tracking of data is done in an event-based manner. For energy consumption data, an event is a significant variation in the consumption flow. Sensor data are also modeled as events e.g. switching light on/off. An energy consumption event contains references to the user, device, room and has a time stamp and of course a consumption value measured in watts. As a first step, we will simply track these events in a number of offices and then analyze the data regarding its quality for making assumptions about the user.

[3] http://www.plogginternational.com

[4] http://www.arduino.cc/

Research Goals

The vision behind this research is that of a ubiquitous system that helps users to sustain an energy efficient lifestyle, regardless of their original attitude and motivation. With the research described in this paper I aim at providing some relevant answers to the question: How can ubiquitous computing contribute to change our behavior towards an energy efficient lifestyle? In detail, these results will be:

1. An approach to classify users. The main goal of tracking user behavior within our smart office system is to derive information regarding their current level of motivation. I we can classify users according to the TTM, we could use such classifications to provide adapted interventions to the user. This would be a huge step towards really user-oriented smart energy systems.

2. A deeper insight into peoples' energy related behavior. By tracking and analyzing user behavior we can learn when and why people consume energy. Based on this, we can also try to find out if and why they are wasting energy. Further, we might learn something about psychological parameters that constitute motivation (attitudes, believes, and values [8]).

3. A development framework for prototyping smart energy systems. We aim at making our ubiquitous energy system as open and extensible as possible. The goal is to have a framework, that allows for fast setups of the system in different environments, so we are able to run evaluations with different kinds of input and environmental determinants. Ideally, the system will be able to manage a set of interventions and support flexible combination of these.

Conclusion

I argued that the current trend towards feedback-based systems that do not take into account people and their motivation, knowledge, environment, etc. will not necessarily lead to sustained behavior change. Although there are approaches to enrich such systems with findings from behavioral psychology, a structured approach is not recognizable. While of course, considering the individual characteristics of people is a very complex problem, ubiquitous computing provides a basis for tracking and analyzing user behavior.

Therefore, I employ a ubiquitous office system to track relevant user events (including power consumption of devices, lighting, presence, etc.). In the next step I will analyze these data and try to extract information to classify users. One possibility will be to map these classifications to the stages of the TTM.

I believe that taking a closer look at the user and his behavior in an ubiquitous energy system can help to understand his attitude and motivation towards energy efficiency. An understanding, which I think is essential for the design of smart ubiquitous energy systems.

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