Putting the user in charge: end user development for eco-feedback technologies

Impressions from a Living Lab based design case study

Timo Jakobi
University of Siegen
57068 Siegen, Germany
timo.jakobi@uni-siegen.de

Tobias Schwartz
Fraunhofer Institute for Applied Information Technology FIT
53754 Sankt Augustin, Germany
tobias.schwartz@fit.fraunhofer.de

This paper aims at sensitizing stakeholders for the benefits of an end user development perspective in eco-feedback technology. Motivated by experiences gathered from a Living Lab-based design case study, we want to advocate a thinking that emphasizes end user development as a crucial part of the success of interactive eco-feedback technology. From our point of view, the field of end user development offers the potential to foster flexibilization and contextualization of energy feedback, thus improving opportunities to apply individual reference systems for end users in the situated and socio-technical surroundings of their private home.

Keywords: end user development; energy feedback;interaction design; design case study

I. Global Introduction

Energy is one of the most important resources for a modern society's welfare. Its efficient usage is a trending topic on the international agenda of politics as well as in commerce. At the same time, private end-consumers constantly make energy-relevant decisions in their every day lives, and account for up to as much as 20% of the energy consumption in industrialized countries [1]. Still, the ongoing shift towards considering factors such as sustainability and the carbon footprint, as an important factor in decision-making, currently leaves behind the private households needs to a large extent. For them, energy as a ressource has shown itself to be a complicated issue when trying to make it accountable[2]. Pierce and Paulos [2] show how problems, such as imperceptibility and invisibility in use, cause a lack of awareness and inability to identify means to effectively control energy consumption. Acknowledging this grievance, in recent years the HCI-community has increasingly experimented with prototypes. Considerable parts of research focused on exploring designspaces in the field of interactive eco-feedback-solutions through design case and impact studies [3, 4]. While trying to make use of developing information and communication technologies, research has focused on improving peoples understanding of energy and its consumption. By this time within the HCI-Community it is regarded as undisputed, that feedback on energy consumption enables energy consumers to better understand the usage of resources and to identify energy savings potentials [3, 5].

Current research on the design of energy feedback systems is dominated by a rationalistic paradigm, where principles of efficiency and rationality are applied at a household level [6, 7]. A point of criticism that the rationalistic approach has to face, is the tendency to conceptualize feedback as information that is universally useful for every consumer in the same way. Addressing this blind spot, research has focused on consumption practices in people's daily lives and has made progress in the last years. Strengers [8] for example, shows how people have difficulties making sense of the information that eco-feedback systems provide. The topic of the situated use of energy feedback remains, by large however, an open issue.

Taking in account the role of daily practices, we argue that energy consumption is highly situated and embedded in a socio-technical context [9]. We therefore aim to uncover existing and possible future practices of private households making energy accountable in order to enable designers to address these when developing eco-feedback-technologies. We believe, that in addition to psychological or normative approaches, addressing everyday-practices of making energy-consumption accountable, thus customizing feedback mechanisms to the needs of the individual everyday practices, can help to exploit further energy saving-potentials. In this WIP Paper we present early findings from field trails of feedback systems in homes.

II. Approaching the User

With the intention to make ethnographic input continuously available for the design of eco feedback technologies, we chose a user centered design approach referring to the concept of Living labs. Living Labs ensure the consideration of different stakeholders throughout the design process. Additionally, they also provide researchers with a stable long-term framework for qualitative exploration of social practices and evolutionary prototyping. Considering that the usage of eco feedback is interwoven into the practices of everyday life, one major concern was to expand our knowledge on existing and possible future practices of the usage of supportive technologies within the home. Based on our field work we start thinking about useful indications for the design of eco feedback technologies and will present some high level objectives for the design of eco feedback.

A. Establishing the Living Labs

In Spring 2010 we worked with nine households of different consitution in terms of demography and living conditions. The participants ranged from 26 to 67 in age, from single households to families, living in flats or houses, they were owners or tenants living in rural, suburban or mid-sized city regions. For these households a comprehensive infrastructure to measure and feed back data of energy consumption was conceptualized and brought out in practice. As one of the prerequisites, the participants homes were equipped with an intelligent metering device.

The Smart Meter provides the user with interfaces for reading and digitally processing the energy consumption data of the entire household. Therefore it was one of the two datasources in our Home Energy Monitoring System (HEMS).

In order to enable more detailed views on energy consumption, we conducted workshops, in which the participants could install smart-plugs on nine of their appliances, which were of special interest to them. These smart plugs communicate through a low-power wireless network protocol and can measure live-consumption (watts) as well as the consumption in each hour (kwh). A Media Center computer which acts as the HEMS-Server and is connected to the households main television set, saves the incoming data and provides interfaces to possible frontend visualizations. In our case, we used a local website running on the server to feed information on the energy consumption back to the user.

In workshops and semi structured interviews, we explored impressions of existing and possible future practices and refined our understanding of the design space. Using an evolutionary user centered design approach, we alternately implemented, tested and evaluated prototypes in close cooperation with the participants.

B. Ascribing individual meaning to consumption

On a software-level we were faced with the question of how to aedequately model information from the data sources. In order to supply households with the opportunity of using their individual sense-making processes through the HEMS, we implemented a tagging-mechanism. Tagging is a widespread technique used to assocciate meta-data with objects [11]. Its application origins are in programming and it has gained popularity with the emerging web 2.0 and its increasing opportunities of user participation. Within the context of our research, tagging is used to enrich information about the organization of the smart plugs, to build up a taxonomy of their position and the connected appliances in the household. The tagging-mechanism therefore enables the user to assign consumption to categories. Inspired by early interviews, we included four tagging categories to the system: activities, rooms, appliances and persons. The aim was to let the participiants tag the smart plugs, hence parts of their consumption, thus adding meaning to the previously undifferentiated and now disaggregated consumed energy. As part of the workshop on installing the smart plugs, the tagging categories were filled out by the participants themselves and then fed in to the system on installation time.

III. Early Results

In course of the research and design process, we found that participants often defined their energy consumption either as useful or wasteful, depending on the context of its use and individual assessment of the situation at hand. Most of the time, universal reference systems, such as money, were perceived as not suitable to reconstruct in-situ determinants and categorize the consumption in a manner described above. For other universal systems such as measuring energy in terms of carbon-footprint or kilowatt hours, we found even more obstacles that rendered usage impractical. In line with Kempton and Montgomery [10], our interviews revealed that people do not understand these units enough and therefore cannot integrate them into their attempts to make their energy consumption accountable. From our understanding, this is due to the special characteristics of energy consumption being situated and socio-technically embedded. Instead, households often tried to justify their consumption by referring to the context in which it took place. We therefore believe that situational factors play an important role when it comes to deciding if a certain consumption is termed to be 'waste' or 'useful'. Reflection processes are often temporally detached from the consumption itself, e.g. when triggered through using the HEMS later on. Therefore, an important task is to overcome this time gap and conserve context-relevant information for the user. In our research we found, that the already introduced tagging-mechanism, in combination with temporary classification provided by the sensors, has a high potential to provide enhancing information for the user of our HEMS-prototype. Without any context information, the understanding of the situation, thus the determining factors of the consumption, quickly blur in the users memory, making it impossible to apply the appropriate means necessary to be able to judge the actual consumption.

As a consequence, we argue that when designing energy feedback technology, the contextualization of data is crucial in enabling the user to apply individual energy practices when judging her consumption. At the same time, we believe that only the user is equipped with the necessary resources to adequately describe the context at hand in a way so that she can reconstruct it for time-independent sense-making purposes: her very individual valuation, feelings and intentions in the specific situation. This dependency on user-input calls for a very flexible system, because at design time, possible usage scenarios cannot be anticipated to full extend. Furthermore such a solution should allow for simple and parenthetical creation of context-enriching data, in a way that the user is not distracted and can switch back to her original activities instantly. Existing eco-feedback technology does not support such flexibility. Therefore, motivated by our experiences, we want to advocate for an increased consideration of the potentials of end user development when designing eco-feedback technologies.

IV. SUPPORTING FLEXIBILITY IN HOME ENERGY MANAGEMENT

End user development provides designers with elaborated tools for the flexibilization and customization of software. The core benefit of an end user development perspective is to put end-users as the owners of the problems in charge and to make them independent from high-tech scribes [12]. Activating the user to enrich her energy consumption data with self-made "memory-points", can help to better adjust eco-feedback to the actual usage-situation existing at the time. We suggest focusing on two different aspects when trying to address flexibility-issues of eco-feedback technologies, which we will outline in the following.

A. Reacting on changes of Hardware infrastructure

In our research, we noticed that participants were quickly comfortable with using the smart plugs, and were keen on measuring different appliances and usage scenarios. Since our first prototype only covered capturing up to nine devices, some households altered the configuration and changed the places where the smart plugs were first installed or switched appliances. With the initially implemented tagging-mechanism still in place, this would have corrupted the context data. Because of users curiosity and sovereignty, we think that hardware-changes should be possible at any time. This includes such cases as the desire to make changes to the hardware infrastructure in use, such as switching appliances (Fig.1) or when installing them in the first place. Users should also be easily able to tag or re-tag their smart plugs in case of such events. Therefore the administration of measurement-lifecycles should be considered in design as well.

B. Enabling in-situ documentation

A second common phenomenon was the participants desire to reconstruct usage scenarios of the past. When talking about HEMS and its visualizations, sometimes the user found points of particular interest. Most times these were motivated by the user remembering a specific usage situation with unknown consumption, or triggered by the feedback mechanism, where the amount of consumption raised curiosity concerning the root of the consumption (Fig.2). Both cases show, how participants tried to combine context and feedback data to receive information that enabled them to apply individual energy practices. We therefore think that opportunities to effectively transport context, such as reference systems, can contribute to

Figure 1: Oftentimes, flexible switches were chosen. Where different appliances are to be plugged in, the infrastructures flexibility becomes a key issue for data integrity.

supporting sense-making processes of the user over time. This could be made possible by allowing the user to create "memory-points" with the current configuration of the HEMS infrastructure and individual context information. These reminders can support the user in reflecting on her energy consumption, without the need to drop out of the current occupation. Instead the context-data allows the user, as the creator, to put herself into her own position when tagging a certain usage situation.

C. Improving the tagging-mechanism

Both scenarios imply a change in how to handle the tagging-mechanism by designers. When we first started, we provided households with a fixed taxonomy that allowed tagging in categories such as activities, rooms, appliances and persons. This classification was inspired by early interviews and presented a showcase for generally conveying the underlying idea of tagging as a concept to the user. In the course of research it has become clear that this taxonomy is by far not sufficient to cover the user-needs concerning the flexibility of the infrastructure. As with web 2.0, the user is the best to decide, how to tag her own data. By nature, externally defined taxonomies "tend to establish only one consistent authoritative structured vision. This implies a loss of precision, erases the difference of expression, and does not take into account the variety of

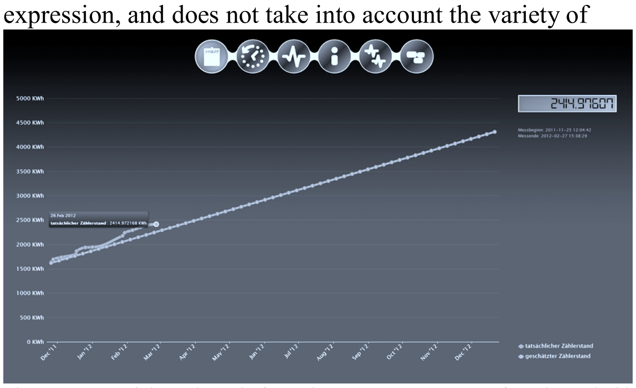

Figure 2: Anticipated and factual energy consume of a household. Individual context data could support sense-making of deviations.

user needs and views."[11] Therefore, we vote for letting the participants build their own understanding and resource language of how to organize tagging, hence reflection support of their energy consumption.

D. *Exemplary prototype for flexibility support*

As a suitable artifact, to further explore end user development and flexibilization issues for eco-feedback, we think that smartphones could provide a fertile ground. Technologically they hold great opportunities, equipped with cameras, speech-to-text applications, text-recognition, QR-Code reader, near field communication, a keyboard and app-development APIs. Besides enabling direct access to the HEMS through an integrated browser and Internet -/LAN-access, they oftentimes also are a ubiquitous companion even at home. Always being at hand, they meet the requirements to act as the carrier of an interface able to spontaneously create input for the HEMS. In the following we want to outline a possible support of the above described scenarios within a native app and its hypothetical dialogues.

When changing the hardware-configuration of the infrastructure, the HEMS-app would guide the user through the process of adapting a new configuration. Within this dialog, the smart plug could be identified through a QR-code for example. Basing on favorites, local positioning of the module, last used tags or other logics, the system could suggest new positions and tags for the smart plug. Additionally the user could take a picture of the new application domain and insert a personal statement via text-to-speech or keyboard. Because of the smartphone being connected to the internet or LAN, the HEMS-server would also be able to automatically put the old configuration of the smart plug out of order and replace it with the newly enacted tags and additional information.

For in-situ documentation of a usage context at hand, the supporting dialogue should be short and demand only little data, because the user should not be too much distracted from her occupation. On the other hand, it should offer many possibilities, each optional, for data-input by the user herself. These could involve text, pictures, or even video, geo-information and any kind of written tag. To grasp the current situation, technologies such as near field communication or RFID could be used to automatically identify the smart plugs in the users surrounding. They could be pooled, connected to the tag and saved as a group for future (re)use.

These concepts for putting a mobile HEMS-environment to use are just two of a manifold of conceivable options. Still, they convey the core ideas of end user development in terms of flexibility and customization. They also mark a step towards creating eco-feedback technologies that help people carry out their own individual sense-making processes in the field of private energy consumption, hence supporting practices of making energy accountable.

V. Future work

In the future we plan on implementing the described prototype for smart phones and bring it into practice within the Living Labs. The development of solutions to support greater flexibility and end user development will be integrated into the ongoing research-through-design approach. We hope to find further indications on how to design for the users' everyday practice by cooperating with and listening closely to our Living Lab participants, as they are the actual experts in this special application domain. Furthermore we hope to pave the way for an increased consideration of end user development in the field of eco-feedback, in order to improve reflection processes and energy efficiency in the home.

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