Extreme-user approach and the design of energy feedback systems

Lassi A. Liikkanen

Helsinki Institute for Information Technology HIIT
Helsinki University of Technology TKK, Finland

Abstract

New automatic meter reading and smart home devices can provide increasingly detailed information about electricity consumption in households. This information can be considered as feedback about electricity use, which implies that in can be useful in raising energy awareness and promoting electricity conservation practices. For three decades, feedback methods have been studied a considerable literature exists about effective feedback. However, applying the principles of successful feedback to in the design of electricity feedback products is never straight forward, because the feedback must coupled with some product or service that the user finds useful or entertaining.

In this paper the *extreme-user* design method is introduced as a way of discovering what requirements users have for feedback systems. Through a case study of 20 electric power meter users, I illustrate the potential of this method in providing ideas for design. Through a semi-structured interview I examined how the power meters are used, user satisfaction with the meters, and motivations underlying the loan. Three categories of users were discovered and labeled *wisdom seekers, detectives*, and *judges.* They had different attitudes towards electric devices, being interested in *learning, revealing,* or *evaluating* energy consumption facts. These differences in user attitudes indicate that different users likely require dissimilar functionalities from the feedback application. It was also discovered that loaning the meter changed the attribution of consumption from devices to habits. Initially the participants were looking for a faulty device that could explain their electricity bill. However, after the measurements, their attribution changed and they understood that their own habits would need to change in order to reduce consumption.

Introduction

The introduction of new electricity metering technology and new smart home networks is about to completely change the accessibility of electricity consumption information. This has the potential to significantly raise the level of awareness in household electricity consumption assuming that inhabitants receive the right kind of information or feedback. However, designing new information and communication technologies (ICT), such as those centered on energy awareness, is always a huge challenge. Instead of helping and supporting, poorly designed ICT can be useless or mislead users, for instance, relying blindly on GPS navigation has caused several car accidents [1]. This is also true in the context of energy feedback. Poorly designed system may not only be ineffective, but may increase electricity consumption if it signals that you can safely consume more than you do now.

This paper proposes a method to inform the design of energy feedback systems. This method is called extreme-user approach. We propose that one segment of extreme users in the context of technology-mediated energy feedback (North-Europe, 2009) are *people who use electric power meters*. In this paper, we introduce this method along with its justifications, and an example study of extreme users. Finally, we discuss the possible benefits of this approach and how it may help in the design of electricity feedback systems.

Electricity Equation and Feedback

Understanding and making a change for household electricity consumption requires understanding what components make up the total consumption. The model of energy consumption presented here is composed of three main components, illustrated in Figure 1 on the next page. The equation starts from the needs of a user, asking what does an individual want to do achieve (Item A). On next level, there are parallel items of how this goal is fulfilled by using what ever equipment available (B1 and B2). Decisions on these two levels contribute to how the total consumption builds up (item C). Take the example of preparing a cup of coffee. Say that the person has three devices that can be used; a stove, water boiler, and a coffee maker. However, the total electricity consumption is not only determined by the choice of an appliance, but also by the way the device is used. For instance, making a full pot of coffee and letting it stay warm all day would lead to considerable waste of energy, in comparison to boiling water on a stove and using the remaining heat energy to fry eggs. But how could the user become aware of these options and make the decision in some rational terms?

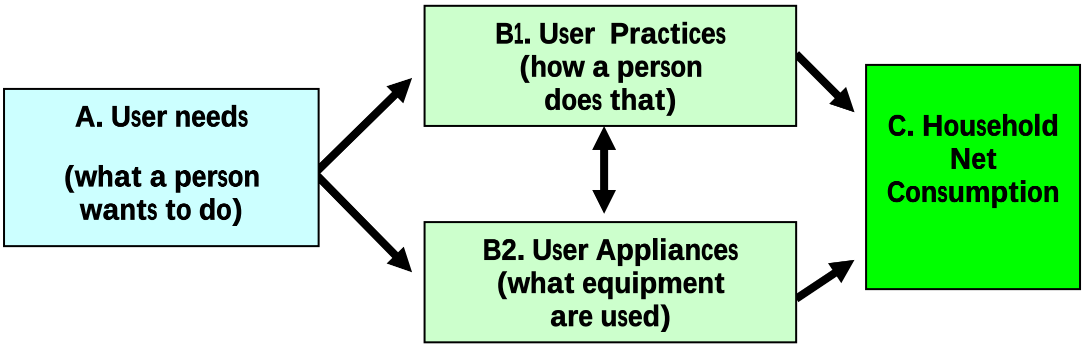

Figure 1. The Electricity Equation describing the components of electricity consumption

One prominent solution for gaining awareness of energy consumption is feedback. Feedback is a very general mechanism that can be applied to changing the behavior of almost any living thing, or modify the beliefs of a person. The concept of energy feedback and its implementation guidelines have been studied for some time. Recently there have been several extensive reviews regarding the topic [2, 3]. Thus these details are not considered here, but it seems appropriate to present the key principles that have been identified to positively impact energy awareness and reduce consumption of electricity. According to Fischer [2], the properties of successful feedback include:

- Grounded in real consumption
- Provided with a short delay
- Are disaggregated by end-usage
- Include opportunities for historical and/or social comparison

The feedback requires a carrier, a medium to convey the message to the user of the energy. In the past decades, feedback has been given through the electricity bill [3]. Although the bills are ubiquitous, as a feedback source they can be uninformative and sluggish. Therefore, in the age of ICT, it is feels natural that the medium should be electronic, embedded in an intelligent software solution. There are already several software solutions that give examples of how the feedback could be provided using the Internet and World Wide Web. The variety of approaches could be divided into *static* and *dynamic* applications. Static tools resemble paper-based feedback, but provide shorter feedback intervals and possibly include customizable views into to the past consumption information. The spectrum of services currently available for public use is illustrated by the examples of Figure 2:

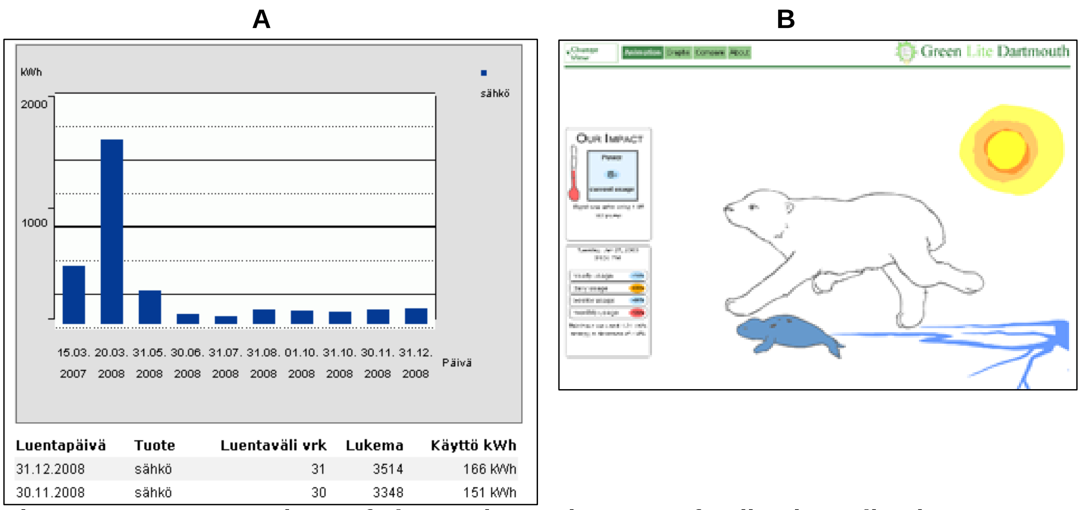

Figure 2. Two screenshots of electronic, static energy feedback applications.
A presents a custom reports from a Finnish utility web service for individual customer
B is an example from Darthmouth College, called Green Lite energy visualization [4].

In contrast to the statics ones, dynamic feedback applications go further by allowing, for instance, users to create goals or prepare custom reports of consumption. A typical application is a dashboard for observing electricity consumption in (close to) realtime. Several examples can be retrieved from the Internet, including TED the energy detective [5] and Lucid Dashboard [6] (see Figure 2).

A B

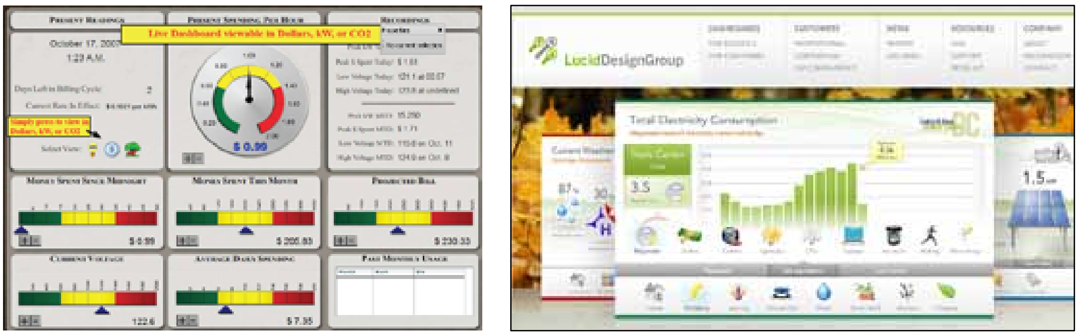

Figure 2. Two dynamic electricity feedback applications. Solution A is the TED dashboard (image taken from [7]), and the screenshot B shows the LucidDesign Dashboard [6].

Beyond these static and dynamic software solutions illustrated above, there are also *product concepts*, such as Power-aware cord that glows according to the electric load [8] and readily available *products*, such as Wattson [9] for keeping track of energy consumption. For more information about these technologies, see a recent review [10]. When evaluating these novel technologies, it should be remembered that they are new and have not yet been thoroughly tested. It is also unknown and not self-evident to what extent they embed, or even try to embed, the principles of successful feedback. This relates to the fact that the design and development of an interactive application is always a considerable challenge with many properties contributing to its acceptability, usability and functionality. Ultimately, the impact that conceptual designs and prototypes can have on user practices needs to be evaluated in real use contexts with real representatives in an experimental fashion.

To create a useful new device for energy feedback, it must be acknowledged that this device will be susceptible to all constraints known to influence acceptability and usefulness of technology. Adapting the electricity equation presented in Figure 1, this technology will be utilized only if users find some need for it, if they feel they can get something out of the device. Therefore the design of this technology should be somehow grounded in the existing needs of people regarding electricity and then implemented. This leads us to assert that technical aids for energy awareness and feedback will be beneficial only if:

a) Feedback devices meet the needs of domestic energy users
b) Feedback devices are implemented in an engaging and useful way encouraging long term commitment to energy efficiency

The goal of this paper is to provide useful information to address the requirement a) and facilitate design. The premise b) is equally important, but is dependent on a) and must be investigated using prototypes of this new technology.

Trends in Design

How to create an application that compels to a wide range of potential users? One opportunity is to find out users needs about a function. Discovering what users want (explicit needs) or what they might want (implicit needs) is one of the most important steps in the process of designing any consumer product, physical or software. A multitude of approaches for need finding is described in the literature about software and product design [numerous methods exist, see e.g. 11, 12]. Formal design method describe need finding is seen as the first step in determining the requirements of the future product. Even if a formal methodology is not followed, all technologies, including energy feedback systems, are designed according to *some requirements* to meet *some needs*. If these requirements and needs are not user-based, they must come from the designer. During the past decades, the involvement of user in the design process has become more important, and for instance ISO standard 13407 describes a *user-centered design process.* Its basic principle is to involve users in the design process. There are many established design methods that facilitate building effective and innovative products. An example of user-centered design methods is extreme-user approach, a design method intended to help in discovering user need and requirements [13]. The idea is to study small, niche groups of people sharing a common activity or interest, which is not commonplace, such as having a pet reptilian or interest in lomophotography. Elaborate study of these people builds understanding and inspiration in designers. This practice is called extreme character [14] or extreme user [15] approach.

The Extreme-user approach resembles somewhat more widely known method called lead-user approach [16, 17]. However, there are certain differences between the two. In the lead-user method, the targeted users are expected to be active developers of solutions (user innovators). They have special needs derived from the special context they are working in. As an example of lead users, the whole genre of mountain bikes was initiated by north Californian bicyclists who took their standard bikes into the wild and soon started developing more flexible and robust solutions [17]. The lead-user and extreme-user method therefore differ by the assignment of design agency. Lead users design solutions themselves where as extreme users only provide inspiration for professional designers, who develop the solutions. Importantly these solutions are grounded in real user behavior and thinking, even though they may, or may not, addressing their needs. However, the present literature does not discuss distinctions in the needs dimension. It may be so that the behavior of extreme users expresses some marginal need or desire that, unlike with those of lead users, is unlikely going to be widely exhibited among their cultural peer group. If this distinction exists, we would need to develop the terminology further to distinguish between different extreme (marginal need), pioneer (common needs), and lead-user types.

Given these arguments, we will describe a case study of applying the extreme-user method to the development of an electricity consumption feedback system [see 18]. In the context of energy feedback, we asked the question, who are extreme users? People who consume a lot of energy? No, rather *the people who seek to understand their power consumption with the help of technology* that is not widely adopted by the majority of customers. In Helsinki, Finland, a segment that suits this description was people who loan electric power meters.

End-User Electric Power meters

The plug-in electric power meter is a device that measures and gives out information about the electric current going through (see example devices in Figure 3 below). The meter is placed into an electric socket and the measured device is plugged into the meter. In some meters, the plug is attached to the main body of the meter by a cord. After the installation, the power of the plugged device meter becomes readable. Recently, wireless models have also become available (e.g. [19]).

Figure 3. Selection of different end-user electric power meters, 15 to 60 € / each. Wireless device on the left, devices with an interface and a display in center and on right.

The power meters display both cumulative energy consumption and instantaneous power. Some can calculate the monetary cost of the consumption, for example in Euro. Additionally they may provide detailed information about voltage, current, power factor, total harmonic distortion, etc. Meters are useful for measuring most alternating current (AC) devices, and can not be used to measure fixed lighting or heating, or three-phase current appliances, such as an oven or an electric sauna stove common in Finnish homes. End-user devices are priced from 15 Euro, more robust and reliable ones sell above 200 Euros, and professional devices for power quality analysis go beyond 2000 Euros. Accuracy of these instruments varies considerably. Recent evaluation of these devices conducted at the Helsinki University of Technology [20] revealed that some of the cheap devices available at discount stores do provide reliable readings across variable conditions, while may provide very poor, underestimated figures about the apparent power and total consumption.

How practical are the existing power meters sold for end-users? Power meters allow to measure only one plug at a time. Using an extension cord can help to measure several devices, but their consumption becomes aggregated. Additionally, meters may not have very good resolution for small currents drawn by stand-by devices (say, magnitude of less than <5 watts, [20]). This will complicate the measuring somewhat, assuming that people are interested about small currents of devices on stand-by [21]. Another difficulty relates to the placement of the meter. Power outlets maybe located at awkward positions in kitchens or in bathrooms. This may render measurement difficult or impossible.

Electric power meter loans

Access to a power meter does not necessarily require buying one. A Helsinki-based utility Helsingin Energia started a power meter loan service in 1991. Since then they have served over 10000 customers, some returning. For the record, there are less than one million people living in the greater-Helsinki area and the company has almost 400 000 customers in total. However, the power meters remain the most popular item and currently the company circulates 49 identical power meters, one of those is shown in Figure 3. For instance, during 2007 and 2008 there were 826 and 1051 loans, respectively.

Figure 3. Meter package including the Christ Elektronic CLM200 power meter. The device has only two operation modes, "Watt" for electric power and "kWh" for consumption.

The customer loaning a meter is commonly required to make a reservation beforehand. When a meter becomes available, he or she then comes to pick up the meter from utility premises located in central Helsinki. When collecting the meter, customer service staff demonstrates the usage of the meter, gives measurement tips, and prepares a one week loan contract. The meter is provided in a handbag which also contains the meter, a user manual and a reference sheet (Fig. 3). The reference sheet provides information about power and consumption of appliances normally found in Finnish homes. The purpose of the reference sheet is to help the user to evaluate their devices' condition.

Summary

We have argued that the design of energy feedback ICT systems is a considerable challenge. We do have information from research to help us define desired characteristics of feedback, but implementation of these principles is not straightforward. Users must feel that the future feedback system is useful for them. One way to achieve this is to design a device that addresses the needs of the user. From design methodology, we proposed extreme-user approach for find out what these needs could be like. In the next chapter, we will provide an example of applying this method.

Research Method

Recruiting respondents

For this study, we recruited customers who had just returned the power meter. There was no intentional selection of respondents based on background characteristics. The interview format was a semi-structured interview. Semi-structured referred to two things: if the person spontaneously provided answers for a question coming up later, then the question was not repeated. Secondly, even though many questions were presented as open-ended, most of them were scored immediately during the interview according to pre-defined scales. If the chosen scale and set of response items did not match the answer, a separate note was made. If there was a need to present any focusing follow-up questions, these questions were presented just for this particular subject.

The first interview was carried out in the utility premises (customer service center), where all the participants were recruited. However, the rest 19 interviews were conducted over the telephone with a short delay after the customer had returned the meter, because recruiting subjects on site turned out too time consuming. The interval between the return and the interview was recorded. No particular incentive was proposed for the participants. All interviews were conducted by the author LL.

Ethics

Subjects participated voluntarily. All informants were adults and provided their consent to be interviewed. The data was recorded anonymously and the purpose of the study was introduced.

Instrument

The procedure of the interview followed the structure of the instrument. The target time for one interview was 12 minutes. The subjects were not informed about the pre-defined response items, unless they could not otherwise explicate their opinion. Responses were transcribed instantly to the printed answer sheet by the interviewer.

The interview questions were prepared beforehand and fell under four categories. The preparation of the instrument started from interviewing the customer service staff of the utility and some other experts in the area of consumer energy advice. The resulting question/answer sheet was printed on a single one-sided A4 sheet (the Finnish original available from the author by request). The sections were labeled as *1) use experiences*, *2) motives*, *3) satisfaction*, and *4) background information*. The sections 1 and 2 were considered the most important for discovering the user needs.

The section *use experiences* included details about the measurements carried out by the subject. The goal was to learn about what people really do with the devices, what they try and what they achieve. To help people in responding and remembering, and to be systematic, we tried to exhaust the list of 11 typical measured appliances. For each these appliances, informants were asked if they owned the device and whether they had measured it. If a device had been measured, the user was also asked that in which kind of operational state it had been measured. We were also interested in social dimensions of using the meter. Who made the measurements, how did other family members think about the meter? Informants were also asked to evaluate the impact of loaning the meter, what difference did it make for their consumption. Finally, the participants evaluated whether one week was adequately long loan time or not.

Motives underlying the loan were also prompted. These covered expectations about the benefit of the meter and the primary inspiration why the person had borrowed the meter in the first place. *Satisfaction* questions probed the contentment and acceptance of the meter. Customers were asked whether they felt having completed their goals and whether they would borrow it again. Customers also evaluated how easy it was to conduct the measurements. This measure of usability was complemented with control question whether they had read the supplied manual or not. The attitudes about upcoming Internet feedback services were probed by asking: "*In future, smart home systems or automatic remote meters may allow your utility to provide you with close to realtime feedback about your electricity consumption, possibly revealing the consumption of individual appliances. Do you have interest in this kind of Internet-based service?*" In the final section of the interview, we recorded *background information* from the subjects anonymously.

Results

Subjects

We recruited 23 customers of Helsingin Energia returning a power meter to the utility and eventually interviewed twenty (N=20) of them (drop out rate 13%). These people are called here extreme-electricity users. The sample was collected between December 2008 and January 2009. On average, people were interviewed within 4.7 days after concluding their measurements. Interviews lasted on average less than fifteen minutes. However, the longest interview took over 30 minutes. Subjects were interviewed individually except for one couple.

The majority of the informants were male (13 men, 7 women) and had variable education levels. Five people with a university degree were included. More than two thirds of respondents were living in a flat and the typical household consisted of an adult couple. Only three participants had children sharing the apartment, and one third of the participants were living alone. The age of respondents ranged from 22 to 79, with the average of 50 years (standard deviation = 17 years). Only a half (11/20) of the subjects could estimate their yearly consumption which was between 1400 and 17000 kWh/year. These people were also quite confident about the figures. The considerable deviation was related to different housing types, flats vs. detached houses. The consumption information was not crosschecked from the utility, as written consent to retrieve this information would have been needed.

Measurements by users

Inquiries about the measurements done started with general open-ended questions. As a follow up, subjects were requested to name individual appliances they had measured, with the help a list of pre-defined items. This was done even if subjects had clearly indicated that they had been interested in some specific item. On average, people had measured seven devices, with a range of 2-12 (standard deviations= 2.9 units). The detailed breakdown of measurements made in Table 1 shows that the most typical appliances measured were white goods, fridge and freezer, and entertainment devices, TV and computer. These figures seem likely to correlate well with the general penetration of these technologies within Finnish households; cold appliances and television are the most common [22].

	Amount of users measuring appliance				Measurement type		
			95 % CI				Normal +
Appliance type	Total	%	Lower	Upper	Normal	Standby	standby
Fridge	13	65.0 %	44.1 %	85.9 %	11	0	2
TV	12	60.0 %	38.5 %	81.5 %	5	1	6
Freezer	11	55.0 %	33.2 %	76.8 %	8	0	3
Washing machine	10	50.0 %	28.1 %	71.9 %	8	1	1
Desk-top computer	10	50.0 %	28.1 %	71.9 %	5	1	4
Dish washer	7	35.0 %	14.1 %	55.9 %	5	1	1
Digital set-top box	7	35.0 %	14.1 %	55.9 %	3	1	3
Laptop	6	30.0 %	9.9 %	50.1 %	5	0	1
Hot drinks machine, cof	5	25.0 %	6.0 %	44.0 %	5	0	0
DVD player	4	20.0 %	2.5 %	37.5 %	1	1	2
Dryer	2	10.0 %	0.0 %	23.1 %	2	0	0
Stereo equipment	2	10.0 %	0.0 %	23.1 %	2	0	0
WiFi router	2	10.0 %	0.0 %	23.1 %	2	0	0

Table 1. Break down of different types of appliances measured by the subjects. 95% CI column indicates the 95% confidence interval for the proportion as a generalization to population.

Receiving information. The majority of users (88%) had used the consumption reference sheet to interpret their results. They discussed their findings commonly in relative terms indicating that the consumption was *relatively small*, *normal*, or *higher than normal*. Many subjects had been surprised to find out that some device, such as washing machine, consumed relatively little and another device, such as TV on stand-by, consumed relatively much. As we did not probe the subjects to discriminate between power, short term, and long term consumption, it remains unknown how well aware they had become of certain appliance's contribution to the total consumption beyond immediate comparisons. Some subjects also referenced the exact power and consumption figures from memory or from their notes. All these references were made in terms of watts or kilowatt hours. The lack of money-based comparisons probably relates to the power meter, which did not convert power figures to money.

The social dimension. The meters were primarily used by a single person (9 out of 12 families). Only in three households did spouses participate in making the measurements, even though all subjects said that the rest of the family supported the measurements. The only family conflict induced by the meter was reported by a mother of a minor, who found it initially difficult to measure her son's computer's consumption because the device was kept almost constantly on. In another household, the male head of the family clearly distrusted his wife and children in making the measurements.

Consequences. Two thirds of the subjects were certain that their electricity consumption would be changed after loaning the instrument. These people stated that they would make an action and change their consumption habits, for instance, by turning ofg lights more frequently, completely turning off televisions and digital set-top boxes, or adjusting the temperature of their cold appliances. Only one person said that she would immediately need to renew an appliance (a fridge) based on the measurements. The remaining subjects did not see any need to change their habits or appliances. Some stated that because they found their devices working properly, they could continue using them as before. Some had even given up powering off devices, because the stand-by consumption was found to be minimal.

Satisfaction with the Acquired Results

The final questions of the interview concerned satisfaction with the meter and the loan service. We inquired about the usability of the meter and found that 95% of subjects thought the meter was easy to use and consulting the user's manual had been unnecessary. One reason for this was maybe that the customer service always shows the customer how to conduct the measurement. This was spontaneously stated by almost half of the subjects. All subjects were also willing to loan the meter again if they should need it, showing that the device had been very well accepted.

Despite these very positive comments, users did have some trouble. A fifth (21%) of the subjects said that they could not get the results they had been hoping for. There were two reasons for this: *physical inaccessibility* and *interpretation*. For the former account, the placement of the meter turned out too difficult for some people and in some locations. For instance, a retired lady had loaned the meter to inspect her fridge, but connecting the meter to a plug hidden beneath the freezer turned out to be impossible. A few others reported similar difficulties. Secondly, some users had difficulties to interpret and understand the results. Even though they acquired the consumption data, they could not recreate their personal "electricity equation", that is to discover how their consumption really added up. This was particularly problematic for subjects who were looking for the source of increased consumption.

We inquired subjects' attitudes about future services and their pricing. Starting from the point in which the power meter is loaned for free, half of the subjects did not see any need to buy a meter for their private use. On the other hand, one fifth of respondents were considering this option. Regarding the future services probe (see Research Method), 65% were definitely interested in Internet-based feedback and might also consider paying a small fee for the service, 37% would not.

Motivations for the Loan

The participants indicated several reasons why they had taken action when asked directly. These statements fell into six categories (see Figure 4 on the next page). The main incentive was economical. Almost half of the subjects reported they had been alarmed by their electricity bill. Another important reason was a suspicion about a device. There were several variations to this, some people had recently received a yearly comparison bill indicating increased consumption, some had compared electricity costs with friends, and some were just concerned about the amount money spent in electricity. The last of three reasons may be related to the fact that the frequent hikes in electricity prices have been well advertised in Finnish news, and consequently people may have become aware of how much money is spent on electricity. The initiatives of the European Union, public dissemination of "green", environmentally friendly values and repeated promotions of energy-efficient lighting in mass media among many may have focused consumers' attention to electricity costs.

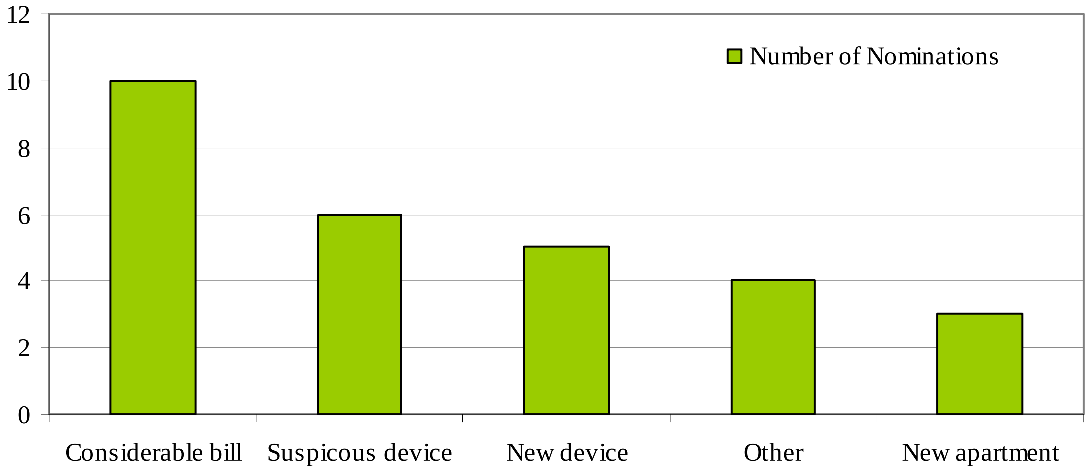

Figure 4. Reasons for loaning the power meter. One respondent may have nominated more than one reason (N=28).

The category of Other reasons embeds primarily different kinds of "epistemic" motivations (the need to know). Four respondents told that they just had a general urge to know about the consumption of appliances. Two of the people interviewed said this knowledge-driven attitude maybe associated with "green thinking" and environmental attitudes. Other two were more technically-oriented and seemed to have more "plain knowledge" motivations, being just curious to learn about their devices.

Categories of Electricity Consumption Needs

After finding out the readily provided motivations, we attempted to analyze them further to gain a elaborate understanding. Through an analysis of all data, three categories of measurement type came out of the data: *extensive walkthrough* of all interesting appliances *without particular focus* (47% of all), *walkthrough with the purpose* of locating an "electricity leak" (21%), and *inspection of suspicious device* or a cluster of devices (32%). These motivations can further be transformed into a set of caricatures or personas describing user types (about the "personas" design technique, see e.g. [23]). Labels chose here were *wisdom seeker, detective*, and *judge*. For some people the electricity bill was a signal that brought out the *wisdom seeker*, interested in finding out a "truth" about their electricity consumption. In *detectives*, incurring costs evoked the feeling that there must be something wrong in their devices because of the amount of electricity that is consumed. Their task was to find out why this happens. Finally, some people had strong prejudices against certain devices and they wanted to use the measurements to *judge* whether or not this device is guilty for consuming excess.

Customer type category	Motivations	Cases	% within category
Wisdom seeker (walk through all)	Considerable bill	5	45 %
	Only 'other' reason	3	27 %
	New device	1	9 %
	New apartment	1	9 %
	Suspicous device	1	9 %
Detective (looking for a leak)	Considerable bill	4	50 %
	New apartment	2	25 %
	Suspicous device	2	25 %
Judge (inspecting device or cluster)	New device	3	50 %
	Suspicous device	2	33 %
	Only 'other' reason	1	17 %

Figure 5. Left: Different customer types and their underlying motivations.
Right: The number of devices as a function of customer type category

This user-types categorization can also be justified through some other variables (Figure 5). Different users types made a distinct number of measurements, wisdom seekers significantly more (7.0 measurements) than the judges (3.43 measurements; $F(2,17)=4.326$, $p=.030$), detectives falling in between with 5.5 measurements.

Attribution of electricity consumption.

An interesting theme that emerges from the data concerns *the attribution of electricity consumption*. Many informants named the electricity bill as a motivator to loan the meter, but reacted to it differently. In particular, *detectives* made the inference that they must possess a defective appliance which is wasting energy. This attribution suggests that they had excluded their own part from the electricity equation. They were not guilty of consuming energy, their appliances were. However, if we consider the responses to the question of “how did the measurements affect your life?”, the changes the subjects listed were dominantly habitual. This means that in contrast to their expectations, they learned that in fact the devices were operating properly, but their own habits were lavish. However, the attribution change was noticed for only half of the people initially suspecting a device, the rest become content with their bill after confirming the function of their devices.

Discussion and Conclusions

In 2009, countries all over the world have to consider ways to tackle climate change. European countries have a special role in this puzzle as they are acting under the new EU climate package intended to show an example for the rest of the world. There are many levels to this battle. Consumers are considered as one important resource if they just can be motivated to participate in the quest for a more sustainable future. One solution for empowering people comes from different energy feedback solutions. With new generation of smart meters and smart home utilities, the technological barriers for realtime, disaggregated feedback are cracking. However, to fully utilize the potential of these technologies, they must be designed carefully in order to achieve desired impact.

In this paper, we have proposed an extreme-user approach to help to developing energy feedback systems. In the context of electricity feedback, we defined extreme users as people who voluntarily make the effort of loaning an electricity power meter for a short period of time to learn more about their electric devices. In twenty interviews, we asked these people about their motives and actions regarding the loaned power meter. Three categories of use cases were discovered: *extensive walkthrough without focus*, *walk through with a purpose*, and *inspecting a suspicious device*. These categories were further labeled as three characters describing the different attitudes of users. The results show that the average awareness of electricity even among the quite selected set of users was very variable. Only half were aware of their own yearly consumption and many did not seem to grasp energy concepts very well. In spite of this, most people did perform several measurements and generally satisfied with the results. It appears that the users clearly seek to utilize these devices as one-shot ailments. This also matches their motives, but contradicts the principle b of successful feedback, i.e. long-term support for sustainable consumption.

Implications for Design

The results acquired here can find several uses for the designing future electricity feedback tools. By first confirming user types by additional studies and then developing further into personas [23], designers can proceed to produce functionalities that best support the needs of wisdom seeker, detective, or judge. Also the fact that the participants had wide interests in individual appliances strengthens the existing principle of disaggregated feedback – information must be available about independent devices and also about their different kind of uses. Although the informants were generally satisfied, there were problems associated with the “power meter as feedback” approach. In addition to the brief exposure to consumption data, the measurements were commonly made by one person only. This further begs the question how well power meters empower the whole family? The limitations and problems with this approach might be overcome with the help of future solutions. We could identify a number of issues that should be considered:

I. *The agency in learning about consumption was typically embodied in a single user*

II. *Physical installation of the sensor could be too difficult*

III. *Interpretation of the results was non-systematic and superficial*

IV. *Storing and sharing the results of the measurements was non-systematic*

Each of these factors could be addressed in upcoming applications. For the first point, allocating the agency of measurements *to the whole family* would be the preferable way to engage them further in the process of becoming energy aware. The devices used for measurements could, for instance, be accessible over the Internet, so that all family members would have an equal opportunity to perform experiments and access the results. This would be facilitated if there were multiple measurement devices. The second issue is related to development of the measurement devices. We should expect that the manufacturers, once aware of the problem, will in future invest efforts to produce smaller and more easily installable units, for instance using a radio protocol (such as Zigbee) to get rid of the wires, or conducting the measurements at the fuse box level.

The third and fourth issues could both be resolved by a novel feedback application. The application should not only provide direct electric power or consumption figures, but contextualize and present them in a way that the user can directly see how the device contributes to the total consumption of the household. This inevitably includes user evaluations about how much, or how often, they use certain appliance. An application that can *store* consumption and power data comes already very close to the possibility of *sharing* this information. An Internet-based interface could allow the user to give their friends and relatives access to their measurement data. This would greatly facilitate social comparisons, and lead personal evaluations of electricity efficiency or wastefulness. This data might also be anonymously contributed for creating a comprehensive database of electricity consumption, which could be a valuable resource for other people without this feedback system or researchers interested in typical consumption figures (but see the discussion about privacy issues in [24]).

Future Work

In this paper we have proposed a method to help designing energy feedback systems. This work is just a start and in future we need to gather more experiences and experiment with prototypes to see where we are headed. We believe this approach can be beneficial and we have presented examples how we could leverage present findings to guide the development of future energy feedback and ICT awareness applications. There are many difficult design questions remaining. For instance, what should the energy feedback system at large help people to achieve? We have already revealed some needs of electricity consumers, but we also need to see the big picture. Especially the motivations beyond immediate needs and signals should be acknowledged.

There are also many basic level research questions open for study. We bypassed the level of energy awareness and how the measurements affected it. There could be two distinct types of energy awareness: *general awareness* of the concepts of electricity and technology (the difference of power and consumption, stand-by mode, computer power savings modes, etc.), and *specific awareness* of the energy consumed by particular devices (television, fridge, etc.). If the energy awareness is to be taken seriously in feedback application development, then it needs to be evaluated as well. Also the phenomenon of attribution change, what happens after discovering your consumption, might be an interesting topic for future studies.

Many users believed that the acquired information would make a change in their consumption habit or future appliance investments, but did these change really occur? This could be investigated by a follow-up study, which could confirm whether the levels awareness and consumption changes. The practices of present power meter loaners could also be studied in more detail. For instance, we do not know for how long do people remember the results, or how do they keep track of them? How does awareness relate to consumption habits? In the present data, we already have evidence that increased awareness can actually increase the consumption, if the user for instance perceives stand-by consumption negligible by his or her own account.

Based on the current study, it is uncertain whether device specific consumption information alone can help to consumption practices for the better. The present results suggests that the power meter as it is currently applied, best suits the needs of a judge who is inspecting individual devices suspected “faulty” (what is the criterion anyway) or to be replaced. The needs of a wisdom seeker or detective are not supported so well because their goal is completely different. Instead of pronouncing a verdict to a single device, they are interested in understanding the big picture. Using the meter they do receive some consumption figures, but they could typically use some help in putting them together.

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