Exploring the use and appropriation of smart meters in the household

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This paper emerges from a user-research study done by the Université Libre de Bruxelles funded by, and in close cooperation with, one of the largest energy producer and suppliers in Belgium. This paper focuses on the planning, designing, and setting up of a qualitative study looking into the insights on the user interaction with a smart metering service to be deployed in Belgian households. The aim of the study was to understand if and how the product/service might be domesticated, exploring the interaction, uses and misuses of the online energy monitoring platform and the physical product (*smartplugs*), identifying the hot spots and windows of opportunity to improve the overall user experience, and thus, the service provided. The paper concludes by identifying some of the advantages and pitfalls of the smart metering service, and that of the Cultural Probes tool as a means of engaging people into the user research stage of the design and conceptualization process for products, services or systems for energy use-surveillance.

Key words: energy use, sustainable consumption, user research, cultural probes

1. Introduction

Sustainable development and energy consumption have become top priority subjects for most countries. Legislations and regulations are being introduced to tackle carbon emissions, and shift energy production, distribution, and consumption towards efficiency and low environmental impact. Although new, more efficient technologies are being developed, the increasing overall energy consumption casts a shadow in the savings achieved by efficiency improvement [1]. Governments and industry both have started to take action in the matter. Citizens themselves, as particular energy consumers, are being given more and more responsibility in the fight against global warming by being provided with tools to proactively reduce their energy use. Domestic day to day life has been identified as an energy dissipation scenario, where people are rarely aware of how and how much energy is consumed [2]. Alongside new technological developments, new campaigns and programs are being set into place to make people aware of their actions and their correspondent consequences, both to their budget, and to the environment, hoping that this would raise awareness and potentially produce a change in their energy consumption patterns.

Smart meters, as part of the bigger picture of creating consciousness campaigns (socioeconomically approach) and building smart grids (technological approach), have been recognized as a possible tool to reach the energy reduction goals, control emissions, and tackle global warming in national and regional levels [3]. In Europe, the testing and roll out of smart meters in the tertiary sector is progressively taking place as part of the European Energy Efficiency Plan [4]. Most European countries have already started to plan, test and bring into place

different rollouts and regulations for smart metering and their displays [5], as "*member States are obliged to roll out smart electricity meters for at least 80% of their final consumers by 2020 provided this is supported by a favorable national cost-benefit analysis*" [4:13, 6].

1.1 Consuming energy

Energy, being invisible and untouchable, is not consumed directly, but indirectly through many activities in the everyday life [7]. Hence, it can be difficult for people to make an automatic link between their actions and their consequent degree of energy use [8]. The result is people often opting for the quickest, most comfortable actions, without taking into account how their specific behaviors have an impact on the actual energy use, and ultimately, the environment. The assumption behind the smart meters is that, providing (near) real-time information of energy consumption will help people realize the potential savings that would occur for small and bigger changes in habits, technologies and appliances, allowing them to better control their consumption.

> *"Smart grids, meters and appliances will allow consumers to choose to permit their appliances to be activated at moments when off peak cheaper energy supply or abundant wind and solar power are available – in exchange for financial incentives. Finally, they will offer consumers the convenience and energy saving potential of turning appliances on and off remotely"* [4].

The overall concept and positive effect of smart metering in lowering energy consumption can stand, only if the user experience is flexible enough to adapt to the different uses and contexts in the diverse households and individual users [2, 9], and if its' modular structure can be updated to change along with new technology development.

Technology and society are more and more intertwined, and digital technology is evolving: both are dynamic fast paced: smart phones, tablets, and other portable appliances are elements of everyday life. People evermore connected to different contexts and environments, and smart metering services are taking advantage of this, by exploring on different ways that people can become proactive in their energy saving, so that (sustainable) energy use can become asocial norm [2].

When it comes to displaying energy use, beyond the use of new, more efficient technologies, knowing which information to show, how, when, with which frequency to show it, and whom to target it to, involves a complex design problem to tackle, one that is key to the success of these new services. Exploring and understanding people's context and emotions can help designers to come up with services, products, and schemes that offer experiences that have special meanings for the user: experiences that restrain or persuade certain behaviors, and can result in a decrease of resource consumption [10]. Energy consumption in the household is linked with a number of socio-cultural, financial, technical and regulatory aspects that have to be taken into account in the design process of complex systems, such as smart meters. The research described in this paper dealt in this problem, exploring the use and appropriation of a smart metering service to be then-launched to Belgian general public in the domestic sector. The following sections introduce the path of choosing and designing a user-centred methodology that would fit the academic and business demands of the project.

1.2 The smart metering service evaluated

The product, hardware and platform tested within this study were based on an existing service, which was slightly modified to give it the "*look and feel*" of the energy supplier company that funded the study, which ultimately placed the service in the market. This particular smart metering service allows the user to manage his domestic energy consumption through a set of individual plugs or sub-metering devices (here onwards referred to as *smartplugs*) that measure the energy consumption of the appliances they are connected to, with the possibility of remote controlling them through an on-line platform accessible via web or a smart phone. Individual appliance consumption is collected by the *smartplugs* in near real-time, data is gathered in a gateway connected to the users' wireless connection, and sent to a server within the utilities company, which makes it accessible to the user via the online platform (see Figure 1). Upon manual configuration of the plugs, main functionalities of the user online interface include instant feedback of power consumption, feedback of the status of the plugs (on, off, idle), access to consumption history (day before, week before, monthly), a total monthly cost of electricity in peak and off-peak timings, a possibility of creating on/off schedules, identifying and cutting off appliances in standby mode, calculating consumption measurements into carbon dioxide (CO_2) and local currency by using pre-defined algorithms.

Figure 1. Product/service from a user's perspective

2. Aim of the study and methodology

This study was carried out as part of a research project done in the Université Libre de Bruxelles, in close cooperation with one of Belgium's largest energy suppliers, also the funding party of the project. The overall aim was to better understand the use of smart metering devices in the home, with the aims of producing (re)design recommendations for a then-future product/service.

We wanted to go beyond the usual market research satisfaction questionnaire, and were looking into gathering genuine tangible and explicit insights from users. Having users test the product for a period of time, and report on it would help us understand the features that are regarded as useful, how they are used, the errors and frustrations that come out from the interaction, the overall effectiveness and embrace of that particular smart metering service.

The smart metering service/interface was tested within a group of 30 participating Belgian households, distributed between Walloon, Flemish and Brussels' households, from which a total of 12 successfully completed the here-described one-month study. The participants were recruited via an online questionnaire that allowed selecting user profiles that suited the then-already-set-by-marketing-team target user for the smart metering service. Figure 2 gives an overview of the main stages of this research project, which were brought together to

accomplish the bigger aim of the project, which was to understand the weaknesses and opportunities of the service in order to produce informed recommendations for its further development.

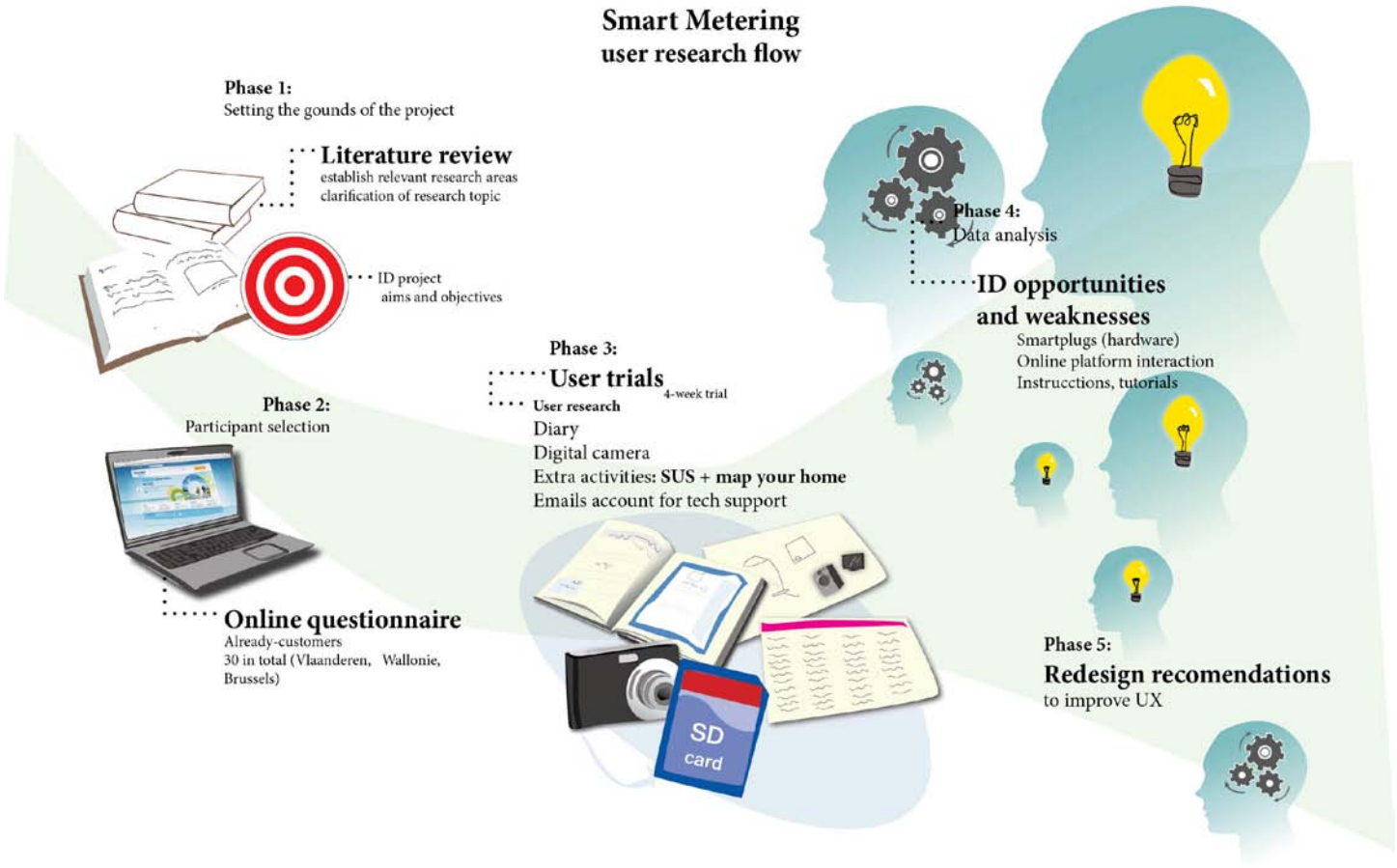

Figure 2. User research process

The chosen user research methods encompassed techniques from design for sustainable behavior, ethnography and usability testing practices, mainly due to the explorative purpose of the research, which looked into user experience in a private context (inside people's homes). Timing, budget, and the objectives of both the academic and business side of the project, resulted in a research approach based on a structured, self-documenting user research process, using an "*exploration pack*" based on Cultural Probes as the main data gathering tool.

Cultural Probes are a qualitative data collection technique particularly useful when investigating and exploring domestic life, especially in sensitive or intimate activities [11-14]. Cultural Probes are normally designed by the researcher and given out to the volunteers, encouraging them to do the data collection themselves. They are also a good way to collect qualitative information over a certain period of time and allow the researcher to study multiple locations simultaneously [13], which was particularly useful for this research, as the participating households were scattered over the country, and needed to be approached either in French or Flemish, for which 2 sets of packs, one on each language were prepared.

The exploration pack given to participants to keep record during the 4 week trial of the service consisted of a semi-structured diary, a digital camera with specific photo tasks, and a series of extra activities. All elements were

specifically designed to guide the user through various levels of interaction with the online platform, from the installation to the more complex functionalities of the service. With the help of these *fun* and *non-formal* activities, people were able to let their guard down and, we perceived, started forgetting that they were involved in formal research, giving way to truthful insights from their daily lives in the smart metering context.

The purpose was to help the user explore the (many) different energy-monitoring tools available with the service, proposing tasks and challenges to test the different possible interactions with the online platform. Figure 3 illustrates the main elements included in the exploration pack, which are further discussed in the following sections.

Figure 3. Elements of the exploration pack

The diary, semi-structured, was designed with colorful and visually attractive graphics. The contents were prearranged in four main parts, one to be completed each week. The diary guided people through the use of the smart metering service, starting with the very receiving of the package (to be ordered on-line in real life), creating an account, installing the *smartplugs* , etc. Then, people would be prompted to explore the different features, such as accessing real-time energy consumption (testing the web-path and the display); programming schedules, stand-by detection and cut-off; creating alerts for odd-consumption patterns, etc.). Using fuzzy and ambiguous questions and statements, the diary also intended to trigger reflection on the users' own energy consumption patterns, perceptions, and home-contexts that might implicate energy use.

Simple usability testing techniques, such as the System Usability Scale (SUS) [15], were adapted into the diaries, and presented weekly, to assess the user satisfaction of the smart metering service throughout the 4-week trial period. The SUS consists in a series of 10 statements on the product/service, some positively worded, some negatively worded, to which the user has to give a score from 1 to 5, the aim being to calculate an overall score for the user experience. By prompting the participants with these quick statements at the end of each week, we were able to have a better idea of how the learning curve and user-friendliness perception evolved during the trial time.

Additional resources were also provided along with the diary. A digital camera with a separated 21 photo tasks list –also prompted in the diary– was useful to understand the real context of energy use in the home, the domestication (or repelling) of the hardware involved, and also gave a more personal touch to the user "personas" that the researchers could imagine upon analyzing the materials.

Along with the diary, which lasted the whole 4-week period, during the first week of the trial, a first extra activity was put in place. Based on the Microsoft *product reaction* cards [16], participants were given a set of 115 words/adjectives (40% with negative connotation) and asked to mark the ones that best described their impression upon the first uses of the service. The given words covered a wide variety of dimensions of the product, mainly to measure its degree of desirability of the Smart metering service upon the first impressions.

A second extra activity consisted in *mapping energy in the home*, which asked people to illustrate in an A3 board the appliances they own, and their distribution in the home. People used pencils, colors, and collages, and the results brought interesting insights in people's perception of their own energy use. They often realized they had more energy using appliances than they thought, or that they were clustered in particular placed of the home.

3. Returns on the exploration packs

From the 30 initial participants, 12 completed packs were returned in total, with equal distribution among the 3 studied regions (Brussels capital, Flanders and Wallonie). The returned exploration packs were source of rich qualitative data that brought to light a series of patterns of behavior, issues, questions, confusion, likes and dislikes of the smart metering service (platform + *smartplugs* + functionalities).

The insights generated served to illustrate different issues in usability and the overall user experience, and set the grounds for the (re)design recommendations. **Figure 4** shows an example of the returns from the participants: activities tended to be well completed, with care, particularly the *map your home* one. People communicated well through the diaries and in general found useful the *discovery process* of the different tools and functionalities by using "challenges" to complete and report on. The photo tasks helped, during the analysis stage, putting into real context the use of the *smartplugs*, identifying issues within the shape, weight, use of *multiplugs* and electrical extensions, situation of the gateway within an already-crammed office, etc.

Figure 4. Example of a returned exploration pack

After the exploration packs were returned, a qualitative cross analysis of all elements (diaries, activities and photographs) was carried out between the Brussels, Walloon, and Flemish participants' returns. All information

was categorized into hardware issues (the *smartplugs* and the communicating gateway), and online platform issues (form, content and functionalities). Insights were further analyzed and categorized around a set of attributes:

- *Familiarity* (it is easy to operate a tool you're already familiar with, rather than one that you've never used before)
- *Responsiveness and feedback* (confirmation to the user that the action (click/upload data) he has taken has been effective).
- *Intuitiveness and efficiency* (related to familiarity, the service is consistent in terms, displays, buttons, etc.).
- *Internally consistent* (so that the user knows where to look and what to expect. Related to the functionalities, but also a visual design perspective)
- *External consistency in functionality* (operates similarly to other products the user might be familiar with).

4. Early conclusions on people/s expectations of a smart metering service

The experiment was in line with previous studies that state that nowadays, people have evermore electric appliances, and rarely know how (much) energy they consume. Most participants mainly wanted to gain a vision of the energy usage in their homes, and were eager to measure different appliances, in order to confirm (or infirm) their preconceptions (*does my fridge really use that much?, how about my TV in stand-by mode?, does the washing machine consume significantly less if in eco-mode?*). Getting rid of vampire consumption, comparing appliances' consumption, and being able to remotely control their appliances, were also features that people confirmed that are expecting to find a smart metering service.

All our participants seem to recognize that there are always things to improve/decrease energy consumption in terms of behavior and user interaction with appliances.

Those who considered themselves responsible/energy aware/energy-economical seemed to be interested in doing even better on that subject, and those who considered themselves neglectful/careless acknowledged that they *should* make an effort and try to behave more responsibly (though again, comfort seems to get in the way of true change).

A Smart metering service targeted to these two main categories of users, should be flexible enough to satisfy the needs and goals of these different users:

- The *neglects* (but with remorse/will to change) -> who offer great potential to change/save; and,
- The *already-doing-an-effort* users, who want the tools to better understand their energy use, and reduce it.

4.1 Exploring and documenting the smart metering service

The diary and other activities' returns gave an overall idea of contentment with the use of the Smart metering service. This general perception was first observed with the *product reaction activity* included in the exploration pack –based on Microsoft's Product reaction cards method. The result of this activity was a *worldcloud* (Figure 5) which provided an insight on how people perceived the user experience in the early use-stages, and helped setting the axes to base on the analysis of the rest of the data gathered. After all, it is sure that first impressions can have

an important impact on the development of a product/user relationship. The most prominent words (the ones with the higher count) that arose from this activity were *useful, convenient, accessible, innovative*. Terms like *time-consuming* and *inconsistent* also came up, though in a lower count, as so did *slow* and *hard-to-use.*

Figure 5. Participant's first impression word-cloud

It is clear that people's first impression on the Smart metering service was rather positive, with some hiccups that were later better defined with the help of the diaries. Participants seem to think that being able to visualize and understand consumption is quite interesting, but have doubts about the long term usage of the smart metering service.

> *"It is cool during the installation and the first uses, but the excitement diminishes over time"*
>
> *"I was curious on how much energy certain appliances were using, but after a couple of weeks, once I got to understand that, I really didn't use much the online interface".*

Only half of the participants chose to hang on to the smart metering service after the end of the four-week study, even though this would be free of any activation/monthly fees (offer exceptional to participants/ new customers would have a start payment and a small monthly fee for the service). This sets place to a deeper question on how to design the smart metering as an embedded part of people's lives.

4.2 Use of the exploration pack

Regarding the actual data collection methods used, participants showed an interest in reporting issues and document the use of the *smartplugs* with the ensemble of elements provided. The photo tasks proved to be an insightful complement to the information gathered in the diary. The pictures helped the researchers and the marketing team to understand what really happens once the product is bought and installed. Interesting issues that arose during the trials were highlighted by the participants with the aid of the diary, and illustrated by using the

digital camera provided; completing the narratives and giving a whole picture of the circumstances in question (see Figure 6). Diaries and photos worked well together to identify specific problems with the hardware and some issues with the visual display of the online platform (i.e. navigation menu confusion, glitches in the mobile application, etc.).

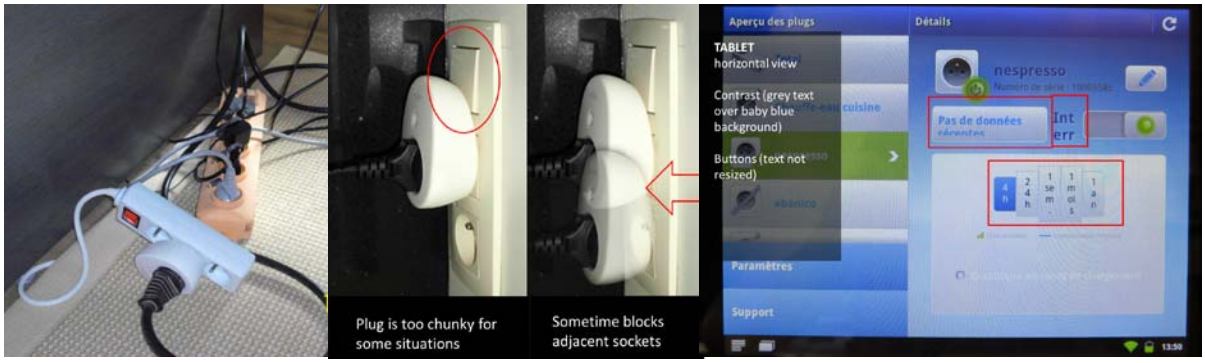

Figure 6. Example of photos returned by users

5. Conclusion and discussion

Smart metering services enhance customers' and service suppliers' ability to monitor, control and predict energy use. From the utilities side, sub-metering is a key to the development of effective and efficient smart grids. For the common user, it can be a powerful tool to understand and be educated on their energy use, to control it, and develop practices that aim to minimizing energy waste.

Integrating the smart metering with information and communication technologies (ICT), and making energy monitoring available remotely via tablets and cell phones has great potential and has an attractive pitch to users. Nevertheless, the risk of falling into the "*yet another gadget*" realm should be tackled by a flexible design, which would avoid forcing a new (free or paying) service on to users that ends up consuming time (money) and effort, and not so much provides actual solutions. Understanding how the smart metering usage evolves (learning curve, different uses for different people in the household, different reasons behind wanting to get involved in smart metering) is key to designing progressive and customizable services that can truly have a beneficial short and long term impact in energy consumption.

The *exploration pack* trial, based on Cultural Probes approach, provided interesting insights of the direct interaction with the service, and gave a glance at the diverse contexts of use in which these services (hardware and software) would potentially be used. These can be directly taken into account in the design process to improve the user experience.

The diaries helped to test the complex service in a somewhat tight timeframe: users had the opportunity to test and pilot a smart metering service in four weeks. They were guided through the (assumed) most important functionalities of the service, challenged to perform certain tasks, to then evaluate them in the diary and different activities. At the same time, the photo tasks helped to pin the issues raised in the diary to the real environments and picture the context in which they happened. During the analysis and recommendation building phase, the elements from the exploration pack acted as spring- boards to identify further improvements to the service.

Ideally, though not possible in this project due to timing and funding constrains, a series of focus groups with the participants would be carried out in a post-analysis phase, to confirm assumptions, further develop the design

recommendations, and open a door to a series of co-design workshops in which users could actively be involved in the improvement of the flexibility/customization of the different functionalities.

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