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PLEASE MIND THE BALANCE. USING DESIGN TO ENGAGE HOUSEHOLDS IN THE SMART GRID SCENARIO

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ABSTRACT

In the future Smart Grid scenario, load balancing is considered one opportunity to cut the peaks on the electrical grid, in order to reduce the negative effects of electricity production on environment. Load balancing can be performed by households, who actively shift their electricity-consuming activities to reduce peaks. Therefore, household customers need to become "active" concerning their electricity use. As smart grids are implemented into society, there is an increasing need to know how the transition into this new role should occur. There is also a prevailing view of households as rational mini-energy managers. The paper challenges this view by using a Research through Design (RtD) approach to explore the changing roles of households in the smart grid. As a first step, we performed 10 interviews with households. We used the interviews' outcomes to set a number of principles that guided the design of solutions aimed to encourage users being more flexible in their electricity use. The creation of emotional experiences was considered an effective direction to engage users in the smart grid scenario. With a RtD approach we developed four concepts, which were reflected upon in a focus group and further developed into two main design concepts. We describe those steps and how the concepts embody the knowledge we gained from the design and research activities and future possibilities and scenarios. This work gives insights about how design practice may be used in an explorative study to serve different goals, and how it can contribute to a wider explorative and interdisciplinary research.

Keywords: Research through Design, Smart Grid, Emotional Design, Sensory Experience, Multimodal Ambient Displays

1 INTRODUCTION

Change of daily practices is pointed out as crucial in the transition to a more sustainable society. This applies to areas such as transportation and consumption, but it also applies to the way in which we use electricity. New "smart" technology is directed towards making the energy system more effective through peak load management, energy conservation, and local production of renewable energy. The term "smartness" denotes the integration of information and communication technology into the power system. This future electrical grid will be more sustainable than the present one, partly because it will allow for the integration of renewable energy sources.

In connection to the implementation of the smart grid, households' roles are expected to change (SG3 Roadmap, 2010). The most dramatic changes are directed towards households producing their own electricity and towards balancing electricity-consuming activities over the hours of a day and night (Katzeff and Wangel, 2014). As smart grids are implemented into society there is an increased need for knowledge in how the transition into this new role is to be taken. For instance, the Swedish committee directive to the Swedish smart grid council reflects a view that household customers need to become "active" concerning their electricity use – "Active customers**"** is actually the most frequent expression about people in the Swedish smart grid directive.[1] Central questions regarding households circle around how electricity consumers may become more active and how they may "obtain relevant, easily accessible and comprehensible information about their electricity consumption and costs, which they may act upon" (Katzeff and Ramström, 2014). The questions address the issue of load balancing of electricity consumption in relation to economic incentives and in relation to increasing households' knowledge about their own consumption through feedback. The lack of addressing other incentives than economic is striking in the committee directive.

In the present paper we challenge the position regarding households' incentives to reduce and load balance electricity consumption as purely economic. We also challenge the position of regarding households as mini energy managers. In accordance with Strengers (2014) we view households' electricity use as embedded in a social context with dynamic social practices. Strengers criticizes a dominant set of design approaches aiming at effecting change of energy use for neglecting this context. This leaves "a discourse based on assumptions of change coming about mainly through provisions of data and technology" (Strengers, 2014). By this approach we risk losing sights of the day-to-day lives we're living, including dirty dishes, piles of laundry, need for pleasure and cultural activities, and the pressure of combining work with taking care of kids and elderly parents.

The present paper aims to offer alternatives to the view that numerical data on electricity consumption play the key role for changing roles of households. It presents a study based on assumptions that everyday practices are at the centre of households' attention – not electricity use. The study used a Research through Design (RtD) approach to explore the changing roles of households in the smart grid. The primary question posed was: What factors will motivate households to balance their electricity load in the future electric grid? Rephrasing this question with a stronger emphasis on everyday activities, this became:

In view of the social context of households, what factors will motivate them to move their electricity consuming activities in the future electric grid?

This major research question was approached by first examining households' views on moving electricity-consuming activities to other times during the day and to see how the question could be further explored through a RtD approach. The examination of households was also intended to guide the process in breaking down the primary research question into more specific areas.

The results of RtD processes can be twofold. (1) The design artifact itself embodies the knowledge of the design and research activities leading up to it. (2) The design artifact is a tool for creating and investigating future scenarios as they could be. The designed service, experience or product therefore embodies that possible future, which can be explored by further investigations (e.g Frayling 1993, Koskinen et al. 2011, Zimmerman et al. 2010).

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[1] http://www.swedishsmartgrid.se/

Please mind the balance. Using design to engage households in the smart grid scenario

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There is a debate within the field of Human-Computer Interaction (HCI) regarding the ways in which Research through Design can and should develop. Zimmerman et al. (2010) suggest that the approach needs to formalize and agree upon ways to document the process, results and its production of theory. Gaver (2012), on the other hand, argues that a formalized approach is limiting and risky and suggests that rich artifacts, in themselves, are the results from which we can gain knowledge. According to Gaver, a distinguishing quality of the RtD approach is its aptitude for exploring and speculating.

In this paper we first describe interview data collection process by interviews which guided the design for the changing role of households in the smart grid. Following, we describe the steps of the design process of ideation, synthesis and conceptualization leading up to four design concepts. Those were presented and discussed with expert users in a focus group and were further developed into two main concepts. We consider the final concepts as the result of our RtD activity as they embody the knowledge we gained during the process.

We conclude by briefly outlining how these artifacts can be used as a tool to investigate future scenarios and to raise deeper questions about the future of smart grids.

2 METHOD

Based on the research question identified, two different approaches were used to inform direction and explore the households' active role in smart grid. The methodology comprised qualitative interviews and an RtD process.

First, interviews with households were performed to investigate the general research question and assess the households' openness towards taking on a more active role in their use of electricity. Secondly, the issue was explored by performing an RtD process, which used the design activities and its outcomes as research tools. The scope of the RtD process was to design concepts that encourage users to perform a more flexible use of electricity through modifying their own daily patterns of electricity-consuming activities to reduce peaks. The two methods were interdependent as the interview results fed into the design activity.

3 HOUSEHOLD INTERVIEWS

Semi-structured interviews were conducted with ten households recruited through a local business network. Five households were families with one, two or three children living at home. Six households consisted of couples. Three of those had children that moved out Eight households lived in large houses, one on a farm and one in a town house. The informants aged 36-60, six were women and five were men. The households got a cinema gift card as compensations for their participation. Interviews took between 1 and 2 hours. Questions were open-ended and addressed the following themes: Attitude towards environment and energy; domestic activities; motivations for change; and flexibility of activities. Interviews were recorded and transcribed and transcripts were analyzed.

3.1 INTERVIEW RESULTS

The informants reported that they could be rather flexible in their use of electricity. Some practices were non-negotiable (e.g. food preparation) but some others were not strictly connected to a specific moment of the day. To be able to plan their activities differently, the informants required information about the current and future conditions of the electrical grid. For instance, they should know in advance during what periods of the day they should avoid to use electricity. They would need to know how long that period would be a couple of days before but they also needed a reminder a little time before that period starts.

Also, households prefer to be actively in control of the electricity use, but in a soft way, without being told what to do and when. It also emerged that pleasant, sensory and emotional experiences could support their engagement in the smart grid scenario. The informants would not want penalties as feedback of their unsustainable behaviour. Thus, there was an emphasis on soft imperatives serving as advice rather than requests.

4 DESIGN PROCESS

Based on the above results, a set of principles to guide the design process was defined. The design should:

— Offer information about what periods during upcoming days are unsuitable to use electrical appliances according to the condition of the electrical grid.
— Give information before the period starts
— Engage users at the sensory and emotional level, targeting their motivations, and to encourage users to adapt their activities to the electricity availability.

In order to focus on the use of electricity in a social context by more than one person, the design should avoid screen-based interfaces and should focus on the use of tangible products and ambient sensory media to display information. To explore the research question and to fulfil the design requirements, the design process was divided into different phases of design, selection, testing, and refinement of ideas, generating four concepts. The process and outcomes are presented below.

4.1 IDEAS GENERATION AND EVALUATION

The first phase consisted of a brainstorming activity. This creative session aimed to propose design solutions able to support behaviour changes by engaging the user at the sensory and emotional level. In order to generate ideas, the design team followed two methods: the Sensorial Brainstorming (Curedale, 2012) and Forced Association (Osborn, 1963). The brainstorming sessions resulted in 53 basic ideas. An interdisciplinary team of four researchers evaluated the ideas on the basis of the following criteria:

— Engagement: whether the idea was emotionally engaging
— Persuasiveness: whether the idea could motivate users to change their behaviour
— Feasibility: whether it was practical to implement the idea within the time frame of the project and whether available technologies supported the development of the idea

— Strength: an overall evaluation on the effectiveness and the engagement potential of the idea.

Next, the eight best-ranked ideas were further developed during an internal workshop. Subsequently, four ideas were selected and refined to be tested. A brief description of the four concepts follows.

4.2 DESIGN RESULTS

For each concept, we underline in what ways it responds to the design principles and what limitation it has.

4.2.1 ***The Energy Tapestry***

The Energy Tapestry is a haptic 24-hour clock strip, activating a sound when touched, in order to inform about the upcoming grid states (figure 1). Each hour is represented by a material patch, which allows a material memory of the hours. The different sounds emitted when touching the patches communicate the state of the grid for each of the upcoming hours: good, medium or bad. The sound can be both abstract (changing in roughness) or realistic (three different chirping birds: pleasant, neutral and unpleasant).

Figure 1. Early prototype of the Energy Tapestry concept.

This concept offers information about the grid state by sound signals. Its engagement potential lays in its unusual way to display information by sound, and in the fact that the user has to touch material patches to get data. The concept enables users planning 24 hours ahead of time but does not provide reminders of when an unsuitable period to use electricity is coming up.

4.2.2 ***The Sound Wheels***

This concept consists of two toothed wheels hanging on the wall, which rotate at different speeds (figure 2). One wheel represents the household's real-time consumption and the other depicts the grid state. When the consumption passes the available energy, the 'teeth' of the wheel strike a thin metallic strip that creates a repeating mechanical sound, to alert the user. Users should try to match the rotation of the household's consumption wheel with that of the available energy wheel to avoid an unpleasant audioscape.

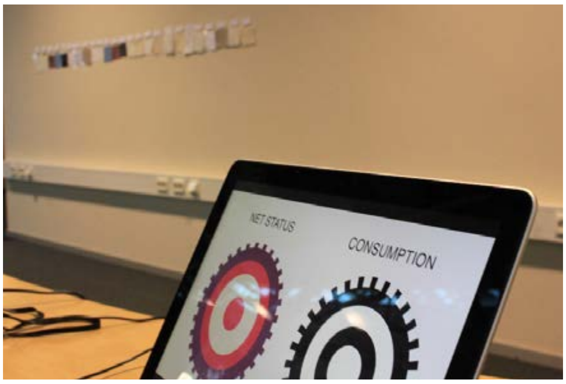

Figure 2. Early visualization of the Sound Wheels concept

The sound produced by the wheel delivers instant information about the condition of the grid in relation to the household's electricity consumption. Being an ambient feedback, sound can immediately gain the user's attention. Moreover, engagement can be generated by the challenge of keeping the consumption under the critical threshold, which turns into a sort of game. However, no information is given to users about the future grid states, the concept focusing only on feedback about the current situation.

4.2.3 ***The Water Amplifier***

The water amplifier is a real-time meter of the energy used by the household. This meter uses falling drops to signal the amount of electricity used real time (figure 3). Drops have different colours according to the grid state, so that in the end of the day it is possible to see the different layers of liquid colours, as a general feedback of the user's behaviour. The drop rhythm shows the amount of energy used real time: the quicker the rhythm is, the more electricity is being consumed. The sound of the falling drops is amplified in the house, so the message is conveyed through both vision and sound. As the artifact shows real-time and past consumption only, a mobile app has been conceived to communicate future states of the grid, to offer a possibility to plan activities.

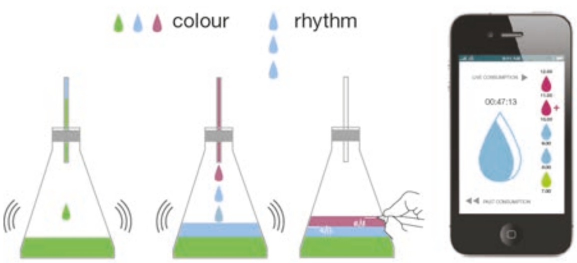

Figure 3. In the Water Amplifier the amount of drops signals the current use of electricity

In this concept, users can be engaged by the physical representation of electricity consumption by liquid drops. Colours are used to display the current grid state, while sound gives a feedback about the household's consumption. In this concept, planning is made possible by the support of an external digital application.

4.2.4 *The Peace Hours*

In the Peace Hour concept, the focus is on turning the negative hours (when it is unsuitable to use electricity) into something positive. Indeed, the "bad" hours are highlighted as positive hours that users can exploit to relax (peace hours). When a 'peace hour' starts, it is communicated by the sound of a breath and by a good smell released in the environment, which indicate that it is time to take a break and to relax. Users can also see the grid state for the upcoming 24 hours by LED lights on a clock (figure 4). When an hour is surrounded by three lightened circles there will be much energy available during that hour. Only one light up circle indicates a 'bad hour'. This gives a visual display of the grid state. The center of the clock has a lid that could be opened to activate the smell and sound feedback.

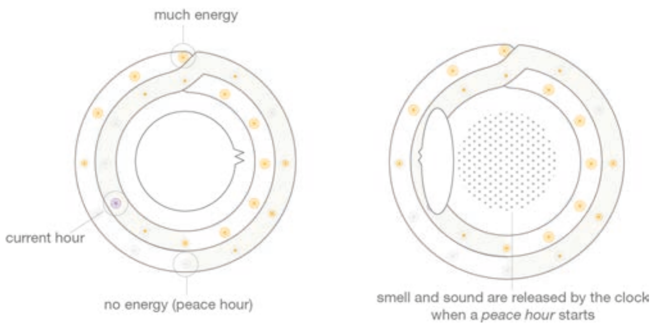

Figure 4. Illustration of the Peace Hour concept

In this concept, sensory engagement is the main element. Sound and smell are used to generate pleasant signals that alert the households of upcoming negative time spans. Therefore, they invite users take some rest to not overload the grid. The object supports the planning activity, by the clock, and let the user decide the amount of information to receive (by opening or closing the lid).

5 INTERNAL FOCUS GROUP

The selected ideas were tested in a focus group with other design researchers. Rough prototypes of the ideas were created, in order to have physical objects to test and reflect upon. The aim of the focus group was to use the design ideas to empower dialogue around the issue under study and to assess the concepts in order to identify relevant issues design should face to generate engaging and effective solutions to encourage households being more flexible in their domestic electricity use.

The group was composed of experts within the field relevant for the design of the concepts. The group's knowledge was expected to render deeper insights and useful suggestions on how to improve the concepts. The participants were experts in engineering, industrial design, interaction design, experience design, psychology and anthropology. All experts had long experience in the energy, design and/or the HCI field.

The participants were divided into three groups mixing different backgrounds. The four concepts were presented at separate stations. During the presentation of each concept, the leader of each station presented the prototype and a scenario story to introduce the idea.

5.1 FOCUS GROUP RESULTS AND DISCUSSION

The focus group resulted in insights about the design concepts' possible effects on the user experience. The initial research question was reframed and design directions were specified. Overall, all four concepts were considered engaging. Informants reported that the physical presence of the artefacts could make people *aware* of the need to change their habits, because it reminded the users of their actions by its mere presence, and by the strong activation power of the sensory media.

The Energy Tapestry was not considered practical, because "*you would not go and touch it every day*". It was perceived as an art installation, rather than an object that could fit a domestic environment. Although they felt encouraged to explore the object because it was a fun interaction, it would not encourage actual changes in people's attitudes. This example is paradigmatic, because the design team saw great potentials in this idea. However, there are obvious limitations for domestic usage. The team reframed the initial design principles, and found out a new need for users: the information about the electricity grid state should be available without the user having to look actively for it. Another important element that emerged from the focus group is that the sensory medium could strengthen or weaken the link to the environment. For instance, the sound of tweeting birds in the Energy Tapestry was preferred to abstract sounds. Users explained that chirping sounds created a more engaging experience, because the sound of birds was more easily associated to nature, and this let them reflect about the importance of adjusting their behaviour on the electricity grid state to save environment. On the other hand, using water drops was misleading, because it created a wrong metaphor (i.e. saving water instead of electricity). Again, in the Peace Hours, they would prefer a consistency between the sensations (smell, sound and lights) and the product aesthetics. According to participants, the stronger the metaphor is, the more engaging the concept will be perceived. They also suggested that creating metaphors to environment and nature by the use of object's aesthetics and sensations could reinforce engagement and increase attention.

5.1.1 *Concepts refinement*

In the refinement and selection process, results from all previous phases combined to move the process forward by breaking down the primary research question into more specific questions. More specifically, three central themes emerged in relation to this question. They were: Attention, information delivery and type of motivation to actual behaviour. Further sub-themes consisted of specifications of the central themes as shown in table 1.

Level one themes	Attention	Information delivery	Motivation to behaviour
Level two themes	Soft (peripheral) rather than hard (central Advice rather than request	Planning: 1-2 days ahead, duration of non-use of electricity Reminder: A few minutes before	Encouragement rather than punishment Pleasant sensory engagement (by multiple sensory modalities) Emotional connection to environment

Table 1: Emerging Themes regarding motivating factors for moving electricity consuming activities

The Peace Hour concept was redesigned, to create consistency among the different elements of the concept, by connecting the aesthetics and the sensory media to the message. The main concept was shifted from ‘personal wellbeing and relaxation’ to ‘being in balance with nature’, to keep environment as the main incentive for behaviour change. The concept was also renamed Peacetime. It was decided to focus the physical artefact just on the current “peace time”. The possibility to plan activities around future peace times was incorporated into a mobile application that supported the physical artefact. The final concept (figure 5) consisted of a crouched nest hanging from the ceiling and a set of wooden birds to be placed in the house. The nest moves down when a Peacetime starts. Fragrance is also released in the environment at the beginning of each Peacetime. Three different sounds of chirping birds, varying in length, signal the upcoming peacetime 30 minutes, 15 minutes and just as the peacetime starts.

The sound wheel concept was developed in its aesthetics and function to support a more cognitive expression in its sound and visual expression. The Sound Wheels concept (figure 6) was also integrated with a dedicated application communicating both the current electricity consumption and the future states of the grid. In the end, the most complex information, related to future grid states, were conveyed by conventional displays, instead of the physical objects, in both concepts.

Figure 5. The Peacetime prototype consists of a crouched nest hanging from the ceiling and associated birds

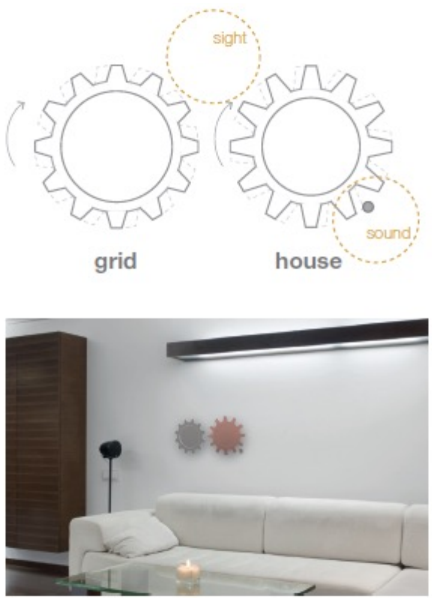

Figure 6. The prototype of the Sound Wheels

6 GENERAL DISCUSSION

In addition to deepening the general and initial research question, the design activity helped to discover new needs and expectations for households in the smart grid scenario. These needs and expectations were, then, used to discuss, detail and refine the design principles identified at the beginning of the research, which stemmed from the interviews' outcome. The design process and the creation of the artefacts generated insights, which at the same time were substantiations of the designers' tacit knowledge. In this sense, the resulting artefacts represent the type of "epistemic objects" referred to by Rheinberger (1997) and Mareis (2012). The artefacts' appearance and sensory stimuli were used to create metaphors and connections to the environment and nature. This was found to be useful to leverage on households' motivations for being more flexible. Also, there was a clear benefit of adopting an RtD approach because of the explorative and interdisciplinary character of the study.

First, by designing and making, it was possible to envision otherwise unforeseen possibilities. It was also possible to suggest innovative solutions responding to the identified needs of households. The design concepts themselves add to knowledge in the research area being studied, by acting as "epistemic objects" (Rheinberger, 1997, Mareis 2012, Gaver et al. 2012), which embody solutions to a given problem. Their function and aesthetics are all results of an inquiry process from which others can gain knowledge and build upon.

Secondly, the design concepts convert into tools for researching future scenarios such as the one the role of households in load balancing. Indeed, building and testing ideas can enable dialogue and discussion among users and researchers, which in turn can help to:

— test the relevance of the initial research question to eventually reframe it and identify more specific sub-questions;
— get insights and basic knowledge about users' reactions, needs, desires, and attitudes, that inform and feed the design process further. In the reported, by designing, prototyping and testing ideas, practical design guidelines emerged to develop real solutions able to engage users in the smart grid scenario. The findings emerged by this activity could help other designers develop solutions in similar fields.

7 CONCLUDING REMARKS

The study reported in this paper has challenged the idea of households as rational mini-energy managers. The RtD approach allowed us to critically examine the field of load balancing and smart grids. The resulting artefacts reflect images of households very unlike those of the rational energy manager portrayed by the energy industry. Our designs reflect images of households where electricity use is a background priority of everyday life rather than a primary interest. Also, the households consist of multi-dimensional human beings with other sensory modalities than only the visual. We also see our documentation of a design and research process resulting in RtD artifacts as a contribution to the development of RtD. In accordance with Gaver (2012), the RtD approach allowed us to openly explore the research questions as well as manifest the results in new, conceptually rich artefacts.

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