Coffee Maker Patterns and the Design of Energy Feedback Artefacts

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ABSTRACT

Smart electricity meters and home displays are being installed in people's homes with the assumption that households will make the necessary efforts to reduce their electricity consumption. However, present solutions do not sufficiently account for the social implications of design. There is a potential for greater savings if we can better understand how such designs affect behaviour. In this paper, we describe our design of an energy awareness artefact – the Energy AWARE Clock – and discuss it in relation to behavioural processes in the home. A user study is carried out to study the deployment of the prototype in real domestic contexts for three months. Results indicate that the Energy AWARE Clock played a significant role in drawing households' attention to their electricity use. It became a natural part of the household and conceptions of electricity became naturalized into informants' everyday language.

Author Keywords

Interaction design, sustainability, energy use, ambient display, households, user study

ACM Classification Keywords

H5.m Information interfaces and presentation (e.g. HCI): Miscellaneous

INTRODUCTION

People's behaviour is commonly pointed out as an important factor in reducing problems caused by increasing levels of CO_2 emissions. Households are responsible for approximately 15-20 percent of total energy related CO_2 emissions and this proportion is expected to keep rising [3]. Since the seventies, the use of electricity in Swedish households has increased with about 50 percent and behaviour patterns are considered responsible for a major part of this increase. A change in households' energy related behaviour might, thus, contribute to a more sustainable society.

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In focusing the role of design and technology for promoting energy efficient behaviour, the human computer interaction community may play a significant role. Sustainability in interaction design has recently been pointed to as an important field of research [4]. Even a low-tech experiment from the 70's – The Twin Rivers project – illustrates the role of interaction design for encouraging energy efficient behaviour [17]. Although its major focus is not on design, it lifts issues on visualization of feedback and how these issues relate to a reduction in electricity consumption. Participants in the study received feedback of their electricity consumption from a manual presentation each afternoon on their kitchen window. Results showed that households receiving feedback reduced their electricity consumption up to 15.7 percent. Feedback decreases the experienced gap between the production and consumption of energy. Electricity is produced in large-scale power plants and consumed in the small scale through electrical appliances in the daily life. Before the production became centralized, people had a more direct relation to the use of energy. For example, through the very act of chopping wood they experienced the effort involved in the production of energy for heating and cooking [5].

Effects of feedback on energy conservation behaviour have recently been the focus of a considerable amount of research [7][6]. Darby concludes that the norm for savings from direct feedback – from a meter or an associated display monitor – ranges from 5 to 15 %. In addition, a recent public survey conducted by the Future Foundation in the UK for LogicaCMG found that 82% respondents would consider changing their energy behaviour if they had a "screen telling the homeowner how much energy they are using at any one moment" [13].

Automatic Meter Reading

State agencies are now implementing a set of strategies to reduce excessive electricity consumption. Promoting the development of energy-efficient technologies are important parts in this work as well as information dissemination and fostering behaviour changes. With a focus on the latter state agencies in the UK and in Sweden, are now implementing legislation resulting in new types of electricity meters with Automatic Meter Reading (AMR). With the AMR data, measurements on electricity consumption are sent to the

power company regularly. This yields adequate bills based on actual measurements. Most households in Sweden now have AMR meters installed. Some of these have displays showing the household how much electricity it is consuming. The underlying assumption of introducing this technology into the home is that the feedback it provides will lead to behavioural changes and reduce energy consumption. However, research on the presentation and design of feedback to fit in with everyday life of households and to behavioural change are still at its early stages.

Despite multi million Euro investments in AMR meters, only little effort has been made to reflect upon the design of the interface to the user. Most energy feedback interfaces are designed from a traditional engineering standpoint. A common method to provide feedback to users is, for instance, that electricity companies now offer personal websites where customers may log on to. The key feature of the web-based solutions is that they provide *aggregated overall data on the consumption of the home* and this data is visualized with a histogram to show when consumption is low or high. More advanced systems provide real-time information on the consumption, user configurable alarms, billing information, payment services, details by floor, room, appliance, circuit, or utility and they can even provide automatic calculation of carbon footprint and have trend analysis and historical comparatives. However, these advanced visualizations are still very rare but are expected to be more common in the near future. A clear disadvantage with the web-based approach is that users must log in and access the information via the Internet, which is an extra barrier to the use of the service.

To measure energy used by individual appliances, homeowners can today purchase plug-in electricity meters. These devices are basically placed between the power inlet and a home appliance and they provide both real-time readout of the electricity consumption (kW) and measures consumption over time (kWh). They can aid the user by identifying major energy consuming thieves as well as devices that consume much standby electricity.

Ambient interfaces to energy feedback

This paper focuses on the design of ambient interfaces; a class of user interfaces bridging the gap between the physical and the electronic world [20]. Ambient devices – also referred to as calm technology [19] – embed digital information into the objects and environments that surround us. These interfaces provide the user with information in the form of sound, air pressure, motion, light, smell, and other media that complement the full range of our human sensory modalities. They are designed to work with our peripheral senses, where they provide continuous information without being distracting or obtrusive. One example of this is the Power Aware Cord [11]. It is a re-design of a traditional power strip that displays the amount of energy passing through it by glowing patterns produced by electroluminescent wires moulded into the transparent electrical cord. Figure 1 shows the Power Aware Cord. However, since ambient displays are fairly new interface technology, there are few devices available on the market. One energy related example is Wattson, an electricity-monitoring device that has been praised for its style and simplicity [8]. By clamping an external wireless sensor to the home energy supply (mains fuse box), this device shows the running total in real-time of the wattage output as well as the cost. This is represented in a digital readout on the Wattson display or with ambient light.

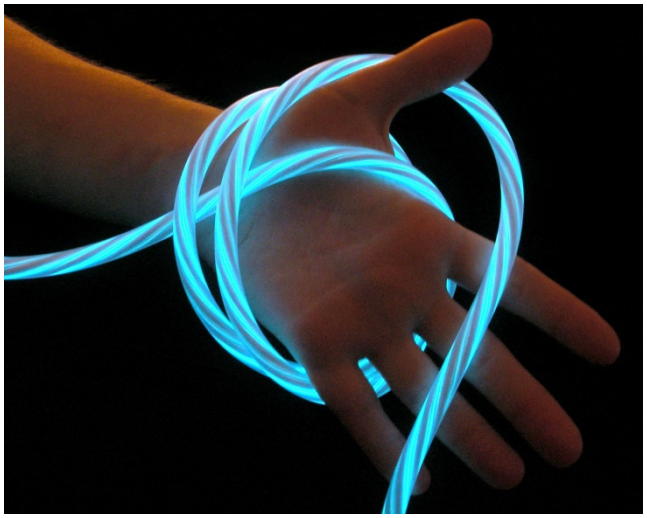

Figure 1: The Power Aware Cord

In a recent study, Routarinne and Redström introduced two different prototypes of ambient energy artefacts in the homes of eight different families to see how they where domesticated in households [15]. Households' responses were then compared with the designers' original intentions of increased energy awareness. One display was the "Energy Curtain" and the other the "Erratic Radio". How users would receive these prototypes and how these new objects would fit into the ecology of the household were other questions addressed. The open-ended character of the domestication probes put the respondents' mind to work in trying to make sense of how the new objects should be related to and used [10]. Results showed that users reflected upon their values and attitudes in a way that highlighted the complexity of saving energy.

The present study

The present paper approaches the problem of behavioural change from a design perspective. Previous research shows that providing people with feedback on their energy behaviour under appropriate conditions will lead to a reduction in energy use [7][1]**.** However, little is known about specific characteristics of these conditions. For instance, how do issues of *information presentation* relate to user context and individual differences between users? How do *physical attributes and location* of the actual display relate to users' everyday context of users?

The paper discusses a novel design for visualizing electricity consumption – the Energy AWARE Clock (in the rest of the paper referred to as EAC). By this, the paper aims to contribute to knowledge on the design of interfaces to the electricity system in a home environment. To better understand the design space for this class of artefacts, the user study explores users' behaviour when living with EAC in their homes for three months. The reported work is carried out within a research-through-design framework [9]. Important in this process is the *concrete hands-on work with prototypes* that foster reflection and new ideas [16].

METHODS

The following sections describe the design process intended as an instrument for exploring psychological and social dimensions of household energy consumption. Thus, the goal of the design process is twofold:

1. Insights into the nature of psychological and social mechanisms of households' relationship to energy consumption in their home.
2. Creating a concrete example of an artefact substantiating and exploring identified critical aspects of this relationship.

These two goals are interdependent. The creation of the prototype is central and it plays an active role before, during and after its concrete construction. The design process is a vehicle to drive the exploration of the problem forward. We will explore the nature of households' relationship to energy consumption in their home from one perspective before the creation of the prototype and from a different perspective when the constructed prototype is placed and empirically studied in its intended context.

In the following sections we describe the phases of the process. Phases and their respective purpose are overviewed in Table 1.

Design phase	Purpose
Field study of nine households	To inform concept formulation
Design workshops	To synthesize findings from the field study with design knowledge and results discovered through the design process
Construction of prototype	Further refinement and understanding of the specific design context by material properties and an envisioned use
Contextual study of use of prototype in nine new households	To generate knowledge and new inquires concerning the relation between design and domestic electricity consumption

Table 1: Overview of the design process

FIELD STUDY

The goal of the field study was to inform the design by gaining an understanding of the individual households' living spaces and context. For this we used qualitative methods collecting data through home observations, photographs and interviews with members of households. Nine households in Stockholm, Sweden were selected for this purpose. The constellation of the group was intended to reflect different and divergent living conditions and lifestyles.

Each interview took about two hours and was followed by a walk in the house while discussing and photographing things of interest for the study. Interview questions revolved mainly around three topics: The home as the material framing and context for everyday actions; motivators for energy conservation and efficiency; and how and where electricity is used.

Interviews were transcribed and observation notes and photographs were categorized. These data were, then, analysed to identify general topics and ideas.

Results Field Study

Three major design themes were identified. These themes were clearly salient and recurring in the data: *complexity*, *visibility* and *accessibility*. From a socio-technical perspective, they can be seen as indications of how the home energy system is intertwined with social aspects of everyday life.

Complexity

One of the central aspects for understanding how to save electricity in the home is to be aware of *when* and *how* the household is consuming electricity. The electricity bill and the present meters did not provide enough feedback although these were primary communication channels of on electricity consumption to the informants. Thus, energy related feedback on activities in the home was delayed until the arrival of the electricity bill every third month. This is too long a period for being able to remember what activities had lead to the level of energy specified on the bill. Moreover, information on the electricity bill was too detailed and too difficult to comprehend. The unit of measurement used on bills was kilowatt-hours, a concept which most of the informants were not able to explain or relate to, neither in terms of energy or money.

Information on the meters was also difficult to understand. This confirms the results from several other studies on feedback [7][1]. None of the informants had a smart meter installed and no one accessed any information about their electricity use over the Internet. The most senior informant, 81 years old, had an electricity diary where he wrote down the current position of the electricity meter every day at noon. With this routine he could keep track of the electricity consumption from day to day as he went down to the basement to write down the numbers (see Figure 2).

Figure 2: The workplace in the basement where our senior informant kept log of the households electricity consumption.

Visibility

Informants found it difficult to understand how much electricity different artefacts in the home consumed. Many informants mentioned turning off lamps as a way of saving electricity. While lighting currently represent 20-25% of the total electricity use in households [2] there are many other objects in the home that have a "hidden" energy use that is not as easy to spot. Some electrical appliances may consume more in a year in stand-by mode than when actually used. This has been true for many microwave ovens for example. Also, related to this, the representations of the electrical system is more or less successfully disguised; hidden behind covers and assimilated to the background surface, for example painted white (Figure 3a).

Figure 3a: A hidden air pump. Figure 3b: An electricity meter uncovered in the basement.

Accessibility

The electrical installations, like the mains fuse box of the home, are often hidden away and located at places isolated from the everyday living area. We can see such boxes and cabling at wardrobes, in the basements, and in the garage [14]**.** These places are seldom exhibited or shown to neighbours and friends and it seems like the aesthetical expression of these devices is not particularly important. However, due to the placement and, partially, how residents move around, certain members of the household will be granted access and obtain control of this technology. Engagement in electricity consumption, thus, would be easier for these members than for those who have little or no access to spaces where the technology is installed. Our homes consist of different areas and places that are implicitly coded to different activities and (thus) give access to just some members of the household. Gender seems also to play a role in this. Women still take the main responsibility for the household and children, whereas men are responsible for the maintenance of the house. Hence, women and children have different movement patterns in the home and mainly move around in the part of the home where little of the electricity system is shown, while the male domain is in the garage, the workshop and the basement where the electrical system is more visible. Movement pattern has implications for accessibility, which in turn is connected to engagement. It is hard to become engaged in electricity consumption of your household when information concerning it is difficult to access (Figure 3b).

Conclusions and Implications from Field Study

Clearly then, the field study reveals problem areas in households' understanding of their energy consumption. Reasons behind these problems may be summarized as:

- Lack of direct feedback on energy related activities
- Complexity of concept of kilowatt hours used on electricity bills
- Complex presentation of electricity consumption on electricity meters
- Many electrical appliances has a "hidden" consumption of electricity
- Inaccessible or unknown location of electricity meter
- Lack of engagement in electricity consumption

The results of the field study cover the first steps in exploring psychological and social dimensions of household energy consumption. Identified themes and problems constitute a base for the formulation of design concepts together with contextual and personal inputs from the on-site observations.

DESIGN AND DEVELOPMENT OF THE ENERGY AWARE CLOCK

Major questions to the design process dealt with how the problems and themes identified in the field study were to be approached in terms of design properties. Then, these questions were explored in design workshops. Eventually, a set of about 30 concepts was formulated in response to the identified problems and these were further filtered down to six concepts. This stage of concept formulation evolved around how to understand and address different situations and problems observed in the field study. Crucial issues dealt with in what ways design could affect behaviour in relation to engagement by for example triggering users' curiosity and appealing to their emotions. Ways of using visual and tactile persuasion and social scripts were also considered at the design stage. A visible and engaging artefact as well its location in the house was assumed to be significant for whether households would be motivated to relate to feedback provided. Finally, six concepts were developed into fully working prototypes. One of these prototypes was the EAC, which intended to substantiate the themes of complexity, visibility and accessibility. EAC is the design case discussed in the rest of the paper. The next section describes the properties and function of the EAC.

Figure 4: The Energy AWARE Clock in the 24 hour view, showing the electricity consumption for the whole day and two days back in time.

Subsequently, we account for how themes from the field study were addressed in the design.

Properties and functions of EAC

The EAC is a new kind of energy display that uses a time (i.e., analogue clock) metaphor to visualize a homes' electricity consumption. Just as a clock, the EAC may be hung on the wall. By further connecting to the clock metaphor we wanted to get away from the concept of a meter and to wash away technological references to the discourse used in the domain of electricity. Another intention was to facilitate transfer of some desired behavioural patterns of the ordinary wall clock such as glanced at regularly. The overall idea of EAC was to make electricity use more concrete in relation to ordinary activities as well as being a tool that could encourage discussions about electricity consumption in the home. The EAC wirelessly connects to an AMR meter in the home. The refresh rate is several times per second and it requires less than 5 watts to operate. Hence, it can be run on batteries or be connected to an outlet using a power adapter. Figure 4 shows the EAC.

The outer shape of EAC resembles a house with a dark acrylic front. Behind the glass there is a colour display. This display shows a circular graph that portrays the home's present use of electricity (kW) and also the historical consumption over time (kWh). A complete turn represents 1 minute, 1 hour, 24 hours or one week, depending on which view is selected. The angle of the dial represents the current time – similar to an analogue clock – and the length of the dial represents the amount of power used at that specific moment (i.e., kW). When an electrical appliance is switched on this can be seen on the display immediately in terms of a longer dial (Figure 4).

As time progresses, the dial leaves a trace behind on the display and this area depicts the historic energy consumption (i.e., kilowatt-hours and kilowatts for specific time points). The previous graphs gradually become darker as they are "moved back" for every complete turn. The areas for several days can be seen and compared in this way. Three overlays can be seen at the same time, which represents three days in the 24-hour view.

We added two touch-buttons to control the clock: One button with an icon depicting a light bulb that makes it possible to toggle between additional information such as time, watts, acquired kilowatt-hours in the present turn, alternatively no added information at all; A second button with an icon shaped like a clock changes the time scale for one complete turn between minutes, hours, days and weeks.

Addressing Complexity and Visibility

In an effort to ease the understanding of electricity use and reduce the complexity in gathering and interpreting information, we wanted to create an artefact that communicated more directly the amount of electricity used at a specific moment as well as historically. Direct feedback has proven successful in several studies as a way to decrease electricity use [7]. The comparison between present and past consumption was meant to facilitate for the understanding of how much electricity individual

electrical objects in the home consumed. Since kilowatt-hours is a complex concept we wanted to move away from this, and focus on relations in a more visual way. By getting feedback both from the circular graph about how much electricity the household is using at that specific moment we thought it would be easier to compare and understand the historical patterns. The "overlay effect" also strengthened this concept allowing for comparison two steps back in time. The idea that the user would discover and learn about the electricity patterns over time was essential to the EAC concept.

To approach the problem of electricity being hidden, the EAC was designed to stand out as an object in its own right making electricity ubiquitous and tangible. The energy clock is shaped like a house to symbolize the household as a whole, where the circular graph and the electricity patterns become central to the house. The mere presence of the artefact was meant to act as a reminder and a strong symbol for energy awareness. It was important to try to make it interesting and aesthetically compelling so that it would be visible and placed in a central location in the home. The display was also intended to be ambient in the sense that a quick glance at it would indicate if something were out of the ordinary. The shape of the graph would indicate what had happened during the day.

Addressing Accessibility

In an attempt to engage the whole household in reflecting upon electricity use and establish a relationship to the electricity system in central areas of the home we again used the metaphor of the clock object. The clock metaphor is intended to signal to residents to put the EAC in a central, shared space, of the household – just like an ordinary wall clock. The dark and polished surface and dark grey casing were meant to resemble status symbols like some brown appliances, for example flat screen televisions and stereo equipment.

USER STUDY: ENERGY AWARE CLOCK IN CONTEXT

The EAC was, thus, designed to incorporate the general themes of complexity in comprehending electricity consumption; visibility of consumption; and the aspects of accessibility of information. Important design intentions were also to create engagement trough playfulness, exploration and reflection related to the creation of an electrical history. The purpose of the user study was to explore how the EAC was used in a real life domestic setting.

Method User study

We used a domestication probe methodology [15][10], as a means to evaluate our prototype and to understand the problem situation. In accordance with this method the prototype is installed in the home to stimulate a dialogue about the object and the new situation. Interviews are typically used to collect the views and ideas from the residents. Domestication probes are particularly useful to capture and understand the more difficult and underlying social aspects that may have an impact on the design of an artefact. The next section describes how we employed the domestication probe methodology in our user study.

Data collection and Analysis

The study was carried out in a recently built neighbourhood in a suburb to Stockholm, Sweden. Households in a block of nearly identical terraced houses were systematically approached by the research team until 10 households were recruited for the study. Finally, nine households (one fell out due to technical problems) took part in the main, qualitative interview part of the study and were equipped with an EAC placed centrally within their home for three months. The meter was installed in such a way that it would only measure electricity use from appliances in the household. Measurement of heating was excluded with the exception of floor heating in bathrooms.. The purpose of this was to keep visualization feedback simple. Young families mainly inhabited the neighbourhood. Eight of the nine interviewed households were families with adults between 30 and 35 years and one to two small children or babies. The eighth household was a couple around 60 years with no children in the house. All families had moved into their homes a year prior to the study.

Data from the 9 families who tested the EAC were collected through qualitative in-depth interviews at the end of the three-month period. Interview questions were based on a guide targeting major themes of households' experience, behaviour and learning in relation to the clock. Interviews were free in their form, allowing the interviewer to follow the informant and the development of the conversation. Interviews were one to two hours long and made alternately with both or just one of the adult members of the household.

Results User Study

Interviews were transcribed and transcripts analyzed. Themes were then identified describing behaviour and experience in relation to the EAC. In this paper we focus on the following emergent themes: Patterns of use and behavioural change; Awareness of electricity consumption; High and low consumers; Interpretation of direct feedback; and individual differences. Below, we present excerpts from interview protocols to illustrate each theme.

Patterns of use and behavioural change

Interview data indicate that households' use of the EAC travels through at least two phases. In the first phase the electricity consumption of electrical appliances in the home is explored. This phase is characterized by a playful curiosity and driven by a goal to map out the amount of electricity used by the appliances of the home. This exploration phase lasts for 3-4 weeks. The following quotations illustrate:

Anna (35): "…those first weeks…you went around checking the whole time…this was quite exciting. I'd say… during the first month you just went around looking… now it's more of a routine…".

Gisela (30): "…in the beginning we had fun looking at it and then you could run to switch something on and then go and look [again]. But once you've done this for a while…you've become aware of [how much electricity] everything uses…".

The above quotations also illustrate how the clock plays the role of a tool for learning. It also seems to trigger a playful attitude in users motivating them to explore electricity in their household. The EAC apparently appeals to *homo ludens* – the playful creature [12].

Figure 5: The Energy AWARE Clock in the kitchen in one household in the user study.

After a few weeks with EAC, usage enters into the second phase - the confirmation phase. In this phase EAC provides the user with information needed to check that the household's electricity consumption is normal. This phase is characterized by a checking behaviour and by EAC being domesticated into the household [18]. The role of EAC during the phase of confirmation seems to be that of a traditional clock on the kitchen wall – an artefact you throw a glance at now and then to relate to the current situation. As these informants put it:

Gisela (30): "… It's become more of a habit. It's like looking at an ordinary kitchen clock"

Claes (30): "…You just check it. It's like looking at the oil gauge in the car. You just take a quick glance…see that everything's OK. That's how you use it when you've got used to it…"

Several households seem to have identified their "normal" consumption levels and connected this to the ongoing activities and the appliances running. The EAC also made some informants feel that they had more control over their electricity use:

Claes (30): "Yes [the watt-number is on] because it gives a good picture of the present and then, in the evening, when everything is calm and only the TV is on, then it can drop down to 500...Then you know, since it follows a pattern, then you have control that... everything is normal."

Knowledge constructed at the exploration phase is, thus, used as a stepping-stone to understand the normal electricity consumption for the household at a given moment and to control that consumption is normal. In this second phase the clock was also used to modify one's own behaviour to become more energy efficient:

Berit (62): "…I say…'Wow, it's on 2000 – what do I do now? Aha, the washing machine'… I think… did I fill it up or should I fill it even more…or I think that [the washing] could wait a while until it's full…"

Awareness and insights of electricity consumption

According to informants in all households, the mere presence of EAC contributed to an increased awareness of electricity consumption. Consumption became visible in a more direct way than before. A recurring observation from interviews is that EAC through visible feedback is a reminder of electricity consumption. Consequently, it also serves as a reminder to households to switch off things that don't need to be on. EAC seems to have increased the visibility of electricity even in households who say that they haven't used the clock that much. Although one informant, Erik (30), replies "no" to a question on whether he believes EAC has changed anything in the family's view on electricity consumption, he later says:

"But you've become more aware of… you see when you run the micro wave for example that [the effect goes up]…"

The role of EAC as a reminder is particularly interesting for electrical devices that are consuming electricity in a "hidden way" like floor heating for example.

According to Gisela (30), some guests automatically interpreted the visibility of electricity use as an urge to *lower* consumption. If you then think that you cannot lower it without "giving up life", this visibility is interpreted as interfering and negative. She continues:

"Then we say that 'it doesn't have to be a surveyor, you just see better what you use'".

High and low consumers

EAC has also generated insights to households concerning the electricity consumption of specific appliances in their home. High consumption was discovered in tumble dryer, washing machine, spotlights, TV, floor heating and coffee percolator. Also, one household discovered that the digital TV box consumed electricity in its stand-by mode and thus, switched it off manually:

Anna (35): "We noticed that the TV, DVD and the box…if they were on they used pretty much compared to when we switched them off. So we started to switch them off at night ".

In some households EAC was also instrumental in the discovery of low-consuming devices, such as the Christmas tree illumination:

Claes (30): "We could see that the Christmas tree illumination didn't matter…there was no deflection at all".

For some households EAC has acted as a catalyst for reasoning about electrical phenomena. Anna (35) compares eco programs with regular programs:

"…you run the eco programs…I have compared these to the regular programs on the dishwasher and the washing machine…I like seeing that less electricity actually was used [for the eco program]…".

Cecilia (30): "I don't remember exactly how much the dishwasher used, but I was surprised that it used so little [electricity] […] I admit that I use it more now. He, he."

Interpretation of direct feedback

For interpretation of electricity consumption, the Watt number was the primary feedback used. Households used the Watt number in the exploration phase as well as in the confirmation phase. It is used in order to determine normal consumption of the household, and to check against daily levels of electricity related activities. Figure 6 shows typical patterns of the clock during a day and the quote below is an example of its interpretation:

Gisela (30): "…After a while [of having EAC] we could see very clearly…when we go to work and when we get home… lights are switched on and the TV is on… everything is on maximum. And then, you notice how it drops…you see how everything is switched off…".

Claes (30) makes an illustrative comment:

"Yes, now it goes from 500W to… over 1000, so it [the coffee maker] adds 500W. […] That is something you don't think about otherwise. I had no idea that it used 500W, that is quite a lot. […] It is more than the television. Yes, the television we can see, it uses 200. So we have understood how much different things use…".

Individual differences

How the users interpreted and used the information from the clock varied from one household that understood and used all of the information provided by the circular graph to another household, which did not understand it at all. Berit (62) calls the clock a glowing painting:

"But I would like to be able to make a diagram or something, and see like... yesterday… at what times are we using the most [electricity]? And kind of connect this with that I did the washing or the dishes or something".

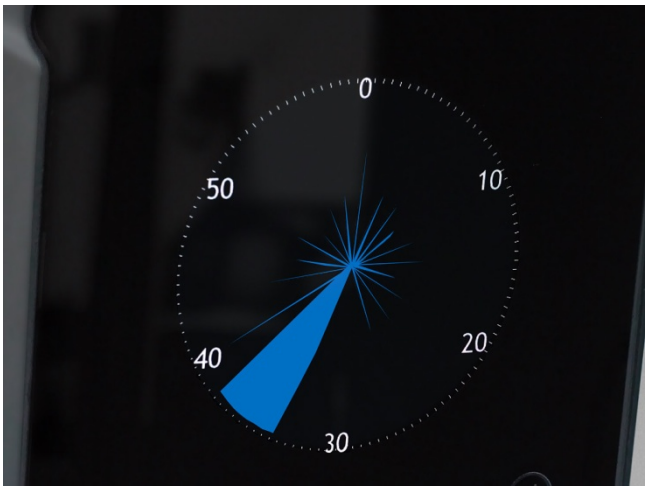

Figure 7: The coffee-maker pattern recreated in the hour view. Starting making coffee at around 34 minutes and keeping the coffee warm for the remaining hour.

This informant did not interpret the information from the clock as a graph and information over time. Only the watt numbers were used to understand how much electricity different appliances consumed. On the other end, there was a household that fully grasped the concept of the three different layers of the graph that could be used to compare present values with previous ones. They also explicitly appreciated the circular graph and talked about different electrical appliances that left their own specific patterns on the clock (Figure 7).

Claes (30): "Yes, like right now, this is fun. That pattern is the coffee maker, you recognize it immediately… before it could be switched on the whole Saturday before lunch, but now when you see this you are reminded of how darn much effect… [it uses]".

For this couple, the graph was the most important source of information. For them, the numbers were secondary but used to create meaning in relation to the graph.

Despite the fact that the user group was very homogeneous, with similar ages and family constellations, the feelings towards and interpretations of the clock were surprisingly different. This is probably partly explained by previous knowledge and experience. Often, these different interpretations where polemic: Aesthetic ornament or tool? Pretty or ugly? Surveying or simply visualizing? Was it a clock or a meter? Erik (30) clearly categorized it as the latter:

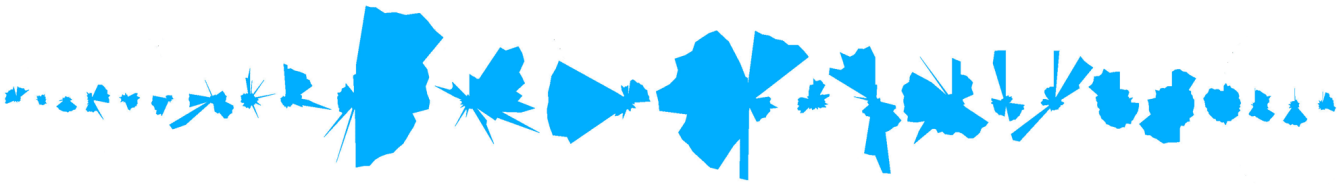

Figure 6: 24 one hour patterns recreated from data stored from one household (Cecilia and Claes) on Saturday, the 18th of April 2009. First pattern on the left is one a clock in the morning and the last one to the right where completed at midnight.

"I think that the number there… for my part it could have been just a small display with only the kilowatt number...".

Cecilia (30) and Claes (30) were much more positive to the design and used it for exploring their own electrical patterns. Cecilia (30):

"Here we can see that we put on some coffee… or the washing machine. Yes, yes, yes, the dishwasher was on when I got home, so it probably is that that caused this [pattern]".

Significance of place

One household perceived the EAC negatively and was so stressed by its presence and appearance that they moved it to the laundry room quite early.

Isabella (35): "It was just too present, […] and we felt that we can't affect our energy use that much... I mean, to use the dishwasher and the washing machine as much as we need to. It has kind of a high priority now when we have children and limited time and so on. So we felt that [the clock] added unnecessary stress. Because we try to keep it [the electricity consumption] down as much as we can anyway. So, really, it was quite negative".

In one household with two younger children, Anna (34) appreciated the placement of the EAC in the kitchen:

"…because you are a lot in the kitchen, with the kids... Then you can… look at the clock quite… often".

She also said that when she happened to pass the energy clock and react on what it showed, she started to think and perhaps experiment – for her it was not something planned. But she also added:

"It is nothing that bothers you that it hangs there... If you would have it permanently it would perhaps not be as prominent as in the kitchen, even if it looks good. Then you would perhaps have it in the… laundry room perhaps".

DISCUSSION

How did the implicit design intentions correspond with what happened when the clock was immersed in real domestic life? First, the EAC obviously made electricity use more visible for households. Results from the user study demonstrate that EAC played a significant role in drawing households' attention to their electricity use. It became a natural part of the household and electricity became naturalized into the informants' everyday language. During the three-month domestication period the deployment of EAC went through the clear discernible phases of exploration and confirmation. Informants learned about their household's normal consumption during a day and they discovered high- and low-consuming appliances. At the exploration phase the clock encouraged reflection and when users gradually entered the confirmation phase it was used more as a reminder.

The design intentions of accessibility and visibility greatly affected engagement and interaction. The location and visibility of an energy awareness artefact seems to be essential. The mere presence of such an object seems to have an effect in itself, regardless of the design and as long as it is clearly visible. Interview transcripts revealed that even informants who said that they were not affected by the EAC were in fact influenced to alter their behaviour in a more energy conserving way. Worth noticing is that this central placement and visibility sometimes became a bit of a provocation in itself, preventing some of the households to fully accept the energy clock as a true member of the ecology of household goods. One family decided to move the EAC to the laundry room at an early stage because they felt it was too present and disturbing – in a way, rejecting its centrality.

Another result, originating from the central placement of the EAC was an even engagement within couples concerning the use of electricity. The clock's accessibility made both men and women aware of the household's energy consumption. This should be contrasted with the field study which pointed to electricity being a matter for a single individual – typically a man. Merging the concept of a meter and a clock did not just transfer connotations that were beneficial for understanding but also added confusion on how to read and understand the circular graph and the overlapping of different layers. Contradictory to our design intentions, few understood and made use of the circular graph. This may have to do with previous experience and knowledge of the informants. Informants who understood how to read and interpret information provided by the clock also put more effort into the learning process. These informants were also more excited to use the clock. Appreciating the EAC as an individual object seemed to have motivated a higher engagement.

The clock metaphor and circular graph were not used to its fullest potential as envisioned in the design process because many informants found the graph hard to understand and preferred the numbers. One reason for this could be that the layers in the graph were not drawn as clearly as intended in the original design due to various practical problems in the construction of the prototype. This addresses interesting issues regarding the significance of good craft, the importance of details and its relevance for the overall interpretation of a new design. Also, some informants didn't understand the information as consumption over time since they were unfamiliar with the concept of a circular diagram. Some households did not like to have the energy clock so centrally located and were not charmed by its visual appearance. There were ambivalence and contradictory emotions. The intended neutral way of displaying information was sometimes perceived as surveying and giving the users bad conscience. In psychoanalytic terms, these users probably projected the pressure they felt onto the EAC.

It is interesting to note some further observations from the user study reflecting social issues concerning a tension between quality of life and the need to conserve energy. For instance, one informant mentioned floor heating as an unnecessary luxury. In the early 20th century energy companies were looking for ways to increase consumption

during daytime and a series of kitchen appliances were invented in rapid succession that helped achieve this goal. The dishwasher, electric stove, toaster, kettle, iron and many more enabled an easier, more efficient lifestyle that erased some of the more straining every day task that had been part of a the reality before. Building on this, it is clear that resurfacing our use of electricity is not without complications since it imposes different kinds of burdens that have to be motivated somehow. Compromising on quality of life is not a desired alternative as exemplified by one informant who talked about "giving up life". Perceived added values such as usefulness, aesthetics and joyful types of interaction could act as motivators to change behaviour.

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REFERENCES

1 Abrahamse, W, Steg, L, Vlek, C, and Rothengatter, T. A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology* (Jan 1, 2009), 1-19.

2 Bennich, P, Bladh, M, Krantz, H, and Persson, A. Swedish Homes-Towards a Delight Future? *eceee 2007 Summer Study: Saving Energy - Just do it!* (2007).

3 Biesiot, W and Noorman, K. Energy requirements of household consumption: a case study of The Netherlands. *Ecological Economics* (Jan 1, 1999).

4 Blevis, E. Sustainable interaction design: invention & disposal, renewal & reuse. *CHI '07: Proceedings of the SIGCHI conference on Human factors in computing systems* (Apr 1, 2007).

5 Borgmann, A. *Technology and the character of contemporary life: a philosophical inquiry*. University Of Chicago Press, Chicago, 1987.

6 Chetty, M, Tran, D, and Grinter, R. Getting to green: understanding resource consumption in the home. *UbiComp '08: Proceedings of the 10th international conference on Ubiquitous computing* (Sep 1, 2008).

7 Darby, S. Making it obvious: designing feedback into energy consumption. *2nd International Conference on Energy Efficiency in Household Appliances and Lighting. Italian Association of Energy Economists/ECSAVE Programme. Naples, Italy. Retrieved January*, 4 (2000), 2006.

8 diykyoto. *http://www.diykyoto.com*. 2008.

9 Frayling, C. *Research in Art and Design*. Royal College of Art, London, 1993.

10 Gaver, William, Bowers, John, Boucher, Andy, Law, Andy, Pennington, Sarah, and Villar, Nicholas. The history tablecloth: illuminating domestic activity. *DIS '06: Proceedings of the 6th conference on Designing Interactive systems* (Jun 1, 2006).

11 Gustafsson, A and Gyllenswärd, M. The power-aware cord: energy awareness through ambient information display. *Conference on Human Factors in Computing Systems* (2005), 1423-1426.

12 Huizinga, J. *Homo Ludens: a Study of the Play-Element in Culture(The International Library of Sociology: The Sociology of Culture)*. Routledge, 1998.

13 *LogicaCMG Energy Efficiency report: Energy Efficiency - Public Attitude, Private Action*. Future Foundation, 2006.

14 Löfström, E. *Visualisera energi i hushåll – metoder att synliggöra sociotekniska system och individ- respektive artefaktbunden energianvändning*. Tema Teknik och social förändring, Linköpings universitet, Linköping, 2008.

15 Routarinne, S and Redström, J. Domestication as Design Intervention. *Proceedings of the 2nd Nordic Design Research* (Jan 1, 2007).

16 Schön, D. *The reflective practitioner: how professionals think in action*. Basic Books, New York, 1983.

17 Seligman, C, Darley, J M, and Becker, L J. Behavioral approaches to residential energy conservation. In Socolow, R S, ed., *Saving energy in the home. Princeton's experiments at Twin River*. Ballinger Publishing Company, 1978.

18 Silverstone, R and Haddon, L. *Design and the Domestication of Information and Communication Technologies: Technical Change and Everyday Life. Communication by Design: the Politics of Information and Communication Technologies*. Oxford University Press, Oxford, 1996.

19 Weiser, M and Brown, J. Designing calm technology. *PowerGrid Journal* (Jan 1, 1996).

20 Wisneski, C, Ishii, H, Dahley, A, and Gorbet, M. Ambient Displays: Turning Architectural Space into an Interface between People and Digital Information. *Lecture Notes in Computer Science*, 1370 (Jan 1, 1998), 22-32.