# Exploring the Flexibility of Everyday Practices for Shifting Energy Consumption through ClockCast

**Majken K. Rasmussen[1], Mia Kruse Rasmussen[2], Nervo Verdezoto[3], Robert Brewer[4], Laura L. Nielsen[2], Niels Olof Bouvin[4]**
[1]Department of Engineering, Aarhus University, Aarhus, 8000, Denmark
[2]People, Technology and Business Lab, The Alexandra Institute, Aarhus, 8200, Denmark
[3]Department of Informatics, University of Leicester, Leicester, LE1 7RH, UK
[4]Department of Computer Science, Aarhus University, Aarhus, 8200, Denmark
mkirkegaard@eng.au.dk, mia.kruse@alexandra.dk, nervo.verdezoto@le.ac.uk, rbrewer@excitedcuriosity.org, laura.nielsen@alexandra.dk, bouvin@cs.au.dk

## ABSTRACT

[1] Encouraging sustainable living by raising awareness of resource consumption has long been a topic within HCI. However, getting people to change behavior when it comes to energy consumption is difficult. This is one of the major challenges ahead for future energy systems, in particular if resources are renewable and plentiful. We developed the ClockCast prototypes (web and clock forecast) to explore demand response and the flexibility potential of everyday practices. We wanted to reframe the conversation on demand response: from highlighting when not to use energy to highlighting when to use it. The ClockCast prototypes display the best times to use electricity, and they were complemented by proactive and positive suggestions. We conducted a pilot study with five different households to uncover the socio-technical challenges around shifting consumption and the participants' experiences with the prototypes. While the participants increased their awareness of the environmental implications of their actions, shifted some electricity use, and found the forecasts useful, some participants also reported newfound guilt when they did not follow the forecasts.

## CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**;

## KEYWORDS

Sustainable HCI; energy; demand shifting; practices; design

**ACM Reference format:**

M.K. Rasmussen, M.K. Rasmussen, N. Verdezoto, R. Brewer, L.L. Nielsen, N.O. Bouvin. 2017. Exploring the Flexibility of Everyday Practices for Shifting Energy Consumption through ClockCast. In *Proceedings of the 29th Australian Conference on Human-Computer Interaction, Brisbane, Australia, November 2017 (OzCHI'17)*, 10 pages. https://doi.org/10.1145/3152771.3152803


OzCHI '17, November 28-December 1, 2017, Brisbane, QLD, Australia

ACM 978-1-4503-5379-3/17/11...$15.00
https://doi.org/10.1145/3152771.3152803

## 1 INTRODUCTION

The HCI community has a long tradition of addressing sustainability challenges, and a range of different strategies [12] and motivations [21] have been pursued to encourage people to act in a sustainable manner. However, despite the substantial efforts to encourage people to live more sustainably, getting people to change their daily routines to lower their energy consumption has proved to be challenging, especially over time [2,19,33].

Many different strategies have been explored to make people aware of their energy consumption, such as the implementation of energy feedback displays and meters [3,14], ambient displays [28,44], and game-based approaches [2,17,41]. Most of these technologies have been informed by the field of persuasion [10,25]. Moreover, a common denominator for many of these projects is that they focus on getting people to reduce the amount of energy that they consume. However, acting sustainably does not necessarily require people to reduce the amount of electricity they use. More and more countries generate an increasing percentage of their electricity from renewable sources that vary from hour to hour and day to day, such as wind and solar. Since power generation must closely match the demand for electricity, dispatchable generation sources (such as coal and gas) must be used to cover any shortfall. Therefore, when generation from renewable sources is high, the overall $CO_2$ *intensity* of the national grid (the amount of $CO_2$ emitted per kilowatt hour of electricity generated) is reduced, and when renewable generation is low, the intensity is

**Figure 1: The ClockCast prototypes: clock & web forecast**

typically increased. In fact, there can even be times when renewable generation exceeds the total demand, so the excess capacity must either be exported or simply dumped. The variable $CO_2$ intensity of the electrical grid means that reducing $CO_2$ emissions could become less a matter of *how much* energy is used, and more a matter of *when* it is used.

Viewing energy not in terms of kWh used, but in terms of the $CO_2$ emitted by energy consumption, people could maintain or increase their level of consumption, while saving $CO_2$, if they were willing to shift their energy consumption to the times when renewable generation is high. However, few studies have explored this perspective in real households, trying to understand the challenges of shifting the timing of consumption activities [5,8,25,40,48].

Leveraging prior work on shifting energy consumption, we designed the ClockCast prototypes; a physical clock and a web forecast (see Figure 1) alongside proactive sustainable suggestions, aimed at shifting the focus from discouraging energy use during specific times of the day, to *encouraging* energy use when there is plenty of renewable energy available. We conducted a pilot study with five different households to uncover the socio-technical challenges of shifting consumption and the participants' experiences with the prototypes, and how they reflect on their own sustainable intentions.

## 2 RELATED WORK

Several strategies exist to encourage people to decrease their resource consumption, including: regulating or powering off certain appliances, trimming electricity use, switching or upgrading to more energy-efficient appliances, as well as shifting electricity use to a different time or place [38]. To support electricity curtailment, more and more technologies are being implemented to provide people with feedback about their resource consumption under the common framing of supporting the individual to change behavior. These technologies range from simple digital in-home displays and energy meters [3,14] to more interactive screen-based visualizations combining mobile and dashboard capabilities to facilitate the exploration of historical consumption data [3,14,32,36]. To reduce the cognitive load induced by these technologies, more elaborated techniques utilize ambient feedback through either designing artistically inspired visualizations as aesthetic objects [3,4,31], or augmenting everyday objects in the home e.g., radiators [18], power cords [16], and outlets [22]. Although these technologies have managed to raise awareness about resource consumption, people still find it difficult to adopt them over time [49], which decreases their effectiveness [23]. In an effort to increase users' engagement, several studies applied game-based approaches [15,41] to motivate the use of feedback technology.

While most of the foregoing strategies and technologies have been implemented to support electricity curtailment, there are also some attempts to support residential shifting of energy consumption, such as screen-based displays of $CO_2$ emissions to give users information about the level of sustainable power available [24,25,48], including expected demand [24], time of use pricing [20,30], smart meters, and smart appliances [11,33]. Additional strategies include text messages to suggest the best times to do laundry [5], and a provocative artifact that restricts the use of electricity during laundry practices [40]. Also, there has been an attempt to motivate residential users to shift resource consumption through a casual mobile game [7], and an ambient multimodal interface that suggests peaceful activities to do during peak hours that do not require electricity [53]. While information displays can make people aware of better or worse times to use electricity [25], making people understand the concept of shifting is more complex than understanding curtailment [8]. Shifting electricity consumption is more challenging due to the dynamic nature of $CO_2$ intensity. People need to receive and make sense of a variety of different types of information (e.g., forecast of desirability, historical electricity use and historical forecasts [8]) to be able to shift consumption, and this often interferes with people's practices. Even game-based approaches are difficult to sustain over time [7]. Furthermore, some studies have reported cooking as a non-negotiable practice that people are unwilling to shift [13,37,52], and laundry routines [5,11,37,48] as a more viable option for shifting. However, this is not always the case due to additional constraints, such as rules for using laundry facilities [13]. Apart from laundry practices, shifting the time of using the dishwasher has been found feasible using renewable energy forecasts [48].

Demand response traditionally seeks a reduction in peak demand through shifting of demand to off-peak times to increase the efficiency of the grid [43]. Most of the aforementioned technologies have been designed from the smart grid perspective and the traditional way of demand shifting, looking for people to restrict their energy consumption. This has resulted in people often mistrusting technology due to the fear of being charged too much by the utility [43]. However, when there is an excess of renewable generation, shifting electricity consumption also becomes a matter of enabling greater usage of renewable energy. Here, regulatory approval is required for pricing the time of energy use, and household appliances would need to be upgraded to more expensive smart versions, and be able to negotiate with the users about the possible times for shifting [8]. Rather than only focusing on promoting behavior change or promoting the traditional way of demand shifting, there is a growing interest in the HCI community to explore the social [35] and learning [46] aspects of feedback technology, including the complexity of use in everyday settings [50]. People engage in everyday practices without seeing themselves as consumers of electricity [52]. Additional aspects, such as societal structures, the physical environment, tools used [13] and government policies [43] play an important role in the overall energy infrastructure. Aligned with these efforts, we designed the ClockCast prototypes to explore the potential flexibility of everyday practices, while encouraging shifting energy consumption to better match renewable generation, moving away from the concept of *discouraging* energy use.

# 3 THE CLOCKCAST CONCEPT AND PROTOTYPES

Aligned with [53], we also take a more positive strategy for demand shifting and conceived a concept that highlights when it is OK to use energy, rather than instructing the user what not to do, or when not to use it. The concept consists of three main components (see Figure 1): 1) a physical clock (ClockCast) that displays the next hour when a high level of renewable energy is available, 2) a web application that displays whether there is a high or low level of renewable energy for up to the next 24 hours, and 3) tailored suggestions sent as text messages that encourage people to use energy in a positive manner when there is a high level of sustainable energy available. While the ClockCast prototypes provide the user with an idea about the level of sustainable energy available, it also attempts to go beyond persuasion by combining this simple information with the participant's daily routines and plans for the week, enabling us to personalize the forecast information and tailor suggestions to the participants during our pilot study (see section 4.2). In the following sections, we describe each of the three main components, their design considerations and technical implementation.

## 3.1 ClockCast

Leveraging prior work (e.g., Energy AWARE Clock [9], the FORE-Watch [25], the eForecast application [24], and the color-coded clock in The Box application [40]), we employ a clock metaphor as the strategy to provide energy information. ClockCast (see Figure 1) is a physical clock that displays the next hour that has a high level of renewable energy available within the next 12 hours. Through moveable disks overlaying the clock face, the clock displays an hour segment slice, indicating a high or a low level of renewable energy. If an hour has a high level of renewable energy, it will be displayed as a wood-colored slice (see Figure 2). The wooden slice is physical and changes position to illustrate the next hour of renewable energy as seen in Figure 2A, where the clock indicates that there a high level of renewable energy from 15:00–16:00. Whereas Figure 2B shows that the next available hour of renewable energy is from 18:00–19:00, and lastly Figure 2C shows that there are no hours with a high level of renewable energy within the next 12 hours. To complement the physical clock, we implemented the ClockCast web forecast (see Figure 1) that displays the forecast for up to the next 24 hours as having either a high level (dark green- grey), low level (white), or as of yet unknown level (light grey) of renewable energy.

While ClockCast has some similarities to the FORE-Watch [25] and the digital clock in The Box application [40], it differs through the design considerations that impacted the design of the clock, as well as through the complementary web forecast and text message suggestions. Furthermore, our text messages suggestions consider, to some degree, several aspects of everyday life and practices, going beyond prior work that only gave suggestions limited to the good times for doing laundry [5].


**Figure 2: Renewable energy availability in ClockCast**

## 3.2 Design Considerations

We considered three different aspects in the design process: 1) shifting as a matter for planning or spontaneity, 2) blending into people's homes and 3) the implicit values embedded in the design. The design considerations were further influenced by user feedback collected during a workshop session, carried out with 35 participants from a student accommodation with fully equipped 1-bedroom apartments, representing single person households. The workshop started with a description of several different design concepts we were working on within our research group. Afterwards, the participants were asked to discuss the concepts in groups of 6-8 people supported by a facilitator. The discussion was structured using trigger cards with pictures and questions and lasted 30 minutes.

*3.2.1 Shifting in Relation to Planning and Spontaneity.* Previous studies [8,37,45,48,52] have illustrated that people's willingness to shift activities, and by how much, differ depending on the activity. Cooking is an activity that people are less willing to shift [13,37,52], as it is often associated with and structured around other practices, such as leisure activities, work, or children's bedtimes. Washing clothes, on the other hand, is an activity that people are more willing to shift [5,11,37,48]. Laundry is less connected with other practices, and can be planned in advance, especially when living in a building with shared laundry facilities. However, special attention should be given to rules and constraints that might restrict the times for shifting laundry in shared facilities [13].

In communicating when it is a good time to use electricity, we support two strategies: 1) enabling people to *plan* activities with a high-energy demand in periods that have a high level of renewable energy; and 2) supporting *spontaneously* changing or arranging activities with a high energy demand, when possibilities arise.

The clock is designed to support people spontaneously shifting their activities. Consequently, the clock has been designed as an ambient information display [39] that shows whether or not the energy that is supplied is more sustainable in a very simple manner. As such, the clock provides an ambient representation of whether there is, in the near future, a period that has a high level of renewable energy. This ambient feature can support people seeing possibilities for shifting their activities to align them with the hours that have a high level of renewable energy available. Providing a simple and readily available source of information can facilitate small shifts of activities during the day. Or seeing a period with a high level of

renewable energy might inspire people to, for example, bake a cake or play Xbox.

The clock does not support long-term planning, as it simply displays the next good hour within the next twelve. However, when the clock was presented as a standalone concept at a workshop, many of the participants expressed a desire "*to see a longer time span, to make it easier to plan*", or that "*it would make more sense if you could see how the whole day looks like, and not just the next time when renewable energy is available*". Consequently, to support the desire of planning ahead what activities could be shifted and to when, rather than simply seizing opportunities as they arise during the day, we also developed a web forecast application (see Figure 1) to complement the ambient information display. Graphically the web forecast was made to match the physical clock, but it differs in two ways. It shows 24 hours of forecast information rather than 12, and it also shows the "goodness" of each hour, not just the next good available hour. The two complementary designs illustrate different approaches to potentially enable people to shift consumption.

*3.2.2 Blending into People's Homes.* When designing for the home, it is important to consider both the aesthetic features of the technology as well as the particular setting in which the technology is being discreetly introduced [3]. Consequently, one of the main aims of the design of ClockCast is that it should blend into people's homes without "screaming" eco-feedback display, while still providing readily visible information about the available renewable energy (see Figure 3). Existing research has illustrated a wide range of ways to provide users with feedback about resource consumption, from approaches that seek to integrate the information into existing artifacts already present in the home, such as power sockets [22], clocks [9], or power cords [16]. Others add novel artifacts to the home, such as a robotic pet [1], ambient displays [26,28,31], or screen-based information displays [32,49]. However, despite the variety and even beauty of some of these devices, they often tend to draw attention, rather than blending into people's home.

The predicted electricity generation from different sources can be combined into a forecast that shows the expected hourly $CO_2$ intensity of the grid over a 24-hour period. Although our national grid has substantial renewable generation, it is also composed by imports and exports from multiple nearby grids, each with very different mixes of generation such as solar, wind, nuclear, hydro, and fossil fuels. Thus, the availability of renewable energy is very dynamic, even looking out the window is it not possible to predict with certainty when the wind is blowing so much that there will be a high level of renewable energy available. Consequently, to pursue our exploration, and the possibility of increasing one's consumption without increasing the environmental impact, is an ongoing dynamic process where new practices can be started, such as for example: hanging clothes out to dry, rather than using the dryer, or using the residual heat of the hotplate and oven when cooking. To create awareness of the current availability of renewable energy, the display needs to be an integral part of people's everyday

**Figure 3: ClockCast in a study participant's home**

practices. Thus, we integrated this information into an existing artifact in order to blend it into the home and its physical properties (wood and plastic material with a white color scheme). Ambient features in ClockCast were intended to facilitate easy integration into the home and routines as proposed by [39]. During the workshop, most of the participants remarked that they liked the look of the clock, although few pointed out that they would rather have a screen, or simply a smartphone app. Despite this feedback, we still believed the physical nature of the clock would enable it to blend into the home more easily than only using a screen-based interface, and we held onto this design.

*3.2.3 Implicit Values in the Design.* When designing, values and assumptions are (consciously or unconsciously) designed into the product [47]. In contrast to the FORE-Watch [45] that uses red, yellow and green to indicate whether or not to use energy, or green and red in The Box [40] to show energy status and availability of renewable energy, ClockCast uses a wood-coloured slice to indicate a high level of renewable energy, rather than green, to avoid the 'traffic light' metaphor. By using a green color, the other hours might implicitly be considered red, and thus bad hours, or warn the users to stop using energy, which was not our intention. Given that we sought to highlight when to use energy, rather than when *not* to use it, the clock face and the hours indicating a low level of renewable energy are both white to attract less attention if there are no hours with a high level of sustainable energy in the near future.

## 3.3 Positive and Proactive Suggestions

Understanding practices [13,52] becomes important when asking people to change *when* they use energy, as people are asked to change how they normally act and reason about energy savings. As the patterns for availability of sustainable energy are dynamic, people cannot consistently make new routines. To assist people in changing their normal daily routines, we enhanced the ClockCast prototypes with tailored suggestions in the form of text messages (SMS) as a way to take advantage of the day's energy forecast and people's daily routines. We took a proactive approach in sending suggestions [5] to enable people to continue their normal activities, but supported planning by

informing them of the best times for performing certain activities to emit less $CO_2$ according to their schedules. Some suggestions used a positive approach, for example by providing recipes that required minimal energy to cook to match the renewable energy and participants' schedules.

## 4 CLOCKAST PILOT STUDY

We carried out a pilot study with five households to uncover the socio-technical challenges of shifting consumption, and the participants' experiences with the prototypes, and the positive strategies towards shifting embedded in the designed artifacts.

### 4.1 Study Design and Data Collection

Our study took place in five different households to explore the flexibility potential of everyday practices, the opportunities that the prototypes can offer for shifting consumption and how people experience and use the prototypes. Initially, our study took an exploratory approach [34] with three single-person households, and then we added two other types of households (a couple and a family household) for heterogeneity sampling [34] to further explore and extend our initial analysis from the initial type of household [54]. The three single-person households were all living in highly equipped student dormitory apartments (P1-P3) whereas the young couple was living in a residential apartment (P4). The family consisted of two adults and two teenagers living in a suburban house (P5). The participating households were recruited through the dorm's Facebook page and extended network. Overall, the five participating households were purposefully selected from the most common type of households in Denmark to explore how the ClockCast prototypes could uncover some of the challenges and opportunities of using the prototypes to support people's shifting of consumption.

Each household participated for one week. We started with a pre-interview, where the participants in each household were asked about their thoughts on energy consumption and sustainability. We also gathered information about the participant's daily routines, and plans for the week to personalize the forecast information and suggestions. During the pre-interview we used a small booklet containing text and illustrations to introduce the concept of shifting energy use to match renewable energy production and explain the aims of the prototypes. The booklet also contained descriptions of the functionality of the clock and the web forecast. During the interview, the clock prototype was installed in each household. Furthermore, the participants were given a small journal containing calendar pages to write daily reflections, and pages aimed at instigating reflecting, posing questions such as "how has it been to have the clock in your home". We sent suggestions to each participant by text message during the week according to their personal schedules, and they were instructed to reply, with a 'Yes', 'No' or 'Maybe', depending on whether they planned to act on the suggestion or not. We also logged the use of the web forecast.

After a week, a post-interview was carried out in each household, asking about each participant's experiences. Questions focused on: how they had used the clock and web forecast, whether they had shifted any consumption, which types of consumption they had shifted, and how ClockCast had impacted their lives and routines. Furthermore, the interview sought to gain an understanding of how the participants had perceived the overall opportunity for shifting energy consumption to the times when it is OK to use it, shifting the focus of sustainable living away from the amount of electricity used to the $CO_2$ produced from the usage, and whether the experience felt positive.

### 4.2 Providing the Forecast Suggestions

Although $CO_2$ intensity forecasts (over a 24-hour period) can be downloaded from the local utility provider, we chose to construct a tailored forecast for each of the households to account for relevant envisaged events [11,42] and participant's everyday practices. The intention behind creating a forecast, rather than using the real data, was based on three considerations: 1) by creating the energy forecast we could ensure that each household would experience a similar forecast rather than whatever the weather and grid happened to provide. 2) While the forecasts had a similar pattern for each of the five households, they were tailored to match the participants expected activities for the week, to ensure that the suggestions we sent matched both the forecast and the participants' schedules. We sent suggestions to participants 4-7 times during the test period depending on the participant's schedules, for example good times to do laundry that would correspond to times when they were expected to be home, or recipes that require minimal energy to cook. 3) Tailoring the suggestions to participant's schedules enabled us to create a best-case scenario, where all suggestions should hypothetically be possible for the participants to follow and would result in reduced $CO_2$ emissions. As part of the post-interview debriefing we told participants that the provided forecasts were adapted to favor the best-case scenario.

### 4.3 Data Analysis

All empirical material collected during the study from the interviews, diary, and text message conversations were transcribed and translated into English for analysis. We took a data-driven approach and conducted an inductive content analysis [6] of the collected material. Three rounds of analysis were performed by a multidisciplinary group of researchers with different expertise (e.g., computer science, design, ethnography). During the initial round of analysis, we identified the most relevant themes coming from the pre- and post- interviews from the single-person households (P1-P3) following the thematic analysis guidelines [6]. In addition, we sequentially added the pre- and post- interview data coming from the couple (P4) and family (P5) households and performed a more focused and comparative analysis across the different types of households. This heterogeneity of households provides the maximum

variation [34] and the re-occurrence of themes across the different types of households indicates consistency of the emerged themes. During the second round of analysis, we added and combined the empirical material from the interviews with the material from the diary and text messages conversations, especially looking for new themes.

The last round of analysis combined our qualitative data (interviews, messages, diary) with quantitative data coming from weekly forecast data, the real electricity usage and the webcast logs to triangulate [27] and support the emerging themes. Themes emerged from the most frequently discussed and emphasized topics by the participants. Considering the short duration of the study and the number of participants, very relevant insights emerged from the participants' sustainable intentions and the use of the prototypes. However, findings are indicative rather than definitive.

## 5 INSIGHTS FROM THE PILOT STUDY

The aim of the pilot study was to gather insights on the socio-technical challenges and potential flexibility of everyday practices (in a best case scenario) and how the application of a positive and proactive strategy to emphasize *when* to use energy was experienced and used in different types of households. Overall, participants were positive towards the concept. Participants were generally environmentally inclined and could thus be expected to be more willing to shift than the average person. Despite considering themselves as being focused on sustainability and the environment, they explained that they would be willing to shift only a limited number of activities, and their use of the clock and the web forecast differed greatly.

### 5.1 Shiftable Consumption and Flexibility Potential

Aligned with other studies [7,13,48], participants felt that only a small amount of their energy consuming practices could be shifted to different times. Consequently, they saw their flexibility potential as being limited and indicated their busy schedules as well as the interconnectedness of their daily practices as reasons that made it difficult for them to shift their energy consumption. Most participants expressed a willingness to try to change things according to the forecast but ended up having a hard time following through on their intentions: *"I don't really feel like I can change much in my everyday life, and the information I get from the clock does not really change that"* [P2]. Cooking was the activity that the participants felt that they could change the least, as it was dependent on a range of other practices and routines. Laundry, dishwashing and cleaning, on the other hand, were among the practices that most of the participants managed to shift, or at least talked about as practices they would be willing to shift, had circumstances been different. For instance, the young couple timed their weekly cleaning activity to start in a good hour: "*We did not manage to do all of our cleaning within the good hour, but then we started with the vacuum cleaner because that uses the most energy."* [P4]. However, external conditions, such as rules for the communal laundry machines at the dorm, or noisy appliances, limited the possibilities to shift their activities.

### 5.2 Shifting: Spontaneous or Planned?

Participants generally felt that shifting is something they have to plan ahead and expressed that they would only consider shifting plannable activities that do not affect their other practices (or comfort) too much. In that sense shifting is not a spontaneous action. Only certain types of consumption are taken into account as being "shiftable". For P4, surprisingly, cooking was seen as one of the activities they would try to shift, whereas watching TV was seen as an activity they could then do (to kill time) until there was a "good" time for cooking, not as an energy consuming practice that could be changed in its own right: "*We would glance at the clock while sitting on the couch watching TV, and then if it showed that there was good energy from 7 o'clock, we would be like: 'Cool, then we can stay here and watch some more TV while we wait for the good energy'"* [P4]. Even waiting to charge your phone until a high level of renewable energy was available was not considered an option for any of the participants.

Many participants felt they needed more information than just the next good hour to be able to shift consumption and therefore many of them also checked the web forecast to be able to plan further ahead: "*In the evening, I used the web forecast to see what the next day looked like. I think it is good to have the web forecast as well because the clock can only show one hour at a time, and often it is nice to be able to plan further ahead*" [P3]. Furthermore, one single person, the couple and the family household participants planned and shifted some activities according to the forecast. For instance, the young couple stated that they had been matching their cleaning and laundry schedules to when there was a high level of renewable energy, but also indicated that this was partly due to the fact that they were on holiday and felt that it would be harder to follow in their normal routine. The family had both a dishwasher and a washing machine that could be programmed for a specific start time. However, this did not mean that they took advantage of the high availability of renewable energy at night, the machines were simply considered too noisy to use at night: "*We are never going to use the washing machine at night when we are all asleep. It is too noisy, so it would wake us up"* [P5]. Instead, they planned the timer function to make the machines run while at work after consulting ClockCast.

### 5.3 Ambient Overview versus Detailed Forecast Information

Participants responded positively to the look of the clock and felt that it fitted in well with the rest of the things in their homes "*I really like the look of the clock and the way it blends in, it is easy to just glance at it, but I still often feel like I also have to look at the web forecast to get the information I need. For instance, if the clock shows the next good hour to be at 3pm, I would open the web forecast to see for how long"* [P4]. While the clock and the web forecast seem to complement each other well by providing

different levels of information and in different ways, some participants felt torn between the ease of simply glancing at the clock, and the desired level of information provided by the web forecast "*I prefer this [the clock] over a tablet. On the other hand, a tablet would give you the opportunity to have all the information in one device, but then it would also be more of an effort to go look at it and find the relevant information. With the clock, you can just turn your head and you see it, and then you are automatically reminded that at 5 pm there is good energy – then I can make something nice for dinner.*" [P3]. While looking at the physical clock easily reminds people to think about renewable energy, the web forecast to a greater extent supports the experienced need to plan ahead as stated by P3: "*then it is much better there are four hours, so it is easier to plan*".

Most participants used the web forecast throughout the study. Participants used mobile browsers exclusively to access the forecast, reflecting the need for information on the move. Three participants even continued using the forecast after the study had ended. In particular, P1 was still checking the site three months after beginning the study. After the last interview, the forecast was changed to actual data, so that the web forecast now reflects the real $CO_2$ intensity.

### 5.4 Suggesting (Alternative) Actions

The SMS suggestions were introduced as an element to support new ways of thinking. The suggestions were well received by participants: *"There are a lot of things I do not think about on my own, so it gives you good ideas, and I really like that*" [P3]. The messages were not perceived as annoying but as an easy source of useful information: "*Generally, I liked that the text messages were not something that I had to go look up on my own. They were just delivered to me and I did not have to do anything actively. They are just suggestions and then you can decide if you want to do it or not. Either way, it is a nice reminder*" [P2]. However, despite the aim to frame the suggestions in a positive way, the participants were not conscious of it. Although the suggestions were evaluated as overall positive, they did not lead to direct changes in consumption.

### 5.5 Sustainable Guilt

The aim of the design approach was to enable people to maintain their normal energy use without feeling guilty, by encouraging shifting consumption to different periods, and even encouraging energy use at times with a high level of renewable energy available. However, in some cases it also provoked feelings of guilt. Adding an extra layer of information to an already complex phenomenon, energy consumption, makes things even more complicated and also means that there is one more thing you can potentially do wrong.

The sense of guilt expressed by one of the participants was associated with the loss of information after the experiment ended. The participant felt that there was something empowering about suddenly getting forecast information and being able to take it into consideration. However, when the study ended, she felt left in the dark again and expressed that "*I am really going to miss the web forecast – I think I will probably start feeling guilty when I do laundry from now on because I don't know if it is a good time*" [P4]. The participant felt this way despite having been told that the forecast data they had seen was tailored for the study and not for the actual $CO_2$ intensity.

Adding this extra layer of information to people's existing knowledge of sustainable living also increased the risk of people failing to live up to an ideal green lifestyle. As P1 reflects: "I thought I was doing quite well in terms of acting green - I always turn off the lights and unplug devices when I don't use them - but then when I looked at the clock, I could see that I use energy at all the wrong times" [P1].

## 6 DISCUSSION

The following section discusses three key aspects raised by our user study: 1) whether shifting is a viable strategy, 2) did the setup create a positive experience about shifting rather than the traditional way, or just sustainable guilt, and 3) reflections and opportunities for future design.

### 6.1 Shifting: A Viable Strategy

Shifting has been presented as a strategy for overcoming the unpredictability of a grid supplied by a high proportion of renewable energy sources. Shifting encourages users to move some of their energy usage to periods when there is excess renewable energy, rather than having to lower the prices, or even pay to get rid of the excess energy. However, the pilot study illustrates that there are certain practices that people are willing to shift, even if it requires extra planning, making them fit both people's busy schedules and the energy forecast. Among the participants, the laundry practice was the most "shiftable energy practice", which aligns with prior work [5,37,48]. Similar to [48], we found that dishwashing was also a practice with good potential for shifting. As seen in our study, the societal structure (dorm rules), infrastructure (common laundry room), and near materiality (availability and functionality of home appliances) of everyday practices [13] constrain and pose challenges to people's ability to shift energy consumption. However, looking beyond cooking, cleaning, washing clothes and dishes, few other activities were considered shiftable. This lack was for example due to people's unwillingness to wait too long for sustainable energy, e.g., when charging mobile phones. While other activities, such as watching TV, surprisingly, was not even considered in relation to shifting energy use.

Although we attempted to encourage the participants to use energy, they rarely engaged in new activities simply because of energy availability. However, the participants still had to pay the regular price for the electricity they consumed, so while the environment might not be impacted by their actions, their wallet still would be, which maybe affected their actions. Consequently, for positive strategies to work, reduced cost might need to be added to the reduced environmental impact through variable pricing [30].

The case study illustrated that the interconnectedness of everyday practices made it difficult for the participants to shift

their energy consumption, even if they had the willingness to do so. Consequently, to deal with these challenges and see shifting as a viable strategy, a more holistic view of the existing ecology of practices [51], including the existing ecology of artifacts and devices (e.g., TV, mobile phones, washing machines) in each household is needed, in order to identify the opportunities for shifting consumption. While the web forecast facilitated planning and coordination of everyday practices, leading to the identification and shifting of some practices, the physical clock provided a spontaneous view at a glance. Although our participants valued the simple information, similar to [5], the physical clock acted as an energy consumption awareness artifact [29], embedded seamlessly into the existing ecology of devices, triggering the opportunities for shifting. Providing energy forecasts 24 hours in advance leads to challenges because, like weather forecasts, they are very unpredictable. The dynamics of power generation together with the dynamics of people's everyday practices challenge the viability of shifting, but rather than seeing this as a barrier, we should look for the opportunities for encouraging people to shift their energy use to the times when it is OK to use it, rather than asking people to reduce their overall consumption.

### 6.2 Is Sustainable Sinning Possible Without Guilt?

Our positive approach contradicts what most of us have been told throughout our lives: to turn off the lights when we leave a room or not to leave the TV on when we are not watching. Moving from matching the grid to the possibility of making better use of renewable generation without the need to reduce energy usage, distinguishes itself from traditional demand shifting. However, giving people a new kind of information about the impact of their energy use, in some cases, instead of enabling participants to "sin" sustainably, e.g., use energy for non-essential or frivolous purposes, resulted in feelings of guilt for not being able to match their consumption to the hours with a high level of renewable energy. The log of the participants' use of the web forecast showed that some of our participants kept using it after their individual participation in the study was over, even when they knew that the data was tailored for the study and not for the actual $CO_2$ intensity. The basis for the continued use of the web forecast might be attributed to Halkier's notion of the individual [19] as an increasingly autonomous moral agent, and providing a narrow view of consumption as an individual rather than a political responsibility. Having to actively reflect upon your actions can be quite stressful, especially in areas such as energy consumption where people often do not have a clear set of rules or insights to navigate from. ClockCast can be seen as a way of overcoming the doubts and ambivalences that individual decision-making entails, as the clock makes the complex and previous invisible information easily available.

Furthermore, by using ClockCast, the participants could relinquish the need to reflect on whether their actions are bad or beneficial – the clock does this for them. ClockCast was designed to lessen people's guilt and enable them to use energy without feeling guilty, but in some cases, it ended up just doing the opposite. Nevertheless, ClockCast made participants aware that the footprint of their consumption was not only a matter of kWh used but also of timing.

### 6.3 Towards a Positive Experience for Demand Shifting

As behaving in a sustainable manner sometimes conflicts with people's desires for comfort, convenience, or luxury ("sinning"), as presented in our study, there are times during the day where energy can be consumed with a clearer conscience than other times, making possible the desire to sin (e.g., use energy for non-essential or frivolous purposes), as long as the sinning takes place during particular hours of the day when renewable energy is available. When an increasing amount of power comes from renewable sources, resource consumption can be maintained or even increased while reducing greenhouse gas emissions. Thus, the rise of renewable generation provides an opportunity to explore positive ways for supporting the shifting of everyday practices.

Our study was not entirely successful, as participants shifted mainly practical activities, such as washing or cleaning, instead of more frivolous uses of energy, such as watching TV. However, changing people's mindset on energy use from the traditional conservation to shifting is challenging in a single week, when the cultural understanding remains the same. The aim of our approach was never that all energy use should be done in the hours with a high level of renewable energy, but to inspire people to shift activities when opportunities arose. This was less the case, as many of the activities that were shifted were planned, rather than occurring spontaneously. However, despite these hesitations, our positive approach to shifting introduces a new and positive perspective on energy. Additional scaffolding around people's shiftable intentions might be needed for the positive approach to succeed, such as dynamic pricing. A second point illustrated by the design is the notion of blending into people's homes [44] to facilitate its fit into the existing ecology of practices and devices. Making an artifact that people would be willing to keep in their home could support people's sustainable intentions, considering that the availability of renewable energy is unpredictable. The qualities of the physical clock not only provide a familiar object but also a reference point overviewing time, making it acceptable in the home [3].

## 7 CONCLUSIONS

In this paper, we presented the ClockCast prototypes and our positive design strategy for demand shifting, which encourages people to use energy when it is OK to use it e.g., in periods with high availability of renewable energy. Our positive strategy enables people to follow their desires for comfort, convenience, or luxury ("sinning"), rather than promoting energy curtailment with a typical negative framing for consumption, where people are told what not to do or when not to use energy. We conducted a pilot study to uncover the socio-technical

challenges and participant's experiences in five households. During our short-term study, participants ended up using the prototypes to plan shifts of essential activities like cleaning and laundry, rather than seizing opportunities to shift as they arose during the day. We also uncovered that leisure activities, such as watching TV, were not even considered shiftable activities. However, our findings are far from complete and indicate the need for further long-term studies to explore people's sustainable intentions and the potential of shifting in relation to the practices and artifacts in people's everyday life.

## ACKNOWLEDGMENTS

This work has been supported by The Danish Council for Strategic Research as part of the EcoSense project (11-115331) and by the Danish Energy Agency project: Virtual Power Plant for Smart Grid-Ready Buildings (12019). We would like to thank both project teams and our participants for their feedback.

## REFERENCES

[1] Sherif Abdelmohsen and Ellen Yi-Luen Do. 2008. Energy puppet: An ambient awareness interface for home energy consumption. In *Digital proceedings of the 7th International Workshop on Social Intelligence Design (SID 2008)*. Retrieved from http://cumincad.scix.net/cgi-bin/works/Show?9609

[2] Magnus Bang, Carin Torstensson, and Cecilia Katzeff. 2006. The PowerHhouse: A Persuasive Computer Game Designed to Raise Awareness of Domestic Energy Consumption. In *Persuasive Technology*, Wijnand A. IJsselsteijn, Yvonne A. W. de Kort, Cees Midden, Berry Eggen and Elise van den Hoven (eds.). Springer Berlin Heidelberg, 123–132. Retrieved September 15, 2015 from http://link.springer.com/chapter/10.1007/11755494_18

[3] Lyn Bartram. 2015. Design Challenges and Opportunities for Eco-Feedback in the Home. *Computer Graphics and Applications, IEEE* 35, 4: 52–62. https://doi.org/10.1109/MCG.2015.69

[4] Lyn Bartram, Johnny Rodgers, and Kuise Muise. 2010. Chasing the Negawatt: Visualization for Sustainable Living. *Computer Graphics and Applications, IEEE* 30, 3: 8–14. https://doi.org/10.1109/MCG.2010.50

[5] Jacky Bourgeois, Janet van der Linden, Gerd Kortuem, Blaine A. Price, and Christopher Rimmer. 2014. Conversations with my washing machine: an in-the-wild study of demand shifting with self-generated energy. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, 459–470.

[6] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2: 77–101.

[7] Robert S. Brewer, Nervo Verdezoto, Thomas Holst, and Mia Kruse Rasmussen. 2015. Tough Shift: Exploring the Complexities of Shifting Residential Electricity Use Through a Casual Mobile Game. In *Proceedings of ACM SIGCHI Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '15)*.

[8] Robert S. Brewer, Nervo Verdezoto, Mia Kruse Rasmussen, Johanne Mose Entwistle, Kaj Grønbæk, Henrik Blunck, and Thomas Holst. 2015. Challenge: Getting Residential Users to Shift Their Electricity Usage Patterns. In *Proceedings of the 2015 ACM Sixth International Conference on Future Energy Systems*, 83–88.

[9] Loove Broms, Cecilia Katzeff, Magnus Bång, Åsa Nyblom, Sara Ilstedt Hjelm, and Karin Ehrnberger. 2010. Coffee maker patterns and the design of energy feedback artefacts. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, 93–102. Retrieved September 16, 2015 from http://dl.acm.org/citation.cfm?id=1858191

[10] Hrönn Brynjarsdóttir, Maria Håkansson, James Pierce, Eric Baumer, Carl DiSalvo, and Phoebe Sengers. 2012. Sustainably unpersuaded: how persuasion narrows our vision of sustainability. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 947–956.

[11] Enrico Costanza, Joel E. Fischer, James A. Colley, Tom Rodden, Sarvapali D. Ramchurn, and Nicholas R. Jennings. 2014. Doing the laundry with agents: a field trial of a future smart energy system in the home. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 813–822.

[12] Carl DiSalvo, Phoebe Sengers, and Hrönn Brynjarsdóttir. 2010. Mapping the landscape of sustainable HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1975–1984.

[13] Johanne Mose Entwistle, Mia Kruse Rasmussen, Nervo Verdezoto, Robert S. Brewer, and Mads Schaarup Andersen. 2015. Beyond the Individual: The Contextual Wheel of Practice As a Research Framework for Sustainable HCI. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI '15), 1125–1134. https://doi.org/10.1145/2702123.2702232

[14] Jon Froehlich, Leah Findlater, and James Landay. 2010. The design of eco-feedback technology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1999–2008.

[15] Anton Gustafsson, Magnus Bång, and Mattias Svahn. 2009. Power explorer: a casual game style for encouraging long term behavior change among teenagers. In *Proceedings of the International Conference on Advances in Computer Enterntainment Technology*, 182–189.

[16] Anton Gustafsson and Magnus Gyllenswärd. 2005. The Power-aware Cord: Energy Awareness Through Ambient Information Display. In *CHI '05 Extended Abstracts on Human Factors in Computing Systems* (CHI EA '05), 1423–1426. https://doi.org/10.1145/1056808.1056932

[17] Anton Gustafsson, Cecilia Katzeff, and Magnus Bang. 2010. Evaluation of a pervasive game for domestic energy engagement among teenagers. *Comput. Entertain.* 7, 4: 1–19.

[18] Magnus Gyllensward, Anton Gustafsson, and Magnus Bang. 2006. Visualizing Energy Consumption of Radiators. In *Persuasive Technology*, Wijnand A. IJsselsteijn, Yvonne A.W. de Kort, Cees Midden, Berry Eggen and Elise van den Hoven (eds.). Springer Berlin Heidelberg, 167–170. Retrieved from http://dx.doi.org/10.1007/11755494_24

[19] Bente Halkier. 2001. Routinisation or reflexivity? Consumers and normative claims for environmental consideration. *Ordinary consumption*: 25–44.

[20] Thomas A. Heberlein and G.Keith Warriner. 1983. The influence of price and attitude on shifting residential electricity consumption from on- to off-peak periods. *Journal of Economic Psychology* 4, 1–2: 107–130. https://doi.org/10.1016/0167-4870(83)90048-X

[21] Helen Ai He and Saul Greenberg. 2008. Motivating sustainable energy consumption in the home. Retrieved September 8, 2015 from http://prism.ucalgary.ca/handle/1880/46793

[22] Florian Heller and Jan Borchers. 2012. Physical prototyping of an on-outlet power-consumption display. *interactions* 19, 1: 14–17.

[23] Sébastien Houde, Annika Todd, Anant Sudarshan, June A Flora, and K Carrie Armel. 2013. Real-time Feedback and Electricity Consumption: A Field Experiment Assessing the Potential for Savings and Persistence. *The Energy Journal* 34, 1: 87–102.

[24] Jesper Kjeldskov, Mikael B. Skov, Jeni Paay, Dennis Lund, Tue Madsen, and Michael Nielsen. 2015. Eco-Forecasting for Domestic Electricity Use. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, 1985–1988.

[25] Patricia M. Kluckner, Astrid Weiss, Johann Schrammel, and Manfred Tscheligi. 2013. Exploring Persuasion in the Home: Results of a Long-Term Study on Energy Consumption Behavior. In *Ambient Intelligence*, Juan Carlos Augusto, Reiner Wichert, Rem Collier, David Keyson, Albert Ali Salah and Ah-Hwee Tan (eds.). Springer International Publishing, 150–165. Retrieved from http://dx.doi.org/10.1007/978-3-319-03647-2_11

[26] Stacey Kuznetsov and Eric Paulos. 2010. UpStream: motivating water conservation with low-cost water flow sensing and persuasive displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1851–1860.

[27] Wendy E. Mackay and Anne-Laure Fayard. 1997. HCI, natural science and design: a framework for triangulation across disciplines. In *Proceedings of the 2nd conference on Designing interactive systems: processes, practices, methods, and techniques*, 223–234.

[28] Stephen Makonin, Philippe Pasquier, and Lyn Bartram. 2011. Elements of Consumption: An Abstract Visualization of Household Consumption. In *Smart Graphics*, Lutz Dickmann, Gerald Volkmann, Rainer Malaka, Susanne Boll, Antonio Krüger and Patrick Olivier (eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 194–198. Retrieved September 15, 2015 from http://link.springer.com/10.1007/978-3-642-22571-0_25

[29] Carman Neustaedter, Lyn Bartram, and Aaron Mah. 2013. Everyday activities and energy consumption: how families understand the relationship. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1183–1192.

[30] Guy R. Newsham and Brent G. Bowker. 2010. The effect of utility time-varying pricing and load control strategies on residential summer peak electricity use: A review. *Large-scale wind power in electricity markets with Regular Papers* 38, 7: 3289–3296. https://doi.org/10.1016/j.enpol.2010.01.027

[31] Nick Nielsen, Sandra B. P. S. Pedersen, Jens A. Sørensen, Nervo Verdezoto, and Nikolai H. Øllegaard. 2015. EcoBears: augmenting everyday appliances with symbolic and peripheral feedback. In *Proceedings of the 6th Augmented Human International Conference*, 155–156.

[32] Jeni Paay, Jesper Kjeldskov, Mikael B. Skov, Dennis Lund, Tue Madsen, and Michael Nielsen. 2014. Design of an appliance level eco-feedback display for domestic electricity consumption. In *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: the Future of Design*, 332–341.

[33] Alexandra-Gwyn Paetz, Elisabeth Dütschke, and Wolf Fichtner. 2012. Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions. *Journal of Consumer Policy* 35, 1: 23–41. https://doi.org/10.1007/s10603-011-9177-2

[34] Michael Quinn Patton. 2002. Designing qualitative studies. *Qualitative research and evaluation methods* 3: 230–246.

[35] Petromil Petkov, Felix Köbler, Marcus Foth, and Helmut Krcmar. 2011. Motivating domestic energy conservation through comparative, community-based feedback in mobile and social media. In *Proceedings of the 5th International Conference on Communities and Technologies*, 21–30.

[36] James Pierce, William Odom, and Eli Blevis. 2008. Energy aware dwelling: a critical survey of interaction design for eco-visualizations. In *Proceedings of the 20th Australasian Conference on Computer-Human Interaction: Designing for Habitus and Habitat*, 1–8.

[37] James Pierce and Eric Paulos. 2012. The local energy indicator: designing for wind and solar energy systems in the home. In *Proceedings of the Designing Interactive Systems Conference*, 631–634.

[38] James Pierce, Diane J. Schiano, and Eric Paulos. 2010. Home, habits, and energy: examining domestic interactions and energy consumption. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1985–1994.

[39] Zachary Pousman and John Stasko. 2006. A taxonomy of ambient information systems: four patterns of design. In *Proceedings of the working conference on Advanced visual interfaces*, 67–74.

[40] Dimitrios Raptis, Rikke Hagensby Jensen, Jesper Kjeldskov, and Mikael B. Skov. 2017. Aesthetic, Functional and Conceptual Provocation in Research Through Design. In *Proceedings of the 2017 Conference on Designing Interactive Systems* (DIS '17), 29–41. https://doi.org/10.1145/3064663.3064739

[41] Byron Reeves, James J. Cummings, James K. Scarborough, and Leo Yeykelis. 2015. Increasing Energy Efficiency With Entertainment Media: An Experimental and Field Test of the Influence of a Social Game on Performance of Energy Behaviors. *Environment and Behavior* 47, 1: 102–115. https://doi.org/10.1177/0013916513506442

[42] Stuart Reeves. 2012. Envisioning ubiquitous computing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1573–1582.

[43] Tom A. Rodden, Joel E. Fischer, Nadia Pantidi, Khaled Bachour, and Stuart Moran. 2013. At home with agents: exploring attitudes towards future smart energy infrastructures. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1173–1182.

[44] J. Rodgers and L. Bartram. 2011. Exploring Ambient and Artistic Visualization for Residential Energy Use Feedback. *Visualization and Computer Graphics, IEEE Transactions on* 17, 12: 2489–2497. https://doi.org/10.1109/TVCG.2011.196

[45] Johann Schrammel, Cornelia Gerdenitsch, Astrid Weiss, Patricia M. Kluckner, and Manfred Tscheligi. 2011. FORE-Watch – The Clock That Tells You When to Use: Persuading Users to Align Their Energy Consumption with Green Power Availability. In *Ambient Intelligence*, David V. Keyson, Mary Lou Maher, Norbert Streitz, Adrian Cheok, Juan Carlos Augusto, Reiner Wichert, Gwenn Englebienne, Hamid Aghajan and Ben J. A. Kröse (eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 157–166. Retrieved September 8, 2015 from http://link.springer.com/10.1007/978-3-642-25167-2_19

[46] Tobias Schwartz, Sebastian Denef, Gunnar Stevens, Leonardo Ramirez, and Volker Wulf. 2013. Cultivating energy literacy: results from a longitudinal living lab study of a home energy management system. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1193–1202.

[47] Phoebe Sengers, Kirsten Boehner, Shay David, and Joseph "Jofish" Kaye. 2005. Reflective design. In *Proceedings of the 4th decennial conference on Critical computing: between sense and sensibility*, 49–58.

[48] Will Simm, Maria Angela Ferrario, Adrian Friday, Peter Newman, Stephen Forshaw, Mike Hazas, and Alan Dix. 2015. Tiree Energy Pulse: Exploring Renewable Energy Forecasts on the Edge of the Grid. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, 1965–1974.

[49] Stephen Snow, Laurie Buys, Paul Roe, and Margot Brereton. 2013. Curiosity to cupboard: self reported disengagement with energy use feedback over time. In *Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration*, 245–254.

[50] Stephen Snow, Dhaval Vyas, and Margot Brereton. 2015. When an eco-feedback system joins the family. *Personal and Ubiquitous Computing*: 1–12. https://doi.org/10.1007/s00779-015-0839-y

[51] Isabelle Stengers. 2013. Introductory notes on an ecology of practices. *Cultural Studies Review* 11, 1: 183–196.

[52] Yolande A. A. Strengers. 2011. Designing eco-feedback systems for everyday life. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2135–2144.

[53] Stina Wessman, Rebekah Olsen, and Cecilia Katzeff. 2015. That's the smell of peacetime – Designing for electricity load balancing. In *Nordic Desigh Research Conference, No 6 (2015) : Design Ecologies*.

[54] R. K. Yin. 2009. *Case study research: Design and methods*. Sage publications, INC.