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# Designing Eco-Feedback Systems for Communities: Interrogating a Techno-solutionist Vision for Sustainable Communal Energy


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## ABSTRACT

The notion of establishing energy communities where householders collectively participate in using renewable energy is highly topical. In this paper, we interrogate a design vision of sustainable communal energy developed through a techno-solutionist narrative. The vision is exemplified in a recommendation-based mobile app, the Community Energy Planner app, that provides individual and collective energy feedback on renewable energy actions. To obtain insights into how householders understand and experience embedding such recommended communal energy feedback into domestic energy-consuming practices, we deployed the app with six households for one month. Through a qualitative study, we report on householders' experiences living with the app on an individual and at a community level. Our findings are presented in four themes, revealing that recommended feedback on individual and collective energy actions is challenging to align with the messiness of domestic life. Finally, we discuss alternative design visions for sustainable communal energy. The main contribution of this paper is twofold: 1) a field deployment study of a techno-solutionist narrative of communal energy facilitated through an app and, 2) a discussion on alternatives to this design vision.



## CCS CONCEPTS

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

## KEYWORDS

Energy community; sustainability; techno-solutionist; communal eco-feedback; energy recommendations; field deployment study





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## 1 INTRODUCTION

As part of exploring sustainable futures, a variety of research and industry projects have investigated, developed and demonstrated smart energy technologies with a vision to radically transform the way the energy system operates [28, 100]. As the driving force in many of these projects is on technology design, smart energy technologies tend to be conceived from a techno-solutionist perspective [10, 49], in which there is a *"belief that technological innovations in their own right can solve complex societal challenges"*[2]. However, recent research has clarified that technology design and development can profitably align with environmentalist movements [54], a statement that implicitly acknowledges that techno-solutionist perspectives dismiss too quickly the importance of social dynamics.

In the vision of a sustainable energy system, renewable production technologies, e.g., solar panels and wind turbine, are pivotal. Hence, it is expected that the growth of renewable energy will continue to increase, especially in the form of self-consumption [18]. However, as the availability of renewable production technologies fluctuates with weather conditions, it often argued that householders are to actively participate in stabilising the energy system [17, 71]. Hence, future smart energy technologies of the home are often envisioned as tools that will empower householders to *"shift"* energy consumption to times when renewable energy is available [74]. Recent HCI studies [5, 15, 44, 80, 85] illustrate social perspectives of bringing smart energy technologies into our homes that can assist householders to shift energy-consuming practices to align with renewable energy production, and highlight both opportunities and challenges of smart and automated technology being embedded sustainably in domestic practices.

This focus on technology design can also be observed in the sustainable energy strategies of the EU [16]. In these strategies, householders are often envisioned as citizens willing to produce, store and consume renewable energy empowered through new smart energy technologies [17, 18]. To move such visions forward, energy stakeholders are envisioning a world where consumers are taking energy conservation to another level by coming together as energy communities [17, 103]. The vision of communal energy is to let householders cooperate as a unit in the pursuit of collectively acting sustainably [36, 39, 62]. In this, both individual household and communal actions are expected to influence how the energy system operates, while supported by new technology [60, 98, 100, 103].

However, these initiatives are often designed from a techno-solutionist perspective, where technology design is based on developers' expectations of energy consumers while neglecting to embrace the complexity of the social dynamics of energy use [39, 49, 87, 89], not to mention the absence of more-than-human approaches so vital to think about the ecological crisis [1, 13]. From this techno-solutionist perspective, householders are usually portrayed simply as either energy consumers or prosumers, driven to action by environmental or economic benefits [49, 87, 88]. Nonetheless, most of these sustainable initiatives speak to the rationality of consumers by providing, e.g., shifting or reduction recommendations through eco-feedback [27, 91]. But, how do communal energy technologies align with the dynamics of everyday practices? Do such technologies fit into the idea of collective action? Do communal recommendations provide support for the collective acting sustainable? Or are they obtrusive or simply a hassle to use?

In this paper, we interrogate if a techno-solutionist design vision of sustainable communal energy actions aligns with intended members' everyday practices and willingness to change habits. In other words, we wish to investigate if the intended use of such technologies corresponds to real-world scenarios. Our investigation is be based on the participatory use of an unreleased web-based app, called the Community Energy Planner app. The app conceptualises communal energy shifting through recommendations and the establishment of energy communities. Based on this, the Community Energy Planner app supports community members to take advantage of time intervals where electricity from home appliances is favourable to consume. We follow six households through an exploratory field study and report on their experience of living with the app for one month. Based on this, we discuss alternatives to the techno-solutionist design vision.

## 2 RELATED WORK

### 2.1 Eco-Feedback Design

Since Blevis coined the term "Sustainable Interaction Design" [4], investigations into how digital technology can be designed to instigate sustainable change are quests HCI and design research has engaged in for over a decade [66]. However, to bring a more human-centred perspective into the design of digital technology aiming to conserve energy, a common framing is to look towards individual users and focus on how design can help with their problematic unsustainable behaviours. Most design studies pursuing sustainable behaviour change make use of the conceptualisation of eco-feedback systems [27]. The argument for designing eco-feedback systems is found in Fogg's framework of persuasive technology [26] that draws on theories of behavioural psychology, therefore forgetting about aspects like political economy [67], the cohabitation of humans and non-humans [58, 86], or ontological and political aspects [94]. In fact, using the framing of eco-feedback to instigate change through design will assume individuals can be persuaded to change behaviour through positive feedback on pro-environmental behaviour alone [25].

In HCI, such design efforts tend to explore different visualisations of historic, real-time and predicted energy information materialised through various forms like mobile phones [43, 82], ambient feedback [33, 34, 48, 61, 81], or through physical materials [73, 78, 102]. In this body of work, we also see studies aiming to design for shifting [71, 74] on household-level [53, 61, 73, 79] with some studies targeting shifting specific energy-consuming household practices like; washing [6, 20, 45], heating [14, 15, 19, 44, 76] and EV driving and charging [5, 47, 93]. We have also seen recent studies that explore the opportunities and challenges of letting automated energy technology assist householders in shifting consumption to times that are sustainably favourable [5, 15, 24, 44, 80].

However, to make the most of an eco-feedback system will require a new type of energy consumer who will engage in this vision while significantly benefiting from its possibilities [28, 87]. Strengers conceptualises this new consumer as the "Resource Man", imagined as an ideal rational energy citizen [88]. The Resource Man is a smart energy consumer who is tech-savvy, gendered, and interested in managing his own consumption [87]. He understands his own energy habits through energy data and rationally seeks to operate domestic appliances efficiently to reduce consumption or receive financial benefits. Moreover, it has been suggested that actors in the energy sector [10], smart home industry [32, 68, 90, 104] and political funding agencies like the EU [17, 28] are part of shaping the vision of the Resource Man.

Despite eco-feedback studies illustrating the potential of influencing energy consumption patterns of the individual [27, 52, 53, 79], other studies show that impacts of eco-feedback are challenging to maintain over time in a messy everyday life [35, 92]. This has led to a growing critique in HCI of framing designs as an energy management problem that can be solved by motivating individuals to change behaviour [7, 21, 22, 75]. The critique on which we focus here is the one pointing to such a techno-solutionist discourse as a misconception of the general energy consumer [31, 49, 68, 87, 88].

### 2.2 Sustainable Communal Energy

The concept of sustainable communal energy has been investigated in the last couple of years in an effort to explore alternative future energy systems [101]. Despite the large amounts of attention from tech-driven fields to establish the vision of "energy communities" [12, 17, 41, 56, 98, 99, 103], the concept still appears somewhat intangible. Due to this, investigations are still exploring different understandings of this emerging concept. However, most of these investigations follow a techno-solutionist vision, focusing on the endless possibilities of new emerging energy technologies rather than human adoption [30, 98, 101].

Investigations subscribing to a techno-solutionist vision tend to focus on making renewable energy shareable between members of a community through smart energy technology. These communities are supported by various technological artefacts such as visualisation in communal eco-feedback systems [3, 23, 34, 56, 62, 70, 77, 85], through smartphone applications [34, 63, 85] or other communication channels [3, 23, 29]. In addition to this, some of these communities are virtual [23, 34, 77], which indicate that the members do not necessarily have any personal or geographical relationship.

Shifting on a community level has sparsely been explored in HCI [34, 70, 85]. Simm et al. [85] investigated sustainable communal energy on the Scottish island Tiree, where members share a community-owned wind turbine that distributes energy to the members. In the study, the authors explored how well eco-feedback managed to inform members about the availability of renewable energy. Likewise, Hansen et al. [34] explore a virtual energy community envisioned through an ambient eco-feedback system with the goal of making it favourable to shift energy-consuming practices. Both studies indicated that changing habits towards shifting can be influenced by social engagement in a community.

Currently, most of these 'energy communities' are still being investigated on a conceptual basis [12, 34, 40, 60, 63]. The techno-solutionist narrative of this vision assumes that if people are equipped with the 'right' technological artefacts that can provide the 'right' kind of information, they will become empowered to change habits effortlessly. Furthermore, this vision of an energy community emphasises financial gain as the primary motivational factor for changing consumer habits [60, 98]. As an example, Mahesh et al. [60] conceptualise smart energy communities supported by blockchain technology, which empower consumers to start trading renewable energy among members that are motivated by financial gains.

This design narrative encapsulates the "Social Man" - a close relative to Resource Man [88]. Social Man is a social personification of Resource Man in *"the sense that he is interested in sharing and comparing his energy performance with other Resource men through apps"* [88]. However, Resource Man and Social Man are not just imagined arch-types by actors in the energy sector. Research indicates that potential smart energy home users also aspire to become Resource and Social Men through the empowerment of smart energy technologies [104].

Together these examples illustrate a trending ambiguity within the development of sustainable communal energy. Most research is being put into developing new technologies and their possibilities, but only a small portion of these technologies have been empirically deployed and evaluated in real-world scenarios [28, 60, 100].

Despite this focus on constructing technical solutions, others suggest alternative and more inclusive co-design approaches to envision and develop such future energy communities [8, 39]. Wilkins et al. [103] elaborate on how to design for future sustainable communal energy by including potential members through a participatory design process to explore the potential of Peer-to-Peer energy trading. Hasselqvist et al. [36] designed an amateur energy advice system for housing cooperatives and found that sharing energy advice among members facilitates learning and engage householders. Meurer et al. [64] explored communal eco-feedback as a tool to support sustainable mobility in a city. Cila et al. [12] make use of an imagined and fictional decentralised community energy system to argue for potential dilemmas of community-based resource commons. Although these examples give insights into the production, use and trade of renewable energy on a community level, Jabbar et al. point out that the community aspect is still a rather unexplored area within HCI [41]. In an effort to bring new insights to this area, our study aims, first and foremost, to empirically interrogate a techno-solutionist vision of sustainable communal energy, highlighting potential benefits and challenges of designing for Social Resource Men in everyday life and, in this way, paving the way for a much-needed change of perspective, toward a more commons-based [12], more-than-human [1, 13], and aware of the politics and political economy of energy [67, 94].

## 3 THE COMMUNITY ENERGY PLANNER APP

To interrogate how households experience a system designed for people to collaborate and collectively act on using renewable energy, the research team partnered with a local start-up company. The company has expertise in exploring and developing future smart grid technology. This expertise is made available through a concrete solution bundle consisting of various software infrastructures and services. The services can monitor and control single energy-consuming devices in people's home and generate consumption recommendations based on various criteria. The company's conceptualisation of communal energy is primarily conceived from a techno-solutionist narrative where people can gather in virtual energy communities and get recommendations specifically for their members.

For the purpose of this study, we choose to study one of the company's services, specifically targeted households; The '*Community Energy Planner*' app. The application is based on a recommendation and automation engine that supports households using energy produced from renewable sources. Embedded in this vision lays an assumption that householders are willing to 'shift' their consumption needs to a different time [71]. Furthermore, the empowerment to shift energy-consuming activities is envisioned through consumption recommendations of optimised running times for specific energy-consuming home appliances.

The Community Energy Planner works as a web-based mobile application, accessible through smartphones and personal computers. The app is connected to external data centres that provide a prognosis of electrical prices and CO2 predictions. Most functionality is visualised in different interfaces. The Community Energy Planner app's key component is to provide shifting recommendations based on 1) how households use energy both individually and collectively and 2) intelligent and automated computational models based on efficiency data prognosis. The app does not automate any of these recommended actions on behalf of householders, as we specifically wanted to explore the potential of how such recommend eco-feedback may foster community relationships and if it supports sustainable behaviour.

The two perspectives and how they are materialised in the app is described in the following.

### 3.1 Individual Household Engagement

The Community Energy Planner app aims to support individual households to shift consumption through various features. In the app, household members can specify any energy-consuming home appliances they wish recommendations of. Information and consumption recommendations of each home appliance are made available through a 'My Demand' view (see Fig. 1 A). To act on recommendations, household members can press 'start now' for immediate use of an appliance or press 'start later' to postpone the use to either a recommended environmental or economically favourable time (see Fig. 1 A). Additionally, individual households can specify how far in time they want shifting recommendations. For example, households can state their willingness to postpone operating the washing machine to a maximum of 8 hours. The app will then produce a recommended time to start the washing machine within the next eight hours. Lastly, the app has an integrated point system that works collectively, meaning the 'start later' option will award 10 points, whereas the 'start now' option will deduct 10 points from a community score.

## 3.2 Communal Energy Engagement

The 'Group Demand' view (see Fig. 1 B) is the community feature of the app, as it allows members to join specific groups. In the app, the vision of community engagement is materialised as a collective goal of the group, which can either be stated as wanting to 'save money' on electricity or 'save the environment' by using CO2 friendly electricity. If the former goal is chosen, the system will provide recommendations based on when energy is cheap to consume. If the latter is chosen, recommendations are based on when renewable energy is available to consume.

The 'Group Demand' view also allows members to monitor collective consumption patterns over time and see how individual actions affect the community, as actions are recorded and included in the group data. The 'Group Demand' view resembles the concept

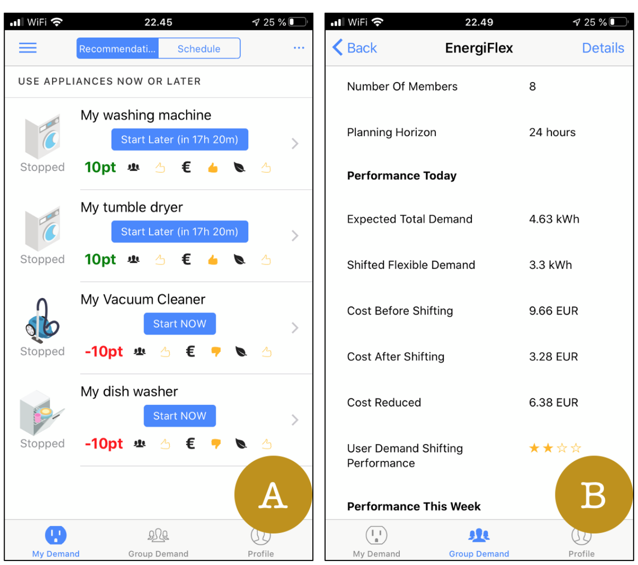


**Figure 1: The Community Energy Planner Application: 'My Demand' information view for a single household and 'Group Demand' information view in the EnergyFlex community. The EnergyFlex community was created for the purpose of this study.**

of a virtual energy community. This implies that members of the community do not necessarily need to obey location constraints to join a specific community or know each other socially. This view provides information about overall savings in kWh and euro, predictions of how much energy the community is expected to consume on the day, and how much of the group collectively has followed the shifting recommendations (Fig. 1 B). Furthermore, each group is given a star rating, which is based on their performance and ability to hit point rewarding time slots recommended by the system.

# 4 STUDY

We conducted the study in a Scandinavian country heavily reliant on wind turbines to provide renewable energy. In this context, government, research and industry partners persistently lobby for the construction of smart energy technologies that can assist with problematic unpredictability embodied in renewable energy sources like solar and wind [10].

Our investigation focused on how households may experience a virtual energy community facilitated by the Community Energy Planner app. To interrogate if the techno-solutionist narrative of the Community Energy Planner app aligns with its intended users, we wanted to explore how actual householders experience the app in their everyday life and how they understand the concept itself. To do so, we conducted a field deployment study, as we wanted to gain insights into how householders experience the Community Energy Planner in situ and understand *"how users accept, adopt, and appropriate a system in actual use over time"* [84].

## 4.1 Participants

We recruited six different households for our study by snowballing within our social networks. We selected households that did not have a personal relation to each other beforehand, as we wanted to explore what happens when the app is the sole mediator for facilitating a virtual energy community experience. In addition to this, we recruited households consisting of at least two people to better interrogate how the concept of communal energy and shifting conforms to the social dynamics within a household.

We also ensured that every participating household had at least three of the following four home appliances: washing machine, dishwasher, tumble dryer and vacuum cleaner. We chose to focus on these appliances as we assumed they were frequently used, flexible when used, and highly energy-consuming. Furthermore, the chosen appliances that have a certain chore shifting characteristic to them, as leisure appliances (e.g., t.v., gaming devices) and appliances of sudden needs (e.g., kitchen stove, microwave) are not that suitable for shifting [50, 52, 79]. At the same time, we did not include any fully automated devices (e.g., heating, fridges), as shifting of these in practice tend to let energy consumption remain back-grounded and hidden [9, 44].

The total number of participants in these households were 18 people, whereas the actual users of Community Energy Planner were 12 adults whose age ranged from 28 to 70 (see table 1). The households were all located in different cities. Throughout this paper, we refer to each participant by their pseudonyms and household number, e.g., (René, H-A). After recruiting the six households, we

| **Household** | **Demographics** | **Household Appliances** |
|---|---|---|
| **H-A** | René, 30, electrical engineer<br>Anna, 28, lawyer | Washing machine<br>Tumble dryer<br>Dishwasher |
| **H-B** | Jens, 50, key account manager<br>Lise, 43, department manager<br>Three children aged: 10, 14, 17 | Washing machine<br>Dishwasher<br>Tumble dryer<br>Vacuum cleaner |
| **H-C** | Arne, 68, retired<br>Susanne, 65, retired | Washing machine<br>Dishwasher<br>Vacuum cleaner |
| **H-D** | Michael, 37, sales,<br>Julie, 39, language pathology<br>Two children aged: 4, 7 | Washing machine<br>Dishwasher<br>Tumble dryer<br>Vacuum cleaner |
| **H-E** | Johnny, 58, IT-manager<br>Bettina, 56, self-employed<br>Two children aged 4, 7 | Washing machine<br>Dishwasher<br>Tumble dryer<br>Vacuum cleaner |
| **H-F** | Jannie, 47, consultant<br>Kaj, 70, retired<br>One child aged 14 | Washing machine<br>Dishwasher<br>Tumble dryer<br>Vacuum cleaner |

**Table 1: Household demographics (anonymised)**

gathered the participants in a pre-established virtual energy community named EnergiFlex. To explore the two different concepts of communal engagement, we configured the EnergiFlex community view to display both energy and financial savings.

## 4.2 Data Collection

Our primary data was collected through semi-structured interviews [55] based on open-ended questions [84], structured after an interview guide [69]. Twelves interviews were conducted, two with each household. One before and one after the Community Energy Planner app's deployment. The data collection lasted from the end of March until mid-May 2020, meaning households experienced living with the app in their daily routines for approximately a month. Due to constraints initiated because of the COVID-19 outbreak, we chose to conduct interviews through online video calls, which offer the closest resemblance to onsite semi-structured interviews [42].

The first interview was a preliminary interview and an introduction to the study. The interview was held with both adults in each of the household. This preliminary interview started with a monologue followed by questions regarding demography, environmental standpoint, electricity knowledge and how chores were distributed within households. The participants were also given a thorough guide of the app, and we provided assistance to install the app through video calls. During this, participants had the opportunity to ask questions about the app and the study itself. We explained

**Figure 2: Community Energy Planner used in situ. From left to right, Household C looking at recommendations for when to wash dirty clothes, Household A looking at recommendations to start the dishwasher, and Household F using the timer function on their washing machine to make the best of the recommendations.**

the purpose of shifting and using electricity as a communal effort, and we clarified how this was facilitated in the Community Energy Planner app.

In addition to our interviews, we sought continuous feedback from the participants during the deployment period. This was obtained through short and simple text messages [57] sent to our participants twice a week. These contained short questions regarding participants' interactions with the app, their experiences of the group activity of their energy community, and how they were using their home appliances in coordination with the recommendations provided by the app. To gain better insight into how the app was used in situ, we also asked participants to attach pictures of their use of the app (see fig. 2). The questions were asked in a neutral language [57]. These text messages further helped us structure and inform our second interview guide.

The second interview was held after one month of deployment of the Community Energy Planner app. This interview served as an in-depth interview with both adults of the household. The interviews were carried out by one interviewer as well as an observer. The observer would spectate and silently alert the interviewer through direct messaging with additional and follow-up questions. These interviews concerned the participants' experiences of being a member of the virtual energy community, EnergiFlex. The interview also sought to illuminate usage of the app, including which household appliances were used for shifting most frequently and the motivation for shifting the use of them. The possible difficulties the participants may have faced were also asked to determine whether the app aligned with the participants' everyday practices. After conducting our second interviews, we transcribed the last six interviews in preparation for the data analysis.

## 4.3 Data Analysis

As the first step in the data analysis process, we familiarised ourselves with the data by reading through transcriptions and listening closely to the interviews. We used conventional content analysis (CCA) to interpret meaning from the interviews through inductive category development [38]. The process of analysing through CCA was done in three steps with three of the authors. We thoroughly read through the data and identified code suggestions from expressions in the interviews in the first step. Our first set of codes was produced individually, which meant that some codes had the same meaning but were named differently, e.g. "saving money" and "economic savings". To accommodate for this, we collectively merged corresponding codes. In the second step, we narrowed the codes down to derive sub-categories from the aforementioned code suggestions. In the last step, we aggregated the sub-categories into general categories. By deriving general categories, we established a structure for the extracted themes, opinions and emotions that appeared throughout the data. As a result, we ended up with four overall themes described in the following.

## 5 FINDINGS

The four themes that emerged from our analysis are presented below. The two themes presented first are related to how recommendations on energy shifting were experienced within the home. The two latter themes focus on the communal aspects of living with the Community Energy Planner app.

### 5.1 Negotiating Household Practices

Householders stated they had various difficulties embedding the Community Energy Planner app's recommendations into their households practices. There were mainly two aspects to this. Firstly, households reported that the recommendations required compromises to their daily lives, which were not always easily make. Secondly, shifting recommendations conflicted with the habitual routines already established.

Participants reported that their use of the app span from five to fourteen times a week. Although the use of the app seemed relatively high, some households reported that their use was decreasing during the deployment period. One household reported they used the app *"approximately twice a day"* (Bettina, H-E). However, this household used "Start now" most and referred to themselves as "whoops-users", as they tended to forget to use the app as a planning tool. Instead, they used the app for spontaneous actions due to their busy everyday life. Strengers [91] report similar findings of novelty wearing off when eco-feedback systems are experienced as irrelevant or perceived as non-negotiable. Another household used a notepad and pencil to help remember to start their appliances. However, they incorporated the use of the app as part of their morning routine.

> *"Just like when you start your day by watching the news, you open the app each morning and think to yourself, 'Well, how are the recommendations today? Do they fit my schedule, or are they totally off?"* (Susanne, H-C)

It suggests that householders felt that the app should adapt to their everyday life and not the other way around. Furthermore, our findings highlight that busy, career-minded households and households with children found it difficult to incorporate the app into their everyday practices:

> *"Something that has been difficult about the app has been using it as a family as it was stressful to integrate it into our everyday routine and try to meet the suggestions. This might have something to do with our ad hoc activities."* (Julie, H-D)

This highlights that shifting recommendations interfere with norms of routinised practices and pokes to social expectations, like convenience, in a busy everyday life. These social expectations and norms played a major role in householders' willingness to shift routines in time. Moreover, the composition of the different households influenced how compromises of convenience were managed in some households.

Negotiating changing routines were somewhat polarised because some households had more time to 'sacrifice' to achieve optimal consumption times. This polarisation was evident in households with children versus households where one or both participants were retired. *"We are so privileged not to work anymore so we can wash our clothes in the middle of the day or we can also wait if necessary"* (Arne, H-C). Living with small children also appeared to challenge parents as the social dynamics of the household made it difficult to commit to the shifting recommendation in the app:

> *"As a family with children, I think it's hard for us to compromise our everyday flexibility. It's just difficult to follow the suggestions when you have to have clean clothes ready for the kids next morning."* (Michael, H-D)

Furthermore, some household explained committing to recommendations of the app sometimes conflicted with the logic of activities where multiple appliances are used. Normally, some households would avoid using the dryer and hang their clothing outside after a wash. Applying recommendations from the app did not always correlate with this sustainable routine:

> *"The problem is if the tumble dryer time suggestion isn't right after the washing machine finishes. I think it may bring some challenges if you have to wait 17 hours after your clothes is washed to get it dry"* (Jannie, H-F).

Julie further exemplified this dilemma. She recounted a sunny day where she wanted to dry their clothes, but the app suggested she wash and dry eight hours later when it was dark outside:

> *"In that situation, I pressed the 'start now' button as it simply didn't make any sense to wait and dry our clothes outside when it turned pitch black and humid"* (Julie, H-D).

This implies that not countering for all home appliances of practice when producing shifting recommendations - like washing where both washing machines and dryers are used - may actually lead to unsustainable behaviour.

Overall, it seemed that the social dynamics and the demands of domestic work, including limited hours at home, challenged most participants. The luxury of doing house chores at one's own convenience appeared to be difficult to disrupt. Similar findings are reported by Pierce et al. [72] and Jensen et al.[45] in their studies of shifting, who conclude that expectations of conveniences embedded in everyday practices are reflected in householders' willingness to change them towards conservation action.

### 5.2 Expanding Household Boundaries

Householders reflected that adapting to the app's recommendations required expanding norms and values within the household. Firstly, households reported that the recommendations required cooperation between household members in ways they were unaccustomed to. Secondly, adapting to recommendations required experimenting with adjusting shifting intervals. Thirdly, expectations beyond the boundaries of the household influenced willingness to follow shifting recommendations.

It was common for all households that one adult member used Community Energy Planner more than other members. However, this way of distributing the app was reported to require some level of cooperation between the participants: *"It has been mostly me who have said: "Well Arne, we have to vacuum at 17:05'"* (Susanne, H-C). This suggests that the use of the Community Energy Planner app affected the direct user and the household as a whole. As an example, multiple households reported that one member used the app while the other did the chores: *"It was mostly me who scheduled the times and mostly Kaj who did the chores"* (Jannie, H-F). Another household reported that the cooperation and distribution of the app created some challenges in the household:

> *"As the app has been installed on Michael's phone, I often had to find him in the garden and ask: 'What is the status of the app?'"* (Julie, H-D)

Participants also reported that in an effort to adapt to the recommendations required some experimentation. Some householders would experiment with adjusting their in-app shifting interval, typically going from the standard 24 hours to a smaller time interval. These smaller intervals would help them to better plan accordingly to recommendations provided by the app. However, some participants learned that the full benefits from shifting were mostly gained during larger time intervals:

> *"You learned that if you waited briefly, it was slightly better than using the 'Start now' option but not as good as if you waited 17 hours, for example."* (Janni, H-F)

With an emphasis to accommodate early and late start suggestions, some household also learned new things about their home appliances:

> *"The good part is that we figured out that our washing machine had a timer function, so it doesn't have to run during the day".* (Janni, H-F)

Nevertheless, other problems arose when adjusting to the app. In one household, participants tweaked their in-app flexibility interval and followed recommendations. However, they experienced their actions had a neutral impact on the point system, which meant that they were not able to achieve "positive" consumption behaviour:

> *"I actually haven't really used 'start now', but I have adjusted my flexibility in the app, which has caused me to never get any plus points but only neutral scores. I haven't got plus points the last couple of weeks."* (Anna, H-A)

Another aspect of following recommendations was influenced by norms reaching beyond the physical boundaries of the household. One family was living in a housing cooperative, which further challenged this household:

> *"We live very close to our neighbours, and I don't think it would be nice to wake them at 5 on a Sunday morning. There are some considerations in terms of neighbour respect."* (Lise, H-B)

The norms of respecting neighbours and keeping quiet during the night and early day restricted the household's ability to start the washing machine when suggested by the app, even though it might have been an optimal start time. However, it was not only neighbours that might be disturbed from starting machines in the late hours. In another household, participants reflected that it would disturb their own ability to sleep at night:

> *"We don't want our tumble dryer and washing machine to run at night, because they are pretty close to our bedroom. They simply make too much noise".* (Anna, H-A)

This implies that by challenging the participants' everyday practices, they reflect on their norms and values.

## 5.3 Engaging through Goals

Householders experienced the goal-oriented vision of engagement in the Community Energy Planner in three ways; 1) financial gain, 2) environmental concern and, 3) competition between the other community members. However, these goals to engage participation were experienced differently by householders.

In the preliminary interview, half the participants stated they anticipated that their primary motivation to follow shifting recommendations would be to save money: *"It would be nice if our electricity were cheaper [...] If you knew that you saved several hundred/thousands a year by doing it a more clever way"* (Anna, H-A). After having experienced the financial benefits of following the recommendations, one household was optimistic about the amounts saved as they viewed the difference in percentage:*"Sometimes it may only have been a couple of kroner and øre but compared to what we should have paid, we thought it was a lot when we looked at the percentages"* (Jannie, H-F). However, all other householders explained that the saved amount they gained from following the recommendations did not compensate for feeling a loss of freedom and convenience, a finding reported in other feedback studies of shifting [43, 52, 79, 85].

> *"I don't think there were many benefits from waiting... The numbers and amount saved were so small that I thought to myself, 'Screw this, I need my clothes dry now."* (Bettina, H-E)

The act of being 'green' or environmentally friendly was also anticipated to be engaging at first. Half of the households stated that they anticipated that their primary motivational factor in changing routines was to be more environmentally friendly: *"I think it would be great if we could help save the environment. I think that is our motivational factor"* (Susanne, H-C). Some participants reported that the environmental change they had seen by using the app had been sufficient. Unlike the participants who were motivated by financial savings, these participants seemed satisfied with the savings as long as they felt they made a difference: *"We have to protect the world for the next generations - yes, we are motivated by being green"* (Susanne, H-C). The feeling of being responsible for a generation but also including the children in such actions was shared among most of the households:

> *"The adults can be the pioneers for this app, but I think it could be a lot of fun to include the kids in it as well."* (Michael, H-D)

Although not explicitly suggested by the app, how the communal elements were designed seemed to concert efforts to compete between members in the energy group. This competitiveness was experienced and appropriated differently by participants. Some householders felt a sense of guilt associated with being part of a group that collectively was measured on their individual performance:

> *"It was because we were a part of a group. We definitely didn't want to be the most expensive family. There was a kind of competition."* (Jannie, H-F)

The feeling of guilt associated with eco-feedback systems has reported by other [22, 79]. However, some of the participants stated that their motivation to compete was limited, as they could not compare themselves directly to the other members of the group. They further elaborated that if they had a social connection to other members, they might be even more motivated to 'beat' the others. Some participants suggested a ranking system for the group as a part of the competition element as it: *"would be awesome if it was like 'Team greenhouse is doing amazing! They have saved 50 kroner this weekend; shouldn't you get started too?'"* (Anna, H-A). However, other studies suggest [34] that such competition elements in communal eco-feedback displays can quickly become a question of who is "the best" rather than addressing problematic aspects of acting sustainable.

Moreover, some householders experienced this competition element as disengaging. For instance, Household C explained how they felt that their commitment to the group was sabotaged by the other households:

> *"Sometimes you feel that your great effort from the last 2-3 days can be ruined by some of the other members"* (Arne, H-C).

How householders experienced the nature of the goal-oriented vision of the Community Energy Planner suggests that participation to engage in communal usage of sustainable energy is difficult to maintain through such goal settings.

## 5.4 Understanding Communal Energy

Participating households showed keen interest in the idea of a group collectively acting sustainably when first introduced to the study. However, experiencing the Community Energy Planner app in everyday life led to various understandings of a virtual energy community. Two aspects influenced this; a sense - or lack - of community feeling and social engagement among members.

The participants were asked if they felt any community feeling by being a member of the EnergiFlex group. All households reflected that they neither experienced an immediate nor an intimate community feeling during the study. For instance, Bettina explained: *"we definitely didn't experience any community feeling that is for sure"* (Bettina, H-E). Another household explained they looked at the community feature in the app but did understand what to do with it. Others reflected they did get any communal feeling using the app, as the energy collective was only experienced when *"receiving minus points for using the "start now" option"* (Anna, H-A). Multiple households mentioned that a vital reason as to why they did not feel empowered by the collective was the lack of knowing other members. One household explained:

> *"Well, it was kinda like a platform with some people on the other side, whom I didn't know at all. I didn't feel any responsibility for them about my consumption whatsoever"* (Lise, H-B).

Another householder emphasised this lack of collective responsibility: *"I bet they sat around and cursed because I had pressed 'start now' three times in a row, but I just thought it was kind of funny and I didn't really care"* (Bettina, H-E). Despite missing a community feeling, some households felt guilty when they used the "Start now" option because others were involved, and it was *"embarrassing to be the one who drags the group down"* (Anna, H-A). Another householder explained this as:

> *"I felt a bit guilty on behalf of the group without really feeling it anyway... I also told you, Michael, that we must be the worst participating members. We just drag the group down."* (Julie, H-D)

Others reflected that the difficulties of just following the shifting recommendations and adapt to new routines within their own households influenced how they perceived the group performance for a group of people they did not know: *"We didn't have the energy to think about the group as it required a lot just to follow the app suggestions in our own home. We ran our own routine and didn't have the extra energy to check up on the group"* (Michael, H-D). Overall, it suggests that because participants did not experience any social connection to the other group members, they also did not feel responsible for taking part in collective actions associated with being part of a community. This indicates that the Community Energy Planner app did not facilitate communal engagement as envisioned with the group engagement view.

Although initially interested in this communal part of the study, there seemed to be a mutual desire for more elaborative information about the other members. However, when asked, participants had different ideas about what energy data they were willing to share, as they were reluctant to share too much information to strangers. Multiple participants suggested that a virtual energy community should integrate limited personal information because *"if it were completely public, I wouldn't like John Doe from somewhere to know how much I am using my washing machine. I wouldn't like that"* (Anna, H-A) or at least partial anonymise information: *"I mean, you don't have to see people's faces. It could maybe just be some kind of profile"* (Lise, H-B).

There were multiple examples of participants suggesting that groups in the Community Energy Planner app might be differently experienced if they constituted a social and familiarised community. Some reflected this would arguably also make it easier for them to engage, communicate, and actively participate in being part of a community because *"then you would have someone to chat with like 'It's going pretty good, with the app?' You know, to keep the fire alive"* (Jannie, H-F). Another participant explained knowing people in the groups would be like *"a kind of relationship where it is not just fictitious people you are connecting with. It is actually him* *and her who have this kid"* (Julie, H-D). Furthermore, the participants believed that being able to communicate with others in the community would give opportunities to help each other:

> *"You would be able to share tips and tricks in the group. Maybe someone else figured out a smarter way of doing stuff and would like to share it with the rest of the group?"* (Arne, H-C).

The benefit of knowing other community members was further emphasised by how some of the participating were currently living: *"We live in a housing cooperative, and if we had an energy group, then we would be in it together, and that may have made it easier"* (Lise, H-B).

These findings challenge the notion of virtual energy communities facilitated by group formations working solely on a point-reward system of energy recommendations in an app as a driving factor for sustainable collective action. However, they also suggest that householders do show interest to engage in collective energy actions if they feel part of a social community that enables cooperation, exchange of ideas, and participation in something larger than the interests of an individual household. Similarly, householders willingness to participate in such communities involves dynamics that extend beyond rational decision-making processes.

# 6 DISCUSSION

The findings of this study have raised several questions for discussion in relation to the establishment of future sustainable energy communities. We now discuss the implications of these findings for researchers and practitioners to engage in when designing technologies for communal sustainable energy actions.

## 6.1 Non-coherent Negotiability of Shifting

One of the core principles of Community Energy Planner is to promote shifting as a way to reduce CO2 emission. However, several of our participants questioned if actions of recommending shifting also led to sustainable consumption behaviour: *"If you want to incorporate the sustainability aspect, I don't believe it should concern when you use your appliances but rather how much you use them"* (Jens, H-B). Others have also reported difficulties in understanding the concept of shifting [44, 74]. Others have reported [6, 45, 72, 79] that when the shifting practice is not seen as a whole when producing shifting recommendations, adhering to shifting behaviour may lead to unintended but yet unsustainable behaviours. These studies highlight that designing eco-feedback for shifting may facilitate that some householders start to use their appliances more frequently to fit the suggested times.

Participants in our study experienced similar situations as some stated that their overall consumption increased when they started using the Community Energy Planner app. Furthermore, prior studies also found that shifting may force people to choose unsustainable options as the suggested times may not correspond to when it is possible to e.g. dry clothes outside [20, 45, 79]. The same challenges were experienced in our study. Some householders would deliberate choose the (un)sustainable option and press "start now" as they did not want their clothes to be drying outside at night. Overall, shifting appeared to challenge the social dynamics of the individual households as it required participants to sacrifice convenience in order to comply with the shifting strategy.

In addition to this, several of our participants did not fully understand how shifting could be sustainable as they used the same amount of power: *"Can we agree that my vacuum cleaner uses the same amount of power no matter when I use it?"* (Johnny, H-E). As our participants questioned shifting, they suggested that instead of shifting energy, people should be taught to use less energy in general. This quote adds to the discussion of whether or not shifting is the most suitable and efficient way towards a more sustainable future. Instead, our findings suggest that, when designing technologies to support sustainable practices, the practices should come first, epistemologically and conceptually, and that, therefore, simplifications on users behaviour as the Resource Man or the Social Man [88] are limited in scope and unable to involve people in a meaningful way.

## 6.2 Community vs. Group Competition

Unlike studies focusing on shifting on a household level, our study sought to investigate it on a community level. Our findings showed that multiple households began focusing on themselves through a competitive mindset rather than being a part of the community. Morschheuser et al. [65] argue that individualistic competition can challenge the collective mindset and shared goals. Likewise, Hasselqvist et al. [37] argue that energy communities can be motivated by cooperating and competing against other communities in being the "greenest". Nevertheless, in our study, challenges of competing were also highlighted that the competition aspect could influence consumption in a negative manner: *"You shouldn't start your washing machine multiple times just to win a competition because then you'll start using it more than you even need to?"* (Jannie, H-F). This adds to the discussion of whether the design of Community Energy Planner can even be considered environmentally sustainable. Therefore, the shift from the Resource Man to the Social Man is insufficient to support sustainable transitions. Participatory approaches like participatory design can probably bring in the immediacy of household practices, and they can be the basis for fruitful future investigations.

Furthermore, we found that the current design did not succeed in establishing any relationship between the members as all of our participants stated that they did not experience any community feeling. Some participants suggested that the community should focus on cooperation by helping each other by sharing tips and tricks for sustainable actions: *"If we found a good balance between low price and convenience, we would like to share this with others"* (Jens, H-B). In contrast to these suggestions, the participants felt a sense of guilt by being in the community. This was present when their actions affected the community in a negative way: *"I felt extremely bad every time I had to use 'start now' (...) Even my stomach hurt the times I did it"* (Arne, H-C). This may raise a discussion of whether designing through guilt is an ethical way of motivating members in an energy community? Dourish [22] comments on the problems of framing environmental concern through moral choices and argues that those who are not able to follow sustainable recommendations would be subject to stigmatisation. This correlates with how some of our participants stated that they felt sabotaged when other households did not perform well. In addition, Sengers et al. [83] argue that guilt as a design choice is both unpleasant and counterproductive to positive environmental action. The authors' further state that sustainable design should move away from guilt and instead focus on enjoyment and personal interests. This implies that the vision of techno-solutionist narrative embedded in many of these technologies needs to be re-examined as the current design entails guilt rather than enjoyment. This is in line with previous studies in the design field that have argued for more complex conceptualisations of social relations that can support joy as a mode of engagement [46, 51, 95].

## 6.3 What Design Approach?

Our findings show that the techno-solutionist design approach did not align with the modern everyday of our participants. If this approach to focus solely on the technical facilitation of design is not suitable, how should developers design in order to accommodate the norms and values of households? Others argue [44, 72, 76, 91] that in order for design to shape more sustainable everyday practices, it is crucial to include the social norms and values of energy-consuming household practices and look towards different performers of these practices. Our study adds to this argument, as we found that the use of the app led to tensions and sometimes limited households in acting sustainable. As a way of incorporating more members, Wilkins et al. [103] used a bottom-up approach in the design process of a Peer-to-Peer energy trading system. The authors argue that due to the overwhelming possibilities of future energy systems, potential users need to be active participants in the design process. Through participatory design, the authors found that participants valued the community's ability to gather the community around shared values and configure their own business model for the system. This corresponds to how our participants reflected on how they liked to be able to personalise and segment their energy community. In relation to this, Hasselqvist et al. [36] included community members in an iterative design process of an app aimed to reduce collective energy use. This led to a semi-interactive mockup of the app, which was later iterated based on member feedback to support the community's expectations.

Our study adds to this, as we found that participatory design might only be the first step towards constructing communal energy solutions. As Hasselqvist et al. [36] suggest, we agree that members of a community should experience proposed technologies through an iterative design process. The need for design iterations was also present during our study, as several participants initially stated that financial benefits would be enough to motivate them. After the deployment period, the same participants stated that the financial benefits were too small to motivate them anyway. The participants initially proclaimed themselves with a mindset similar to that of Strenger's Resource Man [87, 88] but eventually found that energy data was not sufficient to keep them engaged in the energy community. This further questions the feasibility of the techno-solutionist design approach as well as the existence of the Resource Man. In other words, we agree that the Social Resource Man is a misconception of the energy consumer and that this perception needs to be readjusted. Actual norms and values of an energy community can be difficult to identify purely by developers and we believe that it is crucial to listen and incorporate actual community members as they are the ones with first-hand experience and domain knowledge. The ongoing conversation on designing commons can be a further direction to be explored, making energy a resource actually managed collectively [11, 59, 96, 97].

# 7 CONCLUSION

In this paper, we presented a study on how a techno-solutionist design vision of an energy community aligned with the everyday lives of six households. This was done by deploying the app, Community Energy Planner, into the households for one month. We qualitatively examined the energy community through interviews and identified four themes concerning topics as negotiation, expansions, engagement with sustainable communal energy. Our findings reveal that the techno-solutionist design vision did not align with the actual norms and values of the community members. Furthermore, our study contributes beyond the findings as we point to potentially alternative design visions for future energy communities. By relating prior research in sustainable HCI, we discussed how design should move away from guilt and instead focus on incorporating enjoyment and personal interests. Finally, we discussed future directions for energy community design by stressing the importance of including potentiel community members in the design process.

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