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The Character of Eco-feedback Systems for Energy Communities

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ABSTRACT

Energy communities are emerging around Europe with a vision to transition the traditional centralised energy system to one where individual households can collaborate to become energy producers. Although the vision of energy communities is still in a formative stage, it seems members of such organisations will need digital technology to manage and organise renewable energy together. The design of eco-feedback designs appears as a digital means to create awareness of this need. Yet, until recently, eco-feedback has been designed to target the individual householder. The research presented in this paper aims to identify design characteristics of eco-feedback systems aimed at collaborative energy communities. We explore two different concept designs that are evaluated in a focus group session with prospective energy community members to establish design characteristics. The findings show that participants not only identified characteristics related to different eco-feedback design characters but also identified a set of properties related to the collaborative and social nature of the community.

CCS CONCEPTS

• **Human-centered computing → Collaborative interaction**.

KEYWORDS

Energy community; eco-feedback; concept-driven design; character of things; sustainability

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1 INTRODUCTION

To reduce CO_2 emissions, the European Union is encouraging its members to move towards developing more renewable energy systems [20, 40]. Although nowadays, most EU energy is produced and governed by centralised energy systems, we are starting to see the exploration of decentralised energy systems where smaller local cooperatives and even individual citizens are expected to become active energy actors [45, 62]. In the EU, the organisation of local energy cooperatives are envisioned as "energy communities" where citizens are able to *"produce, store and sell their own renewable energy"* [7]. The purpose of these emerging EU energy communities is to produce and distribute renewable energy for local citizens to consume [8]. While the vision of energy communities is still in a formative stage, it seems that members of such organisations will require a high level of digitalisation to organise the production, distribution and consumption of renewable energy as a collective [6, 29, 63].

Additionally, the trend of individual households and local organisations investing in solar panels and wind turbines suggests that by 2050 almost half of European households will produce renewable energy from localised energy technology [33]. Although in the future, these energy communities may strive to be self-sufficient, most of them will need to be supported by other institutions like local authorities, businesses or non-governmental organisations [20, 21, 24, 46, 61]. To help realise energy communities, it is expected that participating members need information about the different activities that are part of an energy cycle (e.g., energy production, distribution and consumption) [46]. One way of providing such information might be to raise awareness via digital technologies about localised energy production and how community energy may best be consumed. This emphasises that forming prospective energy communities is indeed a social-technical challenge [23–25, 32].

One stream of research has explored and studied eco-feedback design [17] as a means to inform individual householders about their energy consumption activities [34, 49]. Eco-feedback design typically uses comparisons of past, real-time or future consumption to make householders aware of their consumption. Eco-feedback technologies give different information about energy consumption to households where the design is meant to cause individual behaviour change, e.g., either aiming to reduce [18] or shift household consumption to align with the production of renewable energy [34]. Still, most work in this area focuses on creating energy awareness on an individual level. In contrast, little research focuses on the collaborative characteristics of eco-feedback aiming to support energy communities to manage, organise and govern their energy.

In this study, we explore how an energy community in an EU city may manage their energy (both consumption and production) while strengthening its community sense through design. The paper offers three main contributions. First, we explore two different eco-feedback concepts for a potential future energy community. Second, we evaluate the two concept designs with prospective members of an energy community to define a diverse set of characteristics to consider when designing eco-feedback systems for energy communities. Third, we use these insights to discuss different characters for community-focused eco-feedback designs that future designers may take into account.

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2 RELATED WORK

2.1 Energy communities

Although we are only starting to see the concept of energy communities being explored [6, 29, 31, 32, 61, 63], we can still categorise these according to how they produce renewable energy (production), who is going to benefit from this energy and how (consumption), what are the motivations for joining an energy community (purpose), and which actors take part (participants).

For instance, Walker and Devine-Wright [61] have developed a framework in which ways that energy community projects can be organised. In this framework, the authors describe dimensions that conceptualise energy communities as either distant or private to local or collective projects, while suggesting that an 'ideal' energy community project is closer to the open & participatory and the local & collective dimensions. Building on these dimensions, Gui et al. [20] establish three typologies of future renewable energy communities: 1) centralised energy communities, 2) distributed energy communities, and 3) decentralised energy communities. The authors define centralised energy communities as *"a cohesive network of households and businesses that collectively own or participate in energy-related projects, [...]"*. Distributed energy communities are *' 'a network of households and businesses that generate or own distributed generation individually, connected through a controlling entity either physically or virtually, [...]"* and decentralised communities are those in which *"a community of households, businesses or a municipality that generates and consumes energy locally for self-sufficiency that may or may not connect to the main grid"* [20]. However, while these studies nicely conceptualise different energy communities and how activities in these may be supported, little research explores how to support and organise energy activities in these communities from a design perspective.

In the human-computer interaction (HCI) and interaction design research communities, we do see studies that have explored how design may support sustainable activities in communities. For instance, the Tidy Street project visualised energy consumption between neighbours on the street, which enabled neighbours to compare their activity publicly [2, 35]. The Tiree Energy Pulse uses forecasts to predict energy production from community wind turbines to inform citizens from an island about the energy availability they can expect during the day [55]. Similarly, Francisco and Taylor [15] designed an eco-feedback system to visualise energy consumption in a public building with a community focus, while Li et al. [41] explores how to design for a rural community in Germany that covers citizens' consumption needs with different energy-generating technologies with the help from institutions and the government.

What can be noticed in all the examples above is that they are all very different, but at the same time, the authors consider them as communities of energy. The variety of understanding energy communities demonstrates that theories around the topic still need to be evaluated in future scenarios. In this study, we take inspiration from Walker and Devine-Wright [61]'s framework of energy communities. Thus, in the future scenario, which we wish to explore in this study, we conceptualise an "ideal" energy community as a place where members of a neighbourhood or housing community (open & participatory process) install solar panels in their building to cover consumption needs (local & collective outcome).

2.2 Designing Eco-feedback

The design of eco-feedback systems, among other purposes, aims to influence a behaviour change in peoples' everyday life [17]. As such, the technologies are intended to inform individuals about their consumption and the possible benefits they might gain by making a few changes in their energy-consuming activities. Hence, the feedback materialised in these designs uses different design principles with the purpose of persuading energy consumers to change their behaviour [5, 10]. One design principle used by many designers and researchers in eco-feedback systems is to influence change by comparison. When talking about both individual and collective eco-feedback, the comparison is usually made between past, present and forecasted data to show consumption patterns of household energy-consuming activities [17, 18, 34].

The idea of visualising energy information for the individual household is, for instance, explored by Kjeldskov et al. [34], highlighting that such information is an effective design means in sparking awareness of household energy consumption. Pierce and Paulos [50] explore the concept of householders shifting activities to align with their own produced energy [49, 51]. Others design studies target specific energy-consuming activities. For instance, Costanza et al. [9] explore how digital technology may facilitate shifting laundry activities to times that are sustainably favourable. Similarly, Bourgeois et al. [4] studied the desirability and feasibility of automated technology aiming to support EV drivers in harvesting their domestic solar-produced energy.

When it comes to visualising energy information to communities, we often see comparisons used to contrast different households' consumption patterns. For example, Hansen et al. [22] designed Lumen to facilitate reflections in energy groups showing that energy comparison might actually foster feelings of guilt. This notion of guilt is also reported by Jensen et al. [31] studying how the design of energy comparison is experienced by householders in everyday life. In contrast, Meurer et al. [44] illustrates how citizen perspectives on the design of eco-feedback may support collective understandings of sustainable mobility in the city. To capture social dynamics as part of design, we see an ongoing conversation on designing commons as a means to view resource consumption as a collective problem [14, 60]. For instance, Fritsch et al. [16] illustrates how personal encounters influences relationships and caring practices within distinctive commons.

Kuijer [36] conceptualises different theories on human action and how these can be materialised within the sustainable design field to support change. In this work, Kuijer discusses different types of social doctrines, which are used to understand social action. For this study, two of the theories mentioned have been chosen for further exploration: norm-oriented theory and social practice theory. We describe both in detail later.

3 METHODOLOGY

Stolterman and Wiberg coined the concept-driven methodology [57], which complements research methods that traditionally follow user-centred interaction design approaches. The concept-driven methodology allows for the inquiry of a concept or theory that needs further investigation by exploring futuristic use scenarios, which are manifested in concrete designs.

In the Related Work section, we demonstrated that the topic of energy communities is still under development and needs further research. In particular, we see a need to explore further how digital technology may support these communities in the future. The concept-driven methodology thus fits well with this purpose as it allows us to explore the concept of digital-supported energy communities through future scenarios. We work under the assumption that eco-feedback may be a valuable design means for energy community members to engage with renewable energy activities (e.g., energy production, distribution and consumption) [46]. In this study, we aim to explore this assumption further. As such, we set out to study the concept of energy community eco-feedback systems by developing two concrete design proposals that differ in how to approach and explore future energy communities.

According to Stolterman and Wiberg [57], a concept-driven approach can be conducted following a set of methodological activities, which are very similar to any design process. However, they differ by being exploratory in nature rather than being careful investigations of present user situations (traditional user-centred design). The activities of a concept-driven approach are; 1) *concept generation*, 2) *concept exploration*, 3) *internal concept critique*, 4) *design of artefacts*, 5) *external concept critique*, 6) *concept revisited*, and 7) *concept contextualisation*. These seven concept-driven activities are used to guide the study process presented here. The results of the first five are presented in this section. The results of the two latter are presented in the Discussion section.

3.1 Concept Generation

Conceptual ideas materialised as concrete designs are used to present future realities based on a theoretical concept. Design concepts are not a prototype, but they are probes or investigative instruments that enable researchers to explore new ideas. Hence, in concept generation activities, design researchers may work with metaphors, tensions or associations as means to search for the unexpected [57].

To help us study eco-feedback for energy communities as a concept in this paper, we draw on Janlert and Stolterman [26]'s concept of *"character of things"*. According to Janlert and Stolterman [26], a design's character provides information about the entire object, as it suggests what the design can be used for, how people may relate to the design, and how it may be used among other objects. Thus, exploring design characters is a way to give an accurate description of possible interactions through the design's characteristics. Design characteristics can be grouped into two different categories: 'manifest properties', which are related to physical characteristics like colours and shapes, and 'dispositional properties', which are characteristics associated with actions, feelings, or interactions [26]. Together those design characteristics make up the design's character. Characters are important conceptual devices that can reduce the mental effort involved when designing. When designers ascribe a certain character to a design, they make a simple but powerful description that is accurate enough to appreciate and evaluate the consequences of people's interactions with the design [26].

One of the main activities of energy community members is managing energy [46]. Thus, we believe it to be intriguing to explore design concepts that may support citizens in performing energy activities inside a community. Eco-feedback has so far mainly been used to explore 1) how design may inform individual householders about their past consumption [17, 44], 2) the effects of forecast energy supply to align consumption with production [34, 55], or 3) how comparing consumption patterns with others may change household attitudes of using energy [2, 22, 31, 48]. These studies suggest that eco-feedback could be a first step in creating awareness of the availability of locally produced renewable energy and helping energy community members get an overview of how they consume.

This study aims to explore how future eco-feedback designs, with a focus on energy communities, could be supported by digital technology. We aim to define what character such community eco-feedback designs may carry in an effort to establish characteristics that future designers may consider when developing such future energy systems.

3.1.1 Case study: An Energy Community in Spain. As a means to explore energy communities, the designs explored in this study will be contextualised in a possible energy community. The need for further research on the concept makes it difficult to design for any energy community as they are merely starting to be realised [23, 32]. Thus, we find it meaningful to situate our exploration of future use scenarios and design concepts to keep in mind the possible energy communities we are designing for.

Energy communities usually invest in wind turbines or solar panels to produce their energy. Consequently, a country's climate will shape what types of renewable energy technologies are appropriate for a community to invest in. We situate this study in Spain, one of the countries in Europe with many sun hours throughout the year. This makes it meaningful to work with communities that show interest or already have invested in solar panels.

Until 2018, the Spanish government charged citizens who were self-supplying with solar panels with taxes, which made it more expensive to consume local renewable energy rather than consuming from the main grid [53]. For that reason, Spanish citizens have been reluctant to acquire solar panels [53]. After a law modification, the tax duty was eliminated, but Spanish communities still see solar panels as an expensive energy technology. Energy communities could benefit from solar panels as the first investment would be divided between all the members of the community and the benefits of it would be seen sooner [32]. Based on this, the future use scenarios explored in this study are situated in a Spanish housing association that collaborates on installing solar panels on the rooftop of the building to cover their consumption needs.

3.2 Concept Exploration

Concept exploration activities are all about opening up and exploring new and unseen design spaces [57]. To facilitate such exploration in this study, we set out to explore how eco-feedback systems could be designed for energy communities by identifying different design theories. As energy communities are still emerging and not yet clearly defined [61], it is challenging to develop a single character for them. This lack of antecedents led to the exploration of two different design approaches to probe potential energy community members regarding what they appreciate and understand about different design proposals. To guide this exploration, we are inspired by two different theories of understanding human action and social order; norm-oriented theory and social practice theory [52]. Norm-oriented perspectives understand human behaviours as a result of normative consensuses, such as collective values and social rules. Social practice perspectives understand human action as a certain social and routinised way of understanding, knowing how, and desiring to carry out a practice, e.g., washing clothes, showering, and cooking. The socially shared ways of doing these everyday activities also impact people's energy consumption. Bringing these perspectives into sustainable interaction design, we are inspired by the work of Kuijer [36].

According to Kuijer [36], we can understand norm-oriented eco-feedback as designs that intend to shape collective norms and values. In the context of energy communities, this could, for instance, be about informing members about the availability of renewable energy and making them collectively reflect upon how they consume energy [31, 35, 44, 48]. If we bring this into our situated scenario of the Spanish housing association, a communal eco-feedback may aim to make members aware of the use of renewable energy in the building. Hence, the purpose of the first design proposal should aim to inform and make householders reflect on how they, as a community, can adapt everyday energy activities to balance their consumption needs with the energy they are producing collectively.

Similarly, we can understand designing framed from a social practice perspective as conceptualising designs that consider everyday practice as a unit of design [39]. In essence, this means focusing on how design can be part of reconfiguring everyday practices in desirable and meaningful ways while shaping energy consumption in more sustainable ways, e.g., washing [28], showering [37], EV driving [59], heating [38], and cooking [19]. Bringing this to the context of community-centred eco-feedback could mean focusing design efforts on how an everyday practice can be performed while considering the community's collective energy activities (consumption, distribution and production). Hence, the purpose of the second design proposal is to provoke and encourage members to experiment with playful and new ways to perform an energy-intensive practice.

3.3 Internal Concept Critique

To examine the strength of chosen design concepts, internal concept critique activities seek to critique the uniqueness of concepts and how they relate to theory [57]. In our process, the exploration in the design phase resulted in two design concepts: a norm-oriented design and a practice-oriented design. This phase was a highly iterative process, where we internally explored and critiqued different ways of materialising the different concepts.

For the norm-oriented concept, we studied different materials and languages to identify a visual form to represent consumption and production data. In the case of the practice-oriented concept, we explored different forms of targeting interaction activities (apps, websites, games, planning tools) to find an engaging design to help members to organise laundries within the community. All the sketches and ideas were presented to different people during the design process to get feedback and iterate on the design concepts. Both artefacts are described in detail in the next section.

3.4 Design of Artefacts

As part of "design of artefacts" activities, it is important to materialise and express the concepts in a concrete artefact [57]. Hence, in this section, we present the two concrete design proposals. As mentioned, both designs are situated within the same conceptual community: a Spanish housing organisation where members live in the same building. In our future scenario, they are, as a community, interested in investing and installing solar panels on the rooftop of their building to cover their energy consumption needs.

In this future scenario, we imagine the two concrete designs being placed at the entrance of the building, where all the householders will be able to see them every time they enter or leave the building. We also assume that installing batteries to store energy is too expensive, and therefore it is cheaper to consume energy at the same time it is produced. This means our intent inscribed in both designs is to encourage members of the energy community to shift [50, 51] energy-consuming activities to times that align with the production of energy within the community (see Figure 1).

Because our conceptual designs are based on fictional future scenarios, we choose to materialise the designs using conceptual videos. Concept videos are a type of design fiction which allow us to embed a vision or concept about a possible technological future to help bring forth characteristics and critiques of the vision presented in concept videos [64]. For our study, we designed three concept videos which we later use to describe the context and evaluate the concept of the two eco-feedback designs to potential future energy community members;

- A video describing the concept of energy community and the idea of members needing to align energy activities (See video [12]).
- A video presenting a design materialising a norm-oriented eco-feedback for energy communities (See video [11]).
- A video presenting a design materialising a practice-oriented eco-feedback for energy communities (See video [13]).

3.4.1 Design One: Visualising Energy Data through Lighting. The first design explores a norm-oriented theory through design [36, 52],

Figure 1: Conceptualising and explaining the concept of aligning energy activities after patterns of consumption and production within the energy community [12]

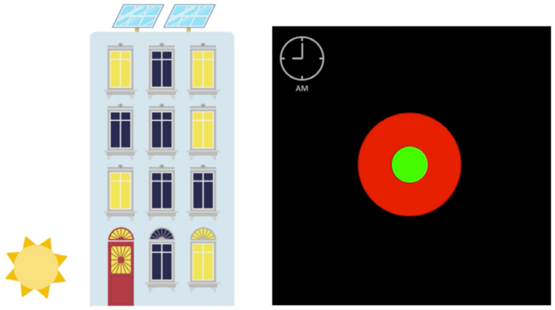

Figure 2: Data visualisation with an excess of consumption. Frame from video materialisation [11].

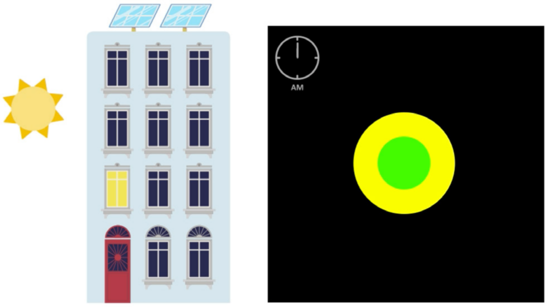

Figure 3: Data visualisation with higher production than consumption. Frame from video materialisation [11].

and the idea that human change happens via normative consensuses, such as collective values. In this design, we aim to visualise real-time energy production from solar panels and the sum of consumption from all the community members in the building (see the concept video [11]). The intent of this eco-feedback design is to make members aware of the difference between production peak hours and consumption peak hours to spark reflections on how to balance their collective consumption with the community's production of renewable energy. If community consumption and production are not aligned, the (un)-consumed energy is sent to the main grid. Community members also pay for (over)-consumed energy from the main grid if the consumption exceeds the availability of renewable energy produced within the community.

This design concept consists of a black wall and two spotlights pointing towards the wall. The red light represents consumption. It will be connected to a device that measures consumption in the building. The projected red light will change its size, according to the collective consumed kWh. If the consumption is high, the diameter of the red light will grow. If the consumption is low, the red light will reduce in size. The second light is yellow; it represents production. It will be connected to the solar panels to measure the kWh of energy being produced. The behaviour will be the same as the red light: according to the kWh being produced, the yellow circle will reduce or increase its size.

The two lights will light up at the same point in the black wall; they will be overlapped. In the design, we take into account that the sum of (red and yellow) light colours creates a third colour. According to the light colour theory, the addition of red and yellow results in green light. When the two lights are overlapped and change their size, their superposition will create different colour combinations. In Figure 2, there is an example of how the data would be represented at 9 am. Let us then assume that consumption in the morning would be higher than production; a big red light represents consumption, and a small green circle (created with the sum of red and yellow lights) represents the amount of consumption covered by the community's renewable energy production. The red area represents the consumption not covered by the community's energy supply from solar panels and hence indicates that the community is using energy from the main grid.

On the other hand, in Figure 3, information from around noon (12 o'clock) is given. In this example, there is high production and low consumption. This will result in a big yellow circle with a smaller green circle inside (created with the sum of yellow and red lights). The interpretation of this visualisation is that 100% of the consumption is covered by community renewable energy. Still, the community is "losing" energy from solar panels, as this energy is not used. Also, the design will have a dial that will allow members to change the size of the red circle (consumption) to visualise the effect of a change in collective consumption activities that is related to the yellow circle (production). Overall, this eco-feedback design intends to form a consensus around the idea of being aware of energy activities and possibly aligning consumption and production as a collective value that benefits the community.

3.4.2 *Design Two: Laundry Planning Wood Game.*

In the second design, we explore energy community perspectives from a social practice theory approach [36, 52]. We do so by targeting a high-intensive energy-consuming practice, namely washing clothes. Inspired by the Box design [28], we aim to trigger ideas of washing practices with a community perspective in mind. Focusing on triggering change through design in a playful and meaningful way, we designed a wood game for planning to do the laundry from a collective perspective (see the concept video [13]).

The purpose of the game is for members of the energy community to schedule their washing machines according to renewable energy availability. The design is inspired by the "Connect Four"

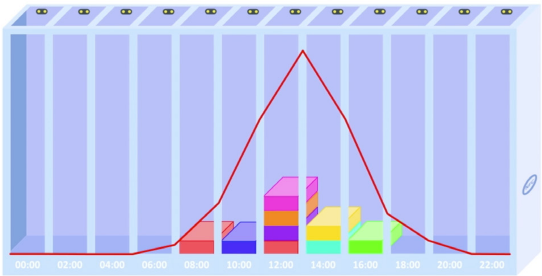

Figure 4: Laundry scheduling wood piece game with production forecast and booked laundries. Frame from video materialisation [13].

Participants	Demographics	Building	Housing Community
P1	P1: 29 years old, electrical engineer Flatmate: 29	Building with 3 apartments	There is a housing community in the building, they meet every 3 months and manage common areas, parking, cleaning... The community owns an outdoor patio that all households can use, if there is any misunderstanding, they try to approach it together. It is a small community and they don't have many conflicts.
P2	P2: 25, designer Parents: 59, 59 Sibling: 27	Building with 29 apartments	They do housing meetings quite often. There is a mezzanine where the building doorman used to live, now it is owned by the community, and they rent it. The money they get from the mezzanine is used to cover community expenses.
P3	P3: 57, retired personal trainer Partner: 60 Child: 23	Building with 7 apartments	The housing community meets at least once a year, and more often if it is needed, where members can expose proposals. Families share a terrace that is managed together within the community.
P4, P5	P4: 23, teacher and physician P5: 30, developer	Building with 29 apartments	There is a housing community with which they meet quite often. There isn't anything owned by the community. They only manage together common areas (like the entrance or the stairs)

Table 1: Participants' demographics and their housing community characteristics.

game and how public laundromats are organised. In these places, laundry is limited by the availability of machines and opening times, which shapes how people collectively organise their laundry tasks. Considering this in our design, we aim for community members to reschedule energy-consuming activities to the solar panel's peak hours, so the community can make better use of their renewable production. Thus, by participating in the game, members implicitly foster more sustainable consumption patterns.

The design consists of a box with twelve columns; each hole represents two hours (see Figure 4). Every morning, according to a predictive forecast of energy production, a red thread will be placed in front of the box. The thread will represent the amount of energy that is being produced every hour of the day. Members will have to place wood pieces in the columns to schedule their laundry. To identify themselves, a colour will be assigned to each family. The size of the wood pieces will correspond to a two hours laundry time. By dropping a piece in a column, they will be planning a washing machine at the time corresponding to that column.

Each wood piece will have an NFC sensor that will distinguish community members. On one side of the box, there will be an NFC sensor. When a community member brings their wood piece to the sensor, it will identify the family. At the top of each hole, there will be a presence sensor; every time a member identifies themselves with the NFC chip, presence sensors will be activated. The presence sensor that observes a wood piece falling in front of it will send this information to the database, which indicates that a member has scheduled to run their washing machine at this time slot. The size of the pieces will be proportional to the height of the thread, to have a realistic overview of the energy being produced and what amount of it will be consumed by washing machines.

Members are able to access the schedule from any device to see the community's bookings. Also, washing machines are blocked from running during that times that have not been scheduled, and members will have to follow their scheduled times to use them. Every morning, the "game" will be restarted to start planning laundries again. In the example seen in Figure 4, the booking of members' running time of their washing machines is made during those times when the community's solar panels are producing energy.

3.5 External Design Critique

In concept-driven design research, external design critique activities aim to expose the concept designs to a public to validate the ideas materialised in the design [57]. To externally evaluate the two design concepts and obtain feedback on their character and characteristics in our study, we formed a focus group session with prospective members of energy communities in Spain (see Table 1). Focus groups are a qualitative research method where a collective discussion is generated to get knowledge from the reflections and experiences of the participants [43]. Hence, focus groups can be used as exploratory research tools where the collective conversation generates new understandings. Although participants may have different opinions, they often try to get a common understanding of the topic that can be analysed [43]. As the purpose of this study is to gain insight from prospective members of an energy community, a focus group session enables the generation of a discussion around the designs and concepts being studied in this research project. Further, as communities have an essential role in the research, a focus group is one way to get external design critique from potential users of eco-feedback designed for energy communities.

3.5.1 Design of the Focus Group. We organised the focus group session around three concept videos [11–13]. By materialising the design concepts in videos, we also make it possible to obtain external critique [64]. For instance, Blythe [3] argues that when working with future realities, designers should not only focus on the design itself but also reflect upon the everyday scenarios in which the design is supposed to play a role and what people are going to use it for. Thus, our design concepts also work as a research tool to facilitate reflection or discussion, and an instrument used to create new knowledge about a topic or concept [56, 57]. Hence, the concept designs are not only used to critique the design itself but also to spark a discussion about how potential energy community members could use such digital technology in everyday life.

The focus group session was structured around five themes: 1) *demographics and energy consumption awareness of the participants*, 2) *energy communities*, 3) *the norm-oriented concept design (visualising data with lights)*, 4) *the practice-oriented design (laundry planning wood game)*, and 5) *design character and characteristics*. At

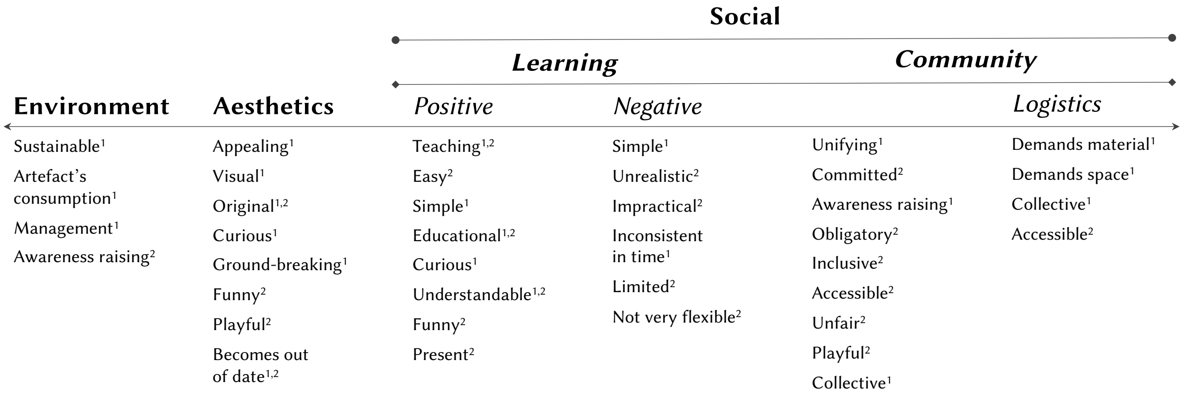

Figure 5: Card sorting categories. (1 = Data visualisation with lights; 2 = Laundry planning wood game).

the beginning of themes 2, 3 and 4, we showed the concept videos to the participants. Following this, we facilitated a discussion about all the themes and possible design characters.

We strived to recruit prospective energy community members for the focus group session. Participants were recruited by snowballing via a broadcast message that was sent to various WhatsApp groups in Spain. We asked for participants living in a building with more than one apartment to ensure they were part of a building community (a common practice in Spain as members meet around once a month to negotiate issues related to the building and the services they have within). Further, we required participants to live in a building where there was a Spanish housing community interested in sustainability or renewable energies. As can be seen in Table 1, five participants with different demographics were chosen. The common characteristic of the participants is their living conditions. They all lived in a building community similar to the future scenario, which was fundamental in our development of the two design concepts.

The focus group was conducted online and lasted 2 hours and 5 minutes. The entire focus group session was recorded, transcribed and translated into English. This data was later used to analyse and describe the design character of each of the design concepts. The focus group session and the subsequent data analysis were conducted by author one under the guidance of author two.

3.5.2 Development of Characteristics. During the focus group, participants were asked to create a list of characteristics for each of the concept designs. During this, both manifest (physical characteristics, e.g., colours and shapes) and dispositional (characteristics associated with actions, feelings, or interactions) characteristics were considered [26]. This part was conducted after the concept video presentation and discussion, where participants were asked to suggest a list of characteristics for each design. In the fifth theme of the focus group, participants organised the identified characteristics through a card sorting activity [47]. The card sorting activity consisted in giving participants 15 minutes to assemble the list of characteristics in different categories. During this activity, they had the freedom to choose the categories and the number of groups, and they could use the same character in various categories. Through a discussion, participants had to agree on the best way to organise the characteristics.

To evaluate the desire for the designs' characteristics identified by participants, participants were asked to answer a Kano Model questionnaire together [54]. The Kano Model helps to determine the perception of each character through functional and dysfunctional questions and an evaluation table. For each characteristic, participants were asked to answer if they liked the characteristic in the design (functional question) or if they preferred the design did not have this characteristic (dysfunctional question). When the two questions are answered, the evaluation table determines the category of each of the characteristics according to users' satisfaction [54, 65]. During the focus group session, participants answered the functional and dysfunctional questions together; they all had the chance to argue about their understanding of each characteristic. The findings obtained from the focus group session are described in the following section.

4 FINDINGS

Our findings are based on an analysis of reflections, discussions, and understandings of the focus group participants. This analysis points to clues to help conceptualise and describe two different characters for community-based eco-feedback designs. The card sorting activity allowed participants to organise the characteristics they had previously identified, while it gave them a chance to discuss what characterises eco-feedback designs for communities. Figure 5 shows the result of the card sorting activity with the characteristics grouped under each category identified by participants. Interestingly, apart from groups of characteristics that defined eco-feedback designs like environment or learning, they also created a community category. The community classifier grouped characteristics that described a way to strengthen the community sense, and even the logistics to make possible an energy community was considered by participants.

The Kano Model questionnaire gave an idea of the desirability of the different characteristics. Having to do the survey also generated a debate among participants about the various aspects of the designs. The list of the characteristics and the categorisation resulting from the questionnaire can be seen in Figure 6. The evaluation table determines the category of each characteristic according to the functional and dysfunctional questions. Characteristics are classified into five different categories: 1) must-be properties; 2) performance properties that are considered necessary and desirable by users; 3) attractive properties that are not essential but will get users' attention; 4) indifferent properties that do not affect users' satisfaction; and 5) reverse properties, that users would like to have the opposite property and it needs to be turned around to fulfil their satisfaction [54].

Figure 6 shows the result of the analysis of the kano model questionnaire. It has been developed following the evaluation table that defines categories according to functional and dysfunctional answers. In Figure 6, reversed properties have been modified and categorised according to the opposite property. Figure 6 is structured following the Kano model, where desirability increases from the bottom-left corner (indifferent characteristics) to the top-right corner (performance characteristics). If attractive and must-be characteristics are strengthened in future versions of the artefact, the desirability of the users will increase [54].

An analysis of characteristics and participants' reflections and discussions resulted in a definition of the character for each of the artefacts. The data visualisation with lights artefact we characterise as **the Sparkler,** as participants see this design concept as a unique and attractive design that also provides information. The laundry planning wood game we characterise as **the Committed**; the design concept demands a commitment from individual community members but also between members to organise practices around the production of renewable energy.

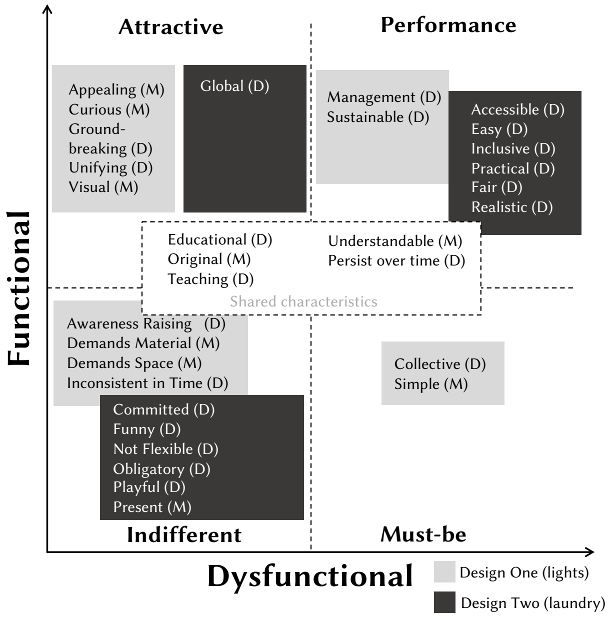

Figure 6: Design characteristics. (M = Manifest property; D = Dispositional property).

4.1 The Sparkler

The first norm-oriented concept design (Figure 2 and Figure 3) was described by participants with many aesthetic properties. Participants were surprised by the ground-breaking way of presenting data, which they had never seen before. At the same time, the artefact was easy to understand as it was very visual; participants saw these characteristics as attractive properties, meaning these characteristics increased the design's desirability:

> "[...] The first thing I would say is that I like the system, I would have expected something more technical (like graphics), but it is very visual and easy to understand at first sight: it's simple: less green means you are doing better." (P5)

Many of the characteristics, which the participants used to describe this design were categorised under learning. Participants described the design as educational, teaching or even that it raised their awareness about the building's consumption patterns. At the same time, they thought it was inconsistent in time as they could only see the real-time data when they were leaving or entering the building:

> "[...] I think it would be optimal to give historical data to see what behaviour has been within the community on the last day, week or month. If you only see the system when you get into the building, you don't know if your performance is affecting it, you don't know if you are having 'good' behaviour." (P5)

This lack of information about their consumption during the day, made them feel that the design would leave their consciousness after some time:

> "[...] Although at the beginning, it is interesting because it is very visual, I only pass by through the entrance, and when I do it, I have my mind somewhere else. I feel that after some time, I would forget about the system, and my interest wouldn't be the same as it would in the first days." (P4)

Prospective energy community members mentioned that the design would become out-of-date over time; they also categorised this property as a reverse one. If this characteristic is turned around, it means that participants expect that the design should persist over time to get better results within the community. Participants saw the design as a tool *"to unify the community"* (P3), but at the same time, they would like to see how their behaviour is reflected in the lights:

> "[...] I would like to know how my behaviour is affecting the community's behaviour, but if no one else is putting effort into changing their everyday activities, it would be difficult to see changes on the lights." (P4)

Overall, participants agreed that they *"would change (their) habits for the community's good [...]. But there are some disadvantages to take into account"* (P3) as sometimes it can be difficult to reconcile changes in a busy work life. What is interesting about the community sense of the design is that participants saw all the characteristics related to members as performance and must-be properties, which means that they understood these essential characteristics for eco-feedback design.

To conclude, the first design concept can be characterised as the Sparkler as it is visual and eye-catching, which results in getting the attention of members who quickly understand the meaning of the lights and have an overall idea of the building's production and consumption of energy. Although participants reflected upon, which energy activities may change during the day, they believed the design is missing historical and detailed information to have a better understanding of the changes applied in their consumption activities. When talking about the community, participants felt that a way to see real-time data would help them adapt their activities to the needs of the community. In summary, they would like to know how their individual behaviour affects the community's energy to adapt their activities to balance their consumption with production for the community's benefit. All characteristics fit well with norm-oriented perspectives on human action [36, 52].

4.2 The Committed

Participants understood the second concept design (Figure 4) as a device that requires members to commit to planning laundries together. Thus, this design facilitates members of the community working as a team to make the best use of renewable energy. All the characteristics relate to the commitment of members to do something meaningful for the energy community.

However, participants also felt that the design was limited for two different reasons. The first relates to the information provided by design. Because the design only enables planning laundries, they thought it was not a realistic future scenario because the design only targets one practice and misses many other everyday practices that consume energy:

> "[...] It is limited because you have to organise your laundry, but it forgets about other consuming activities. I feel that even everyone is doing their best to do the laundry during peak production hours. There is a chance that they don't care about other consuming activities, and they do them when there is not clean energy availability. Data is not realistic in this system; it is limited because it only focuses on washing machines." (P4)

Another reason why participants felt the design concept was limited, is because it provokes members to plan their laundry daily, without accounting for unexpected events that may change their plan during the day. Participants reflected that they prefered to book their washing machines weekly and with more flexibility when choosing the concrete hour during the day:

> "[...] What I feel is that it is difficult to plan laundries daily, I plan my laundries weekly. For example, if instead of having a daily forecast, we had a weekly forecast, we could book laundries on Wednesday if it is sunny but not on the other days because it may be cloudy. I would prefer to have a weekly forecast because it would also be easier to organise laundries between neighbours." (P1)

Regardless, this limitation was also seen as a desirable property because '*'it forces you to commit to it"* (P4), which may prolong over time as members are required to plan their laundry activities to be able to use their washing machines:

> "[...] I think that this limitation is what makes this system interesting. It is beneficial for the community because it makes people organise themselves and the parameters are very clear. If you do it, you will be able to use the washing machine, if you don't do it you won't be able to use it." (P5)

Another property that participants noticed is accessibility. As most of them were young people, they agreed on that it would be easier to plan laundry on a digital platform because the design generates digital data from wood pieces, which makes the process slower and more complicated. On the other hand, they realised that the fact that it is a physical object makes it more accessible to older people who usually don't use digital systems:

> "[...] I also think that it is very accessible because it works with users of any age. For example, I have old neighbours, and it can be difficult for them to use a computer or maybe they don't even have a mobile phone. It is easier for them to use something like this system; it is also inclusive. It doesn't discriminate, and it doesn't make anyone use a technology that may not know how to use." (P3)

On the whole, participants felt that to get results using this design, they have to be very committed to the system. This can be understood as a limitation because of the different lifestyles of members of the community. Yet, because the design takes into consideration all kinds of members within a community according to their technical skills, it is also characterised as inclusive. At the same time, participants considered the design commits itself to the community as it serves as a device that requires members to work together. The design creates dynamics between them, although they would prefer to plan laundry weekly instead of daily. To sum up, this design can be defined as a committed character as it establishes a commitment between the design and the community and also triggers members to commit to renewable energy management in playful and fun ways.

5 DISCUSSION

The work presented in this paper is the result of an investigation into how different concepts of human action situated in a Spanish energy community may be materialised in different designs. We do realise that the findings discussed in this paper are "limited" in the sense that the effect of both design concepts has not been studied in the field with members of an energy community. Yet, we believe that the characteristic identified during our external design critique session identify interesting design characteristics to can be used in the future to describe and materialise eco-feedback for energy communities. We discuss the implications of these in the following sections.

5.1 Design Concepts Revisited

A part of concept-driven design research is to revisit and revise design concepts after exposing the design for critique [57]. In this study, we do so by reflecting on how our external critique relates to framings of eco-feedback [17] and theories of human action and design [36, 52].

Eco-feedback design typically uses energy information to raise awareness to influence individuals to a change in people's everyday life [17, 18]. However, we are only starting to see how an energy community may be supported by such designs [1, 22, 31, 44]. In this study, we have explored two other concepts of understanding human action; norm-oriented and social practice perspectives [36, 52], through concept-driven design [57]. While other studies illustrate the shortcomings of designing eco-feedback for the individual [5, 10, 58], we illustrate in this study that eco-feedback may be designed in ways that are engaging by focusing on characteristics like collective, unifying, inclusive and accessible. According to our participants, those characteristics may help energy community members to work as a team collectively rather than being portrayed as a competition between consumers [22, 31]. The fact that both design concepts explored in this study focus on cooperation among members, seems to be a desirable way for members of energy communities to organise activities around energy availability and members' everyday life.

In our study, we also observed that participants indicated that the purposes of community eco-feedback designs are characterised differently than those designed for individual consumers [17, 18]. While individual consumers often want to improve their consumption by reducing it or changing their behaviour [5, 17], our participants characterised both concept designs for energy communities as potentially desirable ways to manage their renewable energy availability collectively. Although participants considered the Sparkler design concept as impractical because it only visualises real-time data, they still characterised this design as aesthetically pleasing, attractive and educational. Regarding the Committed design concept, participants felt that having to plan laundries at the entrance of the building every morning was a barrier for them. Yet, participants characterised the design as accessible and inclusive although some of them agreed that it would be more practical to have a digital system, which would make it easier for them to change the laundry plan if they had any setbacks during the day. These findings show that eco-feedback designs that embed ideas of collective, fun and aesthetically pleasing experiences may trigger and provoke [27, 37] new ways of understanding design characteristics for eco-feedback design for energy communities.

5.2 Concept Contextualisation

The last activity in concept-driven design research is to relate and position the new concept against the current body of work in our field [57]. We do so by looking towards the broader work done in sustainable HCI and interaction design research communities.

The characteristics identified and analysed by our focus group participants demonstrate that the two design concepts propose alternative ways for designing for eco-feedback with the collective in mind. For instance, while our participants identified categories of environment and learning also seen in other studies [17, 42, 66], other categories focused on the community, identifying characteristics such as unifying, inclusive, accessible and collective. As such, these characteristics ensure that both design concepts embed ideas that an energy community is a place where all the members work together to manage their renewable energy activities [46] resembling works exploring designing for commons [16, 60]. We believe such characteristics need to be supported when designing eco-feedback systems for communities because they look at these activities as something that is a collective responsibility of the community.

Yet, the two design concept also differs in character. The first design concept presented in this study, the Sparkler, focuses on providing energy information to members of the community. The design explores the concept of norm-oriented theory, where *"social organisation is a result of normative consensus and the units of analysis are normative structures, such as values and social rules"* [36]. In this design, community members are to interpret the data given through the lighting design and collectively change their behaviour to achieve more sustainable consumption by working together with other community members. The focus group demonstrated that most of the characteristics assigned to this design concept are attractive properties grouped under the aesthetics category. Other studies show [30] that aesthetic characteristics may shape how people use desirable design in everyday life, also influencing energy patterns. Thus we see this to be an important design characteristic to consider when designing eco-feedback for communities.

The second design, the Committed, explores how social practice theory may be materialised in a design concept [36]. In this design, we explore the triggering of everyday energy-consuming practices through design. We targeted the practices of "doing the laundry", focusing on collective aspects of planning and archiving this. The participants' characterisation of this concept in properties that participants considered as performance and indifferent. Yet, interestingly, these were also the characteristics participants mostly grouped in the community category. This indicates that a practice perspective could be an interesting approach for designing eco-feedback for an energy community as it shapes ideas of being "in it together" when having to manage their renewable energy activities.

We believe that the set of characteristics identified in this study is a valuable starting point for designing eco-feedback for energy communities. We suggest that a next step is to study such design concepts over time with the people having to embed such designs in their everyday lives. Embedding these designs in a messy everyday life might influence desires and use in different ways than assumed in this research, which might potentially form different design characteristics.

6 CONCLUSION

In this study, we explored the character of two different eco-feedback designs for energy communities. Two design concepts were materialised in a video that later was used in a focus group to gather design characteristics from prospective members of energy communities. Five prospective energy community members participated in the focus group to critique the design concept and come up with a list of characteristics for each of them. A discussion and an analysis of characteristics with participants resulted in a character definition for each of the designs: the Sparkler and the Committed.

The findings show that prospective embers expect that eco-feedback systems for communities have a focus on unifying community members and providing useful information to manage energy consumption together. Although participants appreciated aesthetic characteristics, they manifested that design focusing on community and educational characteristics may better align with collective values and action and provide effective results for longer periods. To conclude, this study establishes an initial set of characteristics that in the future may be taken into account when designing eco-feedback systems for energy communities.

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REFERENCES

[1] Mary Barreto, Evangelos Karapanos, and Nuno Nunes. 2013. Why Don't Families Get along with Eco-Feedback Technologies? A Longitudinal Inquiry. In *Proceedings of the Biannual Conference of the Italian Chapter of SIGCHI* (Trento, Italy) *(CHItaly '13)*. Association for Computing Machinery, New York, NY, USA, Article 16, 4 pages. https://doi.org/10.1145/2499149.2499164

[2] Jon Bird and Yvonne Rogers. 2010. The pulse of tidy street: Measuring and publicly displaying domestic electricity consumption. In *workshop on energy awareness and conservation (Pervasive 2010)*.

[3] Mark Blythe. 2014. Research through Design Fiction: Narrative in Real and Imaginary Abstracts. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI '14)*. Association for Computing Machinery, New York, NY, USA, 703–712. https://doi.org/10.1145/2556288.2557098

[4] Jacky Bourgeois, Stefan Foell, Gerd Kortuem, Blaine A. Price, Janet van der Linden, Eiman Y. Elbanhawy, and Christopher Rimmer. 2015. Harvesting Green Miles from My Roof: An Investigation into Self-Sufficient Mobility with Electric Vehicles. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (Osaka, Japan) *(UbiComp '15)*. Association for Computing Machinery, New York, NY, USA, 1065–1076. https://doi.org/10.1145/2750858.2807546

[5] Hronn Brynjarsdottir, 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* (Austin, Texas, USA) *(CHI '12)*. Association for Computing Machinery, New York, NY, USA, 947–956. https://doi.org/10.1145/2207676.2208539

[6] Nazli Cila, Gabriele Ferri, Martijn de Waal, Inte Gloerich, and Tara Karpinski. 2020. The Blockchain and the Commons: Dilemmas in the Design of Local Platforms. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3313831.3376660

[7] European Commission. 2020. Flexibility markets | Energy. https://ec.europa.eu/energy/topics/technology-and-innovation/flexibility-markets_en

[8] European Commission. 2020. In focus: Renewable energy in Europe | European Commission. https://ec.europa.eu/info/news/focus-renewable-energy-europe-2020-mar-18_en

[9] 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* (Toronto, Ontario, Canada) *(CHI '14)*. Association for Computing Machinery, New York, NY, USA, 813–822. https://doi.org/10.1145/2556288.2557167

[10] 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* (Atlanta, Georgia, USA) *(CHI '10)*. Association for Computing Machinery, New York, NY, USA, 1975–1984. https://doi.org/10.1145/1753326.1753625

[11] Èlia Gil Peña. 2020. Data visualisation with lights artefact | Youtube Video. https://www.youtube.com/watch?v=sbXSWfeAPUk&t Retrieved February, 2023.

[12] Èlia Gil Peña. 2020. Energy communities and contextualisation | Youtube Video. https://www.youtube.com/watch?v=iKULTliXij8 Retrieved February, 2023.

[13] Èlia Gil Peña. 2020. Laundry planning wood game artefact | Youtube Video. https://www.youtube.com/watch?v=v4BV2Ud6XuE&t Retrieved February, 2023.

[14] Marcus Foth and Troy John Turner. 2019. The Premise of Institutioning for the Proliferation of Communities and Technologies Research. In *Proceedings of the 9th International Conference on Communities & Technologies - Transforming Communities* (Vienna, Austria) *(C&T '19)*. Association for Computing Machinery, New York, NY, USA, 24–28. https://doi.org/10.1145/3328320.3328398

[15] Abigail Francisco and John E. Taylor. 2019. Designing community-scale energy feedback. *Energy Procedia* 158 (2019), 4178–4183. https://doi.org/10.1016/j.egypro.2019.01.812 Innovative Solutions for Energy Transitions.

[16] Jonas Fritsch, Joanna Saad-Sulonen, and Giacomo Poderi. 2022. The Problem(s) of Caring for the Commons. In *Nordic Human-Computer Interaction Conference* (Aarhus, Denmark) *(NordiCHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 80, 9 pages. https://doi.org/10.1145/3546155.3547287

[17] 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* (Atlanta, Georgia, USA) *(CHI '10)*. Association for Computing Machinery, New York, NY, USA, 1999–2008. https://doi.org/10.1145/1753326.1753629

[18] Jon Froehlich, Leah Findlater, Marilyn Ostergren, Solai Ramanathan, Josh Peterson, Inness Wragg, Eric Larson, Fabia Fu, Mazhengmin Bai, Shwetak Patel, and James A. Landay. 2012. The Design and Evaluation of Prototype Eco-Feedback Displays for Fixture-Level Water Usage Data. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Austin, Texas, USA) *(CHI '12)*. Association for Computing Machinery, New York, NY, USA, 2367–2376. https://doi.org/10.1145/2207676.2208397

[19] Eva Ganglbauer, Geraldine Fitzpatrick, and Rob Comber. 2013. Negotiating Food Waste: Using a Practice Lens to Inform Design. *ACM Trans. Comput.-Hum. Interact.* 20, 2, Article 11 (may 2013), 25 pages. https://doi.org/10.1145/2463579.2463582

[20] Emi Minghui Gui, Iain MacGill, and Regina Betz. 2018. Community Microgrid Investment Planning: A Conceptual Framework. In *2018 IEEE International Smart Cities Conference (ISC2)*. 1–5. https://doi.org/10.1109/ISC2.2018.8656707

[21] Claire Haggett and Mhairi Aitken. 2015. Grassroots energy innovations: The role of community ownership and investment. *Current Sustainable/Renewable Energy Reports* 2 (2015), 98–104. https://doi.org/10.1007/s40518-015-0035-8

[22] Anders Høgh Hansen, Rikke Hagensby Jensen, Lasse Stausgaard Jensen, Emil Kongsgaard Guldager, Andreas Winkel Sigsgaard, Frederik Monder, Dimitris Raptis, Laurynas Šikšnys, Torben Bach Pedersen, and Mikael B. Skov. 2020. Lumen: A Case Study of Designing for Sustainable Energy Communities through Ambient Feedback. In *OzCHI '20: 32nd Australian Conference on Human-Computer Interaction*. ACM, New York NY, 724–729. https://doi.org/10.1145/3441000.3441001

[23] Yilin Huang, Giacomo Poderi, Sanja Šćepanović, Hanna Hasselqvist, Martijn Warnier, and Frances M. T Brazier. 2019. Embedding Internet-of-Things in Large-Scale Socio-technical Systems: A Community-Oriented Design in Future Smart Grids: Technology, Communications and Computing. In *The Internet of Things for Smart Urban Ecosystems* (1 ed.), Franco Cicirelli, Antonio Guerrieri, Carlo Mastroianni, Giandomenico Spezzano, and Andrea Vinci (Eds.). Springer Cham, Cham, 125–150. https://doi.org/10.1007/978-3-319-96550-5_6

[24] Kirsi Hyytinen and Marja Toivonen. 2015. Future energy services: empowering local communities and citizens. *Foresight* 17, 4 (2015), 349–364. https://doi.org/10.1108/FS-08-2013-0035

[25] Karim Jabbar and Pernille Bjørn. 2019. Blockchain Assemblages: Whiteboxing Technology and Transforming Infrastructural Imaginaries. In *CHI '19: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, Glasgow, 1–13. https://doi.org/10.1145/3290605.3300496

[26] Lars-Erik Janlert and Erik Stolterman. 1997. The character of things. *Design Studies* 18, 3 (1997), 297–314. https://doi.org/10.1016/S0142-694X(97)00004-5

[27] Rikke Hagensby Jensen, Enrique Encinas, and Dimitrios Raptis. 2022. Spicing It Up: From Ubiquitous Devices to Tangible Things Through Provocation. In *Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Daejeon, Republic of Korea) *(TEI '22)*. Association for Computing Machinery, New York, NY, USA, Article 33, 15 pages. https://doi.org/10.1145/3490149.3502257

[28] Rikke Hagensby Jensen, Dimitrios Raptis, Jesper Kjeldskov, and Mikael B. Skov. 2018. Washing with the Wind: A Study of Scripting towards Sustainability. In *Proceedings of the 2018 Designing Interactive Systems Conference* (Hong Kong, China) *(DIS '18)*. Association for Computing Machinery, New York, NY, USA, 1387–1400. https://doi.org/10.1145/3196709.3196779

[29] Rikke Hagensby Jensen, Dimitrios Raptis, Laurynas Siksnys, Torben Pedersen, and Mikael B. Skov. 2022. Design Visions for Future Energy Systems: Towards Aligning Developers' Assumptions and Householders' Expectations. In *Nordic Human-Computer Interaction Conference* (Aarhus, Denmark) *(NordiCHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 20, 13 pages. https://doi.org/10.1145/3546155.3546655

[30] Rikke Hagensby Jensen, Yolande Strengers, Jesper Kjeldskov, Larissa Nicholls, and Mikael B. Skov. 2018. Designing the Desirable Smart Home: A Study of Household Experiences and Energy Consumption Impacts. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3173574.3173578

[31] Rikke Hagensby Jensen, Maurizio Teli, Simon Bjerre Jensen, Mikkel Gram, and Mikkel Harboe Sørensen. 2021. Designing Eco-Feedback Systems for Communities: Interrogating a Techno-solutionist Vision for Sustainable Communal Energy. In *C&T '21: Proceedings of the 10th International Conference on Communities & Technologies*. ACM, Seattle, WA, 245–257.

[32] Victor Vadmand Jensen and Rikke Hagensby Jensen. 2023. Exploring Values of Energy Justice: A Case Study of a Burgeoning Energy Community. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, Article 385, 9 pages. https://doi.org/10.1145/3544549.3573864

[33] B Kampman, J Blommerde, and M Afman. 2016. The Potential of Energy Citizens in the European Union - Report by CE Delft for Greenpeace European Unit. *Friends of the Earth Europe, European Renewable Energy Federation (EREF) and REScoop* 16 (2016), 100.

[34] 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* (Seoul, Republic of Korea) *(CHI '15)*. Association for Computing Machinery, New York, NY, USA, 1985–1988. https://doi.org/10.1145/2702123.2702318

[35] Lisa Koeman, Vaiva Kalnikaitė, Yvonne Rogers, and Jon Bird. 2014. What chalk and tape can tell us: lessons learnt for next generation urban displays. *Proceedings of the 3th International Symposium on Pervasive Displays (PerDis '14)* (2014), 130.

https://doi.org/10.1145/2611009.2611018

[36] Lenneke Kuijer. 2014. *Implications of social practice theory for sustainable design.* Ph. D. Dissertation. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=cd3813a4c1658379fc68c2dc3c8f37fcaaaef600

[37] Lenneke Kuijer. 2017. *Splashing: The Iterative Development of a Novel Type of Personal Washing.* Springer International Publishing, Cham, 63–74. https://doi.org/10.1007/978-3-319-33527-8_6

[38] Lenneke Kuijer and Annelise De Jong. 2012. Identifying design opportunities for reduced household resource consumption: exploring practices of thermal comfort. *Journal of Design Research 14* 10, 1-2 (2012), 67–85. https://doi.org/10.1504/JDR.2012.046140

[39] Lenneke Kuijer, Annelise de Jong, and Daan van Eijk. 2013. Practices as a Unit of Design: An Exploration of Theoretical Guidelines in a Study on Bathing. *ACM Trans. Comput.-Hum. Interact.* 20, 4, Article 21 (sep 2013), 22 pages. https://doi.org/10.1145/2493382

[40] Renata Leonhardt, Bram Noble, Greg Poelzer, Patricia Fitzpatrick, Ken Belcher, and Gwen Holdmann. 2022. Advancing local energy transitions: A global review of government instruments supporting community energy. *Energy Research & Social Science* 83 (jan 2022), 102350. https://doi.org/10.1016/j.erss.2021.102350

[41] Li Wen Li, Janine Birmele, Harald Schaich, and Werner Konold. 2013. Transitioning to Community-owned Renewable Energy: Lessons from Germany. *Procedia Environmental Sciences* 17 (2013), 719–728. https://doi.org/10.1016/j.proenv.2013.02.089 The 3rd International Conference on Sustainable Future for Human Security, SUSTAIN 2012, 3-5 November 2012, Clock Tower Centennial Hall, Kyoto University, JAPAN.

[42] Martin Valdemar Anker Lindrup, EunJeong Cheon, Mikael B. Skov, Dimitrios Raptis, and Rob Comber. 2022. Sustainable Foodtures: Exploring Roles of Future Technology in Sustainable Food Shopping. In *Nordic Human-Computer Interaction Conference* (Aarhus, Denmark) *(NordiCHI ’22)*. Association for Computing Machinery, New York, NY, USA, Article 17, 12 pages. https://doi.org/10.1145/3546155.3546641

[43] Orlando Mella. 2000. Grupos focales (“Focus groups”). Técnica de investigación cualitativa. *Documento de trabajo* 3 (2000), 1–27. https://gc.scalahed.com/recursos/files/r161r/w25267w/Gruposfocalesunatecnica.pdf

[44] Johanna Meurer, Dennis Lawo, Christina Pakusch, Peter Tolmie, and Volker Wulf. 2019. Opportunities for Sustainable Mobility: Re-Thinking Eco-Feedback from a Citizen’s Perspective. In *Proceedings of the 9th International Conference on Communities & Technologies - Transforming Communities* (Vienna, Austria) *(C&T ’19)*. Association for Computing Machinery, New York, NY, USA, 102–113. https://doi.org/10.1145/3328320.3328391

[45] Bijay Neupane, Laurynas Siksnys, Torben Bach Pedersen, Rikke Hagensby, Muhammad Aftab, Bradley Eck, Francesco Fusco, Robert Gormally, Mark Purcell, Seshu Tirupathi, Gregor Cerne, Saso Brus, Ioannis Papageorgiou, Gerhard Meindl, and Pierre Roduit. 2022. GOFLEX: Extracting, Aggregating and Trading Flexibility Based on FlexOffers for 500+ Prosumers in 3 European Cities [Operational Systems Paper]. In *Proceedings of the Thirteenth ACM International Conference on Future Energy Systems* (Virtual Event) *(e-Energy ’22)*. Association for Computing Machinery, New York, NY, USA, 361–373. https://doi.org/10.1145/3538637.3538865

[46] Marieke Oteman, Mark Wiering, and Jan-Kees Helderman. 2014. The institutional space of community initiatives for renewable energy: a comparative case study of the Netherlands, Germany and Denmark. *Energy, sustainability and society* 4, 1 (2014), 1–17. https://doi.org/10.1186/2192-0567-4-11

[47] Celeste Lyn Paul. 2008. A Modified Delphi Approach to a New Card Sorting Methodology. *J. Usability Studies* 4, 1 (nov 2008), 7–30.

[48] 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* (Brisbane, Australia) *(C&T ’11)*. Association for Computing Machinery, New York, NY, USA, 21–30. https://doi.org/10.1145/2103354.2103358

[49] James Pierce and Eric Paulos. 2012. Beyond Energy Monitors: Interaction, Energy, and Emerging Energy Systems. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Austin, Texas, USA) *(CHI ’12)*. Association for Computing Machinery, New York, NY, USA, 665–674. https://doi.org/10.1145/2207676.2207771

[50] 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* (Newcastle Upon Tyne, United Kingdom) *(DIS ’12)*. Association for Computing Machinery, New York, NY, USA, 631–634. https://doi.org/10.1145/2317956.2318050

[51] 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* (Atlanta, Georgia, USA) *(CHI ’10)*. Association for Computing Machinery, New York, NY, USA, 1985–1994. https://doi.org/10.1145/1753326.1753627

[52] Andreas Reckwitz. 2002. Toward a theory of social practices: A development in culturalist theorizing. *European journal of social theory* 5, 2 (2002), 243–263. https://doi.org/10.1177/13684310222225432

[53] Juan José Alba Ríos, Vanessa Aragones Ahnert, Julián Barquín Gil, and Eduardo Moreda Díaz. 2017. La regulación del autoconsumo en España:¿ un impuesto al Sol? *Revista de Obras Públicas: Órgano profesional de los ingenieros de caminos, canales y puertos* 3584 (2017), 40–47. https://dialnet.unirioja.es/servlet/articulo?codigo=5906915

[54] Elmar Sauerwein, Franz Bailom, Kurt Matzler, and Hans H Hinterhuber. 1996. The Kano model: How to delight your customers. *International working seminar on production economics* 1 (1996), 313–327. Issue 4.

[55] 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 *CHI ’15: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems.* ACM, Seoul, 1965–1974. https://doi.org/10.1145/2702123.2702285

[56] Pieter Jan Stappers and Elisa Giaccardi. 2017. *Research through Design* (2nd ed.). The Interaction Design Foundation, 1–94.

[57] Erik Stolterman and Mikael Wiberg. 2010. Concept-Driven Interaction Design Research. *Human–Computer Interaction* 25, 2 (2010), 95–118. https://doi.org/10.1080/07370020903586696

[58] Yolande Strengers. 2014. Smart energy in everyday life: are you designing for resource man? *Interactions* 21, 4 (jul 2014), 24–31. https://doi.org/10.1145/2621931

[59] Nadine Sandjo Tchatchoua, Nina Boulus-Rødje, and Val Mitchell. 2023. Green IT Meaning in Energy Monitoring Practices: The Case of Danish Households. *Computer Supported Cooperative Work (CSCW)* (Jan. 2023). https://doi.org/10.1007/s10606-022-09462-3

[60] Maurizio Teli, Marcus Foth, Mariacristina Sciannamblo, Irina Anastasiu, and Peter Lyle. 2020. Tales of Institutioning and Commoning: Participatory Design Processes with a Strategic and Tactical Perspective. In *Proceedings of the 16th Participatory Design Conference 2020 - Participation(s) Otherwise - Volume 1* (Manizales, Colombia) *(PDC ’20)*. Association for Computing Machinery, New York, NY, USA, 159–171. https://doi.org/10.1145/3385010.3385020

[61] Gordon Walker and Patrick Devine-Wright. 2008. Community renewable energy: What should it mean? *Energy Policy* 36, 2 (2008), 497–500. https://doi.org/10.1016/j.enpol.2007.10.019

[62] Martin Warneryd, Maria Håkansson, and Kersti Karltorp. 2020. Unpacking the complexity of community microgrids: A review of institutions’ roles for development of microgrids. *Renewable and Sustainable Energy Reviews* 121 (2020), 109690. https://doi.org/10.1016/j.rser.2019.109690

[63] Denise J. Wilkins, Ruzanna Chitchyan, and Mark Levine. 2020. Peer-to-Peer Energy Markets: Understanding the Values of Collective and Community Trading. In *CHI ’20: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems.* ACM, Honolulu, HI, 1–14. https://doi.org/10.1145/3313831.3376135

[64] Richmond Y. Wong and Deirdre K. Mulligan. 2016. When a Product Is Still Fictional: Anticipating and Speculating Futures through Concept Videos. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems* (Brisbane, QLD, Australia) *(DIS ’16)*. Association for Computing Machinery, New York, NY, USA, 121–133. https://doi.org/10.1145/2901790.2901801

[65] Sachendra Yadav. 2016. The kano model – a tool to prioritize the users’ wants and desires. https://www.interaction-design.org/literature/article/the-kano-model-a-tool-to-prioritize-the-users-wants-and-desires. Accessed: 2021-04.

[66] Rayoung Yang, Mark W. Newman, and Jodi Forlizzi. 2014. Making Sustainability Sustainable: Challenges in the Design of Eco-Interaction Technologies. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI ’14)*. Association for Computing Machinery, New York, NY, USA, 823–832. https://doi.org/10.1145/2556288.2557380