”Do they pass the woman test?”

Navigating and negotiating the gendering of residential solar panels

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ABSTRACT

Residential solar panels are increasingly popular, yet women are largely invisible as customers and users. This creates barriers for reaching gender equality and climate goals where increased renewable energy is key. We present results from a norm-critical study drawing on 10 interviews with solar industry representatives and focus groups with 28 women, either owning solar panels or in the process of buying. The study aims to critically analyze current gender norms related to technology, market, and use, as well as to identify difficulties for women's solar panel engagement. The study shows how women at different touchpoints in the process of buying and having solar panels both navigate and negotiate an ongoing gendering of this technology, despite the industry attempts to present solar panels as gender neutral. While the study focuses on residential solar panels, the contribution is relevant for wider HCI, e.g. work related to smart home technologies.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Empirical studies in HCI.

KEYWORDS

Gender, Norms, Feminist HCI, Solar energy, Sustainability, Norm-critical design

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1 INTRODUCTION

One technology that is becoming increasingly popular in homes is photovoltaics (PV), i.e., solar panels installed for micro-production of electricity. Along with electric vehicles and emerging home batteries, PV systems are envisioned to offer people new opportunities to transition to renewable energy and participate in a broader energy transition. But to whom are solar panels for the home accessible? Who installs PV for the home, and whose needs are addressed in current solutions? Who is in command? The currently dominant buyer of a residential PV system in Swedish middle-class homes is a man with technical interest, knowledge, and economic resources. Women on the other hand are largely invisible both in residential PV research and as PV customers. This is both intriguing and worrying because while many women show an overall high interest in sustainability, this interest does not necessarily translate into or manifest itself as involvement in energy issues and technologies such as PV [29]. From a climate and societal perspective, this is problematic [44, 45]. In order to meet climate and energy goals more people need to invest in technologies like solar panels, including more women. Gender norms related to PV might play a largely unexplored role, which is the focus of this work. As PV systems are increasingly entering the home and getting connected to other technologies such as vehicles and heating – impacting who has access to, knowledge of, and can control these technologies in the home [25, 30, 31, 40] – we believe it is timely and critical to study residential PV from a gender perspective.

In this paper, we report on research that applies a gender and design perspective on residential PV. Specifically, we report on 10 “norm-critical” interviews with PV industry representatives, which explored current norms related to gender, technology, and market in the PV industry in Sweden, and five focus groups involving 28 women in total, which explored drivers and barriers, including gender, that women experience as part of their customer journey of obtaining PV for the home. The aim of this work is twofold: first, by analyzing and making visible current norms and how women customers might be impacted by them in their process of obtaining PV, we wish to problematize and understand why women so far have been invisible as PV customers. Second, by highlighting the needs, concerns, and requirements of women customers, we wish to provide constructive, “norm-creative” suggestions to industry actors on how they could change their work to better include and address women who are interested in PV. However, returning to the fact that PV systems are increasingly entering the home and getting connected to other existing or new technologies, the contribution of this work is also relevant to a wider audience of researchers and practitioners in HCI who are studying and designing for the home context. While this work focuses on PV, it raises questions, concerns,

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and implications for design that are relevant for other technologies, including e.g., smart home systems and electric vehicles.

2 BACKGROUND

HCI has a long tradition of engaging in issues closely related to feminism and gender, for example methods and design to support participation and empowerment and exploring how people and technological artifacts relate to one another more generally. In 2010, Bardzell [4] drew this tradition to attention by proposing an agenda for feminist interaction design. As argued by Bardzell, feminism and interaction design are both concerned with issues such as agency, equity, and social justice, and so by drawing more on feminist thinking in HCI, these and other related social change issues could be made more visible and supported more profoundly in the design and evaluation of technologies. A growing body of work, using aspects of feminism to advance design and thinking in HCI, is now addressing a range of topics, including women's health [1, 2]; intersectionality [12, 15, 34]; methodological questions [5, 41]; technologies such as smart home technologies [22, 39, 40]; and ecological issues [21]. Below, we will relate our work to the home as design context.

The home has a long history of gendered technologies, social dynamics, and gender roles [e.g., 9, 25, 48], which is critical to understand and consider in the design of digital technologies for the home. For example, historically, heating and ventilation systems as well as TVs are symbolically gendered as masculine, while kitchen appliances are symbolically gendered as feminine. The work to use and maintain these technologies is also gendered, where there is a risk that "*women's technical work will become invisible as it becomes symbolically gendered as feminine*" [31:87]. These gendered spheres and roles impact and shape new emerging technologies, such as security systems [30] and as in our case, residential PV. As shown with security systems [30] and smart home systems respectively [22, 40], existing gender roles impact the new domestic work – the digital housekeeping – that follows with these technologies. Strengers et al. [40:1] describe the typical user of smart home technologies "*to be a technical 'guru', commonly a man, who brings smart technologies into the home, and is responsible for setting up, maintaining and introducing them to other householders.*" As Strengers et al. argue, if we are to reach other groups of users beyond the 'technical guru', gender aspects are key to understand and address in design, for example by ensuring that *"women (and all users) are supportive of how smart devices are being used within their home, and are able to operate them safely and securely*" [40:8].

Keeping track of energy consumption is one reason for using smart home technologies [40]. With transition to and digitalization of a renewable energy system, new types of energy services and roles are evolving, where energy consumers are envisioned to take more active roles, for example in demand response and flexibility programs. Energy has been touted as gender neutral [8] which is questioned in more recent research, e.g., showing how gender and division of labor in the home impact new types of work to manage flexibility ('flexibility work' [see e.g., 20, 25, 43] as well as energy injustice [14]). Notably, while energy has been a popular topic in Sustainable HCI (SHCI), gender aspects have been less explored in relation to sustainability (see e.g., [16]). According to the International Energy Agency (IEA), the energy sector globally is performing poorly when it comes to gender equality [18]. Efforts to increase the number of women in professional roles in the sector are considered crucial in order to increase innovation, socially inclusive solutions, and a transition to a renewable energy system [19]. However, gender equality is not only important in professional roles in energy companies. Decentralized, small-scale renewable energy production, e.g., from PV, is highlighted as one opportunity to help increase the equality for women globally, in particular in developing countries [e.g., 26, 32]. There are thus many important challenges when it comes to gender equality and access to clean energy at a global level, but in our work, the studied group is women in the role as consumers, owners, and prosumers of residential PV in Swedish middle-class households. The body of social science literature on gender and energy is growing [e.g., 13, 23–25, 32, 36] emphasizing that understanding gender relations in the home and more broadly is imperative to succeed in transitioning to a more sustainable energy system. Some scholars argue that focusing on women's issues in energy is not enough, and by bringing in feminist thinking more fundamentally, we should aim holistically for feminist energy systems [6].

Residential PV are thus adding yet another dimension to the home, along with new energy services and smart home technologies. However, with few exceptions, there is limited research on residential PV and gender in a Northern European context. Exploring injustices of household adoption of PV in the UK, Sovacool et al. [36] note that patriarchal gender roles play a role and stress this should be a topic of further research. Standal et al.'s recent study [37] of households (heterosexual couples) with PV in Norway and the UK shows that owning solar panels is considered masculine, and that the typical user/owner is a man with significant technical interest and knowledge, environmental concerns, and financial resources to invest in PV (similar to the typical user of smart home technologies [40] and smart energy technologies [38]). The study also reveals that several of the participating women were interested in 'prosuming' (i.e., producing electricity from PV for one's own consumption and selling any excess to the power grid) because of environmental concerns, but that the masculine gendered PV industry was a barrier for women to fully participate or engage in residential PV [37]. In Palm and Eriksson's [27] study of how Swedish households search for information about residential PV, four "ideal types for PV adoption" were generated based on the interview data: non-adopters, environmentally engaged adopters, the professionally skilled group, and the accidental adopters. However, since only the man participated from the majority of the households (52 of 58), women were largely invisible both as respondents in the study and in the results. While solar energy communities (ECs) are presented as a hypothetically more inclusive way to get engaged in solar energy, a Swedish study shows that participating ECs believed they were inclusive but were nonetheless male dominated [23]. In Sweden, where this study was conducted, there is no existing statistics or data about gender and residential PV owners, which further confirms that women so far are largely made invisible in this role. Lacking data and previous research, our initial assumptions and starting point were therefore based on participant observations in residential PV forums (e.g., interest groups on Facebook) and

conversations with experts with deep knowledge about the PV industry.

Before moving on, we will briefly describe the theoretical basis for the work presented in this paper. Feminist theory offers a rich and varied body of work that goes beyond the scope of this paper. We have turned to scholars in e.g., STS to understand how women in this case are shaped by and in return shape the technologies around them. In particular, we are inspired by Judy Wajcman's thoughts on technofeminism [e.g., 47, 48]. Wajcman is arguing for the inclusion of women in all phases of a technology's existence, stating that "*the marginalization of women from the technological community has a profound influence on the design, technical content and use of artefacts.*" [48:149]. This prompts questions about to what degree women are currently involved in the PV community and actively included in activities shaping the design, content, and use of PV. While many questions concern women's inclusion in professional roles in the PV industry, which is an important topic for future work, the main focus in our work is questions related to the role as a customer and user of solar panels. Wajcman highlights how technologies are dynamically gendered both in their design and use [48:149]:

> *"[. . .] gender relations can be thought of as materialised in technology, and masculinity and femininity in turn acquire their meaning and character through their enrolment and embeddedness in working machines. Such a mutual shaping approach recognises that the gendering of technology affects the entire life trajectory of an artefact. [. . .] The gendering of technologies can then be understood as not only shaped in design, but also shaped or reconfigured at the multiple points of consumption and use."*

The idea that the gendering of a technology is not fixed but can be changed through people's interaction with it and each other, is relevant to our work where we explore how women customers navigate but also negotiate the currently masculine domain of residential PV. This is further supported by Judith Butler's understanding of gender as performative [7], which suggests that gender is constructed in/through our interaction with the world, thus also in the interaction with technologies. Finally, we take inspiration from Donna Haraway's embracing of modern technologies as opportunities to create alternatives identities and roles [17]. With PV entering more people's homes, there are opportunities to challenge (to "trouble", see e.g., [22]) established roles in the home through our use of and relations to technology.

Summing up related work, there are strong arguments for taking a gender perspective on energy technologies and practices in the home. While the literature on gender, digital technologies, and energy is growing, there is still a knowledge gap about women in relation to residential PV, which this study aims to address.

3 STUDY SET-UP

In our study, we gathered insights about women and residential PV from two perspectives: from the PV industry and from potential future and current PV customers. These two parts of the study are described in the following sections. In Bardzell's [4] terms, our work is both 'critique-based' and 'generative', and we agree with Ehrnberger [10] that both norm-critique and norm-creativity (or generative work) is important. To create preconditions for change (norm-creativity), we need to understand what we want to change from (norm-critique) [10].

Note that in this paper we use the terms 'women' and 'men' to denote gender identity. We acknowledge that there are more gender identities and that the experiences of all gender identities are as important to study. Yet, as a first step we chose to focus on women customers and on their experiences in relation to a male gendered technology and industry, in line with the argumentation of Rode and Poole [31].

3.1 Interviews with PV industry representatives

To understand if and how the PV industry consider gender issues in their work, we interviewed 10 representatives from the PV industry, see Table 1. Both men and women were recruited to get different perspectives on gender norms. The interviews were semi-structured and covered topics such as their respective roles and organizations, their PV offerings, communication, strategies to find new customers, knowledge about women customers, and ability to work norm-creatively. Two norm-creative innovation tactics from the norm-creative design tool NOVA [3] were used to design a setting for the interviews, allowing any gender norms within the industry to become visible and investigated. The "sledgehammer tactic" is based on the understanding that when norms are upheld, marginalized groups risk being silenced, and their perspectives and needs are not taken into consideration. The "precision screwdriver tactic" is based on the understanding that solutions that are built to cater to the broadest user group run the risk of favoring already-privileged groups and individuals, because special needs may not be met through a general solution. Combining the two tactics and adapting them to fit the study's focus on process and customer experience rather than physical product design, a scenario was designed to allow the industry representatives to step outside of their preconceived notions of who their customers were and force them to consider their offers from new gender perspectives. The scenario, which became a prominent section of the interviews, put the industry representatives in a fictive situation where they were only allowed to sell to women customers: "*Imagine that there is a new directive based on the UN SDGs about increasing the share of women who own a PV system in Sweden. Many men already own PV systems, but significantly fewer women do so. The directive states that the PV industry should favor women customers and is only allowed to sell PV to women with immediate effect, in order to increase the number of women investing in PV.*" They were asked if and how their organizations would be able to cope in this scenario, how they would need to change their communication plans, value propositions, sales tactics, customer understandings, etc.

The interviews were carried out as video calls with two researchers present, one as main interviewer and the other mainly as note-taker. The notes were later analyzed with a norm-critical perspective to identify recurring themes.

Table 1: The PV industry representatives participating in the interviews

Code	Gender identity	Style Tag
F1	Woman	Expert, Solar Energy Technology
F2	Woman	Business Leader, Home Solar & Clean Energy
F3	Woman	Project Manager, Industry Development
F4	Woman	Project Manager and Advisor, Solar Energy and Energy Efficiency
F5	Man	Head of Technology and R&D, Building Company
F6	Woman	CEO, Solar Technology Business
F7	Man	Education Manager, Solar Energy Company
F8	Man	Product Manager, Solar Energy Company
F9	Woman	Sales Manager and Advisor, Solar Energy Company
F10	Man	CEO, Solar Technology Business

3.2 Focus groups with potential future and current customers

For the focus groups, we recruited participants by posting a survey for registering interest on four Facebook forums: one PV, one sustainability, and two technical forums only for women. Among the interested applicants with PV, we selected those who had been actively involved in getting them. Among the ones without PV, we selected applicants living in privately-owned houses as they can make decisions about PV installations. In total, 28 women participated in the focus groups, 9 with PV (participant D1 to E3) and 19 currently without (participant A1 to C5) but with an interest in getting PV, see Table 2.

The participants show many similarities. They are in general well-educated, middle- or high income, and most of them in a relationship with a male partner. They do not as a group necessarily represent other groups of women in Sweden, and there are still large segments of the female population that are not included in this study and who might have other needs than those expressed here.

The focus groups were carried out as 1.5-hour video meetings consisting of four parts: introduction, collage-making, norm-critical discussion, and final reflections. There were five focus groups in total with three to seven participants and three researchers in each. Two researchers facilitated while the third one took notes. The sessions were recorded and partly transcribed to complement the notes.

Prior to the focus groups, all participants received a kit by mail including questions to think about before the focus groups and material to use in the sessions. The preparatory questions were intended to sensitize participants to the topic of residential PV [cf. 35] and gender issues in relation to PV. Examples of questions for participants with PV and without PV respectively were: "Were you able to take the role you wanted to when you got your solar panels?" and "If you were to get solar panels, what would you like to do yourself and what would you like others to do?"

After a short introduction, the participants made collages describing either: why they are interested in getting PV and if they have taken any steps towards getting PV (for participants without PV); or how getting PV was for them and what their lives with PV are like (for participants with PV). The participants made their collages using images and markers included in the kit. Afterwards, participants spoke about their collages with the rest of the group. Making collages is an example of a generative exercise intended to access tacit and latent needs [35].

After collage-making, the participants were asked norm-critical questions intended to highlight gender issues related to the PV industry and potential interaction with its representatives, PV communication, PV as a technology, the PV market, and roles related to getting and having PV. To circumvent a potential issue of participants without PV having limited experience of interaction with the PV industry, we designed three fake visual advertisements. The fake ads were generated based on a norm-critical visual analysis of existing PV ads and company websites, from which three main themes were synthesized: "corporate clean", "solar-powered (green) everyday", and "PV (tech) as identity". We then carefully designed the three fake ads using visuals and text to embody similar sentiments and PV offerings. They served as a common reference point in the discussion. For the focus group participants with PV no such reference point was needed as they all had experience of the industry. As a final personal reflection, participants were asked to provide advice to the PV industry on how to reach more women or – because it can be easier or more enjoyable to think the opposite – provide advice on how to not reach women. Most participants wrote both advice and anti-advice.

The transcriptions were primarily analyzed using a deductively created analytical frame building on the idea that technology is gendered through design *"but also shaped or reconfigured at the multiple points of consumption and use"* [48:149]. Different points of (re-)gendering were used as the analytical frame and the data was then inductively coded to identify reoccurring themes on how PV are (re-)gendered at these points. In line with Bardzell [5] the analysis was characterized by an empathic mindset and a commitment to the participants' experiences.

3.3 Limitations

One important limitation to our study needs clarifying before turning to the result. Our participants can be said to represent a certain group of women who are privileged in the sense of housing (the majority own their home), education and profession (several work in or have backgrounds in technical fields) as well as financial resources. In several ways, these women resemble many men who currently buy PV. Since there is very limited data and knowledge

Table 2: Information about the focus group participants. The data comes from the survey for registering interest.

Code	Gender identity[a]	Age span	Location of home	No of adults (children) in household	Economic standard[b]	Access to electric or hybrid car	Interest in getting PV?	Involvement in getting PV?
A1	Woman	25-34	Small/mid-size city	2	Average	No	Yes	Do not have PV
A2	Woman	55-64	Larger city	3	Average to high	No	Yes	Do not have PV
A3	Woman	25-34	Larger city	1 (2)	Choose not to reply	Yes	Yes	Do not have PV
A4	Woman	35-44	Larger city	2	Average to high	No	Yes	Do not have PV
A5	Woman	25-34	Larger city	2 (2)	Average to high	Yes	Yes	Do not have PV
A6	Woman	25-34	Larger city	2 (1)	Average to high	Yes	Yes	Do not have PV
A7	Woman	35-44	Larger city	2 (2)	Average to high	No	Yes	Do not have PV
B1	Woman	55-64	Small society	2	Average	Yes	Yes	Do not have PV
B2	Woman	25-34	Small/mid-size city	2 (1)	Average to high	No	Yes	Do not have PV
B3	Woman	45-54	Small/mid-size city	2 (2)	Average	No	Yes	Do not have PV
B4	Woman	65-74	Rural	2	Average	No	Yes	Do not have PV
B5	Woman	45-54	Small/mid-size city	3 (1)	Average to high	No	Yes	Do not have PV
B6	Woman	25-34	Rural	2	Average to high	No	Yes	Do not have PV
B7	Woman	25-34	Larger city	2 (2)	Average to high	No	Yes	Do not have PV
C1	Woman	55-64	Larger city	1	Low to average	No	Yes	Do not have PV
C2	Woman	45-54	Larger city	1 (2)	Average to high	Yes	Yes	Do not have PV
C3	Woman	35-44	Larger city	2 (2)	Average to high	Yes	Yes	Do not have PV
C4	Woman	55-64	Suburb	2	Average	No	Yes	Do not have PV
C5	Woman	35-44	Larger city	2 (1)	Average to high	Yes	Yes	Do not have PV
D1	Woman	65-74	Rural	2	Average to high	No	Have PV	Very involved
D2	Woman	55-64	Small society	1	Average	No	Have PV	Very involved
D3	Woman	55-64	Larger city	2	Average	No	Have PV	Did it on her own
D4	Woman	35-44	Rural	1	Average	Yes	Have PV	Very involved
D5	Woman	55-64	Rural	1 (1)	Average	Yes	Have PV	Own decision
D6	Woman	55-64	Rural	1	Average	No	Have PV	Did it on her own
D7	Woman	45-54	Rural	2 (1)	Average to high	No	Have PV	Very involved
E1	Woman	35-44	Small/mid-size city	2 (2)	Average to high	Yes	Have PV	Very involved
E3	Woman	25-34	Small society	2 (1)	Average to high	Yes	Have PV	Very involved

[a] In the survey for registering interest, we asked respondents about their gender identity, meaning what gender they identify as, and formulated the question and response alternatives according to recommendations by a Swedish organization for lgbtqi-rights.

[b] Calculated based on income level divided with the household's consumption units, i.e., a standardized measurement based on the number of adults and children [25]. Economic standard is relative to the national median in Sweden, with 60% of the median representing low standard and 200% high standard. Economic standard was difficult to estimate for several participants due to flaws in the questionnaire design: too low maximum income level and too large income spans in response options in the survey.

about women who buy PV, we deliberately kept the recruitment criteria open (only limited to women living in privately-owned houses). Through recruiting in interest-driven and technology-oriented online forums, we also implicitly narrowed the focus to women who have voluntarily sought such forums. We will return to this limitation in the discussion and to what it implies in terms of how generalizable our insights are and for future work.

4 CURRENT NORMS

We present our results in the two upcoming sections. The first section presents a summary of the norm-critical interviews with PV industry representatives, highlighting their thoughts and understandings of current norms related to gender, technology, and market in relation to residential PV. The summary is not intended to be extensive, but instead serves as a backdrop to the second results section that focuses on the women's experiences.

When the PV industry representatives were asked to reflect on women customers' needs and wants, and how well the respective organizations currently address these needs, it became obvious that there is very limited knowledge about and awareness of women in the role as PV customers and owners. Furthermore, none of the participants knew of existing statistics or data about women in this role, which made several respondents excuse themselves for having to guess and rely on their "gut feeling". Two male participants speculated that because their respective organizations' services, information, and marketing are "*neutral*" in terms of gender, and had not been specifically developed for male customers, they should in theory cater for both men and women equally well. As F10 says "*We make no difference how we address customers; we try to*

keep it simple and accessible to everyone." However, when asked to describe the current typical customer group, all participants provided the same description: a middle-class man with technical knowledge, technical interest, and financial resources (i.e., identical to [38, 40].) This suggests that while there is no explicit strategy to target this particular typical customer, the current information, marketing, support, and services related to residential PV are still formed for and by this group, thus perpetually confirming the bias towards this group [38, 40]. As one female professional (F4) added, this is further confirmed by the fact that men dominate the professional roles in the PV industry: "*Men with interest in technology are implicitly controlling the topic of discussion. If we remove the men, it will become another discussion or public dialogue. It would open up for new discussions that would be exciting, which would also tell us what women's thoughts and needs are.*" All female respondents were aware of this bias, but still expressed uncertainty about what women customers of residential PV want and need.

Reflecting the dominant interests and level of knowledge of the typical PV customer and professional, existing information, services, support, and marketing currently emphasize *technical and economic aspects* of residential PV systems. While environmental aspects are also often included, the focus on technology is strong, which some participants see as a sign that the PV industry is still immature. It is considered positive – even a responsibility – for a customer today to be as well informed as possible, which includes caring about technical details. As a consequence, several participants admit that it is highly beneficial for a customer buying a residential PV system to possess expert technical knowledge as well as project management skills including procurement of technical systems. This supposedly neutral focus on technological and measurable properties of the PV reflects gendered societal norms where rationality and an absence of emotions in decision making is seen as preferrable and as more masculine [4]. This is also reflected in Wajcman's definition of hegemonic masculinities, where the ruling classes of men are characterized by their calculating rationalism and the ability to control technology [46].

Recognizing that the strong focus on technology and details rather than the big picture is excluding other customer groups, some participants are trying more actively to make PV accessible to more people, regardless of technical knowledge and gender. One strategy is actively involving and including both partners in a couple buying PV, another is providing professional PV education to marginalized groups of people such as immigrant women.

The current dominant way for individuals and households to engage in solar energy in Sweden is through *owning* a PV system, which requires both sufficient financial resources to invest and a privately-owned house in addition to the technical knowledge discussed above. When asked to reflect on potential economic barriers that might hinder women customers, the participants again admitted that they do not have enough knowledge about women in the role as PV customers and owners to provide an answer. While some participants were certain that owning PV will remain the dominant business model and logic, others were more open to alternative models, e.g., shares in solar parks, that would potentially make solar energy more accessible to a wider group of people (however, see [23]).

5 NAVIGATING AND NEGOTIATING THE GENDERING OF RESIDENTIAL PV

In the following section, we turn to the participating women's experiences. In our analysis, we have identified current examples of how residential PV are gendered throughout the life cycle and how they impact these women in different ways. We draw on insights both from women who own PV today, and from women in the process of buying PV for their homes. Below, we present four themes. While there can be said to be one before and after phase of buying PV, this process can shift drastically in duration and activities. Importantly, the themes are not necessarily introduced in a chronological order representing a general journey or covering the entire PV life cycle. For example, our study does not explore the functionality and design of PV components and software, which are also likely to shape women's interaction with and relation to PV, or a detailed understanding of the domestication of PV once they are installed [see instead 37].

5.1 Through negotiations in the household and divisions of labor in the PV process

The women in the focus groups showed us that regardless of if a PV installation has already been made or is still in the future, there is both visible and invisible work to be done as well as visible and invisible decisions and decision-makers. Contrasting the picture painted by business representatives of invisible women in the PV process, they describe a very strong involvement, though some prefer to not take an outwardly visible role in the process.

The women who participated in the discussions were highly involved in the buying process, most of them more heavily involved than their partners. In particular, the study shows that these women take on the role as the 'project leader' in the process of buying PV. They have several reasons for taking on this active role, most common is a notion that 'if I want it to happen, I have to make it happen'. As D2 says *"My husband [...] didn't have the time and equally large interest as I had, so I joined a group on Facebook and learned the lingo and reported to him from time to time until we knew enough to ask for bids [on PV]"*. Several other participants shared similar experiences, describing how without their engagement, there would be no PV on their roofs, as their partners were either not interested in PV or just not interested in driving the process. E1 says *"My husband wouldn't do it. He thinks it's great that they are up there, but he just wouldn't manage it"*.

Doing invisible groundwork can also be to motivate and convince others. One woman (B4) found the technical issues difficult and said that when it came to practical matters and installation, her main role was cooking for the family, but she is convinced that PV would be good for her household. Her role was somewhat more passive, but very consistent: *"I've just been there constantly saying "PV! We must have PV!" It's a role that needs a bit of balance because you can't push it too hard. It must be little by little."*

Several of the participants said that they did not mind taking the project manager role and being the one in the household making the PV installation happen. Nevertheless, they framed it as a joint decision, and that their partners' positive attitude is crucial. A previous study by Tjørring [42] also points at negotiations within the household, and the importance of a joint decision, where "*[all] the*

interviewed women claimed that major decisions such as investing in an energy renovation were always made by both members of the household." [42:122] Our focus group discussions mirror these results. The majority of the women in our study lived with a partner, and for them navigating the PV process involved quite a bit of negotiations within the household. Several of the women in our study described how the decision to invest in PV is a joint decision between them and their partners, comparing it to similar larger investments, e.g., buying a car. The women shared their experiences of how they negotiate and use different strategies to get the husband/man onboard. A6 says: *"I haven't yet convinced my husband. We need to change the roof, and these are large investments. I think he'll come around, but he is a bit more afraid of the large investments [than I am]."* Another woman, A1, says that her *"partner is beginning to accept it, he has no interest in it, but he has accepted it."*

This suggests that it is not enough that the woman thinks that it is a good idea to invest in PV, rather the man must also – through her negotiating – be fully convinced. One such strategy can be to gather lots of information in order to convince with facts. Another strategy seems to be that the woman places her own desire for PV 'outside of herself' by making it a 'sustainability must-have' or pointing out that others (mainly neighbors) have it. Or as B4 above, to be very consistent and enduring in the process of convincing. The gendering of the technology in this case requires the man to not only approve but to be fully convinced before decisions to buy PV can be made. Not only is it a large financial investment, but PV being culturally attached to a male domain seems to make it even more important that the male partner is fully onboard in the decision making (see also [36]).

5.2 Through interaction with professionals in the PV industry

In parallel to negotiations concerning PV and taking on the role as 'project leader', the women also talked about how they have to negotiate the gendering of PV through the interaction with various professionals in the PV industry. There are multiple actors involved in the PV industry in Sweden, including salespeople, solar panel installers, and electricians, with new companies and actors constantly emerging, and so it is not possible to describe one series of interactions between customer and professionals. However, given the male dominated PV industry, most of these representatives are men, suggesting that residential PV is seen as a masculine domain.

The participants had both positive and negative experiences of meeting PV professionals. One recurring experience is how male professionals seem to struggle with accepting that the woman in a household is the one driving the process of buying PV and adjusting their communication accordingly. Participants described how professionals had automatically turned to their male partners despite the partners being less involved and how professionals had failed to meet the women at their level of expertise. D5 says: *"You're not viewed as someone who knows the technical stuff. Despite the fact that you meet them in a discussion and show them that you are knowledgeable, it is like they don't really listen, they just go on explaining the basic stuff that you have literally just told them."* As a result, some women described how they had switched companies, or proactively decided to communicate alone without their partner in order to avoid being excluded. A few participants explained that they had to argue with the companies in order to get what they wanted, e.g., a certain technical component or functionality. D2 half-jokes *"You've got to be prepared to use your angry voice"*, while E3 describes a more extreme case: *"We had to break the deal with one company, because [the craftsman] refused to talk to me, and my husband didn't have a clue."* These experiences show how PV technology is gendered through professionals' not associating the technology with the woman (at least not alone) in the household. Consequently, participants who had not yet invested in PV talked about feeling the need for strategies to avoid negative encounters with companies. One strategy was to make sure to be very knowledgeable, which as C2 explains can become a large barrier in itself, for example if you, like C2, are a parent with very limited time:

> "My mother got solar panels 5-6 years ago and the installers treated her in a diminishing way. Since I don't want the same thing to happen to me, I feel I have to be very well informed about solar panels, and then I get stuck in an impossible situation where I need to read up, but I don't have any time or energy to read up, and so I'm stuck here."

However, positive experiences highlight how professionals can support re-gendering of PV through fully acknowledging the woman as a customer and owner of a residential PV system. For example, E1 explains how she was met with respect in her communication with a male salesperson, who quickly acknowledged E1 as the one in the household driving the process and having knowledge about solar panels. The women themselves also acknowledge their role in negotiating and re-gendering residential PV. As C2 reflects:

> "I've thought about it. I see it as a quality control: the day we contact a PV company I'm going to be the person who does it. If they pass the 'woman test' they will be interesting to sign a deal with. I'm sure my partner wants to be part of it too, but it's important to support companies who are actually doing well in terms of including women and people who aren't white Swedish men."

5.3 Through interpreting PV communication

The communication about PV that the participants encountered was, in the participants' interpretation, dominated by technical and economic aspects; PV were communicated as primarily technical artefacts and/or as economic investments. The interviewed industry representatives generally agreed that this is how they want to communicate, and that they interpret such communication as *gender neutral* (see 4). Although the focus group participants did not necessarily interpret the technical and economic focused communication as *masculine* – a masculine way of describing PV or a way of ascribing the PV masculine qualities – it was clear that the participants wanted *other* ways PV could be communicated and interpreted. Environmental aspects of PV and social sustainability were highlighted by many participants as important and not present in the general communication of PV. Further, a common motivation for the participants to invest in PV was making their households more independent and resilient in times of crisis, which

is also less present in the communication. Finally, the participants without PV wanted to see more examples of actual PV installations, and a wider range of representation in those installations – e.g., more types of buildings, people, houses, roofs, and geographical locations.

The technology–oriented communication was generally interpreted as depicting PV as *difficult to understand*, e.g., in social media forums where members (interpreted as men by the focus group participants) discuss technical issues to 'show off' their technical knowledge (cf. technical identity in [31]). D4 states; "*In those Facebook groups, there are a lot of men who claim to know everything about the world".* In a different focus group C2 says that she finds it to *be "mostly men in those Facebook groups, with a lot of gadgets and a negative tone. . ."*

Among the participants with PV, there were both participants with a strong technical identity (cf. geeks in [31]) and participants who, though generally competent, claimed that they "*did not know anything*" (D6) when their panels were installed. Despite this variety in technical ability among those with PV, many of the participants without PV felt a need to understand this seemingly difficult technology in order to feel safe enough to make an informed decision. But also, to challenge what they thought was the industry's image of a female customer: a person with a low technical ability. This wish to understand the technology was present even though some of them questioned if it really is necessary, and that maybe the understanding was needed both to make good decisions and to combat stereotypes:

> *"I feel uneducated and not technically skilled. [. . .] It is frustrating because I don't think it has to be so technical, but I have made up my mind that I'm not going to invest in something if I don't understand it." (C1)*

The technology–oriented communication and stereotypes of women as having low technical ability seemed to contribute to an exaggeration of what technical ability is needed. Interestingly, the participants do not only use industry communication to interpret PV – communication with PV owners on social media is also important.

The focus groups participants, both with and without PV, had few experiences of women representing solar panels, and had seen very few women in social media forums and ads from PV companies. They also want more women to represent the industry, for example female salespeople. One participant described a guided tour she had joined of properties with installed PV in her area. At all sites, men talked about their installations to the visitors. At some of them, a woman stood next to the man but kept silent. Several women with PV recounted that after installing PV, surprisingly few people asked about their installations. D1 who lives alone says: "*My neighbors asked me what supplier I had used, and things like that, there was no one else to ask.*" Participants with male partners noted that their partner got asked more questions than they did, as noted by D7: "*When we just had the system installed, the neighbors came to ask about the system, but they asked my husband. Nobody asked me.*" One participant with PV recounted that her colleagues at work were in the process of getting PV and that they did ask her, but not about technical issues:

> *"I have two male colleagues at work, who are both in the process of asking for bids on PV. They actually come and ask me things, perhaps not about the technical solutions, but I'm still there and pick on it and put my nose in it and then they accept it and listen to what I say. They don't ask me, but I tell them." (D6)*

In a few cases the participants with PV had a forum for sharing their experiences of PV that suited them. One such example was a local social media forum about PV which had generated questions from other women in the same area, as D7 explains: *"Later on we started a Facebook group for PV on the island where I live. Some people have gotten their [PV] after that. But the people who have come and asked questions, that's other women."* In general, the participants with PV did not feel a need to show off their PV skills as such, but to help people or, as D3 states to spread an interest in PV:

> *"You can't really see mine – they face the courtyard. I don't feel a need to tell people about them, but I do think it's a good thing to share, it's valuable if others think that it's a good thing to have too."*

5.4 Through re-gendering PV systems

As stated above, PV are often communicated in technological terms and therefore interpreted mainly as a technological artefact and as technology is interpreted as male, PV are gendered by association. In addition, as PV are a fairly new technology and mastering such technology is associated with technical expertise which is also considered to be a male skill (while mastering technology that is commonplace in the domestic domain is not [cf. 10, 31]). Thus, both the fact that PV are new and interpreted as a technology seem to contribute to PV having a masculine symbolic gender and to a prejudice that women are less able to, do not have to, or maybe even should not deal with PV. Most of the participants in the focus groups were uncomfortable with this prejudice and in their experiences, there are traces of how PV are being re-gendered.

The participants with PV can all be seen as re-gendering PV – they show that PV are something for women as well. Although our data does not allow us to understand if such re-gendering is important for a wider uptake among women, it can give us some clues. First, returning to the women who had forums for getting questions about their PV, the fact that they got questions from other women indicate that this could be the case.

One might speculate whether the participants who had PV had preconditions, experiences, or abilities that made the journey easier for them than for other potential customers [cf. 33]. The data does not tell us the full story but hints at some aspects. One such aspect is the experience of male spheres, where some of the participants were used to male spheres (e.g., due to profession or hobbies) and seemed to be able to use such experiences in relation to PV. Another aspect was technical identity. Participants (with and without PV) who already had a strong technical identity seemed be able to transfer this sense of technical self-efficacy to PV.

Interestingly, opposite to what many of the participants without PV thought, namely that they need to know a lot before buying, one participant with PV said that she didn't have the knowledge before but gained knowledge as a result of buying and owning PV. At the time of installation, D6 says "*I knew nothing. I know*

one hundred times more now than I did then; I have learned loads since then." Instead of requiring technical abilities, PV was a way for D6 to start acquiring technical ability. At the same time, it was a starting point for electrification and optimization: "*I think it adds on. When I'd had them for a while, I realized that I could optimize, change electrical company. . . now I have signed up for an electrical vehicle. It starts with the PVs, but it doesn't end there, it grows.*" Another woman, B3, adds; "*I thought that doing something for the climate would be my main motive, the one aspect that would be most interesting and motivating. But I discovered a tech geek in myself, that I wasn't expecting. Climate is still my main reason, but I do find this to be a very enjoyable journey, and I really want to get on it.*"

Re-gendering of PV can thus be about changing your technical identity (increasing technical ability and self-efficacy and maybe altering presentation of agency) and co-constructing this new identity with gender identity in a different way. Such re-gendering often meant different sorts of *sameness* strategies [cf. 31] towards PV, e.g., women becoming the same type of PV customer as the current (male) norm. However, this might be problematic for women with a low technical ability or self-efficacy, or for women who do not want to be this type of customer. Additionally, even though potential customers can play the role of the customer that the industry is imagining, it might mean that other sides of oneself need to be set aside. Customers are thereby "pressured into accepting" an identity that excludes parts of their self [4:1307].

An alternative re-gendering could be to question the idea of PV as a (primarily) technically advanced artefact. Some of the participants adhered to such questioning, as for example D3 with PV says: "*I'm not interested in the technology itself, I just want it to work.*" Interestingly, the ones with PV generally thought that it was easier to get PV than the ones without thought it would be. It is difficult to know why that is. It might be that the participants with PV were different (as discussed above) or that the process seems more difficult than it is. As D6 says: "*Since I was on my own doing this, I felt that it was my own struggle, to throw myself out there. But after that, it wasn't difficult at all.*"

PV are an example of a prosumer-related technology you either can engage with directly (e.g., checking the current production in an app) or indirectly as a prerequisite for energy-consuming activities, energy-related activities and energy-reliant activities [29]. In two-gendered couples, men typically engage in the energy-related prosumer activities and women in the energy-reliant, such as cooking or doing laundry [37]. One way to re-gender PV lies in tying them more closely to energy-reliant activities, such as electric cars. Several participants without PV already had, or planned to, get electric cars, and producing electricity for the car was part of the motivation for PV. One participant with PV speculated that the lack of questions about her installation could be that people do not know what to ask, but with electric cars you do, suggesting that electric cars seems to be a technology that is easier to relate to in such situations: *"I think perhaps that they don't ask because if you aren't in the middle of getting [PV], you don't know what to ask. With electric cars it's different, you get many questions, people can probably relate more to that. They just don't know what questions to ask."* (D5)

PV are inherently a technology used with other technologies, both technologies that use the energy that is produced, and technologies or services used as interfaces between users and PV, such as apps to monitor production or the energy bill. Such interfaces could become part of the post-installation re-gendering process some of the participants with PV had experienced.

Finally, one participant, who had become a widow in recent years, argued that deliberate re-gendering of technology through acquiring technical abilities and technical self-efficacy is a feminist act. Addressing the other participants, D2 says: *"In general, make sure that you are involved in all things concerning the house, the car and the home. Do not hand over issues to a man. You must make sure that you know everything. You cannot trust that your partner takes care of the technical matters."*

6 DISCUSSION AND IMPLICATIONS

In this paper, we have presented insights from interviews with PV industry representatives and focus groups with women to make visible both current norms in the PV buying process and how the women are navigating and negotiating the masculine gendered sphere of PV. Below, we discuss the insights and implications of our study, providing suggestions for action to actors and companies related to the PV industry, as well as researchers, designers, and practitioners in HCI working with connected technologies in the home, e.g., smart home technologies, as well as energy and sustainability.

Throughout our study, it became clear that the studied group of women in many ways share the same characteristics as men who buy PV systems today – except for gender. We have seen that the interviewed industry representatives have a perception of their customer as being someone interested in technology and environmental technology in particular. They also imagine their customer to be very knowledgeable, almost reaching levels of technological expertise. It is first when this perceived customer turns out to be a woman that it becomes clear that their customer is also imagined as being a man. Many of the participating women are both educated and interested in various areas of technology, with a clearly expressed interest in solar energy. They should, by all accounts, be perfect customers. But as seen, the women did not experience being treated as desired customers. Many described that they had to be over-prepared but were still treated as less knowledgeable than their tech unsavvy husbands. The fact that women are seen as lesser when it comes to knowledge, expertise and interest in technology is also present in wider society, as seen in 5.3.

6.1 Implications for more inclusive PV offerings and customer journeys

The results provide plenty of norm-creative implications for PV offerings and customer journeys, including identified ways for the PV industry to work differently to better acknowledge and reach out to women customers. We have identified both *general* and *specific issues* in relation to the current PV offerings. One *general issue* is how the industry treats its customers, where the PV industry needs to learn how to fully see and acknowledge women customers. As described by our participants, they want to be respected and listened to, they want the interaction to be at their level of competence

regardless of level, and they want their areas of interest and needs to be acknowledged. Another *general issue* is PV communication where a *norm-creative* approach could make PV more inclusive to this group of women, e.g., by bringing more reasons for getting PV to the foreground, beyond the technical installations and economic investments. This mirrors recent results on gender perspectives in solar energy communities that suggest to "*emphasize the connection between energy and the environment, as a way to decouple energy as a man's domain*" [23:10]. Increasing the diversity in communication is another key action to move beyond the typical consumer and house. While changing PV communication and marketing is in the hands of the PV industry, other actors such as energy advisors, PV experts, and local organizations who might organize PV events also have an important role to help re-gendering PV through their communication (see 5.3). Improved treatment and communication that address more customer groups are thus matters for the whole industry. Gender-aware PV companies – for example companies that "pass the women test" (see 5.2) – could get a competitive advantage in the future.

When it comes to *specific issues* that the PV industry can improve to better support women customers, the customer journey can be used as a starting point. Instead of one ideal journey, we have identified many different routes that the participants with PV have taken and the ones without would like to follow. For example, there need to be routes available for customers who are not interested in the technology as such but just want it to function; customers who care most strongly about the social and/or environmental aspects of PV; customers who are interested in self-sufficiency and resiliency in times of crisis; and customers with specific architectural needs (e.g., related to roofs) or ambitions for their homes. Routes should also include different starting points, such as electric cars, a change of roof, or a sudden opportunity to make an economic investment (e.g., an inheritance). In addition, the participants showed us that although they started out on one route, they bridged to other routes throughout their journey as they or their circumstances changed. One example is how a climate interest bridges and expands to a technical interest in PV (see 5.4). Furthermore, the study shows that the PV industry needs to increase its awareness and knowledge of how the division of labor in the home is negotiated, acknowledging it as an ongoing dynamic in the household. This can involve addressing both persons in a two-person household even though only one of them seems to be driving the process at the moment. Another important point is to not see the installation of PV as the end of the journey, but a route that continues as you live with PV. Some of the women with PV have become representatives of PV in their local or social contexts after installing, clearly showing that routes may change as the technology is domesticated in the homes.

6.2 Implications for HCI

Despite the focus on PV in this study, which so far has not been central in HCI, we believe that there are several takeaways for HCI and Sustainable HCI (SHCI). First, the study contributes empirical insights to the growing knowledge on gender and technology in HCI, especially in the context of the home and thus adding to previous studies such as [31, 40]. Similar to these previous studies, this work shows the need to understand underlying social dynamics in the home in relation to technologies, and conscious design work to make technologies more inclusive to more members of the home. As PV systems enter more people's homes, and as they get increasingly connected to both existing technologies (e.g., heat pumps) and emerging ones (e.g., battery storage), we believe that this need will only become more important to address. HCI already works on aspects of some of these technologies, for example interface design and digital systems and services to monitor energy, which can contribute to confirming current gender norms or help re-gendering PV. Past examples of re-gendering technologies include novel energy visualizations that help question gender norms in relation to energy and the home [11] and "troubling" the expectations and gender aspects of digital personal assistants [22].

More broadly, the study also contributes to HCI's work on sustainability by emphasizing the need to take gender and other aspects into account intersectionally, which has not been a prominent theme in SHCI so far [16] but is gaining ground (see e.g., [21]). PV is seen as a 'democratic' technology, but as this and other recent studies [26, 36] are clearly showing, this does currently not hold true in practice, which impacts how we can reach just and sustainable societies. Such aspects need to be part of how we understand the success of our efforts in SHCI, for example whom we involve as participants and how we evaluate [28]. Although referring to a different geographical and socio-cultural context, Ojong [26:9] argues that not only gender but an intersectional perspective is crucial in order to understand the how PV might strengthen some privileged groups while "*reproducing the vulnerabilities of marginalised populations*". As discussed, the women in our study shared some significant characteristics with what the industry consider a typical PV customer, but still did not consider the PV industry to provide solutions adapted to them. For groups who share fewer characteristics with the typical customer (regardless of gender) the barriers to getting PV are likely to be (much) higher. If we want to target climate and societal goals [e.g., 44, 45], we must move beyond values appreciated by exclusive groups (e.g., early adopters) and identify as well as support values and functionality that are important to other groups. This might place the technology in the background and other more holistic values in the foreground. For future work on PV as well as other "green" technologies, it is thus necessary to involve other groups of people, whose context, interests, needs, and wants might differ far more. However, as shown by feminist scholars, technology has historically decreased in status with women users and values [46–48] – something which needs to be taken into consideration as well as managed in e.g., SHCI's efforts to address sustainability.

Finally, this study contributes insights to how HCI can continue to work with norm-critical design. When looking at the results of the focus groups there was clear hesitation among the women to speak about the struggles they faced as being related to their gender and them being the victims of gender-based discrimination. They could however come to this in a roundabout way, as when speaking about strategies they adopt or develop in order to counteract negative implications of them being women e.g., only handing out their own contact information making it impossible to contact their husbands instead of them, using their angry voice to earn respect, or feeling they need to be technical experts before they are even allowed to start their buying process. There was, however, a pattern

where women who were engaged in gender discrimination issues at work, e.g., participating in technology or online gaming gender equality networks, were able to speak about their experiences in terms of discrimination and a lack of inclusivity in the solar energy industry. There seems to be a widely held view among the participating women that because gender should not be a factor in the process of acquiring PV, they have a responsibility to not make it a factor. By "pulling the gender card" they would concede to not being seen as a competent neutral person, but rather as a woman and thus opening themselves up to the societal norm that they are less competent and less worthy. Both the interview and focus group participants struggled to reflect critically about current norms, which suggests that power dimensions are hard to see when they have become internalized, and that expertise in norm-critical methods is key when conducting these types of studies to reveal underlying dynamics and roles. As emphasized in the norm-creative toolbox NOVA [3], it can be necessary in a design or project team to bring in external expertise in norm-critical and norm-creative design to support analysis and design generation. Such expertise already exists in HCI [e.g., 2, 4, 5, 12, 15, 30, 31, 34, 39, 40] and we hope this study will encourage teaming up with experts to continue to build up much needed knowledge on how we can design for a more ecologically and socially sustainable energy system and society.

7 CONCLUSIONS

In this work, we have explored how women customers are impacted by gender norms in the process of buying a PV system for the home, including how they navigate and negotiate the gendering of PV, for example within the household and in interactions with PV professionals. Taking a norm-critical design approach, we have conducted interviews with PV industry representatives and focus groups with women who either own or want to buy a PV system. Drawing on the data, we report how the expected typical consumer of PV today is a man with technical interest and with almost expertise knowledge of PV. While the women in our focus groups share similarities with the typical male consumer, they are still not fully seen and acknowledged in their role as 'project leaders' driving the PV process and as PV owners. This work has taken one step in the direction of making women PV customers more visible and pointing to implications for both the PV industry and HCI. However, the results clearly show that it is necessary to move beyond 'early-adopters', regardless of gender. This calls for understanding the interests, needs, and wants of other groups of people, for whom the barriers are likely be even higher to get PV, and designing for alternative ways be involved in the transition to renewable energy.

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