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Gender inclusiveness in the adoption and use of home energy technologies

Sanna Tuomela
University of Oulu, sanna.tuomela@oulu.fi

Netta Iivari
University of Oulu, netta.iivari@oulu.fi

Tuomo Hänninen
University of Oulu, tuomo.hanninen@oulu.fi

Rauli Svento
University of Oulu, rauli.svento@oulu.fi

GENDER INCLUSIVENESS IN THE ADOPTION AND USE OF HOME ENERGY TECHNOLOGIES

Research Paper

Tuomela, Sanna, University of Vaasa, Finland, University of Oulu, Finland, sanna.tuomela@oulu.fi

Iivari, Netta, University of Oulu, Finland, netta.iivari@oulu.fi

Hänninen, Tuomo, University of Oulu, Finland, tuomo.hanninen@oulu.fi

Svento, Rauli, University of Oulu, Finland, rauli.svento@oulu.fi

Abstract

Home energy technologies, such as smart home energy management systems (SHEMS), are important in reducing energy-related emissions and empowering energy users. However, there are concerns on gender inclusiveness of the adoption and use of SHEMS. So far, information systems research has failed to address this significant challenge. This study examines factors shaping gendered adoption and use of smart home technologies, particularly SHEMS, and the implications this has for sustainability and energy equality. Applying a critical lens, we examine findings from a sensory ethnographic study on the adoption of SHEMS in households. The findings underline the need for more inclusive energy technology design, more understanding of diversity of households and more variety in the approaches for increasing awareness on and facilitating the adoption of energy technologies. We contribute to research on gender and home energy technologies, and to the larger discussion of gender and energy.

Keywords: Smart home energy management systems, gender inclusiveness, sensory ethnography, user experience.

1 Introduction

Energy technologies and services for household energy management, such as smart home energy management systems (SHEMS), are essential on the path towards ambitious climate change mitigation goals (European Union, 2019, IEA, 2017). This study addresses the complex topic of co-creation of sustainable digital futures from the viewpoint of energy technologies and gender, thus advocating the United Nations' Sustainable Development Goals (UNSDGs), particularly 5. Gender Equality and 7. Affordable and Clean Energy (https://sdgs.un.org/goals). More specifically, this study explores the value of gender inclusiveness in the adoption and use of smart home energy management systems (SHEMS).

Information Systems (IS) research has recently paid attention to the use of energy technologies in the context of home (Berger et al., 2022; Berger et al., 2022 a; Gerlach et al., 2022; Lackes et al., 2018; Lossin et al, 2106). The impact of gender[1] has also been studied in IS research – both from the viewpoint of design and use of digital technologies (e.g. Knestis et al. 2022; Kreps, 2010; Olbrich et al., 2015; Serenko et al., 2011; Trauth, 2013; Vainionpää et al. 2021). Gender inclusiveness has widely been recognized as a value in IS research (Knestis et al., 2022; Olbrich et al., 2015; Serenko et al., 2011; Trauth et al., 2018). Inclusiveness in the context of design and use of digital technologies refers to the acknowledgement and empowerment of people who experience challenges for example due to

[1] We discuss gender from the viewpoint of how the research participants describe it, indicating how they identify themselves (Fathallah & Pyakurel, 2020). In line with West and Zimmerman (1987) gender is understood as something people routinely 'do' and perform in everyday interactions.

disabilities, medical conditions, age-related characteristics or social situation (Keates, 2015; Cozza, De Angeli & Tonolli, 2017; Barcham, 2021; Sanchez Guzman, 2021; Olbrich et al., 2015; Trauth et al., 2018). Gender inclusiveness in the context of technology pays special attention to gender issues related to technology design and use, but also in the larger social, cultural, and economic context (Stumpf et al, 2020). Until now, IS research has mostly ignored gender inclusiveness in the context of energy technologies and SHEMS (except for Kreps, 2010), while gender inclusiveness in such a context is a significant concern, for IS research as well as for many others.

The war in Ukraine has given rise to the current energy crisis in Europe. It has reinforced and brought to public knowledge the ongoing energy transition and how it touches all energy users. Equal and just energy transition should empower and enable participation of all energy users. Smart home energy technologies such as SHEMS are means to increase residential energy efficiency, energy conservation and demand flexibility. So far, the adopters of home energy management technologies have been affluent tech-savvy men (e.g., Sovacool, 2011; Strengers, 2013). Therefore, a balanced and heterogenous policy, inclusive planning and design, and guidance on the use of energy technologies are required. Furthermore, in order to achieve higher adoption rates of the technologies intended for reaching clean energy goals and decreasing emissions, the gendered assumptions these technologies are built on should be revised (Anfinsen & Heidenreich, 2017). Though gender has been identified as an important perspective in energy research (e.g., United Nations Development Programme, 2012; Feenstra & Özerol, 2018), there is an identified need for empirical research of the effects and implications of gender imbalance, and of gendered stereotypes and assumptions (Anfinsen & Heidenreich, 2017, Sovacool, 2014). This study responds to this call with empirical research on end-users of SHEMS with specific focus on gender. Our study builds on the equity analysis by Bush (2009), and draws on critical (Bardzell, 2013, Iivari & Kuutti, 2017, Obrist & Fuchs 2010, Kvasny & Richardson 2006), and value-sensitive technology research (e.g., Friedman, Hendry & Borning, 2017; Deng et al. 2016) to identify and analyze the gender inclusiveness and the role(s) of women in the adoption and use of SHEMS.

The research questions of this study are: 1) How do different genders participate in the adoption and use of SHEMS? 2) What factors are associated with gender inclusiveness in the adoption and use of SHEMS? Focusing on values, sensory ethnography observations with interviews were conducted in 28 households representing new, prospective and experienced users of SHEMS. To our knowledge, the adoption and use of SHEMS with three different kinds of user groups has not been previously studied by applying sensory ethnography and the results analyzed from the gender inclusiveness perspective. Gender inclusiveness was a concern that arouse during the empirical study. The results indicate women could be interested and active in the adoption and use of SHEMS and other home energy technologies and digital energy services, if they were approached in other ways than today's male-dominated home energy technology sector does, and if their role in home would be redefined to include energy management as a basic household know-how. This study contributes to IS research on gender inclusiveness and sustainability by offering an understanding of the structural and contextual factors affecting gendered adoption and use of energy technologies and consequently the unbalanced and unequal transition towards clean energy. Also, it contributes to energy policy planning and home energy technology development, design, and marketing.

The paper is structured as follows. After related research, we present the research methodology used and the empirical results on gender inclusiveness, or lack of it, concerning the adoption and use of SHEMS. Next, we discuss the findings as well as propose future steps to be taken in improving gender inclusiveness in the energy technology adoption and use, and more broadly in the energy sector and home energy management.

2 Related research

Technology, including energy technology as well as the energy sector, are male-dominated (e.g., OECD, 2018; IEA, 2019). Technologies are largely made by men, for men, and gender of the designers has been argued to influence gender inclusiveness of technology (e.g. Knestis et al. 2022, Olbrich et al. 2015, Serenko et al. 2011). The literature has indicated that the motivations and experiences of using a software can be differentiated to typical to men and typical to women (Burnett, 2016). Also, different styles of user interface design may increase or decrease the sense of belonging of different genders (Metaxa-Kakavouli et al., 2018). Despite campaigns and initiatives, the Information and communication technology (ICT) sector has gone backward in gender diversity in the last decades (Strengers & Kennedy, 2020; UNESCO, 2019; Vainionpää et al. 2021). However, female education is found to be strongly positively associated with the choice of modern energy and technologies in all studies that include this variable (Pachauli & Rao, 2013).

2.1 Home energy technologies

SHEMS are smart home systems typically consisting of indoor and outdoor sensors that communicate with a central unit through a wireless home network, and the central unit connects SHEMS to the smart grid (Zhou et al., 2016, Pau et al., 2017). Users control and monitor their energy use via a control application, that is connected to the cloud service of a system provider. Increasingly home energy microgeneration system (e.g., solar panels), electric vehicle charging, and many home appliances are being controlled through SHEMS (Panagiotou, 2017; Powells & Well, 2019).

These new technology solutions will provide users with the means to be more conscious and responsible of their use of energy, demand flexibility, and production and sharing of renewable energy in homes consequently reducing CO_2 and other Green House Gas (GHG) emissions (Tuomela et al., 2021; Katzeff & Wangel. 2015; Badar & Anvari-Moghaddam, 2020). Home energy technologies can shape energy use and production by altering everyday practices (Oberdiek & Tiles. 1995). The ongoing energy transition is changing the energy system leading to the shift of power to distributed, local energy communities and households, making them "co-managers of the energy system" (Katzeff & Wangel. 2015; van der Schoor & Scholtens. 2015; van der Schoor et al., 2016). Energy consumers are expected to become active and empowered energy citizens (Kampman et al., 2016; Lennon et al., 2020). Recent socially and politically oriented energy research expects energy technologies and local energy communities to enable reorganization of political and economic power structures concerning energy thus advancing energy justice and democratization (e.g., Heldeweg & Séverine Saintier, 2020; Hanke et al., 2021; Burke & Stephens, 2018) and offering opportunities for all to participate in clean energy futures (Burke & Stephens, 2018; Pearl-Martinez & Stephens, 2016). However, the interest, adoption and use of home energy technologies is not shared equally by all.

2.2 Home energy technologies and gender

Though IS research has not addressed gender in the context of energy technologies, there is literature within other disciplines addressing this topic. Gender equality and women's empowerment is one of the universal values of the United Nations Sustainable Development group (2021), and International Energy Agency (IEA, 2019) has declared that gender diversity in the energy sector is vital for driving more innovative and inclusive solutions for clean energy transitions. In recent years, feminist movement has emerged in the energy sector with the aim to change the economic, political and technological power structures (Bell, Dagget & Labuski, 2020; Wilson, 2018). However, energy sector in general (e.g., Standal, Talevi & Westsko, 2020, Sovacool & Furszyfer Del Rio, 2020; BP, 2021) and electricity sector in particular (IEA, 2019) are still overwhelmingly occupied by men. Energy sector is one of the least gender diverse sectors (Clancy & Roehr, 2003; IEA, 2019). The share of female inventors of environment-related technologies is only 10 %, and even lower (8 %) for power generation and general engineering technologies in the OECD countries (OECD, 2020). The technologies and services produced by such an unbalanced energy technology sector risk deepening gender inequality rather than increasing democratic energy transition.

Gender shapes the choices and opportunities to engage with energy technologies and services, such as SHEMS and energy communities. What is known about gender inclusiveness in energy technology use is largely based on studies with focus on other questions but gender. Like in our study, in other studies too the matter of gender emerged alongside the research results and drew attention. For example, in a survey concerning solar panels the respondents regarded more often the male household member as the person who knows best about the household and is responsible for it (Poier, 2021). Standal et al. (2020) studied the phases of appropriation, objectification, incorporation and conversion of household solar systems, and found they are gendered in the sense that women and men have different economic, social and cultural capital, and this influences their interaction with technology in the transition from consumers to prosumers. Also, studies on energy community members confirm that energy community members and board members are overwhelmingly men with technical, higher education background (Hanke et al., 2021; Yildiz, 2015; Fraune, 2015). Contextual factors such as wealth gap and gender-specific occupational segregation affect the gender gap in the participation and management of energy communities (Fraune, 2015). MacGregor (2016) found that more women adopt 'low-tech' energy saving strategies, such as energy-efficient light sources, in contrast to men who showed much more interest in more advanced and expensive technologies e.g., in solar panels. Additionally, women showed more interest in reducing energy for environmental reasons while men were highly interested in reducing their costs (MacGregor, 2016). Also, women are found to have slightly more environmental values than men (Sovacool et al., 2019). Women in work life often operate in different types of productive activities than men, and have different access to energy technology, energy markets, energy infrastructure and skills (Pueyo & Maestre, 2019). Men are considered the principal decision makers in households, concerning energy decisions. Women living with a man may be even relieved, when men take care of energy and related technologies, thus having 'one thing less to think about' (Strengers & Kennedy, 2020).

It has been shown that the level of energy consumption is also different for men and women (Grünewald & M. Diakonova, 2020), but gendered characteristics of energy use vary also in cultures and social groups. For example, in Europe, men have been found to consume more energy than women (Räty & Karlsson-Kanyama, 2010), and the consumption patterns and timing differ between genders (Grünewald & M. Diakonova, 2020) but in Japan working women are found to use more energy than working men or students (Fong et al., 2007). Also, focusing on the total level of energy consumption hides the fact that home practices entailing energy use may vary between genders (Tjørring, 2016, Clancy & Roehr, 2003). Studies on perceived comfort level with indoor heating confirm that women are subject to more discomfort with lower level of indoor temperature, which is often a consequence of energy conservation strategies with SHEMS (Tuomela et al., 2019; Karjalainen, 2012; Carlsson-Kanyama & Lindén, 2007).

Research on smart home technologies, such as SHEMS, has also shown that the creators and designers of these technologies are overwhelmingly male (Strengers, 2013), and the "smart technology agenda focuses on a masculine ideal consumer" (Strengers & Kennedy, 2020; Strengers, 2013; Sovacool & Furszyfer Del Rio, 2020). Strengers (2013) calls this persona "a resource man", who is "[…] an energy sector's ideal smart energy consumer, intended to realize the industry's ambitions of reducing or shifting a home's consumption through the use of smart home technology". She often identified this fictional "gendered, technological-minded, information-oriented and economically rational consumer" in real-life interviews (Strengers, 2013). In most cases among the users of smart home technologies, a man took the lead in planning and deploying these technologies in the home (Strengers & Kennedy, 2020). Often the ambitions of the "resource men" conflicted or were undermined by the home practices of other people in the household (Strengers & Kennedy, 2020). For many male users, smart home technologies are 'fun' rather than 'necessary', whereas women are left with a pragmatic 'the voice of reason' role in the family (Strengers & Kennedy, 2020). Women have been ignored as a design resource for smart home technologies (Strengers & Kennedy, 2020). Smart home technology industry often "assumes a deficit model where male technology use is normative, while women need to 'catch up' to levels of their male counterparts" (Rode, 2011).

Yet, smart home industry has noticed the pragmatic role women have in the acquisition process and use of smart home technologies, and this "Wife acceptance factor" is growing in importance (Strengers & Kennedy, 2020). Despite being in the scope of home energy technology designers and marketers (men) as an influencing wife, a woman is still seen as an appendix of a man. Single women, either living alone, single mothers with children, or elderly single women are not considered relevant users of home energy technologies, often not even by themselves (Strengers & Kennedy, 2020). Interestingly, many smart assistants in homes have a ‘female character’. The most widespread smart home devices such as Amazon’s Alexa, Apple’s Siri, or Google Home, have default female voices in most markets, and one Indian company has even adopted the name “smart wife” to advertise their home appliances (Strengers & Kennedy, 2020). Also, according to Sovacool et al., (2019) smart home systems linking electric vehicle (EV) to the home electricity system and to the grid have been found to be sexist and agist: “The smart consumer, the archetypical image, is a youngish hip looking, techno savvy white boy in the suburbs … the smart customer is never a woman with two children at home” (Sovacool et al., 2019). Furthermore, women own EV less often than men, drive less kilometers by car, and use more public transportation than men (Sovacool et al., 2019).

Research on energy technology adoption, energy use and energy poverty usually use ‘household’ as a unit for research subjects. This hides individual and gendered differences behind one neutral consumption unit. Furthermore, often a ‘household’ refers to a traditional family composition, and families where gender is constructed non-traditionally (such as same sex couples, single parents raising children, elderly people living alone – typically women as they tend to have longer lifespan than men etc.) are rarely studied in energy research (Fathallah & Pyakurel, 2020). Yet, the number of ‘untraditional’ families is large and growing. In EU, a quarter of women live alone, while less than one in fifth of men live in the same situation. In EU, 40.1 % of women aged 65 or more live alone compared with 19.4 % of men in the same category. 14 % of EU households are lone parents with child(ren) (Eurostat, 2021), and households with a single adult and dependent children are more often headed by women (11% in 2019) than by men (3%) (European Union, 2017). Households with single female adult are usually excluded from the target group of home energy technologies, such as SHEMS. Thus, many households are implicitly excluded from the potential users of energy technologies.

Globally, women and girls are disproportionately at risk of energy poverty, i.e., not having adequate access to energy for coping with everyday life with an impact on wellbeing (Pachauli & Rao, 2013; Oparocha & Dutta, 2011; Sovacool, 2011; Osunmuyiwa & Ahlborg, 2019; Johnson et al., 2019). Energy poverty manifests itself in different ways in Europe compared to developing countries, but also in Europe women are more at risk of falling in energy poverty (Eurostat, 2021; European Union, 2017; Ariston & Onaindia, 2018). Single parent households in EU countries, most of which are headed by women, are far more likely to be suffering from energy poverty than households in general. Slightly larger share of women (22,3%) is at risk of poverty or social exclusion than men (20,0 %) (Eurostat, 2021), particularly women with low incomes as heads of households in single parent families (European Union, 2017). Also, in the US severely energy insecure households are more likely to be headed by younger people, single women, or individuals who identify as African American (Murray & Mills, 2012). Energy poverty is usually a temporary phase for families with children, as children grow up and both parents can work, whereas for single parent families this can be a more permanent situation (Runsten et al., 2015). In addition, elderly women living alone in sparsely populated areas often do not have resources to improve energy efficiency of their home, or to invest in clean energy technologies, and neither is it easy to sell the house in the areas of migration loss (Runsten et al., 2015). The level of income is lower for women than for men, which makes one female adult households to be more at risk of poverty and material deprivation. Economic factors explain gender disparity concerning SHEMS and other energy technologies to some extent. In addition, energy demand flexibility enabled by these technologies can be seen as a capital, which some users possess and can monetize, while others don’t possess, and this can put users in unequal position (Powells & Well, 2019). The capacity to provide the system with flexibility depends on factors such as household constitution, size of electrical loads, presence or absence or energy storage, life stage and health. Less affluent people with little flexibility are in a disadvantaged position for capitalizing flexibility and making profit with energy (Powells & Well, 2019).

2.3 Analytic lens: equity analysis and critical theory

Bush's (2009) equity analysis is based on the conception of technology as a value and equity issue. According to Bush (2009): "Technology has everything to do with who benefits and who suffers, whose opportunities increase and whose decrease, who creates and who accommodates." Bush (2009) identifies four contexts in which technological decisions are made, technical information is conveyed, and technological innovations are adopted: The developmental, the user, the environmental and the cultural contexts. Bush states that of these technology contexts the developmental one is well studied, the latter three less so. The user, the environmental and the cultural contexts, unlike the developmental, are social and cultural contexts rather than technical. Often, they are seen as separate phenomena: "Most people welcome technological change because it is material, believing that it makes things better, but it doesn't make them different. They resist social change because it is social and personal; it is seen as making things different . . . and worse. The realization that technological change stimulates social change is not one that most people welcome" (Bush, 2009). Energy transition is advanced by technological solutions such as SHEMS, but it requires social and cultural changes as well. Therefore, it is essential to understand all four contexts of energy technology through equity analysis.

Critical theory aims to empower people, who are in disadvantageous position in power structures, by seeing through those structures and making them explicit (Bardzell, 2013, Iivari & Kuutti, 2017). Critical theory proposes inter-relation and the dialectical nexus of technology and society (Obrist & Fuchs, 2010) that can be elucidated for example by studying values and contextual multisensory user experiences of technologies. SHEMS may have significant sustainability consequences and influence everyday life in households; therefore, it is important to make the underlying values of these technologies explicit. On the other hand, these energy technologies may be deliberately modified by emphasizing certain values.

3 Materials and methods

3.1 Sensory ethnography

The research is inspired by critical theory and applying sensory ethnography method with a special focus on value of gender inclusiveness. The value of gender inclusiveness emerged in the inquiry as the researcher paid attention to the absence and the silent role of women in the adoption and use of SHEMS, and how single female households were absent in research related to energy technologies. The findings emerged in an empirical ethnographically informed inquiry among potential, new and experienced SHEMS users. It was conducted to "uncover the complex relationships among values, technology and social structure" (Friedman, Hendry & Borning, 2017). In the inquiry, sensory ethnography lens (Pink, 2015; Pink et al., 2013; Mitchell et al., 2014) was applied for paying attention not only to verbal communication, but also to how people physically and sensorially interact with the SHEMS in home and with each other, and how they move in their home and create meanings in different places. Sensory ethnography is a "methodology, which puts the sensory, experiential and affective elements of lived reality to the forefront of research design, conduct, analysis and representation" (Pink, 2015). Sensory ethnography provided the researchers a useful lens for understanding the gendered roles and practices among SHEMS users. In this research, sensory ethnography was applied as a lens during interviews, observations and re-enactments of household practices in the homes of the new, experienced or prospective users of SHEMS. Sensory ethnographic materials were used to unveil non-verbal aspects of user experience and values related to home energy technologies, placing the researcher as a central research instrument, which is an essential element of interpretive research in general (e.g., Klein & Myers, 1999). They were also employed more broadly to examine home practices entailing energy use, how householders use different spaces in homes and what meanings they give to spaces and practices.

3.2 Data collection and analysis

The sensory ethnography observations and interviews were a part of a local energy-efficiency project in Northern Finland in autumn 2018. The project informed in the communal information channels about the project and the possibility to acquire a SHEMS with 50% financial support of the price provided by the municipality and the local utility. Altogether 28 households were observed and interviewed: New users of SHEMS (11 households) were about to adopt the system. Prospective users (9 households) had expressed their interest on adopting a SHEMS and participated in an information event organized by the project, but eventually declined the acquisition. Experienced users (8 households) had used a SHEMS for 2-4 years. Their contact information was given by the two SHEMS providers involved in the project.

The observational interviews focused on values related to the adoption, adaptation and user experience of SHEMS, and they were conducted during autumn 2018 and winter 2018-2019. New and prospective users learnt about the project from the advertisements in the local newspaper and in the social media. They were in touch with the project coordinator and agreed to participate in the research. The researcher visited their homes and interviewed them for their values and motives which triggered the interest and/or the adoption of a SHEMS. New users were interviewed and observed in total three times: once they had decided to purchase a SHEMS, during the installation and user guidance session, and finally after 3-6 months of use of the SHEMS. Prospective users were visited only once, and interviewed for their motives to adopt a SHEMS, and for the reasons they decided not to have it despite the financial support. Finally, 8 experienced users were interviewed to gain a better understanding of the user experience of the SHEMS. Experienced users were interviewed once in their homes.

The researcher informed that all family members may participate in the interview and observations. The interviews lasted about 2-4 hours. All users were asked for their motives and values concerning the adoption and use of a SHEMS. Also, we asked how the decision to acquire a SHEMS was made, and who will use/would have used/uses the SHEMS in the household. Besides discussion, the interviews and observations included mental maps of the home, and re-enactment of daily routines during a home tour. Moving and interacting in the home revealed embodied and sensory dimensions of practices which are not explicitly verbalized in the discussions.

The video- and audio-recorded interviews and observations were coded, and the data was consolidated thematically. Gender emerged in the interviews and observations as a significant factor in decision-making, adoption and use of SHEMS. The thematically coded interview and observation material was analyzed with the equity analysis of technology (Bush, 2009), which focuses on the advantages as well as possible disadvantages a technology may carry within the contexts in which the technology operates. Besides focusing on the developmental and user contexts of technology, equity analysis (Bush, 2009) expands on the environmental and cultural contexts of technology. The empirical section focuses primarily on the user context, while it also touches upon the developmental, environmental, and cultural contexts.

4 Results

4.1 The user context

A significant finding of this research is the dominance of men as research participants in the study. Almost all households that participated in the inquiry were represented by men: of 28 households in 24 only the male adult participated the discussion, in 2 households both the man and the woman in the household participated in the interview, and in two households the woman of the household was more active in the inquiry, and adoption and use of SHEMS.

Applying equity analysis (Bush, 2009) we identify four contexts of technology adoption and use of SHEMS which reinforce the gender gap: 1. The design or development context which includes all the decisions, materials, personnel, processes, and systems necessary to create SHEMS. 2. The use context which includes all the motivations, intentions, advantages, and adjustments called into play by the use of SHEMS. 3. The environmental context that describes the nonspecific physical surroundings in which a SHEMS is developed and used. 4. The cultural context which includes all the norms, values, myths, aspirations, laws and interactions of the society of which SHEMS and energy communities are a part.

In this study it became evident that the adoption and use of SHEMS are largely dominated by men. Energy as a subject and the whole problematics related to it are occupied by men. Information and experiences on SHEMS are usually conveyed between male friends and colleagues. Women who were interested in or used SHEMS learnt about the system by municipality social media channels. None of them had previously known about such systems. Also, one of the women in the potential household said:

> *"I am not usually interested in any new technology, but I thought because the municipality communicates about SHEMS, and promotes the use of it, maybe it is a reasonable system".*

New users of SHEMS were observed during the installation and take-in-use situation. For the buyers of home energy technologies often the only touchpoint during the acquisition process is the person, who comes to install the technologies, for example the SHEMS or solar panels. He also guides the user(s). We have seen 11 installation and guidance events, of which in 10 both the male and the female adult of the family were present. In every one of them the male technician explained to the male of the household the installation and showed him how to use the control application. Except for one household where only the woman was present during the installation, in all observed installations the technician explained the system use for the man in the house. Often, the woman was present but did not participate in the discussion, nor did the technician take eye contact with her or try to include her in the discussion. In one household the man asked also the woman to come and see how the control application is used as:

> *"Both of us will use this."*

Regarding the use context of SHEMS, in the 28 households studied only two women used the SHEMS together with their husbands, and in one household the main user was the woman in the family. Often, in families with the man as the only user, the man commented on the wife's role in the SHEMS adoption and use the following way:

> *"This is my thing; my wife has nothing to do with it."*
>
> *"My wife is not interested in this at all."*
>
> *"I did not have to discuss with anyone about buying SHEMS, with my money I can do what I want."*
>
> *"At work with other colleagues (men) we discuss about SHEMS, that way I got interested in it."*

Some men even expressed surprise when asked about the adoption and use of SHEMS by other family members. For most men, and for most of the few women participating in the interviews, it was obvious the man in the family:

> *"Knows about energy."*
>
> *"Manages all things related to energy and home technology use."*
>
> *"I [woman] don't really understand these things."*

In households with two adults, women often were either on the background or absent in the interviews and observations. From the background they may comment on the acquisition and use of SHEMS, but usually it is a "man's toy". Our findings are in line with other smart home technology research, e.g., (Strengers & Kennedy, 2020) where "men are the main user group of smart home technologies, and for them smart home technologies as 'fun' rather than 'necessary'. The main users of SHEMS are 35-60 years old men, either men who live alone or men with a family. Women in family are either discussed with about the use of family budget for acquisition, or completely ignored by the man managing the acquisition and adoption of SHEMS. Similarly to (Strengers & Kennedy, 2020) women in our study had the pragmatic, 'the voice of reason' role in family. This was evident e.g., in such comments as "he gets excited about new technology, I am not convinced we need it to save energy". Women were more sceptic on value and concrete results of SHEMS. We testified the "wife acceptance factor" (Strengers & Kennedy, 2020) in households where women were asked about their acceptance of the acquisition and adoption proposed by man. Even though SHEMS influences the energy use and sensory experience of all family members, other adults but the man in the family were considered to be mostly passive background characters. They may have had a say concerning the adoption and use of SHEMS, but they did not decide the acquisition or how the SHEMS is used at home.

4.2 The developmental, environmental and cultural contexts

The immediate environment for the use of SHEMS is home, which may appear the same to all residents in the household. Yet, sensory ethnography observations revealed men and women have different home practices, and different values they associate with spaces and other sensory dimensions of home. There are also differences in how men and women perceive and use energy in home. Things related to energy management are considered man's responsibility. Women use energy, and they experience the consequences of the use of SHEMS in the home, for example changing temperatures in rooms (e.g., when SHEMS automatically changes the temperature due to the values set in the system by the man, or when air-heat-pump cannot be used with the remote control anymore, as it is integrated to SHEMS). Women may become aware of the economic benefits of SHEMS. Yet, many women were indifferent to or questioned the need of SHEMS in their homes.

In the cultural context consisting of values, norms, attitudes and interactions, energy is defined as a non-female subject. Some women in our study expressed that for everyone energy is an important domain to know and manage. Yet, in the presence of the male partner women withdraw from the discussion. Women themselves often said dismissive comments on their knowledge on and the capacity to plan energy management at home. When asked about values behind adopting SHEMS, the responses did not differ by gender. Both the men and the few women who participated in the interviews sought mainly economic savings, increased level of comfort at home and environmental friendliness. However, information concerning SHEMS and energy systems does not reach women. We found out women do not discuss energy technologies or other energy related subjects with their friends or other peers, as many men do. The man of the family is expected to know household's energy consumption and how to manage it, but often the knowledge is not shared with other household members. Also, women work less in technology and energy sectors; therefore, the information is rarely conveyed by work domain or by colleagues.

Most of the users of home energy technologies and digital services are men, also when they live with a female adult. There is the unstated assumption that the energy technologies should always be designed and marketed by men and for men. The assumption is strong not only in homes, but also in the energy sector and in home energy technology design and marketing. It is reinforced by the strongly male-dominated workforce in these domains, and it is further reinforced by the absence of women as adopters and users of these technologies. Yet, energy transition touches all householders, and all should have access to solutions such as home energy technologies and digital services to increase energy efficiency and to become an energy citizen.

5 Discussion

This study was set to explore 1) How do different genders participate in the adoption and use of SHEMS? and 2) What factors are associated with gender inclusiveness in the adoption and use of SHEMS as well as in energy technologies and digital services more broadly?

5.1 Summary of the results

Our research identified a striking gender imbalance in the home energy technology interest and use, and a lack of the value of gender inclusiveness in the current institutional, cultural, use and design contexts of energy technologies. In the sensory ethnography observations and interviews during the adoption and use of SHEMS, the technology as such was found useful and easy to use by both men and those few women who used it. However, gender inclusiveness is lacking in the context in which the adoption decisions are made, information about SHEMS is conveyed, and SHEMS is adopted.

Development of these technologies and services is done by energy and technology sectors occupied by men, and the ideal user is an affluent middle-aged male, with or without family; hence, both the development and use contexts of SHEMS are based on an idea of the male in the family as the main user and as the head of energy-related decisions and actions. The chain from energy policies to technology design, marketing and use is occupied by men with few exceptions.

Our research revealed several contextual factors which maintain the gender gap in the adoption and use of SHEMS and in the interest in energy communities. Gender exclusion is implicitly or explicitly expressed by the energy technology sector, by technology markets, by men, and by women themselves. Perceptions on the rights, responsibilities and possibilities of men and women in households and in the society maintain the idea of energy and related technologies as men's domain. The gender biases are also the consequence of gender imbalance in the energy and technology sectors and different living conditions of one-adult families.

5.2 Research implications

As for research implications, our findings bear relevance for information systems research on sustainable development of our digital futures in several respects. We identified a lack of IS literature on the important topic of gender inclusiveness in relation to SHEMS and energy technologies more broadly. We point out a pressing need for IS research to start addressing the topic – in the middle of climate and energy crisis. IS research should have interest in this significant topic: the discipline has emphasized equality and inclusion in relation to design and use of digital technologies in different senses and contexts thorough the years (e.g. Knestis et al. 2022, Olbrich et al. 2015, Serenko et al. 2011, Trauth et al. 2018, Vainionpää et al. 2021). Even if gender equality in the adoption and use of energy technologies or in the energy sector has been ignored in IS research, there are some studies carried out in other disciplines from which we can learn (Standal, Talevi & Westsko, 2020; Fraune, 2015; Sovacool et al., 2019; Strengers & Kennedy, 2020). We should acknowledge that SHEMS and other energy technologies are expected to have a great impact in the energy transition, while it seems that only around half of the population is currently addressed in relation to them: only men design, adopt and use such technologies. For the co-creation of more sustainable futures, women and other genders need to become involved, too. IS discipline with its strong focus on gender inclusiveness (e.g. Knestis et al. 2022, Olbrich et al. 2015, Serenko et al. 2011, Trauth et al. 2018, Vainionpää et al. 2021) as well as existing interest in home energy technologies (Berger et al. 2022, Berger et al. 2022 (a), Gerlach et al. 2022, Lackes et al. 2018, Lossin et al, 2106, Valogianni et al. 2014) should be exploring the important topic of gender inclusiveness of home energy technologies as well as taking action for a more inclusive approach. IS research is already equipped with the critical and value sensitive lenses (e.g. Kvasny & Richardson 2006, Deng et al. 2016), both of which should be made of use of in this endeavor.

Friedman (1999) has identified three kinds of value bias in information systems: preexisting bias, technical bias and emergent bias. Preexisting bias stem from social institutions, practices and attitudes. Technical bias arises from the resolution of issues in the technical design, e.g., not considering the limitations of technology, or trying to make human constructs amenable to technology (Friedman, 1999). Emergent bias emerges in the context of use of technology (Friedman, 1999). In the case of gender inclusiveness of SHEMS all three kinds of bias can be identified, but especially preexisting bias and emergent bias exclude women as users of home energy technologies. Social, economic and cultural factors as well as the context of use of SHEMS and energy communities maintain the gender gap. The equity analysis by Bush (2009) provided a valuable framework to examine diverse contexts of technology design and use beyond tech-fix thinking and helped to identify how in these contextual layers gender inclusiveness, or lack of it emerges with home energy technologies. This research is the first to apply equity analysis in the research of home energy technologies and is the beginning of the new research direction for IS and energy management system research.

We invite IS research to study the dialectical nexus of technology and society (Obrist & C. Fuchs, 2010) in the context of home energy technologies. Our findings are in good agreement with (Tuomela, Iivari & Svento, 2019), pointing out that participation in the design (and utilization of) energy technologies is entangled with gender, power, and knowledge, and intertwined with sociomaterial practices which entail possibilities but also boundaries for actors. We argue gender inclusiveness in the adoption and use of

SHEMS is built on several factors, such as power, democratic participation, economic possibilities, and life management. Normative gender roles, particularly those related to a heteronormative conception of 'the home', shape the way men and women relate to home energy technologies. Gender inclusiveness of SHEMS and other home energy technologies requires thinking households as units in all their diverse forms, and instead of designing for the individual having a user experience, paying attention to the co-experience (Battarbee & Koskinen, 2005) that is created together with others. In addition, single women, either living alone, single mothers with children, or elderly single women should be included as relevant users of home energy technologies, not only by the energy technology industry but also by themselves as well as by researchers. We maintain that the current approaches to manage energy use and increase the use of renewable energy with SHEMS and other energy technologies and services are focusing on technical and economic aspects, but a critical perspective on inclusiveness concerning the cultural and social conditions and outcomes of the adoption and use of these technologies is also needed in order to achieve the ambitious goals of energy citizen schemes. IS research should take a lead in advocating this critical perspective, explicating, challenging and redefining the cultural and social conditions.

5.3 Practical implications

As for practical implications, IS research could support a more gender inclusive approach in the design of energy technologies – in design science research projects as well as in the education of future designers. We see practical implications of our work concerning a number of stakeholders, not only designers of these technologies. There is a need for a recognition of gender imbalance and for highlighting gender inclusiveness throughout the energy sector, energy policy makers, energy technology developers and distributors, and finally individuals in households. More targeted information campaigns may be used to involve all potential user groups of SHEMS. For more democratic and impactful energy transition all individuals regardless of gender or age are to be involved in the use of home energy technologies, including SHEMS but also, for example, solar panels and energy communities. Designers, marketers, and end-user technicians cannot afford to ignore women, either in a household with a man or without. Women can be seen as agents of change, either as end-users, energy entrepreneurs or employees in modern energy or technology supply chains (Pachauli & Rao, 2013). Public organizations, such as states, cities and municipalities should inform and promote home energy technologies for all citizens. This enhances the image of technologies from the ‘boys’ toys’ to widely accessible and useful home technologies, increases trust into home energy technologies, and provides people with a contact for more information (other than male marketers selling to male users).

6 Conclusions

The sensory ethnography study in the households adopting and using SHEMS revealed the absence or the uninvolved role of women. More IS research is needed on this important topic. We propose further research on energy transition and energy technologies with the lens of gender. We need to develop strategies for overcoming gender inequality as well as other forms of inequalities raising from for example age or socioeconomic status, in our quest towards democratic energy citizenship. Moreover, gender considerations should be extended beyond the home to the energy sector and workplaces. For the wider adoption of energy efficiency and renewable energy technologies, it might be necessary to redesign the underlying sector so that it naturally attracts a greater diversity of people and provides more balanced basis for policy and technology design and adoption (see also Johnson, O. W. et al, 2020; Kashar, 2019). As proposed by (Dick et al., 2012; Poderi & Dittrich, 2018) for example participatory design can be used as the method and approach to meet this challenge by involving diverse user groups in the design of energy technologies, thereby empowering people and nurturing their sense of ownership towards energy transition. Besides empowering and engaging users, involving all potential user groups in design process may create new relationships among the actors involved (Capaccioli et al., 2016). Also, value-focused methods, for example value scenarios (Nathan et al., 2008; Nathan et al., 2017) can be applied as a method to vision gender inclusiveness in the adoption and use of energy technologies and societal implications it may bring.

This study has some limitations to be noted. The sensory ethnography interviews were geographically situated in a limited area, 25 of them in Northern Finland, and three in the capital area in Finland. Normative gender roles in homes vary in different cultures, and the findings may not be generalizable in other cultures and circumstances. In addition, most participating households that were interviewed with sensory ethnography, presented traditional family composition. Only one user was a single mother, and three users were divorced men living alone. More heterogeneity is required to get a more comprehensive picture of the diversity of gender inclusiveness in the adoption and use of energy technologies. Additionally, this study includes participants having interest in SHEMS. However, we were interested in gaining an understanding of the current situation with volunteering participants. Different results would have been gained if people without initial interest in SHEMS or only women were included. The participant and researcher interaction may have also influenced the results. This is generally acknowledged and accepted in interpretive research, while it might be interesting in the future studies on the topic to consider variety in the composition of participants during data collection and how it may shape the results – as we are dealing with a value laden, sensitive topic. Also, the research is limited in addressing gender bias and factors influencing it in the adoption and use of SHEMS as it does not go further proposing inclusive energy technology design solutions. This will be a topic of our future research on the value-based energy community.

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