User values of smart home energy management system

Sensory ethnography in VSD empirical investigation

Sanna Tuomela[†]
INTERACT Research Unit/University of Oulu
Oulu Finland
sanna.tuomela@oulu.fi

Netta Iivari
INTERACT Research Unit/University of Oulu
Oulu Finland
netta.iivari@oulu.fi

Rauli Svento
Department of Economics
Oulu Business School/University of Oulu
Oulu Finland
rauli.svento@oulu.fi

ABSTRACT

Ubiquitous computing continues to transform our lives, including our homes and leisure activities. Smart home energy management system (SHEMS) are one example of such a technology. It connects homes to a smart grid and may increase the use of renewable energy by directing the demand to off-peak hours and reducing the overall energy demand. User values of such a technology may be critical in the acquisition, adoption and assimilation of the technology. This research fills the gap of understanding user values of SHEMS users. We studied new, potential and experienced users of SHEMS and their values. Sensory ethnography interview method was applied in the value sensitive design empirical investigation to elicit key user values of SHEMS in 28 families. The users relate to SHEMS values such as economic gains, environmental sustainability, comfort and security. Some SHEMS users' values such as stimulation, creativity, and autonomy, can be in conflict with the values of other family members, and with those which are currently built in the SHEMS technologies. The recognized values of SHEMS stakeholders act as an input for the design of smart grid and smart home services and products. In addition, the research contributes to the theory-building of smart home technology user research.

CCS CONCEPTS

• Human computer interaction (HCI) • User characteristics • Embedded and cyber-physical systems

KEYWORDS

Smart home energy management systems, Energy management system, User values, Value-sensitive design, Sensory ethnography, Stakeholder analysis

MUM 2019, November 26–29, 2019, Pisa, Italy

ACM ISBN xxxxxxxxxxxxxxxx
DOI: xxxxxx.xxxxxxxxxxxxxx

ACM Reference format:

Sanna Tuomela, Netta Iivari and Rauli Svento. 2019.User values of smart home energy management system: Sensory ethnography in VSD empirical investigation. In *Proceedings of MUM 2019, November 26–29, 2019, Pisa, Italy*. ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3365610.3365641

1 Introduction

Ubiquitous computing continues to transform our lives, including our homes and leisure activities. Smart home energy management system (SHEMS) is entering our homes to ease and automate energy management. SHEMS is a cyber-physical system (CPS) [50], which makes home the end-use node of a smart energy system and allows energy conservation and flexible demand [26], [52] thus advancing the use of weather-depended and variable renewable energy sources (RES) consequently reducing our dependence on fossil fuels and our greenhouse gas emissions [2], [19]. In Finland home heating and hot water provision comprise of 83% of all home energy consumption, and about half of the detached houses use electric heating as a primary heating technology [15], [91]. SHEMS may bring 5-22% reduction in energy consumption, thus providing the household with significant reduction in carbon foot-print [76]. SHEMS comprises of sensors, home heating, ventilation and air conditioning (HVAC) devices, control application, and through the service provider's cloud server weather forecasts, and electricity price information [101]. SHEMS may be connected to domestic low-carbon electricity generation and demand (LCED) [28] technologies such as solar panels and electric cars.

Energy use in the home is changing from currently simple, almost invisible, to more complex with smart grids and a new layer of home technology and energy management [52]. SHEMS provides homes means to automatize domestic energy conservation and demand flexibility [92], [101]. In the early stage of diffusion of a new technology user involvement can have the greatest impact on the future use and the integration of the technology into existing socio-technical systems [79], in the case of SHEMS into socio-energy system [60]. Despite the significance of engaging users in the use of home energy technologies, the research of SHEMS has mostly focused on the technical characteristics of the systems, and there is a need for research on the user perspective of SHEMS [57].

In the design of complex products or systems not only the functional requirements but also individual and social values should be addressed [53]. The potential of SHEMS as a tool to implement users' social and individual values in the home is significant. Implementing and even enhancing users' values in the energy technology design may foster acceptability, adoption and more efficient use of SHEMS. Currently users find it challenging to manifest their values in the energy use, as they find it hard to see how their daily tasks and routines influence the broader system [90], to make a concrete connection between their daily activities and energy consumption [22], [65] and with hourly electricity price variations [88, 89]. Human Computer Interaction (HCI) researchers working with SHEMS are challenged by the complex system behind the user interface, carrying diverse motivations, goals and values of the parts of the system.

Value sensitive design (VSD) is a widely known and utilized user-centered design approach, which aims proactively to consider human values throughout the process of technology design [29-33]. The key principle of VSD is that the technology is not value neutral, but rather some technologies are more suitable than others for supporting given values. Stakeholder analysis is a method to identify individuals and groups that can affect or might be affected by a technology [62]. In the framework of VSD the stakeholder analysis is applied to identify direct and indirect stakeholders, their key values and goals, and possible value tensions [30], [33]. Direct stakeholders are individuals or organizations, who interact directly with the system or its output. Indirect stakeholders refer to all other parties who are affected by the use of the system [30]. In this research, stakeholder analysis of VSD is utilized to examine the key values of direct stakeholders of SHEM, who were interviewed and observed in their homes by applying sensory ethnographic method [72]. In the ethnographic interviews the values were elicited with the laddering technique [78], by observing and interviewing as the householders showed their daily routines, and in the discussion about the mental maps the householders drew about their homes.

The paper is organized into five sections. After the presentation of the main scope of the research in the introduction, section two explains the theoretical framework and the state of art in the values research on smart home energy technologies. Section three describes the methods used for the collection and analysis of the qualitative research data. Section four presents the results, and section five discusses the stakeholder values of SHEMS, limitations and proposes paths for further research.

2 Values and SHEMS

SHEMS comprises sensors, interfaces, appliances and devices networked together to enable automation as well as localized and remote control of the domestic environment [16], [101]. The key functions of SHEMS are to monitor, control, and optimize the flow and use of energy in the home. In the future this system will be more integrated into the smart grid and include microgeneration technologies such as solar panels, a storage for energy, and an electric vehicle, as well as a growing number of home energy consuming devices [16], [54], [68], [95], [101]. The costs of SHEMS are comprised of a one-time, initial investment for the hardware and installation, and a monthly service fee of the maintenance of the hardware and energy management dedicated cloud services. Services include a control application, which is the primary interface for the end-user. The control application can usually be used with home computers, laptops, tablets and smart phones. In addition to the features for controlling the operation of the SHEMS, services may include for example a local weather forecast, real-time energy price information or access to social media energy communities.

Technology can lead to value change either by bringing some previously unattainable goal within the realm, of choice, or by making some values easier to implement than before [59]. Home energy technologies offer diverse opportunities to implement some values, and limit others. Smart home technologies are installed into homes with existing social, cultural and material practices [36], [63], [89]. Rather than dictate the changes in practices, technology and users form a socio-technical system which evolves as the elements interplay. In the home energy is an enabler, constituent of practices, lifestyle and 'making a home' rather than an independent variable to be managed separately [86]. More sustainable behavior and lifestyles are essential parts of future 'energy aware' living [84] and technological solutions can help people to become more aware of otherwise invisible energy and give people more control over it. People are balancing with the energy technology transfer and their current practices [87]. Therefore, the designers of smart home technologies should understand the values which the users relate to technologies, and those which are behind the home practices involving the use of energy.

For an end user, a smart system should just do what the user needs it to do without caring about technology [38]. Therefore, understanding what the users want and need is essential in the design of smart systems. Even though many SHEMS are sold as off-the-shelf packets, they are adjusted to each home in the installation phase and the basic settings are agreed with users. After installation, the smart system should hide the complexity behind perceived simplicity, and work as the users expect, without much effort from users' part. However, the full potential of SHEMS still lies fallow, due to the complexity and diversity of the systems, and the suboptimal control strategies [69]. Design of complex systems is often done by building the components and trying to understand their arrangement in the system. Yet a complex system calls for a holistic approach to design since the user experience of a complex system is about how pieces come together [21]. A complex system does not allow HCI researchers to focus on simple applications and user interfaces, but confronts them with the motivations, goals and values of the parts of the system. Therefore, designing SHEMS is not merely a task of connecting necessary technology components, but the design can emphasize or hinder values of stakeholders. By making transparent the values different stakeholders hold in relation to SHEMS the choice of key values can be agreed between stakeholders, which should result in the wider acceptance of the technology, its functions and consequences. However, the identified values inform, but do not necessarily turn directly into the requirements thus constraining the solution space [75].

Previous studies have brought up the user perspective with smart home energy management systems (e.g. [13], [17], [5-6], [96, 97]), stakeholders of smart grids (e.g. [14]), or values in environmental behaviour (e.g. [7], [9], [71]) but the values users of SHEMS hold, and possible value conflicts between different stakeholders, have not been explicitly studied.

2.1 Values in HCI

Values are what people consider important in life [9], [83], and what people prioritize and use as the criteria to select their practices, actions, and to evaluate people and situations [31]. Values may refer to enduring beliefs concerning “desirable modes of conduct” or “end-states of existence in different situations, societies and cultural contexts” [4], [80]. The importance of values in driving or underlying people’s behavior has been acknowledged within a number of disciplines and research fields (e.g. [48]) including HCI (e.g. [42, 43], [45], [61], [85], [98-100]). HCI research has addressed values driving research and design practice (e.g. [42], [61], [100]) as well as values being associated with the use of particular technology (e.g. [42], [46], [51]). User values are defined as internal perceptions of what is important in a certain usage context, and on the other hand as “value for the user”, which the product provides the user within the interaction with the product [46], [67].

However, there are also studies that criticize the generic universal value models and value oriented design methods. The critics argue for approaching values as an open question – they are to be revealed through empirical inquiry without a predefined value set [35], [42], [49], [100]) – they emphasize the dynamic, evolving and context dependent nature of values (see e.g. [35], [49]), as well as challenges involved in engaging or embodying values in design – it is an open question how this can and should be accomplished (see e.g. [43], [55]). This research focuses on values users express related to energy use and to SHEMS use in home.

2.2 Value sensitive design and sensory ethnography

Of a number of proposed instruments for examining values (e.g. [43], [49], [51] and value oriented design methods [29], [41], [51], [61] in HCI popular has been particularly Value Sensitive Design (VSD) [18], [29-33]. VSD aims to consider human values throughout the process of technology design and helps to understand the values of the stakeholders, possible value conflicts, value-action gaps, and to provide a design which supports the selected key values [33]. VSD proposes a three-partite methodology consisting of conceptual, empirical and technical investigations [33]. Ethnographically informed inquiry methods can be applied in the VSD stakeholder analysis to “probe the complex relationships among values, technology and social structure” [32].

It has been suggested that more stakeholder participation should be included in the VSD process [e.g. [8], [18], [46], [74]. In the VSD stakeholder study of smart meter rollout in the Netherlands it was emphasized that the delay, which had taken place, could have been avoided if all the stakeholders and their values would have been heard, and the complexity of smart grid and interrelatedness of its elements had been understood better [53]. Though the end-users (consumers) were considered as the main beneficiaries of the smart meter rollout, they were not represented in the design of the functionalities and the planning. In this paper, the perspective of user values is emphasized in the study of SHEMS.

In this study, we conducted stakeholder analysis by applying sensory ethnography method. Sensory ethnography focuses on understanding of other people’s experiences, values, identities and ways of life by “exploring people’s multi-sensory relationships to the materialities and environments of their everyday lives, and to their feelings about them” [72]. Sensory ethnography intervention brings to a design process insights, which can make the design and user experiences more pleasant, effective and purposeful [72]. Sensory ethnography method has been successfully applied in energy consumption studies e.g. in LEEDR-project [12], [17], [25], [73]. By observing and modelling everyday practices at homes the researchers were able to understand how people make their homes ‘feel right’ and the role of energy demand and use in home life. With the lens of sensory ethnography, the researchers investigated what it is that people are actually trying to achieve when they make their homes feel right and what interventions will help them to achieve this while using less energy. We chose sensory ethnography as a method for our VSD empirical investigation, because it is one of the most suitable approach to study user values related to practices and technologies in homes.

2.3 Values of SHEMS users

SHEMS, like all technologies, offers diverse opportunities to implement some values, and limit others. It can help people to become more aware of otherwise invisible energy and give more control over it. SHEMS can also carry values of the other smart grid stakeholders, because when the SHEMS in the homes is scaled up, that may change significantly energy consumption and in-crease demand response, thus enabling increasing use of RES [23], [94].

SHEMS use is placed at home, in a very personal and private space which is a bunch of socially constructed meanings, rather than a construction of wood and stone [24]. Values are strongly present in home, and they are expressed and enhanced at home more than in other environments. People want their homes to demonstrate their values, reflect their identity and to tell their story, and technology in the home needs to fit this picture in order for it to be appropriated [20], [85].

Previous studies have brought up the user perspective with smart home energy management systems (e.g. [6], [96, 97]) or stakeholders of smart grids (e.g. [14]) but the values the users of

SHEMS have not been explicitly studied. User values of SHEMS are implicit in a large number of studies on smart meter acceptance and adoption (e.g. [1], [11], [14]), smart home technologies (e.g. [34], [36], [54], [57, 58], [81, 82]), and energy and sustainable behavior (e.g. [10], [39], [47], [56]).

In the VSD study of the smart meter rollout delay and SHEMS standardization in the Netherlands [53] the values elicited in the expert group discussion were categorized based on the 23 values found in the VSD literature. The authors argue the universal values of Schwartz (1992) [83] are not the most suitable ones in the research of technological artefacts and technology use. The expert group in the study ranked following top 5 values for SHEMS:

1. Economic development: The system is beneficial to its users' economic or financial status.
2. Universal usability: The system can easily be operated by all users.
3. Privacy: The system allows users to determine which information about them is used and communicated.
4. Autonomy: The system allows its users to make their own choices and pursue their own goals.
5. Reliability: The system fulfils its function without the need to monitor/control it.

However, these values are a result of the expert group, not end-users. Also, the study is an ex post analysis, and the values were not elicited for implementation into a design.

Pre-defined values were applied in the co-design of novel interfaces to home energy management systems for three eco-communities in Scotland [70]. The interface should help the users to synchronize their energy use behaviors with the availability of locally generated renewable energy sources. The workshops resulted a user interface concept, which was evaluated by other community members with a questionnaire. The concept was evaluated on the feature matrix of two value axes: hedonic and pragmatic quality. The results of the user evaluation confirmed the difficulty to design a solution which is both innovative and creative (hedonistic value) and usable (pragmatic value). The users hoped to have more task-related information for load-shifting behaviors, and desired more of the pragmatic value.

Other case of applying pre-defined values is the doctoral thesis by Sandström's (2007) [81] concerning smart home users and their values, namely usability values adopted from Jacob Nielsen [66]. Three pre-defined values usefulness, usability and accessibility were used to evaluate the user experience of living with and using smart home technologies. Sandström interviewed people before they moved to the smart homes for what they expected from it, and after they had lived in the apartment for some months. People seemed to be uncertain why in the first place they should have any smart technologies at home, and even though they appreciated all extra features (more value for the money) they did not have any particular goals for the technology use. The values for the user, that is usability, usability and accessibility, were evaluated after the people had lived in the homes for some months. People did not consider the energy measuring function very useful, but they suggested the control of the indoor temperatures and a device to control lightning in a list of desired functions in a smart home. The technologies were easy to use according to users, yet people used them relatively little and selectively. During the research the chief technological developer of the smart home technologies shot down its business and may functions were left unstable or not installed completely. The trust of the users in the technologies, and in the information the technologies presented was low. In conclusion the energy technologies were rarely used, the information they presented had at times been unreliable, and though they were easy to use, they did not give much value for the users.

In [12], [25], [34] authors elicited specific user values with photographs (cultural probes) in the study of smart home technologies. The research was conducted to understand better what people value within their home environment, and to bring human factors in two prototype smart home systems: an energy monitoring and equipment management system, and an aggregated information, energy monitoring and entertainment services. Eight non-expert users took photos of the things they value in their home, of technologies they like to use and the ones they do not like, and of the things they do in the home to save energy or to help the environment, and discussed the photos. The results reveal people valued people (in particular family), space and memories most highly. Technology and automation are viewed as saving people time and making household tasks easier, rather than adding value.

Though the use of pre-defined values or cultural probes may help to narrow down the key values of users, we did not want to limit the users or our own mindset with any given value system, or pre-define values before the interviews. Yet the interviews in 28 families elicited surprisingly similar user values.

3 Methods

This study represents qualitative research on values surrounding the adoption and use of SHEMS, applying VSD methodology. The research was in 28 homes in the Northern Finland, with two SHEMS which were selected by the cheapest prices for an example house. The main function of the systems in the investigation is to automate and optimize home heating by adjusting the home temperatures based on the preset settings, room temperatures and humidity, the weather forecast and the electricity prices. Hot water boiler and air heat pump can be integrated into the system. SHEMS aims to provide users with reduced energy consumption by lowering the temperatures in the user defined times and spaces, and on the other hand with reduced energy costs by targeting the load onto cheaper off-peak hours. Users can modify and create profiles for temperature settings, set electricity contract type and price(s) and monitor room-specific electricity consumption for heating with a control application on a laptop, a tablet or a mobile phone.

There are three kinds of users in the interviewed 28 families: new users (11), experienced users (8) and prospective users (9). Local energy efficiency project supported financially the acquisition of

SHEMS for 11 new users. The experienced users had used SHEMS for 1-4 years. Finally, the prospective users had expressed interest in acquiring the SHEMS to the project coordinator, but eventually declined despite the offered financial support. All interviewees live in a single-family detached house with electric heating.

The empiric VSD stakeholder inquiry was conducted applying sensory ethnography. As proposed by Friedman et al. [33], two heuristics were used to elicit the values: first, probing 'why' questions to get behind the judgements and experiences of the users, and secondly, by asking about values also indirectly, for example interviewing people about a hypothetical situation, or a common everyday event or behavior in their lives. In this study the researcher first interviewed the family members about values, expectations and perceptions on SHEMS. Then the householders were asked to show their morning, afternoon and evening routines, which are usually the peak hours of electricity use in the home. Reenactment was video-recorded. Lastly the participants were asked to draw a sensory and affective mental map of their home, marking where the 'sense of home' is strongest, and what meanings they associate with different places at home. The drawings were discussed together. All interviews were conducted during the August and September in 2018. Each interview lasted from 1,5 hours to 3 hours. New users were interviewed again after 4-6 months of SHEMS use in January – March 2019. These interviews lasted 1-1,5 hours.

Laddering technique is both an interview technique and a method to consolidate, analyze and visualize the results of interviews [78], [100]. It was used to elicit values in the interview and to analyze them in the data analysis. In the laddering interview the interviewee is first prompted with questions about concrete attributes of the technology. Then the interviewer continues to ask, "why this attribute is important for you?", until 'laddering' to the level of values. In addition to attributes, consequences and values the linkages between these elements are identified [51], [100]. Laddering technique posits that people choose products which have features they associate with the consequences they desire, and the rationale underlying why the consequences are important are personal (and social) values [78]. This research experiments with the laddering technique to identify the key values of SHEMS users. In line with this literature, we view values as what is considered important, and what is the final point in the interview, from which "why -questions" do not lead any further (cf. e.g. [60]).

In data analysis, first in the content analysis of the audio and video recordings of the interviews the key themes were coded, while bearing in mind the abstraction levels of laddering technique (attributes, consequences and values). The three most important values for each family are listed in the appendix. Secondly the identified attributes, consequences and values were consolidated in the value matrix. In the analysis of the values we related them with Schwartz's universal values [83], the values of the Rokeach value survey [80] and with the list of values of smart grid users by Ligtvoet [53], yet none of them was found adequate as such.

4 Results

Based on our VSD analysis we present here the basic findings related to HEMS values. We identify the user types and value categories of the researched families based on their values, goals and life situation.

Full-nesters. Families living their rush years are constrained with time and try to balance with work and family life. The time at home is scheduled with family routines and housework. Full-nesters seek savings in the energy costs, but think also the comfort of all family members, and have will, but not always means, to act sustainably. Parents do not have time to check every room in the house for saving electricity, therefore comfort means also easy control of all the house with one control application. Safety means children cannot cause harm if they play with thermostats, and the situation in the home can be checked easily remotely.

Empty-nesters. Elderly couples whose adult children have moved away have more free time and unused space in their home. Empty-nesters are not stressed by work or house mortgages. They can invest in new technologies such as SHEMS, solar panels and hybrid or electric cars. Empty-nesters cherish simple and traditional lifestyle, which is characterized by frugality and closeness to nature. As the life is not busy and focused on the 'nesting', they can be more altruistic, and emphasize ecologic sustainability. Though they may not wait big savings in energy bills with SHEMS, they do expect the system to pay itself back in few years, and ease of use.

Optimizers. Technically oriented, energy and electricity savvy men. They talk with their friends and colleagues about energy technologies and solutions to optimize home energy use. They appreciated SHEMS with open hardware and software and would have liked to modify the system themselves to suit best their own homes. Optimizers have many ideas for the development of the system, and they discuss with SHEMS providers about how to implement certain features to the system. For them a SHEMS is an intellectual and practical endeavor, and they seemingly enjoy immersing themselves into optimizing the home technologies including SHEMS. Autonomy, exploration and self-direction are the values they prioritize highly. For them tuning the SHEMS, or building one by themselves, is also a way of distinguishing themselves among peers, and of playfully competing with others. Optimizers appreciate an open, modifiable system which operates without much interaction once it is made fit for the house. They want to see savings in energy bills, and they have doubts if the system has sustainability consequences. Some optimizers value the comfort of living more than savings in money or in energy. Optimizers are early-adopters of SHEMS, and often they acquired SHEMS because they knew personally SHEMS developers and producers. Optimizers as smart home users have been profiled also by Jensen et al. [44], yet here the optimizers do not only want to optimize the energy use of their house, but they are also interested in optimizing the technology as well.

4.1 The key values of SHEMS users

The most common values elicited in the discussions about the motivations and goals of the use of the SHEMS were frugality, sustainability, comfort, security and peace of mind, in that order. The results are in good agreement with [53] showing the individual and social values are more important for the users than the functional values of the technology, and with [24] emphasizing the family as a user instead of values of individuals.

Frugality. People expect first and foremost to save money and save energy with the use of SHEMS. Saving in energy is expected to equal saving in costs. Of all participants 54% told for them frugality is the most important value related to SHEMS, and 43% said it was the second or third in importance. For the prospective users the most common barrier to acquire SHEMS was that they calculated the system does not pay itself back within reasonable time. Characteristic to the homes in this research is that frugality means also simple and modest life style. Deliberate frugality [27] is an expression of traditional Nordic way of living, rather than a reaction against consumerism (e.g. [3], [40]) or 'forced frugality' (e.g. [96]), for to the lack of resources. Heinonen et al [37] have studied what they call "situated lifestyles" and the implications for GHG. The Finnish households were categorized in four groups according to the level of urbanization, rural lifestyle corresponding the households in this research. Rural lifestyle is characterized by the lowest consumption in all consumption categories other than transport and electricity, consequently the biggest sources of GHG in rural lifestyle.

Comfort, security and peace of mind. Comfort means that the room temperatures at home are stable, predictable and can be adjusted with one user interface and remotely. In harsh climate right home temperatures are not only for comfort but for security, too. Comfort means also not too hot temperatures, particularly in the bedroom. Comfort was the most important SHEMS-related value for 21% of households, and the second or the third in importance for 54%. One interface for all heating settings frees users from walking from a room to another for adjusting the thermostats. This relates also to security: "Children had turned the thermostat in maximum heat in one room we use little. There had been terribly hot for who knows how long" (N3). With SHEMS the parents can control the temperatures, and the children can continue playing with thermostats without any effect on energy bills. Remote monitoring with the SHEMS control application also strengthens the sense of security. Comfort, security and peace of mind are related values, as increased security amounts to increased comfort and peace of mind. Also, SHEMS relieves the worry for climate change: "I know a smaller house would be enough for two of us. With the available means we try to reduce our consumption of energy and emissions" (N2). For most householders increased comfort means also they can forget adjusting the temperatures once the system has been programmed and the SHEMS has learnt to regulate the temperatures automatically. After the first months, the users usually 'forgot' the system and did not even follow the energy prices any more. As long as it worked without notable problems, the users did not change the settings.

Sustainability. With sustainability we mean ecologic sustainability. Both sustainability and frugality mean saving resources and consuming less. Yet ecologic sustainability was the most important value only for 14% of households, and the second or the third most important for 29%. Optimal SHEMS reduces the consumption of energy especially in the times of high prices, usually profiting the hourly-based electricity prices. SHEMS application helps to spot the most energy consuming places, appliances and practices at home, thus helping to focus the energy saving efforts. SHEMS users are more concerned of their own home's consumption and costs of energy than the impact of their energy consumption outside home. Most interviewees emphasized their sustainable lifestyle in other ways, like recycling, close relationship with nature, and interest in EVs and solar panels, but only two of them said SHEMS is important because it increases demand flexibility allowing larger use of renewable energy: "I am a nature person, I don't throw waste in the nature and I hate to see clear-cut forests. I enjoy walking in wild nature like in Lapland. But I don't really care where the electricity we use comes from." (N7). Three users said they want to save energy not only to benefit the family, but because the menace of climate change requires us all to consume less energy. Yet they had not thought, or did not know, how SHEMS relates to the use of renewable energy, or about the possibility the utility could remotely control the consumption of electricity via SHEMS for example in the time of low supply and/or high demand of electricity. Though a primary motive, economic savings are not always the only motive for acquiring a SHEMS: "We don't go on [with SHEMS] money first… I am skeptical if the savings will be significant. But saving energy is important." (N3)

Stimulation, exploration, self-realization and distinguishing oneself. Rarely the primary values of SHEMS users (only 7%), yet they enforce the interest to adopt SHEMS at home. Particularly technically oriented men were driven by excitement and experimenting with new technologies, and creativity: "I have been thinking I would like to build this kind of system myself, but maybe the software would be too challenging to create" (N1), "We have talked with colleagues at work how to build a system like that. The ones on the market are not optimal for my home, I'd like to build a perfect system just for my home. I have interest, time, and the required skills." (P19). These values are strongly linked to each other, and to express these values users need some economic and social freedom and technical competence. For users who carry these individualistic values SHEMS is a personal project rather than a family system.

4.2 Family as a nest of user values

In home with more than one family member SHEMS is a shared, ubiquitous technology [93]. Unlike personal technologies, smart home technologies can be used by many users with differing goals and values, and influence the life of several individuals. Established families usually have some shared values which form the basis for decisions and everyday living. Yet individual preferences and prioritizations are discussed when SHEMS is adopted: "It is just a fact that women like warmer home than men. We have tried to find a good compromise for both" (E26), "Our teenage daughter has discussed a lot about these things […] that is why we gave up the other car, and thought about having SHEMS, and have sought to live in a sustainable way" (P16).

The temperatures can be a way of showing care or particular affection in family: "When the children and grandchildren come, we naturally increase the temperatures" (N10), "In the room of the princess [only daughter of 4 children] there is obviously warmer than in other bedrooms." (N5).

Although not a focus of this research, it became evident that the division between the male and female participants is strong as the men in the family are usually the main users of the SHEMS (noted also in [36], [88, 89]). In 24 of 28 families the main user of SHEMS is, or would have been, the father of the family. In three families both adults were equally planning to use the system, and one prospective user was a single mother. People living in the home are all direct stakeholders of SHEMS as it influences them directly, but they are not equally users of SHEMS. "I think [my wife] will also use it, the user interface seems simple enough" (N10), "I discussed about the investment with my wife, but other than that, this is my project. My wife could not care less. Maybe she'll say something when the temperatures begin to change…"(N1).

5 Concluding discussion

This research responded to the call for user research of smart home technologies and contributes by filling the gap of understanding user values of SHEMS users. VSD stakeholder analysis was utilized to examine three user groups of SHEMS: experienced, new and prospective users. Values were elicited in sensory ethnography interviews utilizing the laddering technique. As a result, we 1) typified three kinds of SHEMS users with differing values, goals and life situation: empty-nesters, full-nesters and optimizers; 2) identified the most prevalent values of SHEMS users: frugality, sustainability, comfort and security as well as variety in the values of the three user groups – optimizers valuing autonomy, stimulation and exploration of new things; and 3) have shown that there may be value conflicts and controversies, and that family is often to be considered as the user instead of an individual. These results have implications for research on sustainable HCI, for research on ubiquitous technologies and smart living environments and particularly for research on smart energy systems and SHEMS. We have used a combination of methods and techniques for studying users of home energy technologies contributing to theory-building of user-oriented research of smart energy systems.

The users of SHEMS emphasize the values and consequences in the home, rather than in the community or society in large. Users are concerned of ecologic sustainability and climate change, but they feel they do not have clear understanding of the consequences of their own energy consumption practices, nor are they confirmed of the impacts of sustainability efforts. Householders yearn for personalized feedback and guidance for energy efficiency. This is consistent with [64] who proved people are more motivated to environmentally friendly behaviour when the goals are concrete and relate to the daily life, and required actions are small with confirmed results, rather than by high-level abstract goals such as "mitigate the climate change". End-users of SHEMS value concrete impacts of the system, such as comfort, savings and exploration of the new technology, and are not as worried for example about privacy or reliability as smart grid experts [53]. These insights provide paths for future work for the design of SHEMS.

The recognized values can act as an input for the design of smart grid and smart home services and products. However, we do acknowledge that it is a challenging task to engage or embody values in design (see e.g. [43], [55]). In addition, we acknowledge that a straightforward list of prioritized values gives an over-simplified picture of the values in families. The values are overlapping, linked in many ways, and the same values are interpreted and put into action in various ways. Family members have common values, but also differing individual values, value prioritisations, goals and motivations, and they may have different roles in the interaction with the system. People in the home may also compromise their own values due to the values, or assumed values, of other family members. Smart home technology such as SHEMS actuates family members negotiations on the common values in the home [39]. For designers of smart home technologies, including SHEMS, it is significant to acknowledge families as users of technology and associated complexity as well as to integrate value negotiations into the design process.

Moreover, it is important to acknowledge that it is not only individuals and families that need to be considered when designing SHEMS or sustainable HCI. People have different roles towards other stakeholders, increasing the complexity of values and their constellations even further. People are consumers who make contracts, purchase energy and services. They are citizens who are informed and advised, and who consent to public policy measures and support their implementation [19]. They are also part of a community, or rather many communities (city, neighbourhood, work or school, larger family, etc.). Increasingly people are becoming prosumers, not only consuming but also producing energy themselves. Though the value of sustainability is common to all stakeholders, the way it is prioritized and implemented in the system is linked to other, sometimes conflicting values of privacy and liberty of individual choices, versus the common good in the society, and autonomy and independence versus technologies controlled outside home [77].

The VSD methodology has been criticized for failing to provide a systematic method for identifying stakeholders and involving them adequately in the design process [55], [99]. A complex socio-energy system contains tensions on the level of user values, and differing and conflicting motivations and goals of stakeholders. Members of families, but also indirect stakeholders, such as utilities, transmission service operators and SHEMS developers and resellers have diverse goals and values regarding SHEMS. Besides there will be new stakeholders, such as aggregators and data hubs, whose roles and values in the system are still open. For a more complete understanding of the opportunities to design a value-based SHEMS indirect stakeholders' values should be mapped and analyzed. We also acknowledge the dynamic, evolving and context dependent nature of values [49], [85] and emphasize the possibility of value change and evolution among the SHEMS users.

This study informs researchers but also policy makers, energy technology providers and smart grid stakeholders. The users of SHEMS consider the acquisition as an investment, and they expect a return to it, but they do not think the economic savings will be significant. Other factors such as comfort, security, sustainability and stimulation do matter, and they could be emphasized in public energy consultation and SHEMS marketing. Increasing awareness of energy consumption, and the use of home energy technologies is more efficient if the values are openly discussed and targeted [39] and the users are understood as social actors with goals and values. SHEMS is a node in a complex physical, technological and social system, and it can be also a point of negotiation of individual/family good versus public good. This research informs the policy makers, energy technology providers and smart grid stakeholders of what people in home consider important.

The user values of SHEMS are the result of interviews with householders who were interested, had decided to acquire, or already used SHEMS. In most cases the main user of SHEMS is, or would be the male adult of the family, who were also the most vocal in the interviews. In some cases, only the male adult participated the interview and was the only user of SHEMS. Therefore, in most interviewed homes the resulting values are associated to the male adult. Yet SHEMS influences the life of all family members, and in some interviews family members had differing values related to SHEMS. All family members key values should be acknowledged and possibly implemented into the SHEMS.

One limitation is the small group of interviewees, who represent only the house-holders of single-family detached houses in Finland, who use, or have considered to use two types of SHEMS. The participants of this research are a self-selected group of people who expressed interest in SHEMS, and most of them have acquired one to their home. They are probably more interested in energy technology and more affluent than the average Finnish people. The values of other user groups should be studied to gain insights into how to develop energy-saving technologies for all. Nevertheless, our results are rather consistent with [53] and [12], [25], [34], which suggests the values of SHEMS users are not culture-specific, though the ways they are applied in practices may differ in diverse cultures and circumstances. Many factors, such as the structure of the electricity markets, pricing and taxation are not considered. Diverse stakeholder groups need further research as well as the implications of values to design of home energy and other smart home technologies. Despite the limitations our findings do however suggest that the user values related to SHEMS relate to the well-being of the family rather than functional characteristics of the system (cf. [53]), and that in the use of a smart home technology diverse and sometimes conflicting values of the family members are present. Smart home technologies may serve many purposes and relate to a large group of stakeholders, yet they should constitute a coherent, functional and easy-to-use set of technologies to support home life and values. That is one challenge in the analysis of a complex system – there are many actors and a vast number of agents, factors and variables.

ACKNOWLEDGMENTS

ST and RS acknowledge funding from the Academy of Finland Strategic Research Council project BC-DC (AKA292854). ST acknowledges Municipality of Ii, Micropolis, and SITRA (The Finnish Innovation Fund). We also thank all the participants in the observations and interviews.

REFERENCES

1. Z. Abdmouleh, A.Gastli, L. Ben-Brahim: Survey about public perception regarding smart grid, energy efficiency & renewable energies applications in Qatar. Renewable and Sustainable Energy Rev. 82, 168-175 (2018)
2. M. Amer, A. M. El-Zonkoly, A. Naamane, N. K. M'Sirdi. Smart home energy management systems survey. 2014 International Conference on Renewable Energies for Developing Countries, REDEC 2014. 167-173 (2015) 10.1109/REDEC.2014.7038551.
3. M. Aune: Energy comes home. Energy Policy, 35(11), (2007)
4. B. Almond, B. Wilson (Eds.). Values: A symposium. Atlantic Highlands, NJ: Humanities Press International Inc. (1988)
5. N. Balta-Ozkan, R. Davidson, M. Bicket, L. Whitmarsh, L.: The development of smart homes market in the UK. Energy, 60, 361-372 (2013)
6. N. Balta-Ozkan, R. Davidson, M. Bicket, L. Whitmarsh L: Social barriers to the adoption of smart homes. Energy Policy, 63, 363-374 (2013).
7. A. Berfu Ünal, L. Steg, M. Gorsira: Values Versus Environmental Knowledge as Triggers of a Process of Activation of Personal Norms for Eco-Driving. Environment and Behavior, 50(10), 1092–1118 (2018)
8. A. Borning, M. Muller: Next steps for value sensitive design. In: Proceedings of the 2012. ACM annual conference on human factors in computing systems. ACM, New York, 1125–1134. (2012)
9. T. Bouman, L. Steg, H. Kiers: Measuring Values in Environmental Research: A Test of an Environmental Portrait Value Questionnaire. Front. Psychol. 9, 564, (2018)
10. K. van den Broek, J. W. Bolderdijk, L. Steg: Individual differences in values determine the relative persuasiveness of biospheric, economic and combined appeals. J Environ Psychol 53, 145-156 (2017)
11. K. Buchanan, N. Banks, I. Preston, R. Russo, R.: The British public's perception of the UK smart metering initiative. Energy Policy, 91, 87-97 (2016)
12. R. A. Buswell, L. H. Webb, V. Mitchell, V. LEEDR Household recruitment: procedures, materials and methods. Loughborough: Loughborough University. (2015) https://dspace.lboro.ac.uk/2134/16860
13. D. Caivano, D. Fogli, R. Lanzilotti, A. Piccinno, F. Cassano: Supporting end users to control their smart home: design implications from a literature review and an empirical investigation. Journal of Systems and Software, 144, 295-313 (2018)
14. P. M. Connor, C. J. Axon, D. Xenias, N. Balta-Ozkan: Sources of risk and uncertainty in UK smart grid deployment: An expert stakeholder analysis. Energy 161, 1-9 (2018)
15. Consumption of energy in living and housing in 2010-2017, GWh. Helsinki: Tilastokeskus, (2018) http://www.stat.fi/til/asen/2017/asen_2017_2018-11-22_tau_001_fi.html
16. D. Cook: How smart is your home? Science, 335(6076), 1579-1581 (2012)
17. T. Coughlan, K. Leder Mackley, M. Brown, S. Martindale, S. Schlögl, B. Mallaband, J. Arnott, J. Hoonhout, D. Szostak, R. Brewer, E. Poole, A. Pirhonen, V. Mitchell, S. Pink, N. Hine: Current issues and future directions in methods for studying technology in the home. PsychNology, 11(2), 159- 184 (2013)
18. J. Davis, L. P. Nathan: Value Sensitive Design: Applications, Adaptations, and Critiques. In Van den Hoven, J., Vermaas, P. Van de Poel, I. (Eds.), Handbook of Ethics, Values, and Technological Design. Dordrecht: Springer Science+Business Media. pp. 11-40 (2015)
19. R. Defila, A. R. Di Giulio: Two souls are dwelling in my breast: Uncovering how individuals in their dual role as consumer-citizen perceive future energy policies. Energy Res. Social Sci., 35, 152-162 (2018)

20. C. Després: The meaning of home: literature revie10w and directions for future research. J Archit Plan Res, 8, 96-115 (1991)
21. P. Dourish: The Allure and the Paucity of Design: Human-Computer Interaction. May 2018, 1-21 (2018)
22. E. Dütschke, A-G. Paetz: Dynamic electricity pricing – Which programs do consumers prefer? Energy Policy, 59, 226-234 (2013)
23. H. Elkhorchani, K. Grayaa: Novel home energy management system using wireless communication technologies for carbon emission reduction within a smart grid, J Cleaner Prod., 135, 950-962, (2016)
24. H. Easthope: A place called home. Housing, Theory and Society, 21(3), 128-138. (2004)
25. Energy and Digital Living. LEEDR: University of Loughborough http://energyanddigitalliving.com/ (2010-2014)
26. European Commission 2030 climate & energy framework. (2016-2017) https://ec.europa.eu/clima/policies/strategies/2030_en.
27. D. Evans: Thrifty, green or frugal: reflections of sustainable consumption in a changing economic climate. Geoforum, 42, 550-557 (2011)
28. L. A. Faerber, N. Balta-Ozkan, P. M. Connor: Innovative network pricing to support the transition to a smart grid in a low-carbon economy, Energy Policy, 116, 210-219 (2018),
29. B. Friedman: Value-sensitive design. interactions, 3(6), 16-23 (1996)
30. B. Friedman, P. H. Kahn, A. Borning: Value Sensitive Design: Theory and Methods. Washington: University of Washington. (2002)
31. B. Friedman, P. J. Kahn, A. Borning: Value sensitive design and information systems. In P. Zhang and D. Galletta (eds) Human-computer interaction in management information systems Armonk: M.E. Sharpe, 348–372 (2006)
32. B. Friedman: Something of value [social impact award talk]. SIGCHI conference on human factors in computing systems. Austin, 9 May 2012. (2012)
33. B. Friedman, C. G. Hendry, A. Borning: A Survey of Value Sensitive design Methods. Foundations and Trends in Human-Computer Interaction, 11(23) 63-125 (2017)
34. V. Haines, V. Mitchell, C. Cooper, M. Maguire: Probing user values in the home environment within a technology driven Smart Home project. Pers Ubiquit Comp, 11(5), 349-359 (2007)
35. Halloran, J., Hornecker, E., Stringer, M., Harris, E., Fitzpatrick, G.: The value of values: Resourcing co-design of ubiquitous computing, CoDesign, 5(4), 245-273 (2009)
36. T. Hargreaves, C. Wilson: Smart Homes and Their Users. Heidelberg: Springer (2017)
37. J. Heinonen, M. Jalas, J. K. Juntunen, S. Ala-Mantila, S. Junnila: Situated lifestyles: I. How lifestyles change along with the level of urbanization and what the greenhouse gas implications are—a study of Finland. Environ. Res. Lett., 8(2), 1-13 (2013)
38. M. Herczeg: The smart, the intelligent and the wise: roles and values of interactive technologies. Proceedings of the First International Conference on Intelligent Interactive Technologies and Multimedia, Allahabad, India, 17-26 (2010)
39. J. Huizenga, L. S. G. Piccolo, M. Wippoo, C. Meili, A. Bullen: Shedding Lights on Human Values: An Approach to Enagage Families with Energy Conservation. In: Human-Computer Interaction – INTERACT 2015, Information Systems and Applications, incl. Internet/Web, and HCI, Springer, pp. 210–218. (2015)
40. M. Håkansson, P. Sengers: Beyond Being Green: Simple Living Families and ICT. In Proceedings of CHI 2013, April 27–May 2, 2013, Paris, France (2013)
41. M. Isomursu, M. Ervasti, M. Kinnula, P. Isomursu: Understanding human values in adopting new technology—a case study and methodological discussion. Int. J. Hum. Comput. Stud., 69(4), 183-200 (2011).
42. O. S. Iversen, K. Halskov, T. W. Leong: Values-led participatory design. CoDesign, 8(2-3), 87-103 (2012)
43. N. JafariNaimi, L. Nathan, I. Hargreaves: Values as hypotheses: design, inquiry, and the service of values. Design issues, 31(4), 91-104 (2015)
44. R. Jensen, Y. Strengers, J. Kjeldskov, L. Nicholls, M. Skov: Designing the Desirable Smart Home: A Study of Household Experiences and Energy Consumption Impacts. CHI 2018, April 21–26, 2018, Montréal, QC, Canada (2018)
45. M. Kinnula, N. Iivari, M. Isomursu, S. Laari-Salmela: 'Worksome but Rewarding'–Stakeholder Perceptions on Value in Collaborative Design Work. Computer Supported Cooperative Work (CSCW), 1-32. (2018)
46. S. Kujala, K. Väänänen-Vainio-Mattila: Value of Information Systems and Products: Understanding the Users' Perspective and Values. J Inf Tech Theory and Application (JITTA), 9(4), 23–39 (2009)
47. Labanca, Bertoldi, P.: Beyond energy efficiency and individual behaviours: policy insights from social practice theories. Energy Policy 115, 494-502 (2018)
48. A.W. Lai: Consumer values, product benefits and customer value: a consumption behavior approach. Adv Consum Res, 22, 381-381 (1995)
49. C. A. Le Dantec, E. S. Poole, S.P., Wyche: Values as lived experience: evolving value sensitive design in support of value discovery. In Proceedings of the SIGCHI conference on human factors in computing systems, 1141-1150, ACM. (2009)
50. E.A. Lee: Cyber Physical Systems: Design Challenges.In: Proceedings of the 200811th IEEE International Symposiumon Object Oriented Real-Time Distributed Computing (ISORC), 363–69 (2008).
51. M. Leitner, P. Wolkerstorfer, R. Sefelin, M. Tscheligi: Mobile Multimedia: Identifying User Values Using the Means-End Theory. MobileHCI 2008, September 2–5, 2008, Amsterdam, the Netherlands (2008)
52. S. C. R. Lewis: Energy in the Smart Home. In R. Harper (ed.), The Connected Home: The Future of Domestic Life. London: Springer-Verlag (2011) DOI: 10.1007/978-0-85729-476-0_14
53. A. Ligtvoegt, G. van de Kaa, T. Fens, C. van Beers, P. Herder, J. Van den Hoven: Value Sensitive Design of Complex Product Systems. In Policy Practice and Digital Science. Swizerland: Springer International Publishing pp. 157-176. (2015)
54. G. Lobaccaro, S. Carlucci, E. Löfström: A Review of Systems and Technologies for Smart Homes and Smart Grids. Energies 9, 348 (2016)
55. N. Manders-Huits: What values in design? The challenge of Sci. Eng. Ethics, 17(2), 271-287 (2011)
56. K. Maréchal, L. Holzemer:. Unravelling the 'ingredients' of energy consumption: Exploring home-related practices in Belgium. Energy Res. Social Sci., 39, 19-28 (2018)
57. D. Marikyan, S. Papagiannidis, E. Alamanos: A systematic review of the smart home literature: A user perspective. Technol. Forecasting Social Change, 138, 139–154 (2019)
58. S. Mennicken E. M. Huang: Hacking the Natural Habitat: An In-the-Wild Study of Smart Homes, Their Development, and the People Who Live in Them. In: Kay J., Lukowicz P., Tokuda H., Olivier P., Krüger A. (eds) Pervasive Computing. Lecture Notes in Computer Science, vol 7319. Springer, Berlin, Heidelberg. (2012)
59. E. G. Mesthene. E. G.: The Role of Technology in Society. Technology and Culture, 10(4), 489-536, (1969)
60. C. A. Miller, J. Richter, J. O'Leary: Socio-energy systems design: A policy framework for energy transitions. Energy Research & Social Science 6, 29-40 (2015)
61. J. K. Miller, B. Friedman, G. Jancke, B. Gill: Value tensions in design: the value sensitive design, development, and appropriation of a corporation's groupware system. Proc. Supporting group work, 281-290. (2007)
62. R. K. Mitchell, B. R. Agle, D. J. Wood: Toward a Theory of Stakeholder Identification and Salience: Defining the Principle of Who and What Really Counts. Acad Manage Rev, 22(4), 853-886 (1997)
63. V. Mitchell, K. L. Mackley, S. Pink, C. Escobar-Tello, G. T. Wilson, T. Bhamra: Situating Digital Interventions: Mixed Methods for HCI Research in the Home. Interacting with Computers, 27(1), 3-12 (2014)
64. L. S. Moussaoui, O. Desrichard: Act local but don't think too global: The impact of ecological goal level on behavior. The Journal of Social Psychology, 156(5), 536-552 (2016)
65. C. Neustaedter,, L. Bartram, A. Mah: Everyday Activities and Energy Consumption: How Families Understand the Relationship. CHI 2013: Changing perspectives. Paris, France. (2013)
66. J. Nielsen: Usability engineering. Morgan Kaufmann. (1993)
67. P. Nurkka, S. Kujala: What matters - User Values or Value to the End User? CHI 2008, April 5 – April 10, 2008, Florence, Italy. ACM. (2008)
68. Opportunities for Home Energy Management Systems (HEMS) in Advancing Residential Energy Efficiency Programs. Lexington, MA, NEEP. (2015) https://neep.org/opportunities-home-energy-management-systems-hems-advancing-residential-energy-efficiency-programs
69. G. Pau, M. Collotta, A. Ruano, J. Qin: Smart Home Energy Management. Energies, 10(3), 382, (2017)
70. A. Peacock, J.. Chaney, K. Goldbach, G. Walker, P. Tuohy, S: Santonja Climent, D. Todoli,, E. Owens: Co-designing the next generation of home energy management systems with lead-users. Applied Ergonomics 60, 194-206 (2017)
71. G. Perlaviciute, L. Steg, N. Contzen, S. Roeser, N. Huijts: Emotional Responses to Ener-gy Projects: Insights for Responsible Decision Making in a Sustainable Energy Transition. Sustainability, 10, 2526 (2018)
72. S. Pink: Doing sensory ethnography, 2nd edition. London: Sage (2015)
73. S. Pink, K. Leder Macley, V. Mitchell, M. Hanratty, C. Escobar-Tello, T. Bhamra, R. Morosanu: Applying the lens of sensory ethnography to sustainable HCI. CM Trans. Comput.-Hum. Interact, 20(4) 1-18 (2013)
74. A. Pommeranz, C. Detweiler, P. Wiggers, C. Jonker: Elicitation of situated values: need for tools to help stakeholders and designers to reflect and communicate. Eth Inf Technol 14(4), 285–303 (2011)
75. C. Quinn: A Value Approach To Complex System Design Utilising A Non-Rigid Solution Space. Queen's University Belfast (2017)
76. S. Reeves, R. Hastings, R. Lamoureux: Home Energy Management Systems (HEMS) Paths to Savings: On-Ramps and Dead Ends. ACEEE Summer Study 2016. (2016)
77. S. Renström: Supporting diverse roles for people in smart energy systems. Energy Research & Social Science, 53, 98-109 (2019)
78. T. Reynolds, J. Gutman: Laddering theory, method, analysis, and interpretation. Journal of Advertising Research, 28(1), 11-31 (1998)

79. H. Rohracher: The Role of Users in the Social Shaping of Environmental Technologies, Innovation: The European Journal of Social Science Research, 16(2), 177-192, (2003)
80. M. Rokeach: The Nature of Human Values. Free Press, New York. (1973)
81. G. Sandström: Smart Homes & User Values. Open House International Association. (2007)
82. J. Sauer, C. Schmeink, D. Wastell: Feedback quality and environmentally friendly use of domestic central heating systems. Ergonomics, 50(6), 795-813 (2007)
83. S. H. Schwartz: Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. Adv Exp Soc Psychol 25, 1-65 (1992)
84. T. Schwartz, G. Stevens, T. Jakobi, S. Denef, L. Ramirez, V. Wulf, D. Randall: What People Do with Consumption Feedback: A Long-Term Living Lab Study of a Home Energy Management System. Interacting with Computers 27(6), 551 - 576 (2015)
85. A. Sellen, Y. Rogers, R. Harper, T. Rodden: Reflecting Human Values in the Digital Age. Commun ACM, 52(3), 58–66 (2009)
86. E. Shove, G. Walker: What Is Energy For? Social Practice and Energy Demand. Theory, Culture & Society, 31(7), 41–58 (2014)
87. L. Spigel: Designing the Smart House: Posthuman Domesticity and Conspicuous Production. European Journal of Cultural Studies, 8(4) (2005)
88. Y. Strengers: Negotiating everyday life: the role of energy and water consumption feedback. Jour. Consum. Cult.11(3), 319–338 (2011)
89. Y. Strengers: Smart Energy Technologies in Everyday Life: Smart Utopia?. Palgrave Macmillan, Basingstoke. (2013)
90. V. Sugarman, E. Lank: Designing Persuasive Technology to Manage Peak Electricity Demand in Ontario Homes. CHI 2015, Crossings. Seoul, Korea. (2015)
91. Tilastokeskus and LUKE. Pientalojen polttopuun käyttö 2016/2017. Helsinki: LUKE. http://stat.luke.fi/pientalojen-polttopuun-kaytto. (2018).
92. S. Tirado Herrero, L. Nicholls, Y. Strengers: Smart home technologies in everyday life: do they address key energy challenges in households? Curr Opin Env Sust 31, 65-70 (2018)
93. W-C. Tsai, L-L. Chen, Y. Chuang: Balancing Between Conflicting Values for Designing Subjective Well-Beings for the Digital Home. In Proceedings of APCHIUX 2015, Melbourne, VIC, Australia. (2015)
94. G. Walker: Inequality, sustainability and capability: Locating justice in social practice. In Shove, E. and Spurling N. (eds.) Sustainable Practices: Social theory and climate change. London and New York: Routledge, 181-196 (2013)
95. E. v. Werff, L. Steg: The psychology of participation and interest in smart energy systems: Comparing the value-belief-norm theory and the value-identity-personal norm model. Energy Research & Social Science (22) 107-114, (2016)
96. C. Wilson, T. Hargreaves, R. Hauxwell-Baldwin: Smart homes and their users: a systematic analysis and key challenges. Pers Ubiquit Comput, 19(2), 463–476 (2015)
97. C. Wilson, T. Hargreaves, R. Hauxwell-Baldwin: Benefits and risks of smart home tech-nologies. Energy Policy 103, 72-83 (2017)
98. S. Yarosh, I. Radu, S. Hunter, E. Rosenbaum: Examining values: an analysis of nine years of IDC research. In Proceedings of the 10th International Conference on Interaction Design and Children, 136-144. ACM. (2011)
99. F. Yetim: Bringing discourse ethics to value sensitive design: pathways to toward a deliberative future. AIS Trans Hum Comp Interact 3(2):133–155 (2011)
100. B. Zaman, V. Abeele: Laddering with young children in User eXperience evaluations: theoretical groundings and a practical case. Proc. IDC, 156-165 (2010)
101. B. Zhou, W. Li, K. Chan, Y. Cao, Y. Kuang, X. Li, X. Wang: Smart home energy management systems: Concept, configurations, and scheduling strategies. Renewable Sustainable Energy Rev, 61, 30-40 (2016)

APPENDIX

Participating households and their key values

N=new users, E=experienced, or 1-4 years with SHEMS, P=prospective users, who are interested but have not acquired SHEMS yet.

Home	Householders	Value
N1	Technical project manager 46-50 Social worker, 41-45 3 children under 18	Frugality Self-direction, stimulation, autonomy Comfort
N2	Social worker, 31-35 HVAC engineer, 31-35 3 children under 18	Frugality Ecologic sustainability Autonomy
N3	Medical doctor, 31-35 Medical doctor 31-35 2 children under 18	Ecologic sustainability Comfort Security
N4	Work coach, 56-60 School headmaster, 61-65	Ecologic sustainability Frugality Security
N5	Entrepreneur, 41-45 Entrepreneur, 41-45 Student 18-20 3 children under 18	Comfort Frugality Ecologic sustainability
N6	Teacher, retired, 71-75 Teacher, retired, 71-75	Comfort Frugality Security
N7	Entrepreneur, 56-60 Entrepreneur, retired, 56-60	Frugality Comfort Security
N8	Nurse, 50-55 Nurse, 56-60	Comfort, Frugality Security
N9	Nurse, 36-40 Project manager, 50-55 2 children under 18	Frugality Comfort Security
N10	Entrepreneur, retired, 50-55 Entrepreneur, sick-leave, 50-55	Frugality Comfort Ecologic sustainability
N11	Accountant, 60-65 Nurse, 46-50	Frugality Ecologic sustainability Security
P12	Technical product manager, 40-45 Physiotherapist, 40-45 2 children under 18	Frugality Self-direction, stimulation Comfort
P13	Civil engineering, 40-45, Nurse, 40-45 4 children under 18	Autonomy Frugality Distinguishing oneself
P14	Teacher, 40-45 Civil engineer, 40-45 3 children under 18	Comfort Autonomy Frugality
P15	Teacher, 60-65 Pre-school teacher, 60-65	Ecology Frugality Security
P16	Project manager, 40-45 Teacher, 40-45 2 children under 18	Frugality Ecologic sustainability Comfort
P17	Sales representative, 62	Self-realization, exploration Frugality Comfort

P18	Finance manager, 35-44, 2 children under 18	Ecologic sustainability Frugality Security
P19	Nurse, engineer 40-45, Student, engineer 40-45 2 children under 18	Frugality, ecologic sustainability Exploration, stimulation Comfort
P20	House wife, 36-44 Mechanic, 36-40 10 children under 18	Frugality Comfort Ecologic sustainability
E21	Telecom technician, 56-60	Comfort Frugality Ecologic sustainability
E22	IT engineer, 51-55 Entrepreneur, 51-55	Comfort Frugality Security
E23	Construction worker, 51-55 Social worker, 51-55	Frugality Comfort Exploration, self-realization
E24	HVAC designer, 56-60 Director, 56-60	Frugality Comfort Autonomy
E25	Project manager, 51-55	Frugality Self-realization, exploration Security
E26	Real estate manager, 56-60 Public officer, 56-60	Frugality Comfort Security
E27	Executive director, 56-60 Entrepreneur, 56-60	Stimulation, exploration Frugality Ecologic sustainability
E28	Sales director Sales administrator 2 children under 18	Frugality Comfort Security