Understanding potential users of energy community information system: A thematic analysis

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Abstract

The continuing global growth of energy consumers, the war in Europe, and climate change are the driving factors for energy revolution. One solution to this concerning issue has been the transformation of energy consumers to become energy producers. Prosumers can be grouped to establish energy communities. Prosumers, energy communities, and other distributed energy resources (DERs) are possible sustainable energy resources that can be connected to the smart grid.

The literature review of existing research about smart grids, distributed energy resources, and energy communities, is conducted to gain a better understanding of the complex system and its stakeholders. The Second part of the literature review follows the behaviour of the potential smart grid users and its recent studies.

The research questions focus on understanding energy prosumer's perspectives on information system usage in order to discover the advantages and disadvantages of potential information system within an energy community context.

The data were gathered from semi-structured interviews with people who voluntarily replied to application forms which were distributed prior to this study. Qualitative research methods were chosen to be used. A thematic analysis was conducted and as a result a thematic map in which two main themes, 15 sub-themes, and 25 codes were identified.

It was discovered that positive user experience, desired functionalities, monitoring, economic benefits, user interface, beneficial information, and platform availability were the driving factors seen as an advantage of the potential information system. On the other hand, data leaks, undesired functionalities, energy community problems, and negative user experience were seen as disadvantages of the information system.

This study contributes to the field of sustainable human-computer interaction and the findings of this thesis can be used as a foundation for future research and to design and develop the smart grids from the prosumer's perspective. Due to several requests from participants, the text of the thesis has been written with accessibility in mind, so that the text does not require special expertise in the field of sustainable human-computer interaction.

Keywords
Information systems, energy community, sustainable human-computer interaction, distributed energy resources, sustainable energy behaviour, energy prosumer

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Foreword

I would like to thank my superior PhL Sanna Tuomela for the great amount of help with my study. The encouraging attitude and support helped me through the heavy load of full-time work, studies, and personal life. Thank you also for involving me as a research assistant to collect data and get to know this interesting and important topic.

I'm grateful for PhD Tonja Molin-Juustila's instructions throughout the process, which were encouraging and helped to complete the project when it was a struggle. In addition, I would like to thank my supervisor PhD Netta Iivari.

Lastly, special thanks to Suvi. You gave me the extra push and motivation to successfully work through this process and have a joint graduation party with you.

"Peace cannot be safeguarded without the making of creative efforts proportionate to the dangers which threaten it"

Schuman Declaration of 9 May 1950

Helsinki, June 13, 2022

Abbreviations

AMI	advanced metering infrastructure
CE	community energy
CEC	clean energy community / citizen energy community
DER	distributed energy resource
DES	distributed energy system
DIY	do it yourself
ECSETP	European Commission Strategic Energy Technology Plan
EMS	energy management system
EOL	end-of-life
EPC	electricity prosumer community
ESC	energy sustainable community
ESS	energy storage system
EU	European Union
EV	electric vehicle
GUI	graphical user interface
HEMS	home energy management system
ICES	information community energy system
ICT	information and communication technology
IoT	internet of things
IS	information system
KTA	key technology area
MC	main controller
NETL	National Energy Technology
P2P	peer-to-peer
PC	prosumer-community
PV	photovoltaic
QRI	qualitative research interview
R&D	research and development
R&I	research and innovation
REC	renewable energy community
SEC	sustainable energy community
SET	strategic energy technology
SHEMS	smart home energy management system
SM	smart meter
SPV	solar photovoltaic
SS	smart scheduler
TA	thematic analysis
UX	user experience

Contents

1. Introduction

The global production and consumption of energy are a medley of multiple problems that need to be solved. Lizunkov et al. (2018) state that the current rate of population growth is about 2% per year. As the population of the world is growing, also the quality of life is increasing especially in developing countries. This means that more energy production is needed to cover the global demand for energy consumption.

The traditional bulk power grid is inefficient and harmful to the environment. Approximately 25,9% of global carbon emissions are generated from global power generation and it is probable it will fall short of demand. Consequently, the traditional main grid is becoming more fragile, less efficient, and less reliable. (Xu et al., 2017.) The traditional energy system is dependent on oil and other fossil fuels. A significant part of the world's oil reserves are in countries that are ethically restricted and have a higher risk of political conflicts. The fuel prices can rapidly change due to a war or natural disaster. (Alanne & Saari, 2006.) As there is a war in Europe between Russia and Ukraine, fuel prices are rising rapidly, and the availability of energy has clearly deteriorated. Alternative energy sources are in demand to control the energy prices and to meet energy consumption needs. (Hiilamo, 2022; Lassila, 2022.)

Nevertheless, as the sources of fossil fuels are dwindling and the prices are increasing, also climate change is accelerating. The United Nations' climate press release on September 17th, 2021, reveals the urgent need for actions to prevent the global temperature increase beyond 2°C by the end of the century. The search for sustainable and ethical energy resources is urgent. One possible solution for partially tackling this demanding task can be solar panels and energy communities. Solar panels are used to convert the light from the sun into electricity that can be used to power the current electrical load or to restore the electricity into batteries, which are connected to a system which includes the panels. The sun's light is composed of particles of energy called photons, which are absorbed by the solar panels to initiate an electric current. (Hantula & Voege, 2009.)

An energy community is formed by small energy producers. The small energy producers can be individual citizens, associations, or companies. The parties share the profits of energy production and supply. The term energy community was introduced to the public when the European Union (EU) accepted an electricity market reform directive for decentralized energy production (*On the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*, Directive 2009/28/EC). Its objectives are to improve more carbon neutral energy production and unravel the regulation barriers that are blocking the development of the energy communities.

In the future, in a modern smart electrical grid, the energy could travel both ways depending on the need of energy and production, targeting a more efficient energy production and consumption. The billing of transfer fee would also be based on power-based billing rather than energy-based billing. The electrical grid would be connected to a smart information system to provide means for more efficient uninterrupted energy consumption, consequently lowering the energy peaks in the electrical grid and production. (Faia et al, 2021.)

Energy consumers that also produce energy are called prosumers (Parag & Sovacool, 2016). Empowering prosumers to participate in the generation of smart grid's energy supply, can be seen as the key factor in succeeding in the concept of distributed energy resources. Steg et al. (2018) point out the importance of engaging with the affected parties to understand the factors influencing relevant behavior. When designing and developing new technology, using intuition as a source of understanding the users of the technology, can be incorrect. Direct engagement between designers, developers, and end-users can help build mutual understanding and lead to a successful outcome. To develop technology accepted by the prosumers, the development group needs to be aware of the motivation, constraints, and concerns of people. A successful technology will serve the prosumers' individual needs and motivate sustainable energy behavior. Consequently, the smart grid's energy supply will be more reliable, ecological, and ethical. Von Hippel and Katz (2002) state that collaboration and co-creation with customers has several benefits as it can increase the flow of quality ideas, innovation capacity, and innovation rate. In addition, it can reduce innovation risk through community screening and accelerate the times of shipping with new services and products.

European commission's (2019) strategy is to invest in clean energy technology improvements and increase research and innovation (R&I) for new innovative services, business models, and ways of engaging consumers in the energy system. Information and communication technologies (ICT) will be the most essential in the success of the future goals, because the strategic energy technology (SET) plans to have 80% of energy consumption to be interoperable with ICT in 80% of European homes by 2030. Smart technologies and services are transforming the energy market to deliver a more comfortable, more convenient, and healthier environment for consumers to actively take part in the energy network as consumers and prosumers. However, research for prosumer's requirements for energy management systems in the energy communities is deficient even though it is crucial for a successful outcome in the future.

1.1 Research aims and questions

There are two aims for this research. The first one is to build a solid foundation for understanding energy communities, smart grids, distributed energy resources (DERs), and its different stakeholders. This foundation is built by having a literature review of existing studies. In the future, when designing software and information systems to smart grids and local energy communities, it is important to understand the complex needs for the system. This study focuses on the prosumer's perspective.

The second aim for this research is to study the motivation behind prosumers' interests towards information systems based on local energy communities in order to understand the prosumers' needs. This is done two ways. First, literature review is conducted for existing literature. Second, the research data is gathered from semi-structured interviews and analyzed thematically. The results of this study can be used as a guideline for further research and development of software and information system to energy communities and smart grids.

Smart grids, distributed energy resources, and local energy communities are a new concept. The empowering of consumers to prosumers is seen as the path of the future development. In general, this thesis also aims to strengthen and share information and knowledge about the consumers' possibilities in the electric grid of the future and to complete the lack of studies.

This thesis focuses on energy communities that could be composed by solar panel owners. The research questions are as follows:

- RQ1: What are the advantageous features of an energy community information system for the potential members of such energy community?
- RQ2: What are the disadvantageous features of an energy community information system for the potential members of such energy community?

1.2 Research structure and limitations

As a consequence of limited resources, this study has some limitations. The literature review in Chapter 2 and in its sub-sections are limited to a basic understanding of the concept of the smart grid and its stakeholders. More technical details are out of the context of this study. This study is also limited to solar power. There are also other distributed energy resources available such as wind power. It is also important to notice that there is no clear consensus among researchers about the design or technical implementations of the smart grids, energy communities, or DERs. The existing research cover concepts, prototypes, and small-level implementations because no region-level implementations exist.

Furthermore, the analysis of the data is limited to cover only two open questions in the semi-structured interviews that directly affiliate with this study. Other open questions in the interview guide also include answers to the research questions but are discarded due to limited resources. In addition, the participant pool of this study is homogeneous, which can be seen in chapter 4.1. According to Kristensson et al. (2008), the participant pool should be heterogenous as it is one of the key strategies in having realistic study results.

This thesis consists of six chapters. In this chapter, the research problem, structure, limitations, and motivation for this thesis are introduced. In the second chapter, a literature review and existing research are presented. Chapter 3 follows through the research methods. Chapter 4 will outline the findings of the study. Chapter 5 will be for discussion. Final chapter is the conclusion of the study. The question form used in the interviews can be found at the end in Appendix A. Appendix B includes all the codes discovered from the thematic analysis with the participants' background information. The discarded codes which were not included for further studies can found in Appendix C.

2. Prior research

The European Commission Strategic Energy Technology Plan's (ECSETP) goal is to set the energy consumers at the centre of future's energy network. The ECSETP aims to create a peer-to-peer (P2P) energy trading system by empowering the consumers to also become the prosumers by installing energy production sources. (European commission, 2019.) Households can install smart devices that are connected to an information and communication technology (ICT) and distributed energy resources (DERs) i.e., photovoltaic (PV) modules or small-scale wind turbines, and energy storage. The energy storage can be utilized as a battery for overproduction or an artefact such as electric vehicle (EV) can act as a storage for overproduction. (Faia et al., 2021.)

This chapter is divided into seven sections covering the prior research of different parts of sustainable energy network. First section, 2.1, introduces the previous literature on photovoltaics as this thesis is limited to solar photovoltaic panels as the sustainable energy resource. In sections 2.2 and 2.3, the research of energy communities and distributed energy systems are reviewed. Section 2.4 presents the previous research on smart grids. Next, section 2.5 reviews the prior research on energy management systems. Section 2.6 gives an overview of the research for energy prosumers. Lastly, section 2.7 covers the prior research for energy consumers. The future innovations' energy terminology is not yet completely established among researchers, but in this thesis the different terms from different sources are combined under one term. In addition, the literature review focuses more on energy consumers, energy prosumers, and energy management systems. Photovoltaics, energy communities, distributed energy systems, and smart grids are reviewed on the concept level to understand the topic better.

2.1 Photovoltaics

The Sun is an enormous energy source. It is estimated that the Sun's total radiant energy emitted is about $3{,}75\times10^{26}$W. The total of the energy that reaches Earth's surface is about $1{,}7\times10^{4}$ billion KW. In comparison, in one year, it is $3{,}5\times10^{4}$ times more than the total of energy we generate globally. (Yan, Zhang, & Shao, 2013.) Solar photovoltaic (SPV) market is annually around 100GW constituting 55% of the renewable energy source capacity (Gorgian & Shukla, 2020). SPV has high expectations for this century, as it is expected to become the primary global source of energy during this century (Xu et al., 2018).

The first discovery of the photovoltaic effect was made by Becquerel in 1839 in an electrochemical cell (Becquerel, 1839). Adams and Day made the first solid state photovoltaic cell of selenium in 1877 (Adams & Day, 1877). First time SPV were commercially used as solar batteries was in 1957. The aim was to give electricity to man-made Earth satellites, and it was the main purpose of solar cells. The historical movement across SPV development for global use in terrestrial applications started in 1973 when the oil crisis occurred. (Parthasarathi et al., 1995.) Historically SPV's have been used in places that are off the grid (Gorjian & Shukla, 2020) like a foldable module in a base camp in the Indian Everest (Parthasarahthi et al., 1995).

When reviewing renewable energy sources, the Sun's solar energy is the clear winner because of its abundant capacities. It is green and inexhaustible energy that is harvested with SPV devices. (Gorjian & Shukla, 2020.) The basic principle for SPV involve two main steps to gain usable electrical current. First is the creation of pairs for positive and negative charges by absorbing solar radiation into the solar cell. The second step is to separate those charges by potential gradient in the cell. The photons are absorbed in the cell material and electrons within the cell are excited. The flow of the mobile electron pairs from negative semi-conductor to positive semi-conductor is called the PV effect. (Khan et al., 2013.)

SPV panel consists of SPV cells as the basic unit and SPV modules as a larger component of multiple connected cells. As a standard, SPV module uses 36 SPV cells. (Khan et al., 2013.) The SPV's generation potential depends on multiple factors such as local weather conditions, the type of PV material, and the intensity of the solar light. A greater amount of clouds and humidity will decrease the photovoltaic power because the cloud cover and water vapor content in the air weakens the solar radiation. The wind speed can also increase the power generation by cooling down the surface temperature of SPV panels. The SPV cells spectral response has a corresponding relationship between solar cell's photoelectronic conversion characteristics and the wavelength of incident light. The performance of the solar cells are closely associated with the incident light. For the silicon-based solar cells to produce photovoltaic effect, the wavelength range is about 0,4-12 μm. It is also important to consider dust when installing the PV panel. For dry, windy, and dusty areas the surface of the panel will accumulate dust. It can decrease the transmittance of components and even result to a component hot spot phenomenon and will affect the output difference between the inverter tracking accuracy and the junction box. This problem can be solved by regularly cleaning the surface if installation modifications are not possible. (Shahul et al., 2014.) Additionally, one important factor to consider when choosing the right SPV panel is the efficiency of the panel. The smaller the roof, the more efficient the SPV panel should be. (Khan et al., 2013.)

Solar power has several benefits as it is non-polluting, reliable, safe, and efficient. As the SPV technologies are constantly developing, also the prices of solar energy are decreasing. (Chowdhury et al., 2020.) Its CO_2 emissions are negligible (Shin et al., 2017). However, a major concern regarding SPV panels is the end-of-life (EOL) SPV panels, which may become a source of hazardous waste. The average SPV panel lifetime is 25 years and after that period it becomes waste. (Chowdhury et al., 2020; Xu et al., 2018.) As the count of panels is increasing in rapid pace, it is estimated that the total quantity of waste from EOL SPV panels will reach around 9,57 million tons in 2050 (Monier & Hesting, 2011). The most critical situation is in China, which surpassed Europe as the leader of installed SPV panel capacity in 2014. In China, no regulation, policies, or recycle plants exist for SPV panel waste. (Ding et al., 2016.) The second largest SPV panel capacity is in Europe where the work on policies and regulation towards SPV panel waste is beginning to be taken into consideration (Leroy, 2012). Still, this rapidly evolving issue urgently needs more research and development (R&D) (Chowdhury et al., 2020; Xu et al., 2018).

2.2 Energy communities

Prosumers have been struggling with overproduction. All the produced energy cannot be utilized, and the storage capacity of the batteries is limited. One solution has been the selling of the overproduction to the grid but due to feed-in tariff reduction, it is not feasible. For consumers and prosumers, this can weaken the motivation to invest for renewable sources like PV systems. (Faia et al., 2020.) To empower prosumers' full potential, a formation of prosumer groups and working collectively can gain extra benefits for the prosumers rather than working individually (Rathnayka et al., 2015; Rathnayaka et al., 2011).

These emerging energy communities (ECs) have been referred as prosumer-communities (PCs) (Rathnayaka et al., 2011), electricity prosumer communities (EPCs) (Olivier et al., 2017), integrated community energy systems (ICESs) (Koirala & Hakvoort, 2017; Koirala et al., 2016; Mendes et al., 2011; Xu et al., 2015), clean energy communities(CECs) (Gui & MacGill, 2018) which is also an abbreviation for citizen energy communities (Kojonsaari & Palm, 2021), renewable energy communities (RECs) (Dóci et al., 2015), sustainable energy communities (SECs) (Romero-Rubio & de Andres Diaz, 2015), energy sustainable communities (ESCs) (Schweizer-Ries, 2008), community energy (CE) (Brummer, 2018) or local energy communities (Alam et al., 2019; Faia et al., 2020; Huang et al., 2020; Tushar et al., 2019). The communities can also be divided or referred as centralized, local, distributed, or decentralized depending on the geographical structures of the prosumers or their equipment (Gui & MacGill, 2018).

Brummer (2018) studied the definition of EC as a term and concluded the article stating that no clear definition is available as the meaning and content varied depending on the source. Predominantly researchers agree that the concept of EC can be seen as a sustainable energy system, which allows more participation and democratic control. The concept of EC is not about participation without power, harmful technologies, or centralistic structures. The benefits of these variously referred prosumer communities are to increase actors bargaining forces, reduce energy transfer cost and energy loss, enable efficient energy transfer, and permit active participation in the supply chain (Rathnayaka et al., 2011).

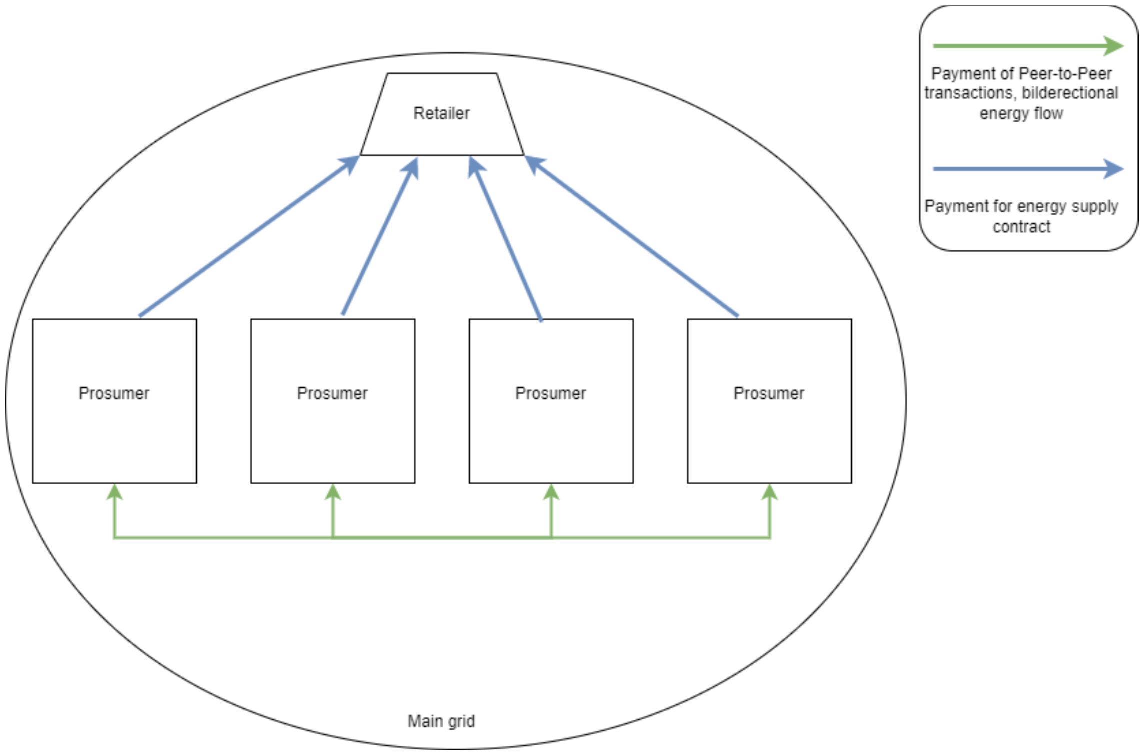

Figure 1. Payment flow in local energy community based on the description of Faia et al. (2020).

Local energy community consist of geologically close prosumers connected to the smart grid, who transact energy within the local community market with P2P transactions or with the retailer as seen in Figure 1. In an optimal situation, prosumers have a PV-battery system to produce and store energy for optimizing the effectiveness and benefits of the local community. Prosumers in the community can buy and sell electricity to the grid or have transactions within the community. The energy payment transaction will be directed to the producer of the energy, namely, prosumer or retailer. The energy supply payment will be directed to the retailer. (Faia et al., 2020.)

Local energy communities in P2P market can have several benefits. It can empower the prosumers and minimize network operation and investment costs. It also maximizes the use of renewable energy and even out the peak loads, and it will lower the cost of electricity. (Tushar et al., 2019.) Local energy community's profitability to buyers and sellers will depend on if the marginal price of P2P transactions is cheaper than retailer tariff and higher than feed-in tariff. (Faia et al., 2020; Huang et al., 2020.) However, the research for P2P energy trading is minimal. There is no clear consensus for data sharing, architecture, or processing infrastructure for local energy communities. (Alam et al., 2019.)

2.3 Distributed energy system

Distributed energy system (DES) includes distributed sustainable energy resources (DERs) (Alanne & Saari, 2006). The DERs include cost-effective energy resources like wind power, solar power, geothermal power, and hydrothermal power. DERs can benefit the main grid by increasing the power generation and power supply reliability. If possible, the DERs should be located close to energy consumers to reduce energy transmission and distribution losses making the resource cost-effective. (Alanne & Saari, 2006; Xu et al., 2017.) Renewable energy resources have several uncertainties and are time- and weather-dependent. Energy storage devices can help even the energy demand in the main grid and lower the uncertainty of power supply. (Xu et al., 2017.)

DES's power supply can be seen as reallocating technology, decision-making, responsibility, expertise, and ownership. The future goal for DESs is to have a mixture of centralized and distributed sub-systems that operate parallel to each other. Substantial concerns for DESs are the compatibility of single units and the lack of common standards, laws, and information formats. (Alanne & Saari, 2006.)

Figure 2 presents a possible smart grid of the future with DESs and storage devices. The smart grid can have traditional consumer households which only consume energy. The industry can act both as a producer or a consumer with or without storage devices. Prosumers can sell overproduction to the grid and buy energy from the grid when needed. Other DESs like solar plants or wind power generators can produce energy to the grid. Energy storage devices can work as a buffering tool to provide stabilization for the energy transmission and distribution. (Alanne & Saari, 2006; Xu et al., 2017.) DESs and energy storage devices play a key role in the smart grid to provide the necessary energy demand (Xu et al., 2017).

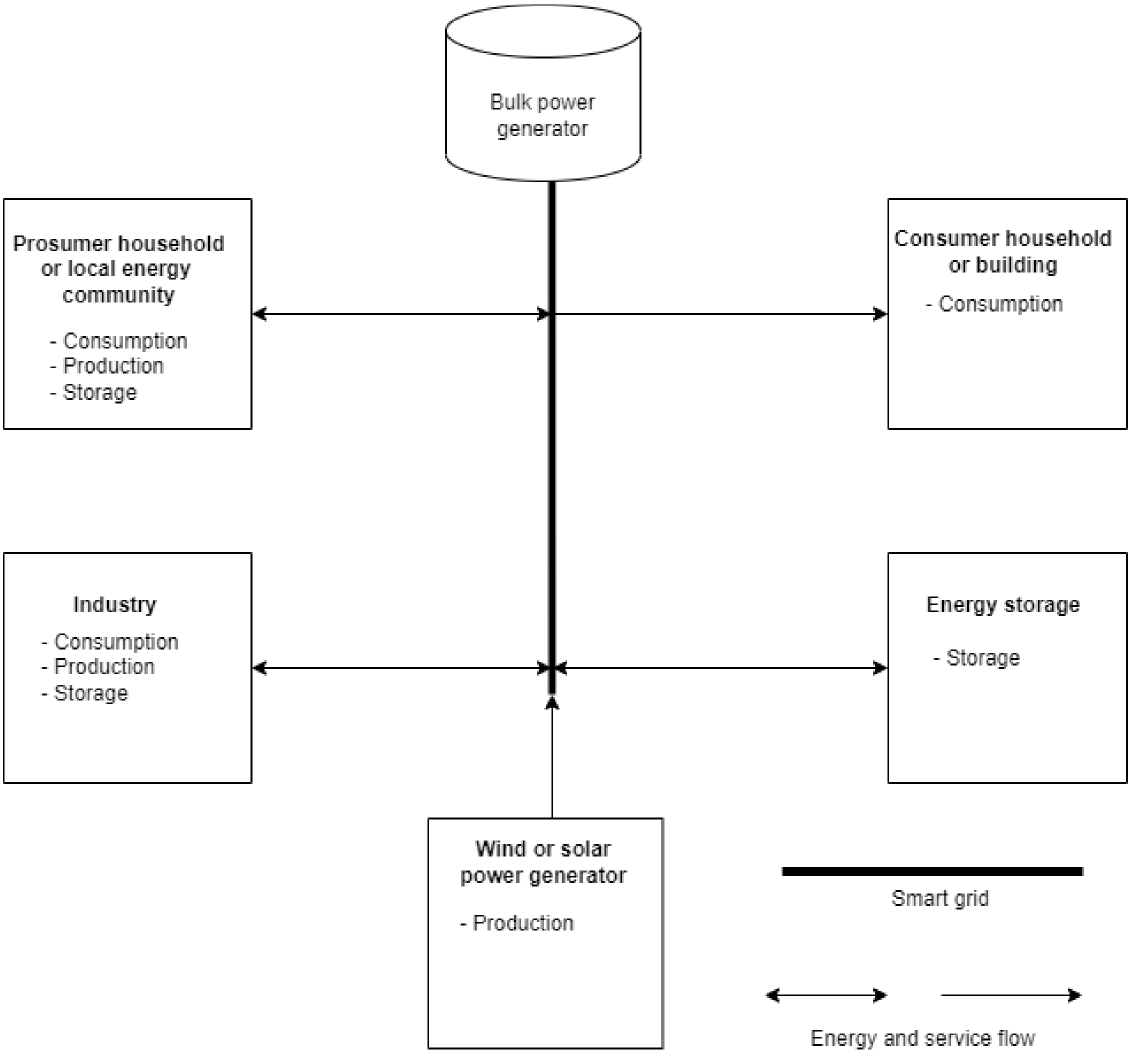

Figure 2. A simplified example of possible future's smart grid with DES and energy storage devices with energy and service flow based on the description by Alanne and Saari (2006) and Xu et al. (2017).

DES and EC share several features and benefits. The DES differs from the EC mainly in terms of the ownership of the system and in the DES the technology is left undefined, and the owners do not need to be in the proximity of DES. The owners can be traditional energy companies, citizens, or any other constellation. Also, DES itself does not require decision-making structure. (Kojonsaari & Palm, 2021.) As with ECs, Allan et al. (2015) remarks there is no agreement or specific definition for DESs.

2.4 Smart grid

Internet of Things (IoT) consists of different physical objects connected to the Internet to provide automatic data collection, transmission, exchange, and computation (Stankovic, 2014). One typical application supported by IoT is the smart grid. The aim of the smart grid is to provide reliable, secure, and efficient energy transmission and distribution to prosumers and consumers. The smart grid can be seen as a traditional power grid, which has been integrated with modern information and communication technologies. (Xu et al., 2017.)

A demanding obstacle for smart grids is to find solutions to effectively integrate DER and energy storages to meet the energy service requirements of consumers and prosumers and at the same time minimize the power generation and transmission costs. Communication is two-way enabled between utility providers and users. Users, like prosumers and consumers, can manage their applications and energy usage that can be based on price or production of their own energy from PV panels. It is also a tool that can help to determine if prosumer should share or deny his own produced energy to the main grid depending on their own usage and production. Utility providers can gather information from the deployed meters and sensors to see the state of the power grid in changes of energy demands, supplies, and costs. It supports efficient operation of the main grid for utility providers. (Frye, 2008.)

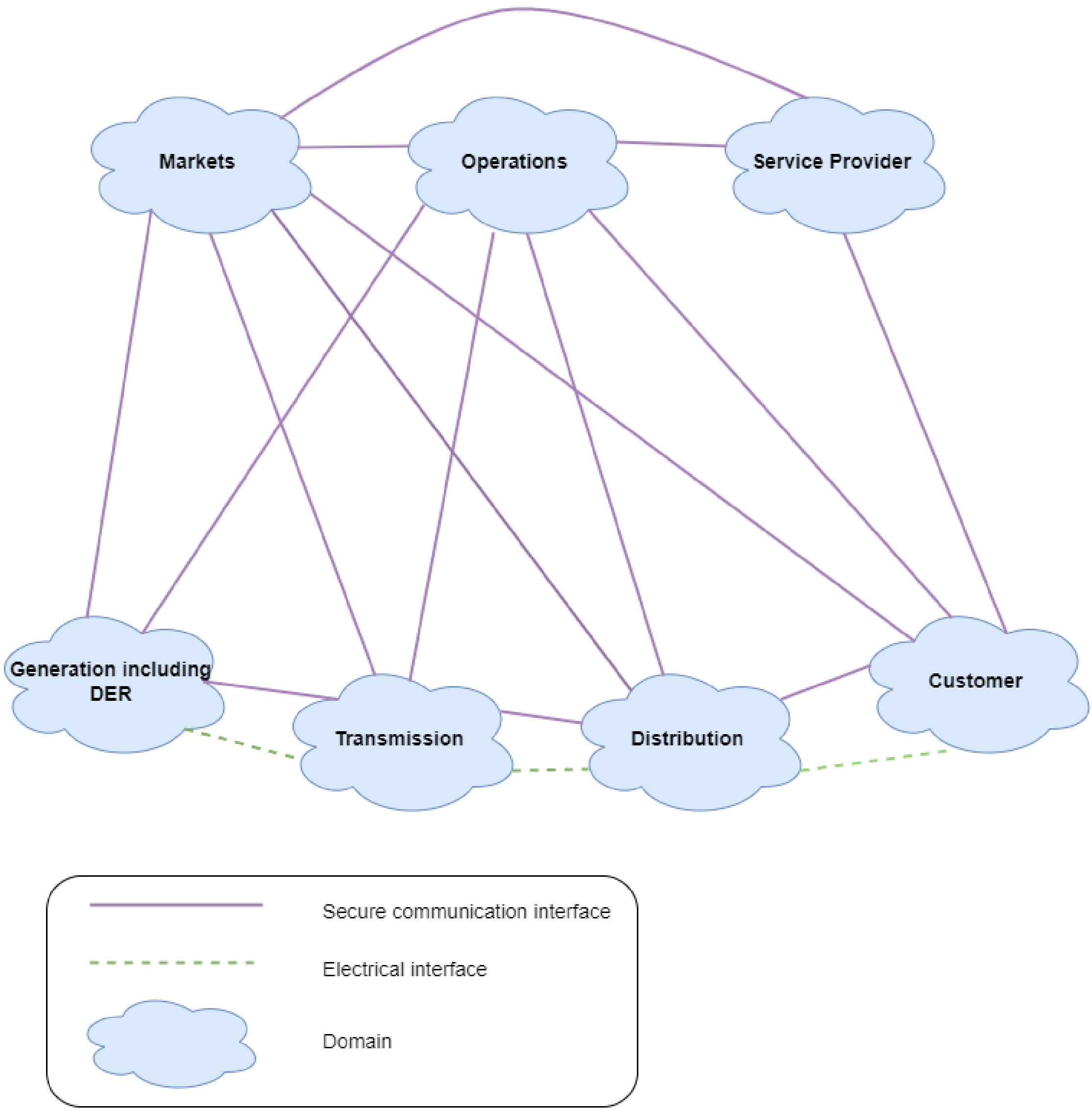

Figure 3. Conceptual representation of smart energy grid. Original version by Grijalva & Tariq (2011), updated version by Demertzis et al. (2021).

In smart grids, prosumer energy management systems are complex. Systems include automation, agent-based market participation, and control systems with ongoing real-time requirements. It also requires software for planning and optimization. When energy management systems are designed and developed, modularity and flexibility need to be taken into consideration. (Camek et al., 2013.) One main issue for energy management systems is security. To get the approvement of the prosumers for these systems, functionality needs to be secure and reliable. The system should support plug and play manner. This easy-to-use open architecture is prone to malicious attacks like privacy violations, data misuse, and data manipulation. (Camek et al., 2013.)

In Figure 3, a conceptual representation of energy smart grid can be seen. The conceptual model divides the architecture of smart grids to seven different domains which interact with each other through electrical or communication flow, while using secure communication architectures, interfaces, and appropriate protocols. (Demertzis et al., 2021; Grijalva & Tariq, 2011.)

The United States' National Energy Technology Laboratory (NETL) (2007) describes a vision of modern smart grid as reliable, secure, cost-effective, safe, and environmentally responsible. It can be grouped into five Key Technology Areas (KTA's): integrated communications, advanced components, advanced control methods, sensing and measurement, and improved interfaces and decision support. Integrated communications need to be high-speed, fully integrated, and two-way enabled to provide dynamic and interactive real-time exchange of power and information. The open-architecture enables plug-and-play environment, which needs to securely network components to interact and monitor. Advanced components are needed for optimal functionality like better battery quality for storage and higher power densities. Advanced control methods like algorithms monitor the power system for rapid diagnosis and appropriate responses to various events. Methods should also support market pricing and efficient operations. Sensing and measurement are technologies that transform data to information to report the health of equipment, integrity of the grid, and support advanced protective relaying. These should also enable consumer choice and demand response. The modern grid requires wide, seamless, and real-time usage of applications and tools for quick and consumer level decision-making with the option for advanced operator training. Improved interfaces and decision support should support these requirements on all levels of the grid.

2.5 Energy management systems

Energy management systems (EMSs) are advanced automation tools for collecting energy measurement data from the field. It is collected to be analysed and transformed into information, to enable and help the management of energy and decision-making to optimise the use of energy. (Segatto et al., 2018.) Home energy managements systems (HEMSs) and smart home energy managements systems (SHEMSs) are gateways for homes to be connected to a smart grid (Tuomela et al., 2019; Tuomela et al., 2021). For smart homes, it provides the opportunities for economic incentives by directing electricity usage to off-hours at lower prices and optimising the efficiency of household appliances and residential energy conversation (Han et al., 2011; Tsui & Chan, 2012; Tuomela et al., 2019; Tuomela et al., 2021). According to Tuomela et al.'s (2021) real-life experiment project, HEMS can reduce the total consumption of energy by up to 30% in the winter months in Finland. In addition, the reduction of energy in the study occurred even though the household valued comfort over savings or ecological sustainability.

Dinh et al. (2020) suggested that the main elements for HEMS can be seen in Figure 4. The proposed HEMS assumes the consumer is a prosumer who is equipped with advanced metering infrastructure (AMI), main controller (MC), energy storage system (ESS), smart scheduler (SS), smart meter (SM), DC/AC inverter, and PV. AMI's main functions are measurement and information collection. It is a fusion of SMs and advanced ICT. Its function is to be the backbone from electricity providers to consumers. MC is the core of the HEMS which controls all the appliances of HEMS. MC can switch on and off the devices based on optimisation algorithms which comes from SS. The information comes from AMI to SS which goes through optimisation algorithms and after that MC controls the appliances according to the results from SS. The ESS can be used to store energy from the PV or from the grid at a low-price time to provide electricity when production is low, or when the grid electricity price is high, resulting to the optimisation of energy costs for the household. The function of the DC/AC inverter is to convert the DC current from the PV into AC current. The appliances can be divided as shiftable and non-shiftable. Shiftable devices like washing machines can be timed to operate at low price times. An example for non-shiftable devices could be security cameras which operating times cannot be interrupted.

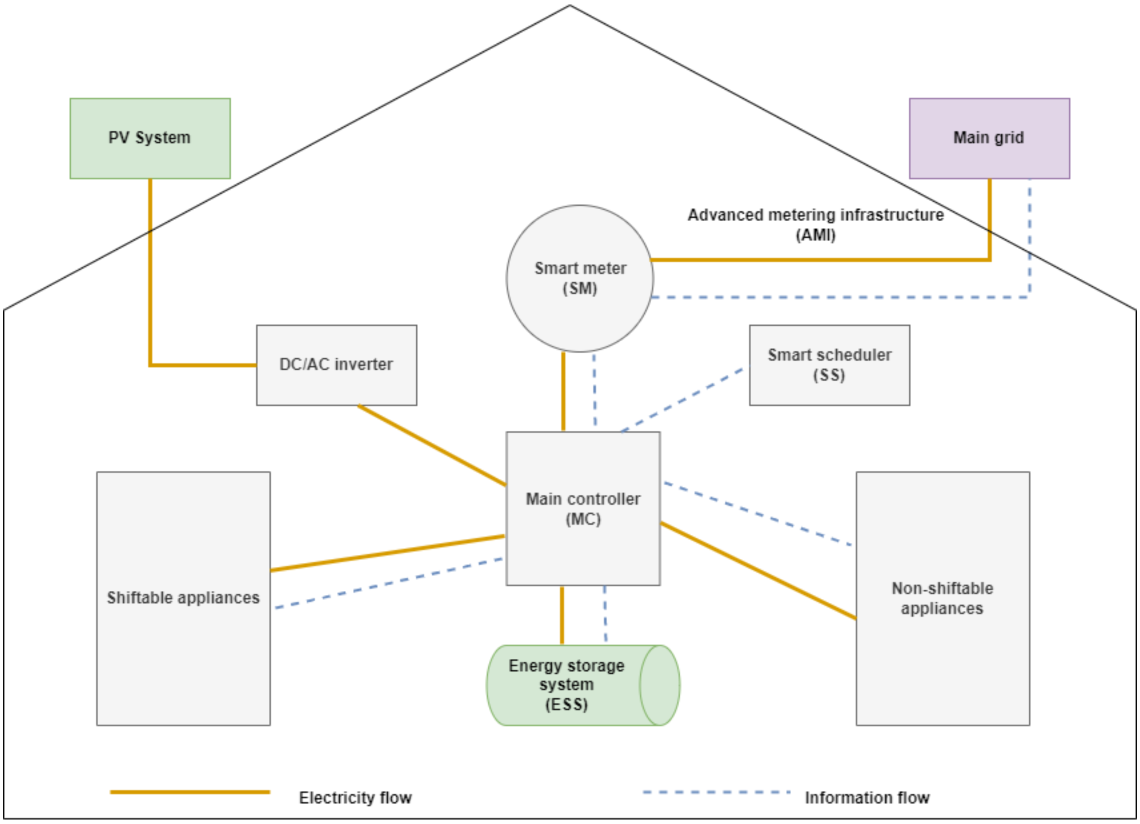

Figure 4. Proposed HEMS architecture by Dinh et al. (2020).

However, end users do not care about the technical side of HEMS (Herczeg, 2010). Tuomela et al. (2019) studied the user values of SHEMS to discover the key values of SHEMS users. SHEMS users expect to save money and energy with the use of SHEMS. A major barrier for not having a SHEM is the prediction of overly prolonged repayment pace. Another important factor for users is comfort, which according to Tuomela et al. (2019) means stable, predictable, and remotely adjustable room temperatures. According to Tuomela et al., comfort is also associated with security. Security is provided by the possibility of adult controlled heating settings that enable the safety of children, so they can play without hazardous results. The remote control is also seen as a security booster strengthening the sense of security and peace of mind. For technically oriented men, SHEMS can be a personal project rather than a family system. In addition, male adults were the main user of SHEM.

Tuomela et al. (2021) interviewed users and potential users of SHEMS to reveal the drivers and barriers of adopting SHEMS from the users' perspective. There were three different user groups, namely, experienced, new, and prospective users of SHEMS. Nine drivers for the adoption of SHEMS were highlighted. All the users expected to save money in energy bills even though some of the new users were sceptical of the amount of money to be saved. Comfortability for living and energy management was another driver for the users. The SHEMS uses machine learning to learn and predict right settings for right indoor temperatures around the year, shortening and levelling the reaction time and temperature intervals to provide steady indoor temperatures and better quality of life. Users had expectations for comfortable energy management, including the possibility for remote control through one user interface on all devices; namely, computers, tablets, and mobile phones are emphasised with the help of automatization to save effort for the user tasks. The users were also interested in having feedback on energy use through SHEMS. Monitoring the energy use with detailed information for devices' energy consumption were desired. New users were excited to have monitoring features. However, experienced users declared that the desire to monitor energy usage did not continue after a while. The importance of environmental impacts divided the participant group. Half of the participants thought it was an important factor and the other half doubted if SHEMS would have any impact. Interest for new technologies acted as a driver for participants, who were ready to use their time and effort into optimizing their energy usage with new technologies. SHEMS was also seen as a safety factor as it could provide beneficial information through monitoring energy usage, temperatures, and humidity with the help of automation levelling the right settings. For the system provider, the users hoped the development and maintenance would be active and stable. Possible features in the future were hoped to be effortlessly integrated into the system like EV charging point and solar PV panel optimization. Social influence was a significant factor for the experienced users as many of the study's participants did not know anything about SHEMS before the provider of SHEMS introduced the service. However, new, and prospective users were not influenced by others. New users were more influenced by the public administrators as their hometown's administrators support towards SHEMS built trust among adopting SHEMS.

Tuomela et al. (2021) addressed eight different barriers for the adoption of SHEMS. A significant barrier was the lack of knowledge. Many of the new and prospective SHEMS users have not heard or did not know anything about SHEMS before an advertisement was published by the SHEMS provider. The users also estimated that the estimated return on investment was too low, and the price of the system was too high even with the project's 50% support bonus which was served to cover half of the expenses. The users were also sceptical on trusting the system provider as it was a small factor in the energy market and the sales pitch was considered unreliable. In addition, the reliability of the sales pitch did not improve, because when the study was conducted, the price of spot-price electricity was high, and the within-day variation of electricity price was low, and the promised savings were alleged to come from the within-day variation of electricity prices. The adopting of SHEMS also drew criticism from those who had already taken measures to improve their energy-saving lifestyle, as the SHEMS was criticized not to bring major savings in energy consumption after the lifestyle improvements. From a technical point of view, it was seen as a barrier that the technology was too complex and the SHEMS was still in the development phase. For some, it was too sophisticated and simpler systems were seen as cheaper and more user-friendly with the possibility for users to modify the system if needed. For others, it was not sophisticated enough, indicating that waiting for more mature systems would pay of better in the future. In addition, for some households retrofitting SHEMS would be a difficult and expensive project.

2.6 Energy prosumers

Prosumers can be seen as households that both consume and produce energy (Espe et al., 2018; Parag & Sovacool, 2016; Rathnayaka et al., 2015). Prosumers are key actors in the energy network as they are in a critical role in the early phases of developing smart grids, but also in the long term to ensure sustainable energy provision (Espe et al., 2018). As technology has evolved, more and more private households are investing in producing electricity at home. The technical and economic development of PVs has made household prosumption possible. In Western countries the growth rates of prosuming have varied significantly depending on the development pathway in each country. Different national policy drivers have an impact on the prosumer growth rate on private prosuming. Support schemes, direct regulatory provisions, information, and third-party installer markets determine the national prosumer growth rates. (Indeberg et al, 2018.)

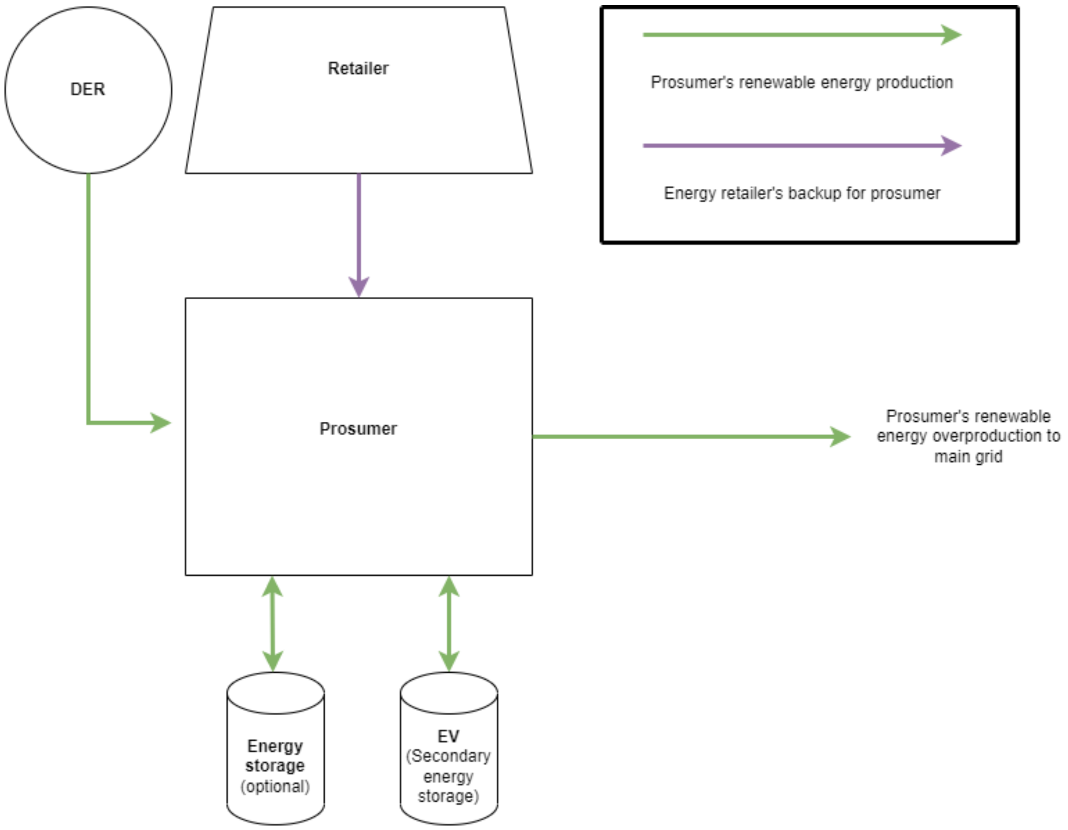

Figure 5. Prosumer's energy production flow based on the study of Alam et al. (2019).

Two possible directions for low-carbon energy system prosumers can be detected. The first one is completely autonomous production and consumption. The prosumers are off-grid and self-sufficient households. This direction is only possible for households that geographically, economically, and technically can install sufficient renewable capacity and energy storage. Also, smart-home or building-management technologies are needed. This passive prosumer segment will probably remain small because of the restricting and demanding requirements. (Parag & Sovacool, 2016.)

The second direction is seen as active prosumers being connected to a grid. These prosumers actively participate in the producing of energy services to the grid by supplementing or even competing with traditional utilities and energy organizations. Whichever direction is chosen, the goal is to save prosumers money, widen and secure energy production by diversifying energy supply, and to lower greenhouse gas emissions from the energy market and private transport. (Parag & Sovacool, 2016.)

Co-creation can be a strategy for bringing different parties together to achieve a mutually valued outcome (Prahalad & Ramaswamy, pp. 4-5, 2004). According to Kotilainen et al. (2016), there's three different types of co-creation roles for prosumers: the engineers, the green users, and the value seekers. The engineers' group is interested in new technologies and actively participate in innovating, testing, giving feedback, and even developing solutions. These do it yourself (DIY)-customers are driven by the dissatisfaction of existing products and services. The second group is the green users, who are interested in adopting sustainable solutions. The DIY-customers can also act in this prosumer group. The green users can actively promote the use of sustainable energy solutions and act as innovation sponsors and opinion leaders among peers. The value seekers are a group looking for benefits like lower costs, optimized use of resources, or better quality of life. This user group may contain more mass-market adapters than the other two groups as they rely on peer recommendations and discard risks. This group is also interested in the performance, quality, and security of a product or service. They may only recommend products or services if the solution meets their needs and involve for the co-creation if there is a possibility to have an impact in the business models or cost structures.

In Figure 5, prosumers' renewable energy production flow can be seen. The retailer's position is to provide backup energy for the prosumer. If the prosumer's consuming is more than the produce of energy from PVs, prosumer can utilize the retailer as backup energy. (Alam et al., 2019.) If prosumer is producing more energy than can be used, the surplus energy can be preserved to an optional energy storage system or to a secondary storage i.e., an EV. If there is still surplus energy or the prosumer does not have storage for surplus energy, the prosumer can sell the excess energy to other consumers or back to the main grid for the retailer. (Alam et al., 2019; Mahmood et al., 2017.) However, Zhang et al. (2017) remark that in many locations, it is more economical to storage the surplus energy rather than selling it to the grid because of high feed-in tariff reduction.

2.7 Energy consumers

Energy consumers are the passive group of the grid. They take and use the electricity from the grid, but they do not provide any goods or services to the grid. (Jacobs, 2016.) The goal for consumer's perspective is to have clean, safe, reliable, and affordable energy (Steg, Shwom & Dietz, 2018) but the energy market is underperforming for consumers as prices are increasing and the ease of switching and comparing offers between retailers do not occur (Andoura et al., 2010).

One way for consumers to decrease their energy consumption is the efficiency of energy-related products. In European energy consumption, these products are estimated to determine 25% of the total consumption and is the fastest-growing energy load. (Stasiuk & Maison, 2022.) Stasiuk and Maison (2022) also asked in their study about the consumers' knowledge of energy efficiency classes. 88% of the study's respondents declared that they pay attention to the energy labels.

Consumers can also change their energy behaviours for the transition to more sustainable energy consumption. To design successful sustainable energy programs and policies, it is important to understand the drivers behind sustainable energy behaviour which can be seen in Figure 6. Values, identity, beliefs, and norms are the individual factors. Access to information, financial circumstances, and social network connections are the features of context where individuals act. (Steg et al., 2018.)

The lack of information is one reason that causes consumers to not have skills for behaving effectively. The use of energy is invisible and the understanding of the impact of consumer's actions is limited. To change behaviour, consumers must be aware of the energy usage, and how to impact sustainability through changes. Consumers are underestimating the impact of bigger changes and overestimating the impact of little changes. Consumers' beliefs are made relative to a reference point, but the difference between the reference and other energy uses are misleading. (Steg et al., 2018.)

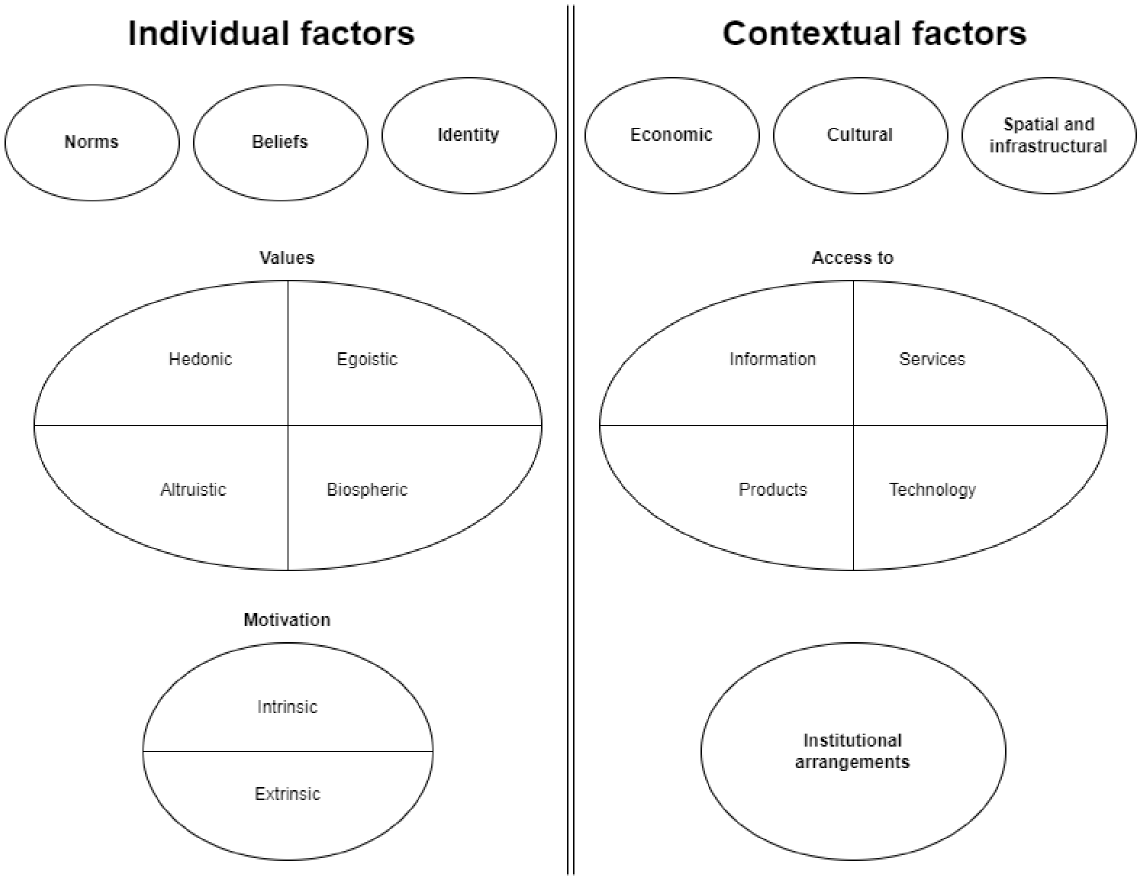

Figure 6. Summary of driving factors for consumers' sustainable energy behavior based on the text from Steg et al. (2018).

Even though knowledge is power, it is not the only driving factor. Motivational factors have a considerable role, especially one's personal values. Values can be described as the general goals that people work toward to in their lives. There are four different types of values to review in the context of sustainable energy behaviour that consumers around the world endorse in some extent. Hedonic values focus on matters that make people feel good and ways of reducing their efforts. Egoistic values aim for increasing person's resources, such as money or status. When focusing on the ways that benefit others, we are addressing altruistic values. Biospheric values are considered when focus is on consequences on nature and the environment. Individual consumers prioritize these values differently, resulting in different perceptions. The first two, hedonic and egoistic values, can work as a barrier for the transition to sustainable energy consumption if the outcome is more expensive and it increases personal effort. On the other hand, altruistic and biospheric values encourage the sustainable energy consumption. Changing these motivators is difficult. (Steg et al., 2018.)

Steg et al. (2018) mention also other factors like personal identity and prices that influence energy behaviours and the choice of the source of energy. When acting sustainably, consumer can see himself as a consumer who acts pro-environmentally encouraging and motivating him to repeat the act and have positive feedback for himself. This can be an important aspect in the transition to sustainable energy systems. Prices, on the other hand, can encourage or discourage the transition to renewable energy, depending on whether the adoption is too expensive. Inexpensive energy from unsustainable sources can also discourage the economical need to change energy behaviour. (Steg et al., 2018.) But often the prices of energy can be seen as a bonus for the consumer. There are more vital drivers such as environmental and moral factors that aim to protect the environment and the quality of life for current and future generations. (Schultz, 2014; Steg et al., 2018; Wilson & Dowlatabadi, 2007.)

Motivation can be seen as intrinsic and extrinsic motivation. The intrinsic motivation comes from within the individual and is driven by internal rewards, satisfaction, and fulfilment. Acting morally and doing good gives them positive feelings that lead to intrinsic rewards. Extrinsic motivation is the opposite, which is driven by external rewards, such as financial outcomes. (Steg et al., 2018.) Intrinsic motivation can be self-sustaining and long lasting whereas extrinsic motivation is not a solid foundation for sustainable energy behaviour (Handgraaf et al., 2013; Seaver & Patterson, 1976; Steg et al., 2018). If the motivation comes from social norms or rules, consumers might be socially rewarded or sanctioned. Behaviours that can be highly visible, like driving an electric vehicle or installing residential solar, are more likely to be socially rewarded. Less visible behaviour in households by consumers, like installing an efficient air-conditioner, will more likely not be rewarded. The importance of encouraging intrinsic motivation without external pressure should not be over-seen. Programs, systems, and policies should be designed so that they engage both intrinsic and extrinsic motivation. (Steg et al., 2018.)

Consumers' decision-making is not always determined by the costs and benefits of their actions. Consumers are also acting habitually without making a conscious decision, using quick cognitive shortcuts. This is happening because consumers can not consider all the possible costs and benefits of every action. If habits are formed, changing the habits require more effort and pointing indications. Creating the opportunity and information for reflection and active decision-making is crucial. (Steg et al., 2018.) Prior research show it is possible to increase sustainable energy behaviour by targeting energy-related practices with defaults with opt-out options rather than with opt-in options. This way sustainable behaviour is settled as default and do not need active conscious participation and decision-making to act sustainable. (Brennan, 2006; Hartman et al., 1991; Pichert & Katsikopoulos, 2008; Todd et al., 2013.) For example, the default program of a washing machine is set to short cycle (McCalley, 2006).

Contextual factors consist of cultural, spatial and infrastructural, and economic factors. It also includes institutional arrangements and access to services, products, technology, and information. For instance, solar panels can be easy to install on some households but might not work on every household. There can also be possible income tax rebates when installing solar panels that can ease the financial cost for some, but for low-income households the initial installation price can be too overwhelming, leading to the rejection of the project due to being financially unable to wait for the rebates. (Steg et al., 2018.)

Having these contextual factors like different policies, can encourage consumers to focus on the consequences of their choices. The nature of the policies' can be described as pull or push measures. Pull measures are rewarding or facilitating policies where push measures are punishing or inhibiting measures. The negative side of push measures is the possibility of public resistance. The change to consumer's energy behaviour is done voluntary when giving consumers carrots instead of sticks. (Steg et al., 2018.)

Information plays a significant role in intrinsic motivation. Providing information or feedback from a trusted source at a time and place close to decision-making is effective in impacting the consumer's behaviour and decisions. (Craig & McCann, 1978; Steg et al., 2018.) It assists in addressing the false beliefs and habits in order to decrease costs and benefit the consumer. It can also be helpful to have the possibility to compare one's behaviour to others' through feedback and information about the behaviour of others. This can be linked to the human desire to be consistent and receive information and feedback on a regular basis. Consumers are more likely to accept the information if it is compatible with their core values and existing beliefs. Tailored approaches work better. With the help of technology, the outcome can be personalized to serve a wide range of different consumer segments. (Steg et al., 2018.) However, the provided information cannot be overwhelming for average consumers. The content should be straightforward and limited so that it can be quickly and effortlessly understood and interacted with. (Iyengar & Lepper, 2000; Wilson & Dowlatabadi, 2007.) Having highly convoluted information and content increases cognitive overload, which often leads to less intrinsically motivating outcome, and people may even perform better in a limited-choice context (Iyengar & Lepper, 2000; Sethi-Iyengar et al., 2004) as people rely on simple heuristics in complex and uncertain decision-making situations (Osbaldiston & Schott, 2012; Shultz, 2014; Steg & Vlek, 2009).

3. Research methods

This chapter presents the research methods used in this thesis. First, qualitative research is reviewed and described through existing literature. Next, participant selection and data collection process are explained. Last, the analysis techniques for the collected data are explained.

3.1 Qualitative research

The integration of qualitative research and information systems (IS) is a relatively new phenomenon. For long, the importance of qualitative research in IS was ignored or even seen unscientific compared to quantitative research. From the 90's, the acceptance for qualitative research for IS has increased. Qualitative research can serve as a medium in developing scholarly knowledge for IS for explaining how individuals, groups, communities, organizations, nations, and the society can deploy computer technology to serve humanity. (Lee & Liebenau, 1997).

Qualitative research has multiple definitions and meanings to different people (Garcia & Quek, p. 451, 1997). Qualitative research offers a different perspective on human interaction and behaviour compared to quantitative research. Quantitative methods aim for discovering an objective truth from the outside world which can be found with measuring relationships between different variables systematically and statistically. The validation of measurements is reviewed by reliable, valid, and generalizable predictions of cause and effect. (Spielberg, 1972.) In comparison, in qualitative research, no clear-cut objectivity or reality is present. The approach is constructive, emerging from phenomenology and interpretative paradigms. The study process is modified by the intimate relationship between researcher and the studied target and the situational constraints for this socially constructed nature of reality. (Glaser & Strauss, 1999.) Qualitative methods are not concerned with examining the meanings of the study by quantity, amount, intensity, or frequency (Garcia & Quek, 1997). Rather than merely having mathematical means to experiment data, qualitative methods lean on other aspects, most important one being the power of scientific explanation (Grönfors, 1982).

Grönfors (1982) states that in some contexts qualitative methods are described as "soft" methods and quantitative methods as "hard" methods. Grönfors does not recommend using this terminology because it can reduce the value of qualitative research methods with implicit assumption of qualitative research having less scientific research methods.

As seen in the summary defining the differences between quantitative and qualitative research in Figure 7, the actual difference between qualitative and quantitative methods is primarily in the methods used to indicate the power of scientific explanation. When defining the scientific reliability of the study, qualitative methods are reviewed by the acquisition of the data because the data collection is seen problematic. The aim is to prove that the data collection process and environment is scientifically accepted. On the other hand, quantitative methods rely on measurement theory and mathematical methods to determine scientific reliability. (Grönfors, 1982.)

It is not always possible to achieve reliable results with quantitative methods. The more sensitive, personal, or intimate subject is studied, the results' unreliability will increase when using surveys, leading to the results landing short and having more of an ideal situation, rather than a realistic situation. To study the mentioned subjects, qualitative methods are needed for more profound and more reliable results. Qualitative methods offer means for understanding social relationships, cultural factors, descriptions of processes, descriptions of communities, behaviour, and participants' frame of reference. To prevent one-sided technocratic solutions, qualitative methods offer tools/means for considering the human existence, feelings, needs, and emotions as a part of the solution. (Grönfors, 1982.)

Qualitative research gives better abilities for participants to get involved in the research process. The more the participants with multicultural backgrounds are involved with the research process, the more significant results are possible to achieve when justifying the research. Especially this is problematic when the studies are performed by the majority and the minority's voice is not heard. To have a successful research, researchers have ethical responsibilities regarding participants' conditions, backgrounds, and issues to be noticed in a discreet and sympathetic posture. (Grönfors, 1982.)

Researcher is the key research instrument in qualitative research because they play a major role in the data collection process. The researcher's skills are being measured when they are in personal contact with the participants. In quantitative research, the eyes are more on the researcher's abilities to create credible forms or surveys and in the data analysis. (Grönfors, 1982.)

Unlike quantitative researchers, qualitative researcher attempts to keep the question layout as open as possible and to avoid presumptions (Grönfors, 1982). This enables to avoid premature closure of potential research areas. On the other hand, quantitative researcher evolves with a theory-based hypothesis which is then tested. (Bryman, 1988.) A qualitative researcher often bases her research on inductive logic, unlike a quantitative researcher bases her research on deductive logic (Grönfors, 1982).

Another difference between the quantitative and qualitative method is the different assumptions for objectivity and subjectivity. Although it is almost impossible to have a completely objective study, the researchers of quantitative methods follow the objective line of research. The goal is to have a study which is independent from the used research methods and from the researcher itself. The researchers often behave as if an objective truth could be constructed. On the contrary, the qualitative researchers recognize the value of subjectivity in increasing the scientific explanatory power. Qualitative research cannot be objective because the researcher is the key research instrument in the study process. It is important to express the researcher's frame of reference in the study to enable audiences the possibility to examine the research and notice the framework from which the data have been collected. (Grönfors, 1982.)

Quantitative and qualitative methods are not competing. They can often be seen as complementary methods which emphasize different matters. In some cases, both methods are needed to answer the research question, or one method is used to get to the next part of the study to use the second. For example, first qualitative methods are used to gather data to understand a phenomenon and limit the research. Then, quantitative methods are used to answer a hypothesis which has been constructed based on the results from the first part of the study. (Grönfors, 1982.)

It is deficient for a researcher to acquire only scientific skills when conducting qualitative research. The researcher should also have personal and social skills to work with people. Natural behavior in every situation, open, warm, and participatory interest towards people and their issues, understanding different groups of people, and ability to listen are the abilities that a qualitative researcher needs for performing a successful study. (Grönfors, 1982.)

Qualitative research	Quantitative research
Subjective	Objective
Inductive logic	Deductive logic
Data collection through participants	Data collection through measurement
Researcher as key instrument	Inanimate instruments
Understand human behavior from participant's perspective	Discover and prove facts

Figure 7. Summary of qualitative and quantitative research differences based on the text of Grönfors (1982).

The motivation for choosing qualitative research methods instead of quantitative research methods for this study stems from the aspiration to understand participant's behavior and their set of values. Thoughtful comprehension of participant's living environments and their energy behavior linked to energy community based on IS, can give valuable additional information and framework for future research and software development. Smart grids, DERs, and local energy communities are the revolution of the electric grid in the same way the invention of the Internet was for communication and interaction between different parties. The future of the smart grid is not carved in stone. To avoid wrong underlying assumptions about what smart grids and local energy communities should have for prosumers and why, an open-minded approach is needed to successfully develop meaningful and accepted information systems. The lack of study concerning prosumers would have made it problematic to design a quantitative research without making radical assumptions for creating a reliable hypothesis.

3.2 Qualitative interviews

Qualitative research interview (QRI) is the most common data collection tool used by qualitative researchers. At the same time, it is also one of the most important one. (Myers & Newman, 2006.) The types of interviews conducted by researchers vary notably (Fontana & Frey, 2000). One way to define the interview is by the participants. Individual interviews have one participant and one or more interviewers. Group interviews have at least two participants and one or more interviewers. (Myers & Newman, 2006.)

Another way to define the type of interview is the structure. There can be structured, semi-structured, or unstructured interviews. Structured interviews have a complete script from beginning to end that is created before the interview and cannot be differed from at or between interviews. There is also no need for the researcher and participant to be in touch to perform the interview. (Myers & Newman, 2006.) Structured interview is useful for quantitative research because it produces quantitative data (DiCicco-Bloom & Crabtree, 2006). For qualitative research, more contributive types of interviews are unstructured and semi-structured interviews. Unstructured interviews are the opposite for structured interviews. (Blackman & Funder, 2002.) There is no interview that can be completely unstructured, but some are relatively unstructured, and the control of the conversation is limited to minimum (DiCicco-Bloom & Crabtree, 2006). The script of the interview is incomplete and there is space for improvisation (Myers & Newman, 2006). Blackman & Funder (2002) state that more accurate and better-quality information is gained through unstructured interviews compared to structured interviews. They also state that face-to-face interviews offer more useful information than interviews through telephones. Semi-structured interviews are something between the two above. The interview is structured around predetermined open-ended questions and other questions can be used to continue dialog between interviewer and interviewee. Semi-structured interviews are the most preferred interview type and usually are the main source of data in a research project. Usually, it is conducted once per interviewee or group and lasts from 30 minutes to several hours. (DiCicco-Bloom & Crabtree, 2006). The focus on this thesis is on semi-structured interviews.

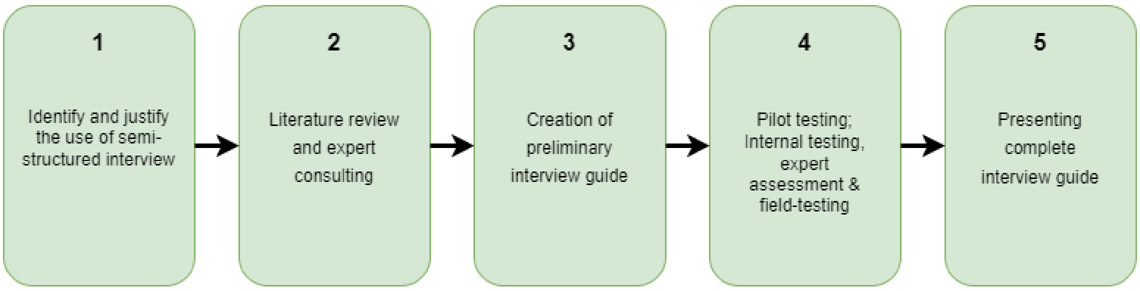

Figure 8. Kallio et al. (2016) five-phased framework for the creation of qualitative semi-structured interview guide.

One of the paramount factors in receiving plausible results from qualitative semi-structured interviews is to have a well-prepared interview guide. Kallio et al. (2016) present a framework where the creation of the interview guide can be divided to five phases. Each phase provides useful information that is needed to proceed to the next phase (see Figure 8). The first phase is to identify the prerequisites for using semi-structured interviews. The goal in this phase is to evaluate the suitability of a semi-structured interview as a proper data collection method in relation to the chosen research question. In brief, it should be asked if the research question could be answered with having a semi-structured interview. The second phase is to explore previous knowledge about the topic. This can be done with a literature review or by consulting the knowledge of experts in the subject. (Kallio et al., 2016.)

The third phase involves the creation of preliminary interview guide based on the earlier phases. Creating a practical interview guide consist of multiple challenges such as balancing theme and follow-up questions, avoiding influencing the participant's answers, and ethical aspects. The fourth phase is pilot testing the preliminary interview guide. Diverse feedback can be collected when employing multiple pilot testing forms. Three useful techniques are internal testing, expert assessment, and field-testing. Internal testing is done by consulting the supervisor of the research. Expert assessment uses outside specialists to review the guide. Field-testing is a technique where the preliminary interview guide is tested with potential study participants. The guide is modified by the feedback before moving to next phase. The fifth and last phase is to present the complete interview guide in the study paper. The goal is to produce a polished and logical interview guide which is used for data collection in the study. In addition, it provides the opportunity for other researchers to utilize the interview guide in their studies. (Kallio et al., 2016.)

3.3 Participant selection and semi-structured interviews

The participants of this study were volunteers who informed their willingness to participate in the additional phone interview in a previous survey concerning energy communities. It suggests that the participants might have a higher interest towards energy communities and might be more likely to join a potential energy community. The invite to participate in the interview in the survey did not require owning a PV panel. The possibility for a more comprehensive participant pool is justified based on Grönfors (1972) claims that versatile participant pool provides more plausible results even though Rossiter and Brathwaite (2013) had a conclusion that the acceptance of a new technology differs substantially between actual and potential users.

Before proceeding to interviews, the interview guide was created. Kallio's et al. (2016) five-phased framework, which can be seen in Figure 8, was followed. The preliminary research questions were created. After discussion with experts, it was decided that the use of semi-structured interviews could answer the potential research questions. Next, existing knowledge and studies were explored to understand the topic and to see what has already been studied about energy communities. The literature review was light because the target was to have an open-minded starting point when conducting the interviews. When enough information was obtained, the next phase was the creation of preliminary interview guide. The interview guide did not only include questions about this study. Two questions out of eight were made to collect data for this thesis. The next phase was the pilot testing. First, questions were judged with the supervisors of this thesis. Then, experts outside the study were consulted. The last step of pilot testing was field-testing. Three different test participants were involved in the field-testing. No major editing needed to be done. Lastly, the next phase of Kallio et al. (2016) framework was followed, and the complete interview guide can be seen in Appendix A. The complete data collection process can be seen in Figure 9.

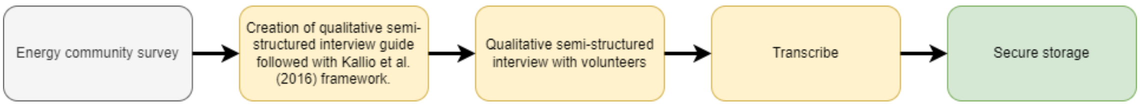

Figure 9. Complete data collection process.

Questions six and seven were used in this thesis. The questions used were:

- One of the visions for the likely future would be for the energy community to link to the information system through people's personal hardware and software, such as a smartphone app or a computer web browser. After all, one of the aims of the study is to map out what would motivate people to use this information system. What kind of features should such an information system have to involve you in the use of the information system, and why?
- What kind of features would you not want to have in that information system?

The interviews were performed in year 2020 between May to August. The preferred language was Finnish, and the participants were from Finland. The average interview lasted 13 minutes, the shortest were 5 minutes, and the longest 32 minutes. The interviews were mainly scheduled outside office hours. The interviews were telephone interviews, and they were audio recorded with an additional tablet. The recordings were transcribed and securely stored. For this thesis, questions six and seven, that can be seen in Appendix A, contribute to this study. More information about participants' background can be seen in section 4.1.

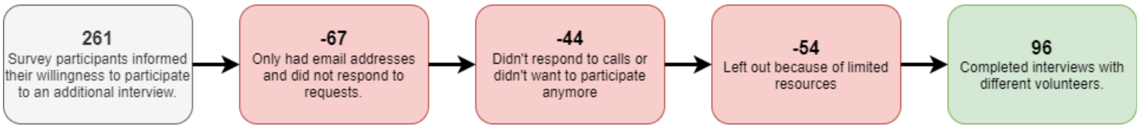

Figure 10. Participant flow.

As seen in Figure 10, not all volunteers were interviewed. Sixty-seven volunteers only provided their email address and did not respond to email requests of sending their phone number. Forty-four volunteers did not respond to calls or did not want to participate anymore. Fifty-four volunteers were left out because of limited resources. Eventually, 96 interviews were completed with the volunteers.

3.4 Thematic analysis

Thematic analysis (TA) is a popular, flexible, and accessible method for qualitative data analysis. TA is used to systematically identify, organize, and have a closer look for patterns of meaning, also called themes, over a data set. The purpose of TA is not only to find common but also meaningful patterns towards the research question. (Braun & Clarke, 2012.)

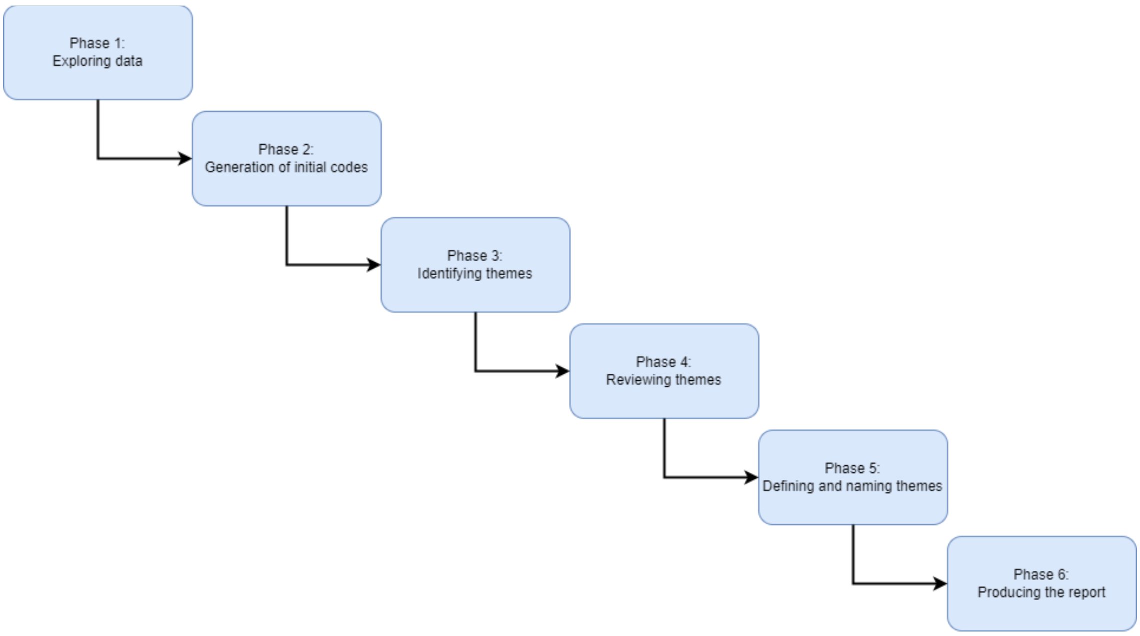

Figure 11. Six-phased framework for thematic analysis process by Braun & Clarke (2006).

Braun and Clarke (2006) introduce a six-phased step-by-step guide of the process of TA. The six different phases can be seen in Figure 11. The first phase is exploring the data. This ensures to have the knowledge of data's depth and breadth. It can be done by reading and re-reading transcripts or notes, listening to audio recordings, and making key notes from the data. This should be an active part for finding meanings and patterns. The second phase consist of the generation of initial codes. Codes in TA are features of the data that might be interesting and meaningful. These codes are potential themes or patterns that can be utilized on later phases. The third phase is to identify themes. In this phase, the list of codes is divided under themes that are created from the codes. The codes are located under main themes, sub-themes, or even discarded.

The fourth phase is to review the created preliminary themes. In this phase, themes which hold up against supportive data are kept where others are discarded or modified. This phase has two levels of reviewing. The first level is done on the level of coded data extracts. For this level, every code under the selected theme is reviewed. If invalid codes are found, decisions need to be made regarding either the problematic code or the theme itself. The problematic codes or themes can be located under a different theme, new theme, or discarded completely. The second level of this phase is the same process as in the first level, but it is done to the whole data set. The validations of the themes are reviewed against the data collection to see if they are plausible. In this phase, it is also recommendable to re-read the entire data collection to see if additions can be added. A preliminary thematic map or maps can be used to describe the summary of themes and sub-themes to easily see the relation and contents for validation. (Braun & Clarke, 2006.)

In the fifth phase, the final defining and naming of themes is conducted. The purpose of this phase is to go through each theme and sub-theme with a critical mindset. Themes should be as simple as possible, avoiding complex themes that seal in diverse data. For every theme, a detailed analysis is written, and it is compared to the main story of the analysis. Additional consideration for the naming of the themes is important, as it must be clear to the reader what is meant. The sixth and final phase is the written thematic analysis. The complete and complicated story should be more than a description of data. The analysis should convince the reader within and across themes with arguments in relation to research question. (Braun & Clarke, 2006.)

3.5 Analysis process

The six-phased framework for thematic analysis process created by Braun and Clarke (2006) was followed with little modifications throughout the analysis process. However, the paper presenting the framework (Braun & Clarke, 2006) did not include the ongoing literature review that followed throughout the whole process for this thesis. Literature review served as a medium in reviewing the identified themes and sub-themes., especially in phase 4. Also, the process was more iterative than linear. Figure 12 provides the complete illustration of the process.

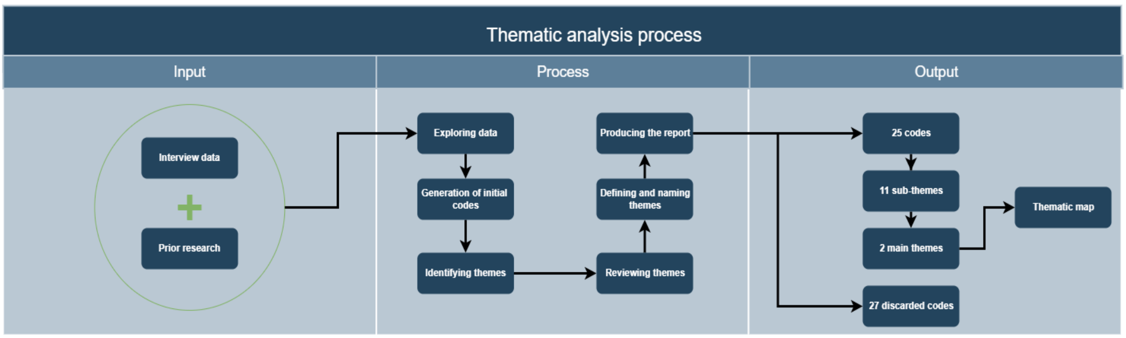

Figure 12. Thematic analysis process.

In addition to the participants background information, only questions six and seven in the interview guide were involved and studied in this thesis. The interview guide can be seen in Appendix A. The transcripts were read multiple times throughout the process of writing this thesis to serve as a reminder and guidance. In the end of phase three, 25 different codes were identified from the data set. The list of the codes was then divided into two different main themes. The two main themes which were identified were advantages and disadvantages. After reviewing the themes and codes involved to each other, sub-themes were identified. The discovered sub-themes were beneficial information, monitoring, desired functionalities, positive user experience, economical, user interface, negative user experience, data leaks, undesired functionalities, and energy community.

Last part was defining and naming the different themes and sub-themes. Few codes and themes were discarded due to lack of plausibility which can be seen in section 4.2. The discarded codes can be seen in Appendix C. The developed thematic map can be seen in section 4.2. The last part of the process was writing stories for every theme.

4. Findings

Chapter 4 introduces the findings of the study. First, participants' background information is summarized. Next, the thematic analysis is presented through three sections. Section 4.2 contains the thematic map created from the themes. In section 4.3, the discovered sub-themes of the theme advantages are introduced and explained. Lastly, in section 4.4, the sub-themes under the main theme disadvantages are introduced.

4.1 Participants' background information

As seen from Figure 13, 86 out of 96 participants were men (90%) and 10 were women (10%). 60 participants owned a PV solar panel (62%) and 36 did not (38%) but had some interest towards having one. 46 were retired (48%) and the rest 50 participants were employed (52%).

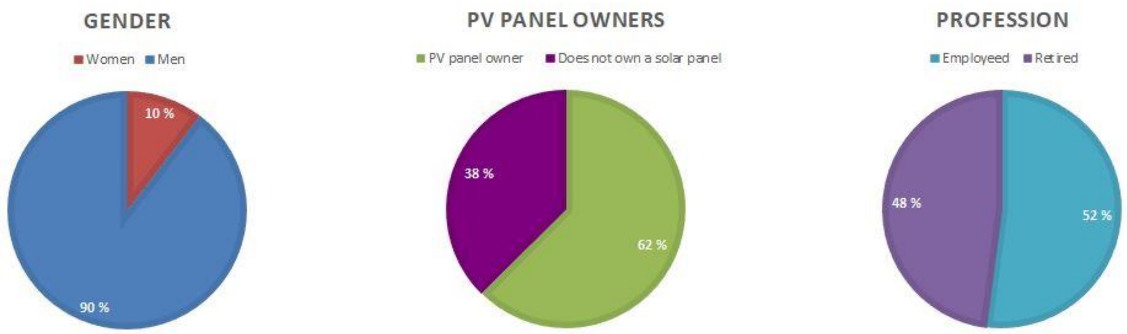

Figure 13. Charts of participants' genders, PV panel ownerships, and professions.

The youngest participant was 34 years old and the oldest was 82 years old. The average age of the participants was 60 years. As seen in Figure 14, 5 (5%) participants were between 34-40 years old, 13 (14%) between 41-50 years old, 17 (18%) between 51-60 years old, 33 (34%) between 61-70, 27 (28%) between 71-80, and 1 (1%) was over 80 years old.

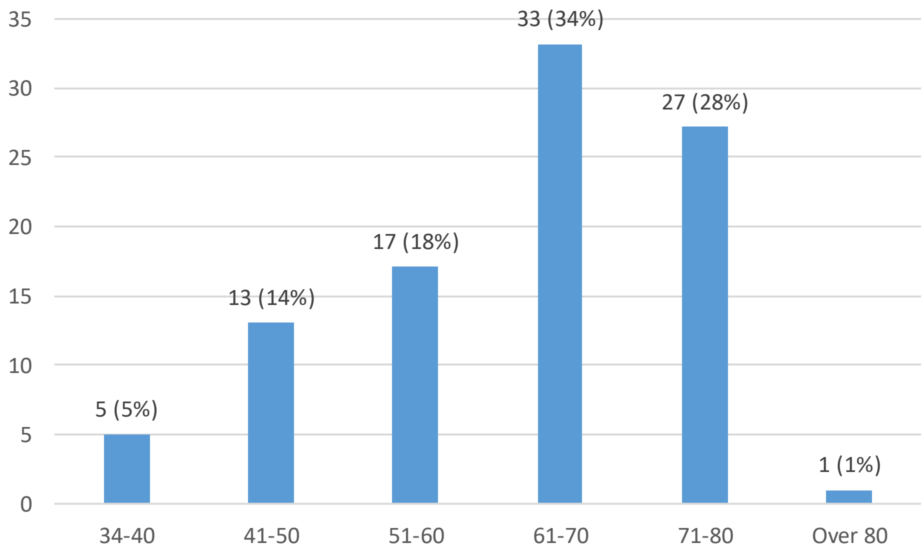

Figure 14. Distribution by age groups.

In Figure 15 the distribution of the number of inhabitants in the household shows 58 out of 96 participants (61%) lived in a household with someone else. Fifteen participants (16%) lived by themselves. Nine participants (9%) told they had 3 inhabitants in the household, 7 (7%) had 4 inhabitants, six (6%) had 5 inhabitants, and one participant (1%) had seven inhabitants in the household. None of the participants had six or over seven people living under the same roof.

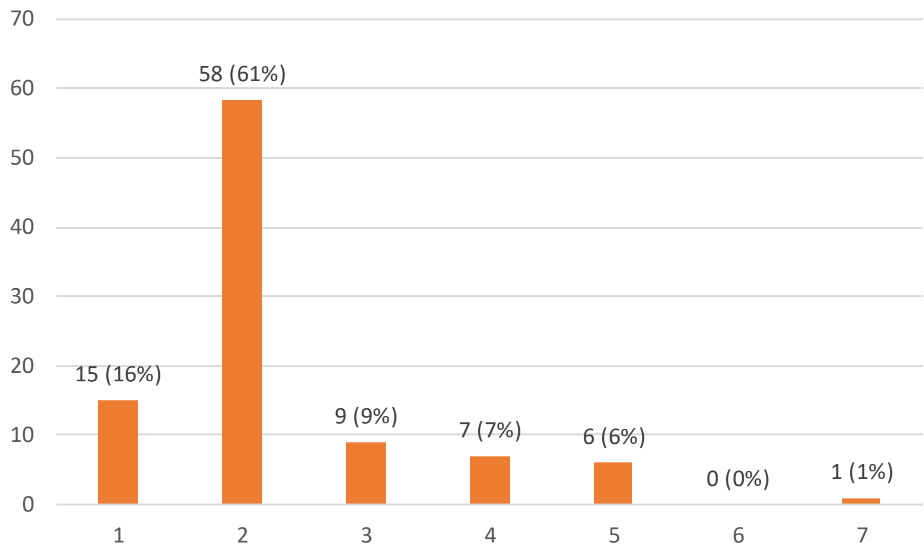

Figure 15. Bar chart of the number of inhabitants in the household.

Ninety (94%) participants had a detached house as a form of housing. The remaining participants reported living in a farmhouse (1%), an apartment house–(3%), a semi-detached house (1%), or a terraced house (1%).

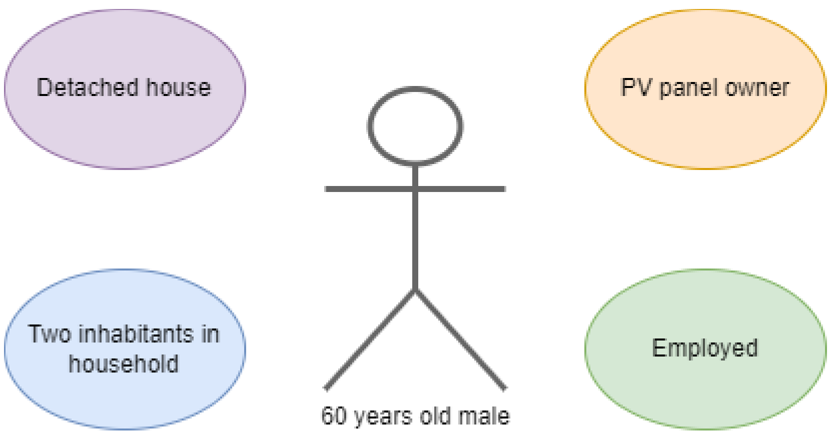

Figure 16. A general participant profile.

As seen in Figure 16, general participant was around 60-year-old employed Finnish speaking male, who lived in a detached house with one other person and owned a PV panel.

4.2 Thematic map

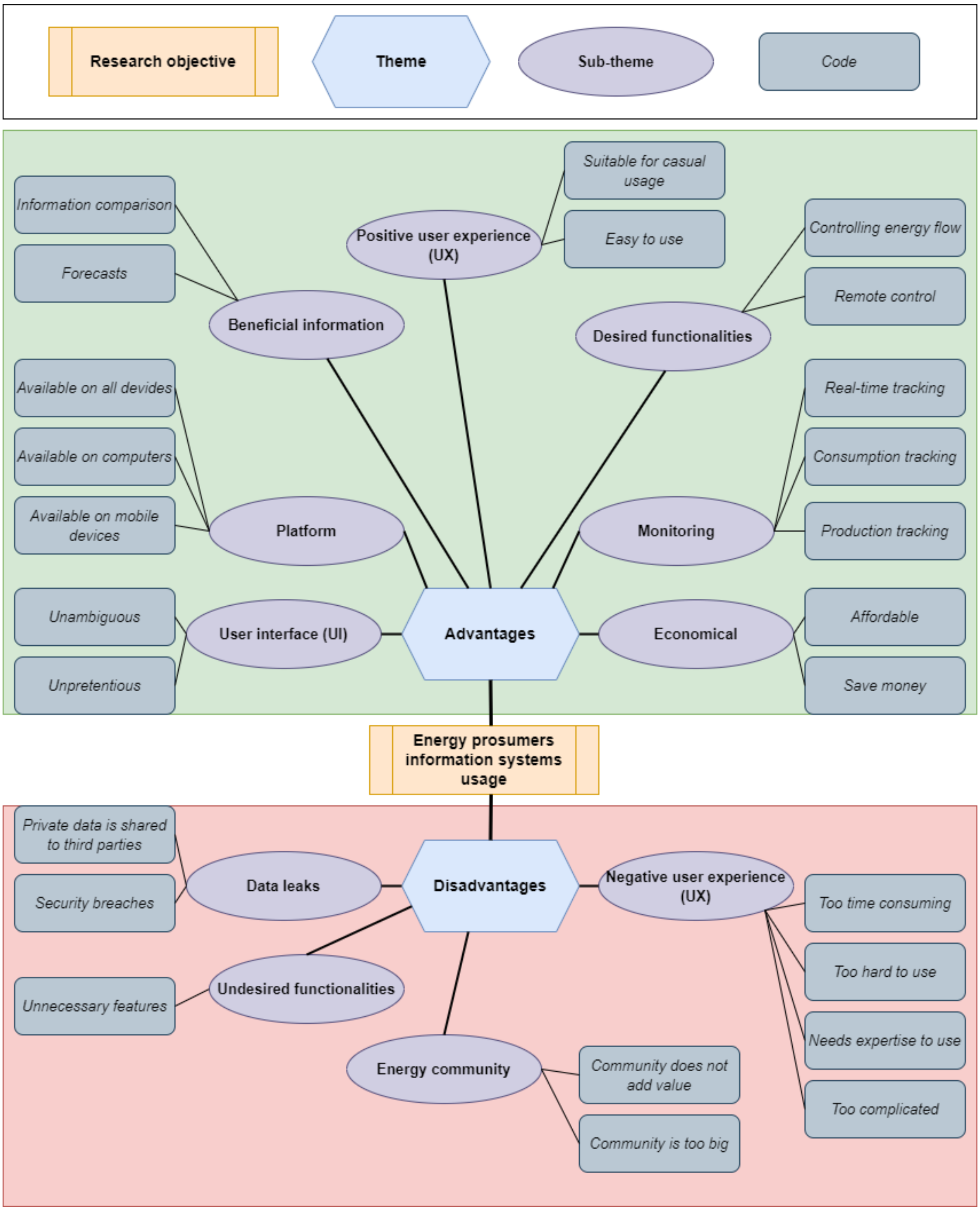

Figure 17. Thematic map

The Figure 17 presents the graphical summary of the findings. A total of 2 themes, 11 sub-themes, and 25 codes were included in the final thematic map. The theme *advantages* is on the green background on the top part of the figure. The final presentation of theme advantages includes seven sub-themes and 16 codes. A more comprehensive description of the linked sub-themes and codes can be found in the next section. On the red background on the low part of the figure, the theme *disadvantages* is summarised. In the final thematic map, four sub-themes and nine codes were justified under the theme disadvantages. The explanation of these sub-themes and codes is in section 4.4. The sub-themes and codes correspond to categories and features respectively of the information system for energy community.

The collected data contained almost 12 000 words. A total of 52 codes were identified but 27 codes were discarded. The data that were collected from question six were more fruitful than the data that were collected from the responses to question seven. That is why discarding codes followed different rules. Advantageous features were removed from the analysis if they appeared in the data only once or twice. If it appeared three to four times, the data was evaluated to see if there was enough qualitative data to be analysed. When the feature was discovered five or more times, it was automatically involved. The codes derived from the responses to question seven were automatically discarded if they only appeared once. Other codes were reviewed and included in the thematic map if enough qualitative data occurred, and it was not *in repetition* of a response to question six. Discarded codes can be seen in Appendix C.

4.3 Advantages

The theme *advantages* include sub-themes and codes that were discovered from the interview data regarding participants' descriptions on advantageous aspects of the energy community's information system. The data is mostly gathered from the responses to question six (see Appendix A). A total of 16 advantageous features were involved in the final thematic map (see Figure 17). Codes representing features that only appeared three or less times in the data were discarded.

In the following, the seven categories of features identified in the advantages theme are described, namely, graphical user interface, positive user experience, platform, beneficial information, desired functionalities, monitoring, and economical.

4.3.1 Graphical user interface

Graphical user interfaces (GUIs) are tools for presenting information which allows users to interact with devices (Toby, 2001). A total of six features were discovered and two of them are included for further review for the category *graphical user interface*.

Unambiguous was mentioned in 13 different answers. A 47-year-old man owning a panel, living by himself in a detached house commented: *"Rather have unambiguous interfaces than small [expletive deleted] pixels so that it's easy to see from the tablet screen what is the situation of the community." [P1]* Shorter statements from few participants were also mentioned, such as: *"It needs to be unambiguous for sure." [P212]* The graphical presentation was also mentioned: *"There should be an unambiguous presentation of the flow of energy about how it comes and goes". [P225]* Regarding the buttons, a 71-year-old man said: *"Unambiguous application, it should almost just work with pressing a button." [P144]*

Unpretentious was found 12 times in the data. Participant 143 said: *"Interface needs to be very simple. With one easy look you should be able to see the community benefits."* A 41-year-old man without a panel added in a compact statement: *"Well, maybe it's all about the unpretentiousness." [P233]* Participant 1 continued along the same line: *"No random stuff. Just as unpretentious as it can be."* For the basic view, participant 27 stated: *"The basic view should be… and unpretentious. Nobody will have the energy to explore it more precisely." [P27]* A 65-year-old retired woman owning a PV panel said: *"As unpretentious as possible, I hate all devices. Nowadays everything is digitalized and there are all these buttons and keys, and you must have passwords ~~to~~ everywhere. It's made so complicated." [P42]* A 65-year-old man stated: *"Yeah, of course I guess that the starting* *point would be that it's as unpretentious as possible." [94]* One participant described the potential implementation as: *"It must be unpretentious so that you just open and see that, okey, I have my batteries full and 30% of it has been transferred to someone and it benefited me this much." [P144]*

4.3.2 Positive user experience

ISO 9241-1 10:2010, clause 2.15, describes user experience (UX) as: *"a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service"*. Under the category of *positive user experience* eight features were discovered. Two features are chosen for further study.

Easy to use had 20 mentions across data. A 72-year-old female described it as: *"First thing. Definitely, easy to use, dummy safe. So that it does not need much. I have this new phone and for ~~the~~ six weeks, I have been struggling with it. Until now, it's not working even though I paid 30 euros so that they will put my stuff from my old phone to this phone. And this should have been easy. With big letters, EASY TO USE. Whatever software or equivalent which a normal person is conducting, it's the most important. It's of course another thing who will define "easy to use"***.** *If it's handed to the younger generations, I will suspect that a grandma like me would disagree. So, if these kinds of software are developed, it should definitely be tested by really old people if they want them to answer." [P4]* One participant stated that it is not about the IS as: *"Well, the information system is not the purpose, but I guess it should be easy to use. I can't say anything else that would get me excited." [P21]* A 48-year-old woman without a PV panel said: *"Well, first and foremost it should be easy to use. Understandable, it would be easily opened. It's just to press open and it could be looked and explored. At least now, if I want to see how I've consumed electricity, logging in must be done through many bends resulting to not look for the consumption, what's consumed and when." [P99]* Participant 77 highlighted: *"Well, at first, very easy to use because I'm not very keen on working with computers. I will check my electricity company's website for the consumption on electricity. It's pretty straightforward. Easy to use would be it." [P77]* Rest of the mentions were shorter statements that the essential factor for them is the easiness of the system.

The second feature that was repeated in the data was **suitable for casual usage**. It was discovered four times in the data. A 51-year-old man gave a short description as: *"Such that it doesn't require continuous use or learning." [P213]* A 66-year-old woman saw a difference between younger and older people stating: *"In order for people to be interested, people who have…say twenties, living online can't afford to buy those solar panels. But we 50 to 60 pros, we can afford to buy them, but we don't have the enthusiasm to play around with their systems and their applications. That's why they need to be done well enough for that service to work. So that it doesn't mean I have to study to be an electrical engineer to get that service to work or as a computer engineer." [P237]* One participant thought it should be suitable for casual but also offer advanced features for advanced users as: *"Of course, the more you are familiar with information technology and its utilization, the more you will benefit from it, but you will have all the basic elements such as consumption and price monitoring, etc. You will get the basic information about it in an understandable form and tips about how consumption could change and how you would benefit yourself, financially, for example. The basics in an understandable format, but if you want to, it can be followed more closely and go deeper." [P94]*

4.3.3 Platform

The term *platform* in this context is used for a generic category that holds all advantageous mentions about electrical devices and software environments throughout the data. Five features were discovered. The features *cloud service* and *wireless* were left out, and the features available on mobile devices, available on computers, and available on all devices are observed.

For the feature **available on mobile devices**, 17 mentions were discovered. A 38-year-old man said: *"Well, of course mobile application is one terribly good factor, so you don't need a desktop as well." [P96]* Participant 142 shared his consideration of desktop usage in working life: *"There are multiple things that come to mind, because I've been pushed to work with technology in multiple levels. I work as a teacher but also in a recording studio and with releasing records and the work consist of a lot of work with the computer and from that perspective, I consider a lot about what data I want to see and in what format. Maybe a mobile environment would be how I would use it even though desktops are not disappearing anywhere. But if you think about it, so that I would monitor it on a daily basis, it must be on mobile devices."* A 71-year-old man pondered the rapid growth of mobile devices as: *"Well, nowadays mobile devices are everywhere, but as you get older, your vision deteriorates to fumble with the devices. On the other hand, same actions can be achieved with mobile devices as with desktops. So now I should be a nerd. It must be a mobile application; nowadays mobile devices are desktops. Mobile application it can be, but for older people the text is too small." [P144]* A 65-year-old man had the same thought as: *"Nowadays all these are used on mobile devices." [P146]* Participant 153 predicted that the usage would increase if it was available on mobile devices as: *"If there was an information system, I guess I would use it more often if it was available on smart phones or tablets."* Participant 217 had the same idea: *"Application on smart phone is much better than using it with a desktop. I would not keep on track the same way than with my phone."* A 69-year-old man said it as: *"Mobile application would be good when everyone has a phone in their pocket so you could check it from there." [P254]*

However, eight participants saw it differently demanding desktop as the main platform. The feature **available on computers** had 5 mentions in the data. A 66-year-old female stated as: *"It should be somehow cloud based and it must be available on desktops." [P237]* A 67-year-old woman had the same idea saying: *"Well, at least I use computer to keep on track for everything so computer would be good for that. Also, I like that the screen is bigger than it is with mobile phones. It's more comfortable to read from a bigger screen." [P226]* Participant 218 reviewed his own previous usage as: *"I'm not used to working with mobile phones. I prefer screens, otherwise I should have my glasses with me all the time. Maybe computer is still…if you need software for remote control. I have a service for the panels, where you see your consumption information and history and watching it is more comfortable on a big screen." [P218]* A 70-year-old man agreed as: *"Through a website. I can't use smart phones as well. Through a website it would be most natural for me." [P151]* Participant 198 shortly stated: *"Well it would be best through a desktop to have the software."*

Six of the participants mentioned that it should be **available on all devices**. A 55-year-old man pondered about the availability as: *"Maybe it could be available both on desktops and mobile devices." [P153]* A 75-year-old female added it should be available at all times as: *"Available on all devices and at all times." [P82]* A 63-year-old man reflected his experiences as: *"When you asked my age at the beginning. Easy to use as if it's only on mobile phones it's problematic for people with bad eyesight. It could be both so that you could also use desktops. It would be important. Many things are nowadays only on* *mobile devices and the menus are hard. Sometimes it's easier to work with computer screens." [P50]*

4.3.4 Beneficial information

The category *beneficial information* has two features that were repeated across the data. Features that had several mentions were forecasts and information comparison.

Forecasts were mentioned five times and three types of forecasts were required: weather, consumption, and price. A 72-year-old man describes it as a helpful tool with weather forecasts saying: *"Well, it should be visible right away the consumption and all these weather forecasts because solar power needs at least specific cloud conditions or it will deteriorate significantly. All this anticipation of everything. It can't be understood in your small head but through information systems and software it is possible." [P17]* Participant 217 also contributed his opinion about weather forecasts and added consumption forecasts saying: *"Weather information could be seen like beware, incoming clouds ahead or if there's going to be freezing cold and so on. So that it shows the consumption and the predictions for it in the future."* The price forecasting was required as: *"In one way or another, some sort of balance record. Maybe like so, that it had the ability to tell a prediction if the electricity is going to be cheap or expensive so that you could decide if you do the dishes today or tomorrow. For these, the information system could bring something." [P213]*

Thirteen participants thought **comparing information** would be a necessary feature. Participant 2 described it as: *"Another thing is that you could see earlier years as like a continuum about how the consumption has been every month, so you are able to follow if right decisions have been done or not. To be able to compare differences between earlier years from something else than an electric bill. To be able to deduce if you're going to the right direction or not." [P2]* A few of the participants had used energy company's software and one of them said: *"Fortum has a really nice comparison between years based on mean temperature and the consumption comparison monthly, hourly, yearly. After a longer period of usage, histories and comparison sections between earlier months and years." [P7]* Participants also mentioned that they are interested in comparing between other energy community members as: *"At least one would be the possibility to compare individual houses in the community and it would proportion the own consumption for something so that it's not maybe good if it's just a single month because it would tell enough so is it good or bad the own consumption so some comparability so to what other's consume or something." [P36]*

4.3.5 Desired functionalities

Two repeated features were discovered for the category of *desired functionalities*: remote control and controlling energy flow. In this context, the meaning of desired functionalities is all the operations the information system should be capable of.

Remote control was repeated eight times across the data. One participant described the need to control the system when on the road as: *"Probably the desire to experiment and that it could be remotely controlled because I have trips in my free time and because of work I've not had the need to travel lately. It could be possible to adjust the temperature and consumption and all that. I know there is existing house management systems." [P35]* One of the participants had already used a system in their farmhouse with remote control saying: *"Its idea is that here we have configured a system which is web based and it controls our old farmhouse's energy production. Here we have the main heat source which is an air sourced heat pump and as a secondary source we have direct electricity. When we are here, we have three bowl ovens and an air source heat pump that works when we are here in winter times as the basic source. It's controlled with an information system where I can control it with my mobile phone and control the temperature when I want to. So basically, when I leave from Espoo to come here and when it's cold, I adjust the temperature near 20 degrees four to five hours before I leave here. It's really good. It saves energy significantly; the consumption drops about 15 to 20%. In money, maybe a few percentages. The system does not cost that much, it's pretty cheap." [P60]*

Controlling energy flow was mentioned 11 times. A 56-year-old man said: *"Maybe at least that you could follow how it's going and maybe you could control your consumption to some direction either decreasing or increasing through software." [P5]* Another participant added that it could be automated saying: *"But now when we speak about smart houses so that you could control and monitor features and there would be sensors and it would be best if it reacts and for example adjust the consumption automatically and there would be sensors and indicators that on the basis of which could be decided so that one and that one can be decreased, and lighting could be decreased automatically." [P142]* One participant notified that for the automation we need a bigger group to consider a solution as: *"Well, that's a bit harder but if we think about automation. Let's say for example that saving energy comes from the adjustments of automation so it would be good to have a bigger group to consider the best solution and what kind of software through mobile phones could be used. Even opportunities for the near future and for improving energy efficiency. Not to be wasted. I have an electric heating system that can regulate room-specific temperatures, which has been working well for 25 years." [P23]*

4.3.6 Monitoring

Interest towards monitoring was wide across the data. It is divided into three features that are real-time tracking, consumption tracking, and production tracking. *Monitoring* was the most popular category with 70 mentions under the three features.

Real-time tracking was discovered 10 times in the data. Real-time tracking was seen as the key to reacting in time, as one participant stated: *"As real-time tracking as possible so that you could react and find out that there's a fault or failure so let's now fix it. Status management system so you know what's happening and what's not." [P2]* A 73-year-old man said: *"Of course what's just in that moment, how the solar panel is working at that time, is it producing, how much and is it consuming. Where is the electricity going? Tracking in every way." [P7]* One of the participants had their own solution telling: *"Well, I have my own information system in my machinery, and I use it all the time. I can keep track of my system in real-time with a tablet or mobile phone let's say it that way. I've used a software called Lynkki which is free and is available in the world and I have my own server so that it's not in a cloud service because they are slow and expensive. I have this so that I can see what's coming in and what going out." [P62]* A 50-year-old man was also interested about the real-time price development saying: *"Well of course real-time tracking of consumption would be interesting. I would follow the development of pricing as real-time as possible." [P98]*

Consumption tracking was the most popular feature discovered from the data with 41 different mentions. A 44-year-old woman not owning a PV panel said: *"Well, I think I would use it. Right now, I'm using those energy company's services. Maybe that you could* *track how the electricity is consumed and for what so that you could compare. Maybe the same you already get from the web services. It could be more specific and maybe in the future there could be device-specific tracking." [32]* A 62-year-old man described how it affects the decision-making by saying: *"In these days I'm already using certain systems for this corresponding energy tracking, energy price tracking and consumption tracking and with the help of these matters I make certain decisions for example what time I will turn on the laundry machine and other. So, when there's a helpful tool like this, you can by yourself have the opportunity to decide if you use expensive or cheap electricity and on the other hand you can review your own basic usage by your own numbers. I would use this kind of software more widely if it was available." [P39]*

Production tracking was mentioned 19 times. Also, the participants who did not own a PV panel were interested in having the possibility to track potential production. A 67-year-old PV panel owner described his existing software as: *"Well, basically I have an antenna in that solar panel inverter, and I can check my mobile phone or tablet to see what it produces in watts and what it has produced all day. It comes with a table that always shows one month at a time." [P58]* For other prosumers, they were interested about both and already had a system for tracking giving their opinion as: *"Well, for example, I currently have one. I can check online how much the panels produce and check what is the daily electricity consumption in the house." [P52]* and *"Fortum has these, I don't remember what their system names are. I have all those applications on my phone. Almost every day I go through how much I have spent, how much has been spent and how much I have produced. It is possible to take it from that system directly via Bluetooth to your phone. Fortum has a good service system." [P53]*

4.3.7 Economical

The category *economical* consists of two features of the system: affordable and save money. The **affordable** feature was repeated six times in the data. One of the participants felt there should be no costs stating: *"Such, which does not incur any cost to anyone." [P224]* Other participants were not so strict as one of them said: *"After all, of course, there shouldn't be a hard price for that again. They always charge for everything even though it is affordable and clear up at first." [P48]*

Twelve participants felt like saving money was the contributing factor. One of the participants described how the system could help save money by saying: *"If we think about the financial benefits and how much you consume and if you consume at the right time. The software could advice you to not turn on that sauna when it's not reasonable or the washing machine. It could benefit me and many others also." [P61]* A 36-year-old man felt like it's all about the money, saying: *"Of course, when electricity is as cheap as possible, then it would be worth using it for something. So, it must be the cheapest possible solution for the consumer. There is no other way to get people involved in these. The benefits of that system must be monetary. It may be of interest to a very small part if it would reduce emissions, for example. But more it is always a monetary motive. It should focus on that financial benefit simply." [P72]* A 38-year-old man thought money is the easiest way of measure, saying: *"And of course, the possible financial benefit is the easiest way of measure. Everything else is more and less messing around." [P87]*

4.4 Disadvantages

For the final resulting thematic map, four categories and nine features were studied under the theme *disadvantages*. The categories were data leaks, undesired functionalities, negative user experience, and energy community (see Figure 17). Participants found the question seven more difficult to answer. The code *I don't know* was repeated 27 times when question seven was asked. The answers were also shorter than to question six. Many of the participants also repeated the same response that they described in the previous question. Therefore, in the case of disadvantages, fewer features were discovered because of the lack of meaningful responses. In the following, the categories of features identified in the disadvantages theme are described.

4.4.1 Data leaks

Data leaks in this context mean that the user's data is leaked outside of the system or community without his or her consent. Two types of features were discovered from the data: private data is shared to third parties and security breaches.

Eleven mentions were found across data concerning the feature **private data is shared to third parties**. A 57-year-old man did not want his data to be automatically shared saying: *"Basically if I consume a certain amount of energy then I may not want everyone to see what I do, or what I spend, what money goes to me or what I buy from someone, so there should be some privacy in it. I decide what I want to share, and it wouldn't automatically share it and then they try to patch up the worst leaks." [P2]* Participants were also concerned about how companies acquire their information and start attacking with marketing spamming as: *"When you sign up there, it starts shooting spam and ads. Nowadays I'm really sensitive that I don't give any information because it's awful how it spreads everywhere even though it is sworn that it won't go anywhere. Then when you are trying to get that information out even though there are provisions you won't get them. It is a genuine and secure community and does not spread to the marketing side." [P9]* Another participant also worried about the big picture, saying: *"But that maybe that's what if it goes to it that it combines my being at home and energy consumption and shopping and going to the doctor and going to the liquor store and going to the health center and it says you've behaved badly you must pay yourself. But yes, this is a small horror scenario. But half is related to the fact that the world is going towards that everything is available through some network. And then available to be abused either ~~by~~ commercially or the military forces will come and use the information for their benefit." [P92]* A 77-year-old man pondered that it depends on the size of the community stating: *"Depending on the number of system users. The system is used by a small community that knows each other so access to information may be more transparent but if used by a larger number of people then privacy becomes important." [P63]*

Security breaches were shortly mentioned four times. All four participants thought it is the only thing they could say that would be negative for them as: *"It's so that the information will remain there and not go to the world. Those to whom it belongs so it would be available so that nobody wouldn't steal them anywhere." [P14]* and *"I can't say nothing to that either. There shouldn't be any security breaches. After all, there are/**is** personal stuff anyway." [P74]* and *"Well, I can't say anything else than it should be safe and not hackable." [P94]*

4.4.2 Undesired functionalities

One feature was identified from the data under the category *undesired functionalities*. The feature was mentioned five times in the data stating that the user should have a chance to decide what features to use.

Feature **removing unnecessary functionalities** was described as: *"Well, I don't deny anything, but you could hide the things you don't need." [P27]* and *"I'm not sure. I can't directly say what there shouldn't be. Basically, so that you could click off those features that you don't want to use." [P36]* A 74-year-old man stated that it should only focus on the basics and have the unnecessary features optional saying: *"Well, those have become such toys. I don't know who sells and markets them all. All sorts of obsessive information are being pushed onto people, which, after all, is not important in terms of family-specific consumption. The various automatic light on and off system are damn nice, but I don't think they have any real value, because when I leave the room, it goes out and when I come into the room it turns on. That automation is involved. This has been done, I can't list those systems. These are sold as a complete package so that with a blink of an eye the radio goes on and all this, in my opinion, it's nonsense. So, with that money. It's a different thing if you want to waste money then it's another matter. Getting value should be simplified to the basics, and everyone can buy those toys whatever they want when it's so easily connected if there are any electrical wires. As this is a relatively new house. It was completed five years ago. I just got involved, I have all the lamps as LEDs, for example. That's enough for me. The fact that I started automatically turning them on and off the from the car, I don't need it." [P97]*

4.4.3 Energy community

Two features were discovered for the category *energy community*. Energy community did not receive any advantageous features. Two disadvantageous features were discovered concerning the negative aspects of the community.

The feature **Community is too big** was repeated four times in the data. One of the participants saw the community would offer value if it was small enough saying: *"There could be a social community where ideas could be thrown. For example, 'I did it this way, have you tried it', so in that way the community could bring extra value for others. The community's size of 50 participants is based on this idea so that it's small enough for having a real conversation and not all this useless stuff which often comes when dealing with big masses." [P9]* A 58-year-old female thought that in lager communities' participants can evade obligations saying: *"That is like clear rules. I don't know if I would necessarily want to be a member with other people, but I would like to know what's in it and what's going on. That there would be people involved who you know and can go to their door knocking and say hello. Then if it expands terribly wide, then laziness is prone to lead to slipping off responsibilities." [P160]*

The second feature was **Does not add value** and it was repeated six times. A 55-year-old man thought people will get involved if it's beneficial enough saying: *"Well, if it's beneficial enough, then people will get involved." [P153]* Another participant thought it should add value to all parties saying: *"Well, the fact that it would be beneficial on both sides." [P144]* It was also said that the value of participating should be clear as: *"It should be really clear when you join that what are the benefits of it and when you join, it costs this much and this much, and you get this and this." [P160]* One the participants concluded saying: *"There must be some value in it. If there is a great system that you've* *paid for and there's two weeks so that you haven't got any information, it won't be desirable." [P40]*

4.4.4 Negative user experience

Negative user experience was challenging to capture. Most of the responses were repetitions of the previous responses and it was challenging to get qualitative data. The features are still included in the thesis for possible future studies. In the end, four features were discovered from the data: too time consuming, too hard to use, needs expertise to use, and too complicated.

Too time consuming was repeated six times and it was summarized by participant as: *"Time is a limited resource, the most precious of all in life." [P28]* One of the participants said he could manage the use of energy community, but he did not want to work extra as: *"I think I could surely succeed with the use of the energy community, but I don't want much extra work because of it." [P150]* A 38-year-old man did not want to increase his screen time by saying: *"As simple as possible, nothing extra. You must spend so much time with the devices that it shouldn't increase screen time." [P87]* One participant gave general feedback about the existing information systems he had used: "*Now there is all these different tracking and monitoring applications but some of them are so laborious. These devices are taking more energy than when you heat the house." [P144]*"

Too hard to use was shortly mentioned four times and was described as: *"Not too hard." [P1]* and *"It really doesn't matter what there is as long as it's easy to use." [P59]* and *"It definitely needs to be clear, and easy to use." [P212]* and *"It should be easy to use and one that does not require constant use or learning." [P213]*

Needs expertise to use was mentioned four times in the data. A 63-year-old man described it as: *"When speaking a language that is understood by an expert and assumed that casual people are experts, it is quite difficult to know whether this means this or that because there are two possible answers, so which one is it. So, these need to be cut off. So that it's clear what to do." [P21]* Another participant described it as: *"Of course, if there is an incomprehensible soap, then the nerves will surely burn but nothing suddenly comes to mind. Of course, I'm dealing with people at work who do not understand nothing at all about information technology. It is a great pain for them to use a computer, to pay the bill. I may not be the right person to answer what I don't want. It's really awkward for some and now it's forced, because of Corona, you now have to learn to use it even if you don't want to and it feels like it's pretty awkward for some. But it's gratifying that many have now learned and become familiar with them." [P35]*

Too complicated was shortly mentioned six times and described as: *"I wouldn't want it to be a complicated system." [P82]* and *"By no means too complicated and too broad but a true simple core idea." [P87]* and *"It can't be that complicated." [P51]*

The last three features, too hard to use, needs expertise to use, and too complicated, are different facets of ease of use.

5. Discussion

In this chapter, the two research questions are answered, and results are composed together with previous literature. This thesis aims to gain understanding of the prosumers and potential prosumers' information systems usage in the context of local energy communities. This study focuses on the advantages and disadvantages the participants communicated in the semi-structured interviews for the features of potential local energy community information system. The research questions were:

- RQ1: What are the advantageous features of an energy community information system for the potential members of such energy community?
- RQ2: What are the disadvantageous features of an energy community information system for the potential members of such energy community?

A thematic analysis was conducted and as a result 15 sub-themes and 25 codes were discovered which can be seen from the thematic map in Figure 17 and the codes with participants' background information can be seen in Appendix B. Sub-themes of the thematic map are referred to as categories of features and the codes are referred to as features. Discarded codes which were not involved in the analysis can be found in Appendix C.

5.1 RQ1: What are the advantageous features of an energy community information system for the potential members of such energy community?

Participants felt more comfortable when describing what they saw as an advantage than what they thought would be a disadvantage in an information system for local energy communities. When describing advantages, the data contained 6872 words whereas the disadvantages included 4645 words. Even though 58% of the participants owned PV panels, there were no clear differences discovered from the data between participants who did not possess a PV panel. All the features included descriptions from both parties. This result differs from the statement of Rossiter and Brathwaite (2013) saying the acceptance of a new technology differs substantially between actual and potential users. One explanation might be that the homogeneous participant pool shared the same values regardless of whether they owned a PV panel or not.

Participants were divided on which platform the IS should work on. Six of the participants saw it should work on both mobile devices and desktops depending on the actions that needed to be executed. On the other hand, eight participants demanded a desktop version and justified it as an easier platform to operate. However, most of the opinions (17 participants) concerning platforms saw mobile devices as the main working environment both now and in the future. The study suggest that the IS should be available on all platforms, desktops and mobile devices, but the demand is more focused on the mobile side. This is consistent with the result of Tuomela et al. (2021) reporting that SHEMS should be available through one interface on all devices as it provides remote access and increases the sense of security for the users. The operating platform was the only discovery that clearly divided people into two schools of thought. Despite the fact that no feature can be assigned to a single group of users based on any background information of this study, the availability on mobile devices were more demanded among younger participants. The average age of mobile-friendly participants was 58 years and for the desktop-friendly participants it was 67 years. This might indicate that in the future the demand for mobile-friendly operating services will grow more and the importance of quality mobile software will increase which might give advantage to system providers who pay attention to mobile software development.

The system was seen as a possible tool with valuable content. Monitoring and beneficial information were desired widely within participants which is in line with previous results (Tuomela et al., 2021). The most popular category discovered from the data was monitoring. Participants wished to have the possibility for real-time consumption and production tracking. The reason for tracking varied. Some saw it as a hobby and for some it was a way to optimize energy flow. The findings suggest that in the system the members should have the possibility to track the energy production and consumption in real-time. However, according to Tuomela et al. (2021), enthusiasm for monitoring with SHEMS faded over time among actual users. Kotilainen et al. (2016) define the three different types of co-creation roles for prosumers that can explain the differences and predict future behavior for the users of the system. The value seeker group uses the system for extrinsic benefits and their interest towards monitoring might be shallow if there are no extrinsic benefits involved. For the value seekers, it would be useful to have the possibility to monitor extrinsic benefits as the interest for real-time consumption and production monitoring might decrease afterwards. The green users and the engineers can be more interested in continuing the various tracking on energy actions as they have more intrinsic motivation. The IS should provide useful monitoring features for the green users and the engineers from their perspective. The engineers who were also discovered in this thesis need precise real-time monitoring to fulfill their intrinsic motivation. Surprisingly, no signs of green users were found, so this thesis fails to explain the green user's perspective for monitoring.

Closely related with monitoring was beneficial information. Information comparison between history data and current data was seen beneficial. The members should be able to decide the timeframes which they want to compare. The data also suggest that the system should have forecasts. It was mostly seen as weather forecasts but also the system should be able to predict prices, production, and consumption for the near future. Steg et al. (2018) outlined problems with the lack of information consumers have resulting in energy behavior not being sustainable. Consumers make false assumptions about the impacts of their actions. The participants had interest towards having more precise and understandable information which confirms the previous studies from Tuomela et al. (2021) and Steg et al. (2018). The system's information should help the decision-making of the user to achieve benefits and provide directions for sustainable energy behavior. Alanne and Saari (2006) indicated the balance issue for smart grids and its stakeholders. Distributed decision-making relies on valid information, and it is also crucial in the complete picture as the health of the smart grid and the energy community is linked to the actions of DERs and DESs which will then reflect on to the prosumers and consumers.

The valuable content could be linked with the desired functionalities that were discovered from the data. Remote control was seen as a helpful tool to control the system when away from home. This is also supported by previous studies (Tuomela et al., 2019; Tuomela et al., 2021) and by the data as mobile devices were the most desired platform for operating. Participants also viewed that there should be a possibility for the participants to control energy flow. They saw the system as a tool for themselves to control how their own energy system should work. Participants desired to increase and decrease consumption and to control how the production should be directed for the other community members and for the main grid. The results propose potential IS to have the possibility to control energy flow which is also supported with mobile devices without the need to be onsite. Surprisingly, the participants did not desire to co-work with other EC members to achieve beneficial results as proposed by Rathnayka et al. (2011; 2015). They were more interested in deciding themselves how and when the consumption and production could be modified. For ECs, DESs, and smart grids this might be problematic when the goal is to achieve stable energy availability and beneficial results as described in previous studies (Alanne & Saari, 2006; Frye, 2008; Kojonsaari & Palm, 2021; Tushar et al., 2019; Xu et al., 2017).

However, as the desired information, functionalities, and monitoring are advanced and complex implementations, the UI and UX should be accessible to users of all levels. The UI wished to be unambiguous and unpretentious, and it was backed up with the desire of UX to be easy to use and suitable for casual usage. These results are consistent with previous results related to other energy related systems (Herczeg, 2010; Tuomela et al., 2019; Tuomela et al., 2021).

The biggest surprise in the data was the values participants possessed when describing advantages for the IS. The data only included egoistic values described by the participants as mostly stating the potential system should enable the participants to save money. As it being highlighted in earlier studies (Tuomela et al., 2019; Tuomela et al., 2021), it was a surprise that there were no mentions about other values like hedonic, altruistic, or biospheric values. Steg et al. (2018) described these different values and claimed that it would be difficult to change these motivators to one way or another as they have a key role in personal behavior. From this perspective, the system should serve the users content supporting their personal values to keep them using the IS and having sustainable energy behavior. The participants also saw that the IS should be affordable which is also supported by Steg et al. (2018). The price of the system can be a barrier for making the investment. However, Steg et al. also said that the price of energy is seen as a bonus for consumers and there are more vital drivers like environmental and moral factors which control the behavior even more. The data of this study states the opposite so that the price of energy and the affordable system are the key factors of investing and using the system. Steg et al. (2018) also writes that extrinsic motivation has no solid foundation for sustainable energy behavior. This is interesting because the findings of this study claim the opposite. Extrinsic motivations, like saving money, had several mentions but there were no references to intrinsic motivation.

The analysis did not reveal explanations for the lack of green users' who were described by Kotilainen et al. (2016). Tuomela et al. (2021) revealed the disbelief of SHEMS's users when asked about the positive impact on environment with the use of SHEMS. Tuomela et al. (2019) also highlighted that the users of SHEMS were mostly men which is also confirmed by this thesis with the users of prosumer technology. It may be assumed that the environmental impacts of EC IS should be highlighted more to current and potential prosumers and members of EC to improve the knowledge and generate interest for the users of EC IS.

5.2 RQ2: What are the disadvantageous features of an energy community information system for the potential members of such energy community?

Participants struggled to propose ideas that they thought would be a disadvantage for them when using the EC IS. It was also problematic as they provided short sentences rather than full descriptions of their opinions. In addition, some of the answers were the opposite of advantageous features or just a repetition of advantageous feature they earlier described. These limitations underline the difficulty of collecting and analyzing qualitative data.

The findings confirm the previous studies on the barriers of adopting SHEMS from the user's perspective (Tuomela et al., 2021). Results indicate that what leads to a negative user experience is a system that needs too much time, is hard to use, needs expertise to use, and is too complex. The data suggests that if a broad usage of the system is aimed for, the designing of operations in the system should be reviewed with the co-operation of regular prosumer households who are the key actors of smart grid highlighted by Espe et al. (2018). The results of this thesis also corroborate with the description of Steg et al. (2018) stating that the barriers for users with hedonic values can act as a barrier for sustainable energy behavior if personal effort is increased. It is proposed that the EC IS's designers should have R&D supporting their design work to avoid rejection on the prosumer market.

The second aspect from the data suggest that IS and EC were seen as a disadvantage if the EC IS does not add value or is too big. Data suggests that the benefits of the EC should be seen in the IS to motivate the members of energy community to continue their involvement. Members also saw it could be a problem if the EC grows too big. Surprisingly, the data was missing advantageous functionalities regarding EC, and it was only mentioned in the disadvantageous features. According to Rathnayaka et al. (2011; 2015), the basic idea of prosumers grouping is to provide benefits and power for the individual prosumers, which was also identified as an expectation from the perspective of potential members of EC in this thesis. Tuomela et al. (2021) described that the lack of knowledge can act as barrier for adopting SHEMS. For potential EC IS marketing, the findings suggest open, credible, and transparent information exchange between potential users and the provider of the system to attract users with the advantages of EC and EC IS.

The existence of unnecessary features was not in itself a problem for the participants, but it should be possible to hide the features of the system which the user does not want to use. Steg et al. (2018) states that with the help of technology a personalized and tailored approach can be developed to serve different consumer segments. The data suggests that the solution for information system should not aim for having one truth that fits all, but instead, having a system that can be customized to serve the wide variety of needs of consumers and prosumers. The three different types of co-creation roles for prosumers by Kotilainen et al. (2016) would appear a clear starting point when designing a customizable and dynamic implementation of EC IS.

The findings show that data leaks were a concerning factor for the participants in two ways. First, participants were worried about security breaches. Camek et al. (2013) states that the security is a main issue for smart grids as it should follow easy-to-use architecture which is prone to malicious attacks. At this time, the war in Europe has activated malicious parties around the world to attack ISs and with that increases the need for proper protection against privacy violations, data misuse, and data manipulation. The security aspect will be an important factor in getting the approval of prosumers for the IS and to provide stable accessibility to energy. Secondly, the participants also worried that the system provider would share their private data to third parties without their consent. The lack of trust was also mentioned by Tuomela et al. (2021) which was in correlation to the size of the system provider. Smaller providers equaled less trust. The operation of the EC IS provider is suggested to be transparent to users to gain trust from the people. Surprisingly, no signs of advantageous security or safety features were mentioned by the participants even though Tuomela et al. (2021) demonstrated the safety advantages of SHEMS from the user's perspective. It could be beneficial for the users to have a realistic snapshot, whether at home or remotely connecting to the system through one interface.

6. Conclusion

This research contributes to the field of sustainable human-computer interaction (SHCI). As the quality of life in developing countries and population on Earth are increasing rapidly, energy consumption is increasing. However, the production is falling behind and is powered by fossil fuels. Sustainable energy production and behavior are needed to stop the irreversible impacts of climate change and in the era of digitalization, information systems play an undisputed role in the journey to success. Another incentive to switching to sustainable energy production and consumption is the provision of necessary energy with an affordable price tag as the prices of fossil fuels are increasing due to the war in Europe.

For this study, qualitative interviews were conducted to gather data and thematic analysis is used to analyze the data. The thematic analysis suggests on having an information system for the energy communities which is available on any platform or device. The system should be a tool for the prosumers with beneficial information like history data and comparison to the present moment. The system should be able to forecast future consumption and production related to weather forecast. The most desired aspect is monitoring in real-time to keep track on the consumption and production. However, the system should be compatible with casual usage without anything excessive. The use should not demand expertise or time and it should not be too complicated. As most of the participants were males and the average age was 60 years, for them, the most important benefit of using the system was the aspect of saving money. As a surprise, only egoistic values and extrinsic motivation were discovered in the study.

As the count of the participants was so substantial, some limiting factors occurred. The interviews could have contained more qualitative conversation that they did. The descriptions reminded more of a list of features than proper descriptions of advantages and disadvantages of the information system. Some of the participants also got tired with the questions. As the interview went on, the first few questions were answered with more passion, but rush and fatigue occurred the further the interview progressed. Participant pool was homogeneous with only ten females and the average age was 60 years. The data could have been analyzed even more but it was so enormous that it was not possible with the limited resources. The fact that there was no proper prototype or any other design or description of the potential information system, some of the participants struggled to answer for the questions six and seven. For future research, it is encouraged to have a more detailed description or prototype for the participants if they struggle to understand the concept.

This thesis can be used as groundwork for future research and development of energy community information systems. The literature review concerning the different stakeholders of the smart grid can be a guide to familiarize to the concept of the smart grid, prosumers, consumers, PV panels, energy communities, and distributed energy resources. The results should be notified when designing and developing information system for prosumers but also for consumers. The findings can also be used for other energy related research and software development. Future research should be conducted to learn more and strengthen the findings of this thesis. Quantitative research could study the discovered codes of this study. As many of the participants in the qualitative interview said, it was hard to come up with ideas without precaution and when the system is in the early design phase, the possible future research should also study the discarded codes that can be found in Appendix C to see if they are valuable features of the system when those are handed in advance. At least few of the discarded codes are mentioned in other energy software related studies (Tuomela et al., 2019; Tuomela et al., 2021). Nevertheless, future research is needed to discover how the findings of this thesis can be achieved in the potential information system. Mostly egoistic values and extrinsic motivation were discovered, therefore future research should also be aimed to have a more heterogeneous participant pool with females and younger participants to see if other values are discovered more in a more heterogeneous participant pool.

This thesis is the first step towards enhancing our understanding of energy community information systems from the prosumers perspective. The present findings suggest several courses of action in order to increase sustainable energy production. Policy makers should encourage household prosuming by enabling economic benefits for the prosumers and supporting the creation of energy communities with extrinsic incentives. The thematic map is suitable for energy community information system providers to design and develop prosumer-friendly solutions. Following the thematic map can mitigate risks of wrong assumptions and save provider’s resources such as time and money. The thematic map might also be useful for other software development projects where the end-users are older males, or the software is energy related.

For the IS research area of SHCI, this thesis contributes valuable information and understanding for energy prosumers’ interaction with technology. The results guide researchers and designers to design and develop persuasive and sustainable technology for energy prosumers. The findings also underline the values of the potential members of EC to be egoistic demanding economic benefits over other values. The findings argue against some of the current studies related to energy behavior which try to highlight sustainability and biospheric values more important.

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Appendix A. Question form

Background information

How old are you?

Gender?

What's your profession?

What's your form of residence?

How many people live in your household?

Semi-structured open questions

1. The survey at the beginning of the year described the characteristics of a potential energy community, such as trading between small electricity producers and electricity consumers, investing in joint, for example, local electricity generation, or combining and selling demand response capacity to the electricity market. We asked you about your interest in participating in the energy community, and you answered that [*answers from the form*]. Why did you answer like this?

2. Next, you had answered that the factors that increase your interest in participating in the energy community would be [*answers from the form*]. Why should these factors be able to involve you in the energy community?

3. In the next section, you indicated that [*answers from the form*] as/**is** something that reduces your interest in the energy community. Why do you feel that this is what could stand in your way?

4. It was then asked what would be appropriate for the composition and size of the energy community. You had replied that it would be [*answers from the form*]. Why do you think that an energy community of this size, organized this way, would be the best?

5. The following was the section where we asked you to tick the features you would like to see in the energy community. It was [*answers from the form*]. Why do these ones feel like good features?

6. One of the visions for the likely future would be for the energy community to link to the information system through people's personal hardware and software, such as a smartphone app or a computer web browser. After all, one of the aims of the study is to map out what would motivate people to use this information system. What kind of features should such an information system have to involve you in the use of the information system, and why?

7. What kind of features would you not want to have in that information system?

8. Then one final questions, that is, if you were involved in the energy community, how would you think or hope it would affect your home and life?

Appendix B. Codes with background information

Generating the background information code:

ID: Gender – Age – Form of residence – Inhabitants – Profession – Panel Owner

Gender:	Male / Female (M / F)
Age	(integer)
Form of residence:	Detached house / Semidetached house / terraced house / apartment house (DH / SdH / TH / AH)
Inhabitants	(integer)
Profession:	Employed / Retired (E / R)
Panel owner:	If true -PO is added at the end

***A**dvantage / **Disa**dvantage

Id	Code	A / DA*	Participant(s) info
1	Easy to use	A	1:M47DH1E-PO, 4:F72DH2R, 13:M78AH1R-PO, 21:M63DH2E-PO, 27:M34DH3E-PO, 42:F65DH2R-PO, 45:N64DH1E, 46:M47DH3E-PO, 48:M72DH2R-PO, 50:M63DH3E-PO, 59:M48DH4E-PO, 71:M68DH2R-PO, 77:M53DH2E-PO, 82:N75DH2R-PO, 96:M38DH5E, 99:F48DH3E, 155:M58DH5E, 199:M59DH2E-PO, 212:M67DH1R, 213:M51DH2E-PO
2	Suitable for casual usage	A	94:M64DH2E-PO, 213:M51DH2E-PO, 237: F66DH1E, 261:M72DH2R-PO
3	Controlling energy flow	A	5:M56DH2E-PO, 23:M72DH2R-PO, 30:M59DH2E-PO, 35:M45DH1E, 45:N64DH1E, 60:M69FH2R-PO, 61:M63DH2R-PO, 72:M36SdH4E, 94:M64DH2E-PO, 142:M63DH2E-PO, 144:M71DH2R-PO
4	Remote control	A	5: M56DH2E-PO, 35:M45DH1E, 45:N64DH1E, 52:M64DH5R-PO, 60:M69FH2R-PO, 94:M64DH2E-PO, 142:M63DH2E-PO, 144:M71DH2R-PO
5	Real-time tracking	A	2:M57DH2E, 5:M56DH2E-PO, 7:M73DH1R, 9:M67DH2R-PO, 46:M47DH3E-PO, 62:M72DH1E, 88:M79DH2R, 92:M60DH2E-PO, 94:M64DH2E-PO, 98:M50-60DH3E

Id	Code	A / DA*	Participant(s) info
6	Consumption tracking	A	1:M47DH1E-PO, 5:M56DH2E-PO, 7:M73DH1R, 9:M67DH2R-PO, 11:M76AH1R-PO, 17:M72DH2R, 18:M60DH2E-PO, 19:M58DH3E-PO, 32:F44DH3E, 35:M45DH1E, 36:M51DH4E-PO, 39:M62DH2E, 45:N64DH1E, 52:M64DH5R-PO, 53:M75DH3R-PO, 61:M63DH2R-PO, 62:M72DH1E, 63:M77DH2R-PO, 66:M67TH2R-PO, 69:M50DH7E-PO, 70:M68DH2R, 71:M68DH2R-PO, 72:M36DxH4E, 77:M53DH2E-PO, 87:M38DH5E, 88:M79DH2R, 94:M64DH2E-PO, 96:M38DH5E, 97:M74DH2R, 98:M50-60DH3E, 99:F48DH3E, 146:M64DH2E-PO, 151:M70DH2R-PO, 153:M55DH2E, 160:N58DH2E-PO, 170:M42DH1E-PO, 185:M50DH2E, 212:M67DH1R, 217:M42DH4E, 218:M51DH4E-PO, 233:M41DH5E
7	Production tracking	A	1:M47DH1E-PO, 7:M73DH1R, 18:M60DH2E-PO, 19:M58DH3E-PO, 52:M64DH5R-PO, 53:M75DH3R-PO, 58:M67DH2E-PO, 62:M72DH1E, 66:M67TH2R-PO, 68:M73DA2R, 70:M68DH2R, 71:M68DH2R-PO, 72:M36DxH4E, 97:M74DH2R, 146:M64DH2E-PO, 160:N58DH2E-PO, 185:M50DH2E, 199:M59DH2E-PO, 212:M67DH1R
8	Affordable	A	48:M72DH2R-PO, 60:M69FH2R-PO, 72:M36SdH4E, 97:M74DH2R, 224:M65DH2R-PO, 261:M72DH2R-PO
9	Save money	A	23:M72DH2R-PO, 60:M69FH2R-PO, 61:M63DH2R-PO, 67:M57DH2E-PO, 71:M68DH2R-PO, 72:M36SdH4E, 87:M38DH5E, 94:M64DH2E-PO, 142:M63DH2E-PO, 199:M59DH2E-PO, 205:M69DH2R, 226:N67DH1R
10	Information comparison	A	2:M57DH2E, 7:M73DH1R, 9:M67DH2R-PO, 11:M76AH1R-PO, 36:M51DH4E-PO, 69:M50DH7E-PO, 70:M68DH2R, 71:M68DH2R-PO, 88:M79DH2R, 151:M70DH2R-PO, 153:M55DH2E, 218:M51DH4E-PO, 237:N66DH1E
11	Forecasts	A	5: M56DH2E-PO, 17:M72DH2R, 62:M72DH1E, 213:M51DH2E-PO, 217:M42DH4E
12	Available on all devices	A	50:M63DH3E-PO, 82:F75DH2R-PO, 153:M55DH2E, 155:M58DH5E, 199:M59DH2E-PO, 212:M67DH1R
13	Available on computers	A	13:M78AH1R-PO, 42:N65DH2R-PO, 55:M72DH2R, 151:M70DH2R-PO, 198:M64DH2R-PO, 218:M51DH4E-PO, 226:F67DH1R, 237:F66DH1E

Id	Code	A / DA*	Participant(s) info
14	Available on mobile devices	A	58:M67DH2E-PO, 60:M69FH2R-PO, 62:M72DH1E, 68:M73DA2R, 69:M50DH7E-PO, 96:M38DH5E, 142:M63DH2E-PO, 144:M71DH2R-PO, 146:M64DH2E-PO, 149:M48DH4E-PO, 153:M55DH2E, 160:N58DH2E-PO, 168:M61DH2E-PO, 170:M42DH1E-PO, 176:M44DH4E-PO, 254:M69DH2R-PO, 217:M42DH4E
15	Unambiguous	A	1:M47DH1E-PO, 19:M58DH3E-PO, 21:M63DH2E-PO, 48:M72DH2R-PO, 68:M73DA2R, 71:M68DH2R-PO, 96:M38DH5E, 144:M71DH2R-PO, 155:M58DH5E, 160:N58DH2E-PO, 199, 212:M67DH1R, 212:M67DH1R, 225:M80DH2R
16	Unpretentious	A	1:M47DH1E-PO, 19:M58DH3E-PO, 27:M34DH3E-PO, 42:F65DH2R-PO, 68:M73DA2R, 94:M64DH2E-PO, 71:M68DH2R-PO, 96:M38DH5E, 143:M57DH2E, 144:M71DH2R-PO, 155:M58DH5E, 233:M41DH5E
17	Private data is shared to third parties	Da	2:M57DH2E, 7:M73DH1R, 9:M67DH2R-PO, 14:M74DH2R-PO, 17:M72DH2R, 28:M35DH5E, 39:M62DH2E, 48:M72DH2R-PO, 63:M77DH2R-PO, 92:M60DH2E-PO, 94:M64DH2E-PO
18	Security breaches	Da	9:M67DH2R-PO, 14:M74DH2R-PO, 74:M74DH2R-PO, 94:M64DH2E-PO
19	Unnecessary features	Da	27:M34DH3E-PO, 30:M59DH2E-PO, 36:M51DH4E-PO, 71:M68DH2R-PO, 97:M74DH2R
20	Does not add value	Da	40:M71DH2R-PO, 144:M71DH2R-PO, 153:M55DH2E, 155:M58DH5E, 233:M41DH5E, 160:F58DH2E-PO
21	Community is too big	Da	9:M67DH2R-PO, 52:M64DH5R-PO, 63:M77DH2R-PO, 160:F58DH2E-PO
22	Too time consuming	Da	13:M78AH1R-PO, 28:M35DH5E, 87:M38DH5E, 144:M71DH2R-PO, 150:M72DH2R-PO, 213:M51DH2E-PO
23	Too hard to use	Da	1:M47DH1E-PO, 59:M48DH4E-PO, 212:M67DH1R, 213:M51DH2E-PO
24	Needs expertise to use	Da	21:M63DH2E-PO, 35:M45DH1E, 213: M51DH2E-PO, 237:N66DH1E
25	Too complicated	Da	19:M58DH3E-PO, 28:M35DH5E, 42:N65DH2R-PO, 51:M69DH1R-PO, 82:F75DH2R-PO, 87:M38DH5E

Appendix C. Discarded codes

Id	Code	Participant(s) info
1	Wireless devices are harmful to health	142:M63DH2E-PO
2	Possibility of a paper invoice	10:M62DH2E-PO
3	The systemdisplaces man	10:M62DH2E-PO
4	Facebook integration	66:M67TH2R-PO
5	Faulty features lead to disadvantageous outcome	62:M72DH1E
6	Big brother is watching	4:F72DH2R, 60:M69FH2R-PO
7	Marketing for recruiting new members	218:M51DH4E-PO
8	Cloud service	213:M51DH2E-PO, 237:F66DH1E
9	Wireless	233:M41DH5E
10	Practical experience involved in information system	3:M82DH2R-PO
11	Does not require the purchase of new equipment	13:M78AH1R-PO
12	Storage tracking	18:M60DH2E-PO
13	Requires nothing else but use	25:M77DH2R-PO
14	Features for advanced users	27:M34DH3E-PO
15	Community status	29:M67DH3E
16	Flexible	31:M64DH3R-PO
17	Sustainable energy behavior tracking	45:N64DH1E
18	Useful	51:M69DH1R-PO
19	Community status	63:M77DH2R-PO
20	System is a development project	67:M57DH2E-PO
21	Automation	81:M63DH2R-PO, 142:M63DH2E-PO
22	Minimarket	153:M55DH2E
23	Reliable	212:M67DH1R
24	Police state	4:N72DH2R
25	Built from the perspective of researched information	45: N64DH1E
26	Slow system	46: M47DH3E-PO

Id	Code	Participant(s) info
27	Advertisement	61: M63DH2R-PO