CHALMERS
UNIVERSITY OF TECHNOLOGY

Households' contribution to flexibility in the electricity system

Challenges and potential support from aggregators

Master's thesis in Quality and Operations Management

Anton Dahlberg
Carl Strand

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF INNOVATION AND R&D MANAGEMENT

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023
www.chalmers.se
Report No. E2023:067

REPORT NO. E2023:067

Households' contribution to flexibility in the electricity system

Challenges and potential support from aggregators

Anton Dahlberg
Carl Strand

Department of Technology Management and Economics
Division of Innovation and R&D Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023

Households' contribution to flexibility in the electricity system
Challenges and potential support from aggregators
Anton Dahlberg
Carl Strand

Supervisor and Examiner: Ingrid Johansson Mignon, Chalmers University of Technology

Report no. E2023:067
Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

Gothenburg, Sweden 2023

Abstract

The journey towards renewable energy sources is accelerating, increasing the number of intermittent energy sources like wind and solar power. In turn, this has resulted in a more fragile electricity network since the intermittent energy sources are dependent on the weather to produce electricity, meaning that power peaks and shortages are more likely to occur. To address this issue, the utilization of flexibility resources in households, including EV chargers, solar PVs, heat pumps, and water heaters, has been identified as a potential solution. However, many challenges can be found in utilizing the flexibility of resources in households, underlining the necessity for an actor to guide and manage these resources. In this study, it has been shown that the aggregator function has the potential in supporting households and their challenges of delivering demand side flexibility (DSF). Therefore, the aim of this thesis was to understand what challenges exist in households delivering flexibility, and what the aggregator function may do to support households in their challenges.

This thesis has covered two research questions, which have both been answered. Research question one refers to what challenges that are found in households delivering flexibility. Research question two, has in turn answered the question of how the aggregator function may support households in delivering flexibility. To find the answers to the questions, a literature review, semi-structured interviews with households and aggregators, and exploratory interviews with employees from an established utility, have been performed.

The findings of this thesis indicate that households experience challenges in the four systemic areas of market, infrastructure, institution, and economy & finance. The different challenges connect mainly to aspects of awareness, interest, simplicity, understanding, guidance, comfort, adaptability, and economic viability. In turn, aggregators were found to be able to provide support to households in the four systemic areas. Important supportive measures that the aggregator function could perform were related to aspects of information, expertise, collaboration, infrastructure adaptability and simplicity, regulatory responsibility and, reducing costs. In addition, the thesis has also identified gaps between the challenges of households and the supportive ability of the aggregator. These gaps were found in handling households of varying interest levels, limited household markets, low awareness and understanding of DSF, and economic uncertainties.

Keywords: Demand side flexibility, aggregators, households, innovation systems, transitions, intermediary, challenges, support.

Acknowledgements

First, we would like to thank our supervisor and examiner Ingrid Johansson Mignon for the support and guidance throughout this master's thesis. Without your knowledge and experience, this thesis would not have turned out the same.

Secondly, we would like to thank Göteborg Energi, especially Mariliis Lehtveer and Henrik Törnsjö, for their guidance in this master's thesis. The discussions brought valuable directions and information.

Lastly, we would like to thank all the interviewees, both households and aggregators, who contributed with their time and effort to make this master's thesis possible.

Thank you!

Anton Dahlberg and Carl Strand, Gothenburg, June 2022

Table of contents

Abbreviations

DNO - Distribution network operator

DSF - Demand side flexibility

DSO - Distribution system operator

IS - Innovation system

Solar PV - Solar photovoltaics

TSO - Transmission system oper

1. Introduction

The backbone of modern civilization is built upon extensive use of fossil fuels which has proven to be a fragile foundation. The negative consequences of fossil fuels for life on Earth have become increasingly clear and the need for drastic changes is apparent (Butler, 2018). Many decision- and policy makers around the world have recognised the urgency of the situation and a transition towards a fossil-free society has begun. One of the main areas of concern is the energy sector due to its large consumption of fossil-fueled sources. As of today, approximately 80% of the world's energy is supplied by fossil fuels (Ritchie et al., 2022). The transformation of the energy sector towards renewable and green energy sources has led to an increased use of solar and wind power. Simultaneously, several energy intensive sectors have started a transition towards electrification which puts further stress upon the electrical grid and increases the need for stable capacity (Energimyndigheten, 2022). These factors have resulted in a complex electrical grid with new challenges and dynamics connected to planning and predictability (Zagerholm at al., 2021). Innovative solutions and adaptations by power producers, grid operators, and consumers are needed to ensure the continued growth and stability of the future electrical market and grid. One of the key concepts in this context is the idea of demand side flexibility (DSF) which refers to the capability and willingness of customers to adjust their energy consumption and energy generation habits in response to external signals (Sáez at al., 2022; Europeiska kommissionen, 2022).

1.1 Background

In many respects, Sweden is at the forefront of creating a sustainable energy system with a focus on replacing fossil fuels with renewable energy sources (IEA, 2019). In the year of 2021 approximately 60% of Sweden’s electricity production came from renewable sources, 43% hydropower, 17% wind and 1% solar (SCB, 2022). This number is expected to increase as Sweden approaches its goal of achieving a 100% renewable power system by 2040 (IRENA, 2020). As the reliance upon renewable energy sources such as solar and wind increases, the planability of the energy system becomes increasingly difficult and complex. The use of intermittent energy sources will make it more difficult to balance the power grid and manage power peaks (SVK, 2023). This is where the concept of DSF can play a significant role in solving many of the challenges. To be able to utilize the end consumers for flexibility needs, one must first establish who the consumer is and how the electricity use should be controlled. The control can either be handled implicitly or explicitly where implicit control aims to affect consumers user patterns and explicit control aims to make use of equipment that instinctively

reacts to incoming signals (Zagerholm at al., 2021). Several actors have the potential to contribute with flexibility and one of the major actors in this case is the household segment. According to Energimyndigheten (2022) approximately 24 % of Sweden's yearly electrical use comes from households which makes them a major actor in this context. However, individual households cannot provide enough flexibility to be useful in a macro context. For households to be of relevance, their individual capacities need to be accumulated into a larger package and offered to the market (Zagerholm at al., 2021). One function in this context is the role of an aggregator. The aggregator provides flexibility to the electrical market by accumulating several small energy production loads and manages them as a single unit to provide grid services that improve the efficiency, reliability, and sustainability of the system (Olgyay, 2020). The aggregator can therefore act as an important piece for the future of the electrical grid when change is moving towards more intermittent energy resources and an overall increase in electrification.

The aggregator role can be seen as a form of intermediary that connects smaller actors to the macro environment of the market by aggregating micro- loads or/and micro power generation sources that can be auctioned off on the market. These micro resources are typically sourced from things such as appliances (fridge, freezer or dishwasher), heat pumps, electrical vehicles, or solar panels (European Union, 2019). Both the European Union as well as the Government offices of Sweden agree upon the importance of aggregators in order to reach crucial sustainability goals while at the same time being able to tackle the challenges that this brings upon the energy system (European Union, 2019; Government offices of Sweden, 2020).

Opportunities for offering aggregated DSF have been identified in several studies. Zagerholm et al. (2021) identified that small actors have the potential to contribute with flexibility within the areas of power balance and grid capacity by controlling loads, which can work as a complement to implicit control and expansion of the electricity grid. Zagerholm et al. (2021) further state that openness and well-defined processes are necessary to increase the number of actors that can contribute to the market and decrease overall costs. In addition to this, Eriksson & Sandwall (2014) and Hammam (2016) found that opportunities exist in lowering the minimum bid volume, provide clarity in terms of roles and grid balance responsibilities, and finding a market-driven system where actors can participate on equal and fair terms in relation to incentives and policies.

The studies also identified several challenges related to realizing aggregated DSF. Eriksson & Sandwall (2014) and Zagerholm et al. (2021) found that the main difficulties were connected to profitability, IT-solutions, complexity, regulations and standards. For instance, the lack of

effective compensation for actors who contribute to general system benefits or in other ways create effective incentives for other actors to provide increased flexibility to the market was identified as a challenge by Hammam (2016). Furthermore, the studies highlight the need for adapting policies/regulations, market structures, and bidding volumes to strengthen and develop aggregators and the value of DSF, which can be a slow and complex process. Overall, the challenges identified by the studies highlight the need for a comprehensive and coordinated effort by market actors, regulators, and policymakers to realize the potential of aggregated DSF.

As households have the opportunity to contribute with flexibility and as the electrical market is changing rapidly, it is of interest to understand the barriers faced by aggregators when delivering flexibility through the coordination of multiple individual households. To facilitate the future of aggregators in Sweden, it is of importance to understand their potential and role in providing flexibility through households. Evaluating the adaptable, usable and changeable elements in the environment is crucial for determining the feasibility of flexibility services and promoting supply and demand. Therefore the aim of this thesis is to firstly, identify possible challenges that exist in households delivering DSF. Secondly, to understand how the aggregator function may support households in delivering DSF. The report will have strong connections to established literature on the subject, but will also seek to provide new observations and discussion around various challenges and the evolving role of aggregators in advancing DSF for households.

1.2 Aim of the thesis and research questions

With the introduction and background in mind, the aim of this thesis will be to understand what challenges exist in households delivering flexibility, and what the aggregator function may do to support households in their challenges. By considering the aim of the master's thesis, two research questions have been established.

RQ1: What challenges are associated with households delivering flexibility?
RQ2: How may the aggregator function support households in delivering flexibility?

1.3 Scope & Limitations

The master's thesis is carried out in collaboration with Göteborg Energi together with the department of Innovation and R&D Management at Chalmers University of Technology. The project will bring information regarding the aggregator function's possibilities to support

households in delivering flexibility from households in Sweden. The project will both cover existing literature and will also consist of interviews with selected aggregators and households, to provide information to Göteborg Energi that may be helpful in further development of their services. In addition, aggregators' digital platforms will also be analyzed to provide valuable information. The master's thesis will be limited to the areas of market, infrastructure, institutions, economy & finance.

2. Frame of reference

In this section, theoretical concepts and information that is necessary to answer the research questions will be presented. DSF can be seen as a part of a system transition or transformation towards renewable energy systems. Hence, it is important to understand characteristics and phenomena associated with the area of system transition or transformation to better understand potential challenges and opportunities connected with the implementation and adoption of DSF. Challenges and opportunities that will be analyzed in this thesis regarding system transition and transformation will be in the areas of market, infrastructure, institutions, and economy & finance. These areas were selected since they cover a wide range of potential issues. Furthermore, the chapter will cover the area of the intermediary function in innovation systems and sustainable transition processes to get an understanding of their role and potential in the areas. This will help in understanding the aggregator function's potential in supporting households in delivering flexibility.

2.1 System transitions and transformations

A transformation or transition process refers to processes of change within a complex and dynamic system. The change can be structured, profound or discontinuous in nature but fundamentally it consists of elements such as innovation, collaboration, learning, and knowledge amalgamation. Transformation and transition processes are typically prone to elements of uncertainty and complexity, and often adhere to mechanisms such as emergence, path dependency and barriers. Furthermore various actors are involved in shaping the change process which adds another layer of complexity where different values, views and needs get entangled. This entails that transformation and transition processes are profoundly political in nature where value conflicts and power strifes are common occurrences. In essence both the process of transition and transformation acquire and provide distinct views on how to define, understand, and support desirable societal change (Hölscher at al., 2018). A major process of societal change can be illustrated as a system-level change as it generally involves several interconnected parts of a complex system (Geels & Kemp, 2006). System transformation and transitions tend to reflect itself not only upon the system it operates within but also impact other sectors, institutions, and actors. An example of this can be seen in how the change towards renewable energy has not only impacted the energy sector but also sectors such as transportation, manufacturing, agriculture (UNDP, 2021).

To better understand and navigate system level changes the concept of innovation system (IS) can be useful to adopt. The definition of an IS is difficult to establish as the concept of IS

can exist in different contexts (e.g. national/regional, sectoral, and technological). However, common to all contexts is that they revolve around the creation, diffusion and adoption of knowledge (Carlsson et al., 2002). The main idea behind the use of IS is that innovation and diffusion of innovations is seen as both an individual and collective effort. The dynamics of the specific organization as well as unique technical characteristics and adoption structures existing in the environment plays a significant role for the speed, direction and success of an innovation process (Negro et al., 2012). In general terms, an IS can therefore be explained as involving all relevant institutions and commercial systems that impact the pace and direction when transforming from one system to another. Which can provide insights into how different actors and institutions can work together to promote system-level changes (Hekkert, 2007).

There are several ongoing system transitions and transformation processes within society today. Some of the more prominent change processes are the digital transformation and the sustainable transformation (Henriette et al., 2016; Solomon & Krishna, 2011; Smil, 2010; Fouquet & Pearson, 2012; Markard & Raven, 2012). These processes are driven by different forces such as advancement in technology, changing customer expectations, environmental and social awareness, regulations, and standards (Henriette et al., 2016, Solomon & Krishna, 2011). System transformation/transitions and their drivers are important for society as they can lead to positive changes in social, economic and environmental topics (Uitto, 2022; Mersmann et al., 2014). Though to be able to address important social changes such as climate change and unlock new opportunities there are often several hurdles to overcome regardless of the system or environment that the transformation/transition takes place in (Markard et al., 2020, Marr, 2023; Sovacool, 2015).

2.2 Challenges and opportunities in system transitions and transformations

IS are concerned with the development, diffusion, and adoption of innovations. They consist of vital components such as actors, networks and institutions that all interact with each other. When a transition in, or between ISs takes place, challenges will emerge in several areas. This thesis will mainly concentrate on challenges and opportunities found in the areas of market, infrastructure, institutions, and economy and finance since they contribute to a wide understanding of challenges and opportunities found in system transitions and transformations.

2.2.1 Market

A market can be described as a place where a transaction of goods and services occur. The exchange takes place between buyers and sellers which are connected to each other, either directly or through intermediate actors (Britannica, n.d.). One of the more complex issues of the market is its structure. Market structure can be defined as the configuration of the present market and what practices and principles it makes use of when selecting innovations (Negro et al., 2012). When selecting innovations, new technologies and services may struggle to compete with established utilities that have already benefited from aspects such as economies of scale and experience. This may result in higher prices and overall lower performance and utility for new innovations. The energy sector has historically displayed these kinds of challenges when new innovations have risen within the industry. Established utilities actively suppressed the acceleration of new ideas by for example suppressing patents or by giving the impression of a journey towards change, but in practice continuing to funnel resources into the existing energy system (Sovacool, 2015). Controlling the market in this way restricts "free" choice of customers and may limit acceleration of new innovation. To overcome these types of initial disadvantages, one could make use of intermediate markets or bridging segments in order to gradually generate increasing returns and eventually develop a mass-market approach (Negro et al, 2012). Nursing and bridging markets enable favorable opportunities for sale of new technologies that can contribute with positive feedback for large scale production, further R&D and increased recognition by customers. Performing market analysis on bridging segments is of great importance in order to evaluate the size of the segment and how attractive the innovation is in terms of price and performance for the particular segment (Andersson & Jacobsson, 2000).

Similar to Negro et al. (2012), Bergek et al. (2005) talk about the needs of nursing and bridging markets for which an IS can experiment and grow. Bergek et al. (2005) further develop upon the importance of performing market analysis and suggest a diagnostic approach where questions to understand how markets are formed and the factors that influence them should be asked. These questions should cover various aspects such as determining market phase, the degree of experimentation with new applications, who the users are and their purchasing process, customer demand profiles and uncertainties, institutional incentives for market development and barriers to use. This monitoring helps in understanding market formation and aids in evaluating the suitability of potential nursing/bridging segments (Bergek et al., 2005).

Another important aspect to consider for changes in innovation systems is the existence of an established market. When a new innovation is introduced, there may be no obvious market for it to operate in, or the market may be poorly developed. This in turn leads to issues of not being able to acquire clear customer demands due to customers lacking the knowledge to articulate such requirements (Bergek et al., 2005). Bergek et al. (2005) further state that institutional change may also be lacking and in need of formulation in order to formulate a set of standards which a market can be built upon.

Another crucial market aspect is the concept of relationships. In this context it refers to the interaction and collaboration between e.g. firms, governments, universities, customers, and consultants. Interaction dynamics can have positive outcomes upon design and development processes of innovations but it can also pose challenges upon the market (Carlsson & Jacobsson, 1997). Interaction failures are generally divided into two different facets: too strong interaction and too weak interaction. Too strong interactions may hinder new partners from entering and may potentially create lock-in effects. This may in turn lead to dependencies which makes search for alternative partners difficult (Woolthuis, 2005). Too strong interaction may also lead to narrow-mindedness where close relationships between actors results in missing out on new external developments. Strong netwrok failures can therefore be seen as individual actors being steered in the wrong direction by other actors in the network, leading to insufficient supply of necessary knowledge between the partners as there is a lack of new external knowledge gathering and questioning of current standards (Woolthuis, 2005; Carlsson & Jacobsson, 1997). On the other hand, weak interaction failures may arise when the connection between actors and complementary technologies are insufficient which tends to hurt aspects of learning, adaptation of technologies and technological advancement. Additionally, weak interaction within a system may also hurt and obstruct the future development endeavors and investment due to not being able to establish a common vision for how to progress (Woolthuis, 2005). An example of failed interactions can be seen in some sustainable transition processes. For example, shared visions of future development efforts between companies and authorities for biomass digestion in the Netherlands were not developed, leading to repeated shifts of attention that eventually scared off investors and stalled future R&D efforts (Negro et al., 2012).

2.2.2 Infrastructure

The concept of infrastructure can be divided into two branches, knowledge infrastructure and physical infrastructure (Negro et al., 2012; Mignon & Bergek, 2015). Knowledge infrastructure refers to assets that can both be physical in nature such as laboratories or other specialized facilities, but also to non tangible assets such as scientific knowledge. Physical infrastructure

instead refers to vital technical elements of society such as electric and gas grids, highway systems, and broadband (Negro et al., 2012; Mignon & Bergek, 2015). Challenges associated with infrastructure are generally connected to missing elements (e.g. reserach institutes or universities) that are needed to support and drive the transformation/transition process (Negro et al., 2012). Policies often play an important part here by supporting and providing vital infrastructural elements for the system change process by for example directing a larger share of public capital towards infrastructural resources or incentivising private investments by facilitating preferential loans and subsidies (Mignon, 2016).

Examples of infrastructural challenges have been observed in the digital transformation process where new technologies and digital tools need to be integrated with already established and existing systems (Henriette et al., 2016; Cho et al., 2021; Maksimenko et al.,2021). This integration process can be very challenging due to a need to develop capabilities in the new systems while at the same time retaining old capabilities and getting the two to harmonize. Often, large investments have been made in old systems and infrastructures, which can further complicate the process. But those who manage to overcome such obstacles and repackage their legacy systems can see them transformed into a valuable resource (Maksimenko et al., 2021).

Another challenge in relation to Infrastructure is technology supply. Technology supply challenges are generally caused by lack of competence, ability, assets or readiness on the supply side. Lacking technological expertise or entrepreneurial competence on the supplier side will affect access to relevant technology which in turn halters the transformation process and weakens the overall knowledge of the specific network. Not being able to depend on the network for technical recommendation introduces more risk in pursuing projects due to a general lack of knowledge and experience (Mignon & Bergek, 2015). This connects back to Woolthuis (2005) article and the importance of structuring and developing strong interaction between various actors to build a competent foundation of knowledge within the market.

2.2.3 Institutions

Negro et al (2012) bring up the importance of institutions in an IS since they are the ones structuring specific elements within the system. The structuring can be seen as policies, and may involve technical standards, labor law, risk management rules, social norms and values, the legitimacy of new technology, and stakeholders' tendencies to trust. These elements may hinder innovation as they dictate the boundaries within which innovation can occur and the ways in which it can be diffused and adopted in society (Yaqoot et al., 2016). In renewable energy transitions, Negro et al (2012) found several challenges regarding policy. One

challenge is the tendency of policymakers to regulate and subsidize certain renewable energy technologies, only to stop and introduce new regulations and subsidies after a short period of time, making investors and entrepreneurs reluctant to take risks. Another challenge identified by Negro et al. (2012) and Mignon & Bergek (2015) is focus shifting, where policymakers cause problems by taking a too short-termed view and only supporting innovations and technologies if they can help alleviate current problems. This leads to a drop in policy attention which can hurt the progress of the innovation. Lack of policy attention can be particularly damaging during phases approaching market introduction. This stage is often associated with uncertainty and high costs, and without appropriate policy attention that can provide the innovation with subsidies, venture capital incentives or smaller, protected markets, it risks never leaving the R&D phase and reaching commercialization (Negro et al., 2012).

Yaqoot et al (2016) state that to tackle issues like the ones brought up by Negro et al (2012), the focus should be on developing favourable environments for the specific innovation by engaging in closer relationships between stakeholders. In practice this means that policymaking agencies have the possibility, by cooperating and listening to relevant stakeholders, to promote and create more conducive environments where aspects such as regulatory frameworks, simplified approval processes, specialized institutions and transparency all play a crucial role (Yaqoot et al., 2016). Soft institutional aspects such as culture, norms, and values that operate within the system are also important to consider. If the social system has a positive attitude toward innovation or a negative attitude toward already established technologies it may help in spreading the innovation (Mignon, 2016).

2.2.4 Economy and finance

Financial challenges can be caused by high initial investment costs. Investment costs can be inflated by aspects such as the need for extensive planning and preparation and high development and design costs. Combined with other risks such as low technological maturity/stability, unstable and changing market environments, and lack of customer demands and knowledge, it risks to steer off investors towards other investment opportunities that are perceived to have higher yields and legitimacy (Mignon & Bergek, 2015; Bergek et al., 2005). Other important elements to consider in relation to economy and finance is the availability of sources for funding investments in capital goods and the presence of necessary financing mechanisms such as loans. If such sources and systems are scarce or missing, raising capital becomes difficult and often associated with high interest rates. To work around the above mentioned challenges, loans, subsidies or legitimacy can be sourced from more local/national institutions such as organizations, industry associations or politics (Mignon & Bergek, 2015). Opportunities for raising capital can also be facilitated by for example working in smaller

projects that require smaller investments as well as offering shares to stakeholders in order to incentivize further investments (Mignon & Bergek, 2015).

Economy may also become a source of opportunity as it can give customers and stakeholders more freedom and opportunity to invest. A stable and well resourced economic environment (e.g. access to sources of funding) can be leveraged by organizations to incentivize customers and stakeholders to invest in their product. Tax breaks, subsidies, R&D for cost reductions, and soft loans are elements which can be leveraged to stimulate incentives and ease the Initial investment costs of customers. Removing affordability barriers is evidently a crucial process for accelerating the adoption of new innovation where government, policy and implementation agencies, and banks play a significant role (Yaqoot et al., 2016).

In table 1, a summary of important aspects regarding challenges and opportunities in system transitions and transformations can be found. Important aspects were found in the areas of market, infrastructure, institutions, and economy & finance.

Table 1: *Summary of important aspects found in system transitions and transformations.*

Area	Important aspects regarding challenges and opportunities in system transitions
Market	Market structure
	Competition with incumbents
	Nursing and bridging markets
	Market analysis
	Established market
	Relationships and interactions
Infrastructure	Knowledge infrastructure
	Physical infrastructure
	Technology supply
Institutions	Institutional structure
	Policies and regulations
	Policy focus shifting

	Cooperation and stakeholder engagement
	Social norms and values
Economy & finance	High initial investment cost
	Financing mechanism
	Incentives and government support
	Access to funding sources

These challenges and opportunities within market, infrastructure, institutional framework, and finance & economy can benefit from the involvement of intermediary actors. These actors can serve as catalysts, enabling smoother communication, fostering collaborations, and bridging gaps (Howells, 2006). Therefore, the intermediary function will be discussed further in the next chapter.

2.3 Intermediaries

A general definition of the term intermediary is a person or organization who has the ability to set a consensus between people or organizations that do not interact or deal with each other at first hand (Cambridge Dictionary, n.d). The definition is broad, and depending on context, the specific characteristics of the term “intermediary” may differ. In this chapter, intermediaries in innovation processes and in transition processes will be studied to get an understanding of how they work in these areas.

2.3.1 Intermediaries in innovation processes

According to Van Lente et al (2003) the need for intermediaries in innovation processes has grown due to an increase in the number of stakeholders and components, which in turn has increased overall complexity of e.g. networks. The concept of “intermediaries in innovation” has been studied for a long period of time where Howells’ concept of innovation intermediaries is widely acknowledged. According to Howells (2006), the intermediary function in innovation processes is extensive, diverse, and universal. Intermediaries in innovation systems set out to play an important role in diffusion and technology transfer, innovation management, and to facilitate relations within a system or network (Howells, 2006).

Diffusion and technology transfer revolves around intermediaries’ ability to spread information (Howells, 2006), where an effective spread of information has shown to increase the speed of

adoption of products and services in e.g. households and firms (Rogers, 1962). Rai & Robinson (2013) further bring up that individuals that are to adopt innovations need sufficient information and trustable information channels. The intermediary function therefore has an opportunity in the dissemination of information and to act as an trustable information channel, increasing the adoption rate of e.g. products, services, and new technology.

Innovation management is similar to the previous process of diffusion and technology transfer but refers to the activities that intermediaries have in facilitating knowledge and technology between organizations, individuals, and firms (Howells, 2006). In this context, the intermediary function may perform several activities such as giving organizations advice and help, helping the organizations to revise their expertise and ideas (Howells, 2006), or to help organizations in their processes of how to search for innovation (Howells & Thomas, 2022).

Facilitating relations is one of the most predominant functions the intermediary function has in innovation processes. Howells (2006) states that intermediaries have the possibility to link different actors, and may even initiate change processes to affect other actors. Intermediaries also have the potential to set up actors that have resources and expertise that can be considered as complementary to each other (Howells & Thomas, 2022). The intermediary function also has the potential in minimizing challenges between actors that can be related to cost of communication (Kivimaa et al, 2019). However, intermediaries working in a transition process, especially in the context of sustainability, have other settings than those in innovation processes, indicating that additional characteristics may be important.

2.3.2 Intermediaries in transition processes

Lately, transition processes within ISs have increased due to a larger set of actors with different settings (Van Lente et al, 2003), increasing the overall need of intermediaries in transition processes. One transition process is in the context of sustainability which according to Kivimaa et al (2019) is broader compared to innovation process theory since it focuses on a broad change for a future that is considered to be more sustainable. Transitions in this context involve long-term and complex changes in the way actors such as companies and intermediaries work and bring/develop innovation (Van Lente et al, 2003), as well as changes in technological and institutional settings (Kivimaa et al, 2020). This has created challenges in settings regarding collaboration, communication, and arrangement between actors. Examples of challenges that have been seen are related to lack of technological understanding of the ones instituting policies, overall lack of understanding between actors such as policy makers and business representatives, irregularity of long-term regulations and subsidies, and gap

between actors when it comes to coordination and what to focus on (Negro et al, 2012). According to Kivimaa et al (2020), in the context of sustainability transitions, the intermediary function has several possibilities, where one possibility is to connect different stakeholders. It can e.g. be to connect the ones that supply technology with the adopters of technology, or to connect the producers of energy with the ones using the energy (Kivimaa et al, 2020). In addition, the intermediary function may translate information between the stakeholders, come up with and advise on specific technologies or goals regarding policies, and help to speed up the processes of transitions. The intermediary function may also help in linking the right skills with the right resources, connect future visions with specific demands or requirements of certain actors and networks, and may help to establish collaboration between various actors (Kivimaa et al, 2019).

Literature on intermediaries in system innovation and transition processes show challenges and opportunities where the intermediary function has the possibility of minimizing the challenges and maximizing the opportunities. The intermediary function has the possibility of e.g. connecting actors, facilitating knowledge between actors, and to speed up transition processes. They also have the possibility of bringing the information needed and act as a trustable information channel, and at the same time initiate policy and technology goals. The intermediary function clearly has a role in influencing and helping in innovation and transition processes. Therefore, it is of interest to analyze how the intermediary function may contribute to maximizing opportunities and minimizing challenges in households delivering DSF in the current transition to renewable energy sources. In table 2, a summary of functions that the intermediary role has in innovation and transition processes can be found.

Table 2: *Innovation and transition intermediaries and their associated functions.*

Intermediary type	**Functions of Innovation and transition intermediaries**
Intermediaries in innovation processes	Dissemination of information
	Act as a trustable information channel
	Increasing adoption rate of e.g. products, services, and new technology
	Advising organizations
	Help organizations to revise their expertise and ideas
	Help organizations in their processes of how to search for innovation

	Link different actors
	Initiate change processes to affect other actors
	Minimize challenges between actors that can be related to cost of communication
Intermediaries in transition processes	Connect different actors
	Translate information between actors
	Proposing policy and technological goals
	Speed up transition processes
	Connect skills and resources
	Connect vision with demand of actors and networks
	Establish collaboration between actors

2.4 Frame of reference and link to the empirical settings of the thesis

Transition processes are complex and dynamic in nature, and consist of several actors with different views and values, resulting in several challenges. The transition from fossil fuels to renewable energy sources has resulted, among other things, challenges of balancing the power grid and managing power peaks (SVK, 2021). To overcome many of these challenges, DSF has shown to be of potential importance (EI, 2016; Olgyay, 2020). DSF can be seen as a transition to a new IS, where collaboration between different actors and institutions are beneficial to promote system-level changes (Hekkert, 2007). In this section of the report, challenges and important factors with delivering DSF from households in the areas of market, infrastructure, institutions, and economy & finance will be brought up.

2.4.1 Market

One challenge with DSF in the market aspect is the minimum bidding size required to participate. As examples, Effekthandel Väst and SthImflex require a minimum bidding size of 0.1MW (Göteborg Energi, n.d; SVK, 2023; Zagerholm, 2021). This can be compared to the average daily energy consumption of a household in Sweden which is approximately 0.05MWh (Energimarknadsbyrån, 2023), which may be considered too low to participate in the markets. With a rather large bidding size, small actors such as the residential, will be limited in participating with their flexibility resources (Wohlfahrt et al, 2019). Another challenge is the different characteristics and requirements of existing markets. Nord Pool, the nordic

electricity market, offers a day-ahead market (trades made for the next 24 hours) and an intraday market (offerings of 15 minutes, 30 minutes, and hourly flexibility products) where actors bid with the minimum size of 0.1 MW (Nord Pool, 2020a; Nord Pool, 2020b). Svenska Kraftnät in turn has the “reserve market” where the minimum bidding size varies from 0.1MW to 10MW and where the activation time varies between 0.7 seconds to 15 minutes (Zagerholm, 2021). According to Wohlfahrt (2019), short response time and a high bidding size will limit small actors' potential to contribute with DSF. Such aspects have also led to fewer market products being developed for the purpose of harvesting smaller flexibility resources which further obstruct the development of household markets and their participation. Overall, the DSF market for smaller resources such as households is still in its early stages (D’Ettorre et al, 2022).

Another challenge, especially when it comes to households, is the lack of interest and understanding of the technology aspects that DSF brings (Hennlock et al, 2023). According to Hennlock et al (2023), households feel that the hassle to find general information regarding technology is not worth the time. D’Ettorre et al (2022) further confirm this and state that “understanding of technology” is one of the main barriers when it comes to households contributing with flexibility. Households’ lack of technological interest and understanding will negatively affect the adoption rate of DSF and is therefore a major challenge. It is not only households’ general understanding of technology that is limited, but also their knowledge of what type of technology is needed to directly control their energy consumption (Hennlock et al, 2023). This aspect also negatively affects the adoption rate of DSF, hence a challenge.

Another challenge is that some households do not understand different electricity contracts and associated costs (Hennlock et al, 2023), indicating that general characteristics and potential savings that may be gained from delivering flexibility is not understood. Hennlock et al (2023) bring up the example of households not fully understanding the difference between e.g. variable price (monthly average price) and hourly rate. Households with an hourly rate have greater potential in planning their energy consumption to certain hours, e.g. when the electrical grid is put under less pressure and when the electricity prices are lower, compared to houses that have variable price. Economy has shown to be one of the most important incentives for actors such as households to start contributing with flexibility (Hennlock et al, 2023; D’Ettorre, 2022; Wohlfahrt, 2019). Therefore, the lack of knowledge and understanding of different electricity contracts, costs related to the contracts, and how the potential to contribute with flexibility is affected by different contracts, is considered to be a great challenge.

2.4.2 Infrastructure

Overall, the implementation and integration of renewable energy and DSF solutions increases the complexity of the electrical grid and will put further pressure upon developing more advanced and reliable information systems that can be easily adopted (Berg & Böris, 2020). There is some uncertainty about which technical standards will ultimately take hold for these DSF solutions, which can be seen as a barrier as a lack of standardization can lead to interoperability issues between components. This in turn can cause disruption and sub-optimal performance. Moreover, the lack of interoperability standards can also cause problems for investors and customers as it limits flexibility by leading to lock-in effects. Lock-in effects may limit stakeholders' future decision space and their flexibility to adapt or change their needs (Good et al., 2017). In another study by D'Ettorre et al. (2022), technical barriers brought forward by end consumers in relation to DSF were presented. The study found that participants mainly had concerns related to the complexity of installing and maintaining the DSF enabling equipment. In addition to these aspects, participants voiced concerns about steep learning curves and sufficient, recurring, technical assistance. The findings suggest that barriers such as ease of use, simplicity and customer support need to be addressed in order to promote the adoption of DSF technology (Ponnaganti et al. 2018; D'Ettorre et al. 2022).

To acquire a significant adoption rate, customers and stakeholders must feel confident in the quality of the DSF infrastructure and its standards. A way to effectively drive standardization comes from forming partnerships and alliances that promote cross-sector collaboration (Good et al., 2017). Attempts to promote such cooperation and standardization in the energy industry are already afoot where the European Commission is one of the actors taking the lead. For example, the Commission has formed the “European Smart Grid Task Force” that is tasked to coordinate the creation and deployment of smart grid standards across Europe (European commission, n.d.).

In addition to promoting standardization, it is important to utilize technological assets that can facilitate consumer adoption of DSF. D'Ettorre et al. (2022) showed that technological aspects can be important as they can provide a higher degree of comfort and control to consumers when adopting DSF. Participants mainly saw ease of use and easy adaptation to personal needs as technological drivers. Automatic control of electrical appliances and monitoring of energy consumption were also seen as technological drivers, but in a more scaled-down sense.

2.4.3 Institutions

The institutional challenges that are found regarding DSF are often not directly linked to households. Instead, households may be indirectly affected by uncertainties and economic incentives that actors such as grid owners, electricity trading companies, and aggregators are part of. Lack of economic incentives of flexibility providers may affect the economic compensation for households, and uncertainties regarding regulations may limit or confuse households in how they may provide flexibility.

Transitions made in the area of renewable energy technologies (RETs) have resulted in many institutional challenges. As examples, the transition has resulted in “stop and go”-policies”, shifts in priority and attention of the ones instituting policies, and missalignment in different levels of policy makers (Negro et al, 2012). Examples can be found in many areas; for example initiated and reinitiated subsidies for RETs in the Netherlands (Negro et al, 2012), failed development of solar collectors when it comes to the market aspect (Jacobsson & Bergek, 2004), and laws and regulations that have been conflicting between actors in Switzerland regarding biomass digestion (Markard & Stadelmann, 2009). In the case of DSF, similar institutional challenges can be identified.

Development of hard institutions e.g. new policies and regulations (Negro et al, 2012), is a continuous process in the energy sector (Langedahl et al, 2019), especially when it comes to DSF. New policies and regulations combined with a rather new phenomenon, which DFS can be considered, creates an environment where it is difficult to keep track of and understand new developments. In turn, this challenging environment may affect households' understanding of hard institutions connected to DSF, and may even scare off households with potential in delivering flexibility. This can be seen as a big challenge when it comes to households delivering flexibility.

Another challenge with households delivering DSF can be seen in the area of soft institutions. Soft institutions refer to e.g. informal norms, values, and culture (Negro et al, 2012), and may be seen as households attitude towards DSF. According to Hennlock et al (2023) households consider DSF to be difficult, time consuming, and not worth the hassle to become more strict with the energy consumption. Households value control and comfort, which can be seen as a barrier when it comes to start delivering flexibility as DSF may intrude on personal control and comfort.

2.4.4 Economy and finance

The size and scope of savings and revenues generated by DSF can be difficult to calculate and predict, which hurts the business case for DSF. This financial uncertainty comes from the economic returns being dependent on the level of demand for flexibility in the electrical grid which shifts depending on environmental conditions (solar PV and wind power is dependent on the weather). Households have no control over such external factors that affect DSF, which leads to further financial uncertainty for them (Cardoso et al., 2020). D'Ettorre et al. (2022) confirm these uncertainties in their article where consumers expressed concerns about the cost benefits of DSF being insufficient and that the cost of acquiring, installing and maintaining the equipment would be too high. The economic factor was seen by participants as both one of the main barriers and drivers for adoption, indicating that it is of great importance for the future of DSF (D'Ettorre et al., 2022; Ponnaganti et al., 2017). Ponnaganti et al (2018) also discuss potential economic barriers with DSF. One of their key findings relates to investments in advanced metering to enable time-based charging, which in turn means that customers' electricity consumption can be measured on the basis of time of day or more frequent billing intervals. Older meters and some newer meters may not have this capability, resulting in potential additional investment and operational costs for the customers.

Despite the financial uncertainties surrounding DSF, there are also significant economic drivers that may be leveraged by businesses and individuals. Participants of D'Ettorre et al. (2022) social survey perceived opportunities for cost savings as one of the major incentives for accepting DSF solutions. In addition to this, being able to offer free installation of the system was also perceived as a major driver by consumers. Furthermore, Berg and Böris (2020) suggested in their paper that even though there are uncertainties connected to the business case there are clear opportunities to capture by for instance making use of government funded loans and subsidies to reduce customers' initial uncertainties around high investment costs. Uncertainties from customers around the business case also comes from a lack of knowledge and information. Therefore, there are opportunities for actors here to acquire a higher degree of participation by making sure to cover knowledge gaps and provide transparency in areas where customers demand it (Pablo Chaves Ávila et al., 2019).

Table 3 presents a concise summary of the key highlights from each systemic area, providing an overview of the significant factors or obstacles identified in the literature relating to households within the context of the DSF.

Table 3: S*ignificant factors or obstacles found in the empirical setting regarding households.*

Area	Significant factors and obstacles identified
Market	Minimum bidding size of 0.1MW
	Different characteristics and requirements of different DSF markets
	Short response time in delivering flexibility
	Lack of interest and understanding of technology connected to DSF among households
	Limited knowledge of households in what equipment is needed to start with flexibility
	Limited understanding of households in different electricity contracts and how it affects costs and potential to deliver flexibility
Infrastructure	Interoperability issues between components related to DSF limits flexibility by lock-in effects, in turn may limit stakeholders' future decision space and their flexibility to adapt or change their needs
	Complexity of installing and maintaining equipment connected to flexibility affecting end-customers
	Steep learning curves connected to DSF
	Concerns about sufficient, recurring, technical assistance connected to DSF
	Improve the quality of DSF by standardization, through collaboration and coordination between sectors
	Technology can provide a higher degree of comfort and control to consumers when adopting DSF
Institutions	Continuous development of policies and regulations associated with DSF creates a difficult environment to keep track of. May scare of households
	Households consider DSF to be difficult, time consuming, and not worth the sacrifice to become more strict with their energy consumption
Economy & finance	Financial uncertainty for households regarding savings and revenues generated by DSF
	Worries regarding costs of acquiring, installing and maintaining equipment connected to DSF
	May require new advanced metering to enable time-based charging which may require an initial investment cost

	Cost savings and free installation costs related to DSF is considered to be important
	Making use of government funded loans and subsidies to reduce customers' initial uncertainties around high investment costs
	Uncertainties from customers around the business case also come from a lack of knowledge and information

2.5 The aggregator function's role in supporting demand side flexibility

Aggregators can be seen as a sort of intermediary since they meditate between actors in the energy sector such as TSOs, DSOs, the market, and prosumers (those who both produce and consume energy) (Zagerholm, 2021). The aggregator function can play an important role in engaging and recruiting end customers e.g. households, towards delivering flexibility to help balance the grid. In addition, the aggregator function has the potential in minimizing challenges and maximizing opportunities that can be found in households delivering DSF which will be covered further in this chapter.

One of the clear opportunities for aggregators is their ability to gain access to smaller loads that cannot be offered to the market as single units (Ponds, et al., 2018). By bridging the gap between households and the market, aggregators can deliver an accumulated unit of capacity that reduces the need for grid infrastructure and enables further deployment of renewable energy. Aggregators gain access to the end-consumer market by offering tailored and automated controls for the loads and appliances that consumers, e.g. households, utilize. Aggregators can customize these solutions to consider the individual needs, preferences and behaviors of consumers which is a vital component to acquire widespread adoption (Ponds, et al., 2018; EI, 2016).

The consolidation of energy resources of small-scale users, enabling them to meet minimum market entry criterias, is one of the main functions of the aggregator. The prosumers' participation in the market does not only yield benefits for the stability of the grid, but also economic benefits for the participating prosumers. This cooperative approach between aggregator and prosumers has been shown to result in financial profits (Yin et al., 2020; Kerscher & Arboleya, 2022). The aggregator contributes to an increased number of participants on the market, which in turn can lead to more competitive pricing, which is beneficial for the individual users (Kerscher & Arboleya, 2022). Aggregators incentivise

prosumers to partake using mainly two kinds of programs, priced based and incentive based. Price-based programs change customer demand based on the cost of electricity, using plans like Time-of-Use, Critical Peak Pricing, and dynamic pricing. On the other hand, incentive-based programs give customers financial rewards to encourage their participation in DSF programs (Golmohamadi, 2022)

Aggregators also play an important role in addressing the information and technology gap present in the network where they provide important expertise and knowledge around the complexity of the energy supply chain which individual customers may not have the ability to navigate themselves. For example, aggregators are the ones that are able to accumulate several small flexibility sources from end-users, and therefore indirectly take responsibility for understanding policies and regulations (Eid et al, 2015; Crespo del Granado et al, 2023). This means that households don't have to understand the development and challenges associated with the new developments. This facilitates consumers' ability to trade on the market and transfers a large part of the complexity and knowledge requirements upon the aggregator instead (Färegår & Miletic, 2021). Aggregators, in turn, also facilitate for utility firms such as distribution network operators (DNO) by providing a form of service that mediates between end customers, e.g. households, and DNOs by constructing compelling commercial and technical propositions to make DSF a valid energy management initiative in line with consumer priorities (Langendahl et al., 2019).

The aggregator function also plays an important role in providing information that enables households to make decisions on DSF. Depending on how effectively and convincingly the aggregator can convey information on incentives, responsibilities, costs, comfort, and control associated with DSF, this will determine consumer confidence and support for DSF (EI, 2016; Langendahl et al., 2019). Communication and collaboration with other stakeholders such as government, policy makers and technological institutions and utility firms can also be seen as opportunities for aggregators to steer technological and institutional development of DSF in a direction that benefits the offering toward the end consumer, e.g. households (Good et al., 2017; EI, 2021a; EI, 2021b; Langendahl et al., 2019). An example of this is how aggregators in Sweden can participate in workshops held by the Swedish Energy Markets Inspectorate where they can voice their concerns about current barriers for DSF with the objective of expanding the conversation with various stakeholders on the market and in turn enhancing comprehension of the challenges faced (EI, 2021b). Another example is aggregators collaborating and forming partnerships with technology firms in order to develop technological capabilities that supports and enables the DSF transition process. This shows that aggregators establish and sustain numerous connections in order to facilitate the functioning

of DSF (Langendahl et al., 2019). In table 4, supportive functions of the aggregator role can be seen.

Table 4: *Supportive functions found regarding the aggregator function.*

Supportive functions of the aggregator role
Plays an important role in engaging and recruiting e.g. households to deliver flexibility to help balance the grid
May accumulate small flexibility resources and bringing them to the market creating financial benefits for prosumers
Aggregators use price-based and incentive-based programs to motivate prosumer participation in DSF programs
May offer tailored and automated control for loads and appliances that are in line with the individual needs of households
Provide important expertise and knowledge around the complexity of the energy supply chain which individual customers may not have the ability to navigate themselves
The aggregator function may take responsibility for understanding policies and regulations regarding DSF
Mediates between end customers, e.g. households, with DSF capacity and DNOs by constructing compelling commercial and technical propositions
Provide information that enables households to make decisions on DSF
May convey information on incentives, responsibilities, costs, comfort, and control associated with DSF, this will determine consumer confidence and support for DSF
May communicate and collaborate with stakeholders such as governments, policy makers, and established utilities to develop DSF in a direction that benefits end consumer
Collaborating and forming partnerships with technology firms in order to develop technological capabilities that supports and enables the DSF transition process

3. Methodology

In this chapter, the research methodology of the study will be presented. A detailed description of research strategy, research design, data collection, sampling, data analysis, and method discussion will be presented.

3.1 Research strategy

Two important research strategies are quantitative and qualitative research. According to Bell et al. (2019), the strategies differ in their ontological and epistemological positions and therefore shape the research conducted and its outcome. It is therefore important to

understand the research that is to be conducted in order to choose the most appropriate research strategy. Although the strategies differ in terms of ontology and epistemology, a combination of the strategies can be used. Quantitative research involves quantification of numerical data collection, statistical analysis and interpretation of results to test hypotheses or establish causal relationships. It typically employs deductive reasoning, where the researcher starts with a theory or hypothesis and collects data to test it (Bell et al, 2019). Qualitative research involves a more subjective approach to data collection and analysis, where words and images often are emphasized. The qualitative research strategy is often conducted through open-ended methods such as interviews, observations and focus groups. The results are then interpreted based on themes, patterns and subjective reasoning where the researcher starts with observations and data in order to develop a theory or hypothesis (Bell et al, 2019).

Since this thesis will be exploratory in nature where data and information from several actors, such as households and aggregators is needed to develop a theory, the inductive reasoning will be suitable. The qualitative research strategy will therefore be used where extensive literature review, interviews, and data collection are needed to develop the theory.

3.2 Research design

According to Bell et al (2019), a research design involves a structured framework for what information is needed and the methods of retrieving the information, to be able to answer the research questions. In table 5, the research questions, information needed to answer the research questions, and methods for retrieving information to answer the research questions, can be seen.

Table 5: *The research questions of the study, the information needed for answering the research questions, and how to retrieve the information.*

Research question	Information needed	How to retrieve the information
RQ1: *What challenges are associated with households delivering flexibility?*	• General knowledge associated with transition processes • Challenges associated with transition processes in the market, infrastructure, institutions, and economy and finance perspectives • Challenges associated with DSF and households in the market, infrastructure, institutions, and economy and finance perspectives	• Theoretical framework

	• Households general knowledge regarding the electricity market and DSF • Households view on DSF • What challenges do households associate with DSF • How may challenges found regarding households and DSF be minimized	• Semi-structured interviews
RQ2: *How may the aggregator function support households in delivering flexibility?*	• General knowledge associated with the intermediary function • The aggregator function's possibility in supporting DSF adoption	• Theoretical framework
	• The aggregator function's possibility of supporting households in delivering flexibility from the perspective of infrastructure, institutions, and economy & finance.	• Semi-structured interviews • Data collection from aggregators' digital platforms

To answer the research questions, both a general and detailed understanding of the topic were needed. The first step was to gain a general understanding by collecting data and information through an extensive literature review. By conducting a literature review, it is e.g. easier to understand what has already been done in certain areas and to avoid mistakes that previous authors have already made (Bell et al, 2019). The literature review resulted in a theoretical framework which was used to give the reader an understanding of the phenomena behind DSF and the empirical setting of the master's thesis. The theoretical framework was also used as a structured way of obtaining relevant information and was used to develop relevant interview questions and to contribute information to the analysis.

In order to gain a detailed understanding of the topic and be able to answer the research questions, the second step was to conduct interviews with households and aggregators. The interviews were held in a semi-structured way, meaning that the interviews include general questions with the ability of the interviewer to ask further questions depending on the interviewees answers. This approach enables the interviewer to keep an open mind in order to gain data that is needed to create desired theories and concepts (Bell et al, 2019). The semi-structured interviews were held with households and aggregators since RQ1 needed the

household perspective to be answered, while RQ2 needed the aggregator perspective to be answered. In total, 10 households and four aggregators were interviewed.

In addition to the semi-structured interviews with households and aggregators, exploratory interviews were held with employees of Göteborg Energi. These interviews were conducted to gain a better understanding of DSF in general, and to get guidance in important aspects regarding RQ1 and RQ2. The exploratory interviews were flexible and offered a forum for discussions to get a deeper understanding of the topic.

The final step of the study was to collect secondary data from the aggregators' digital platforms (websites). This step was done to obtain a broader set of information on the functioning of aggregators and. According to Bell et al (2019) collection of secondary data is less time consuming than primary data collection (interviews, surveys, and focus groups), which was an additional reason for the collection of the secondary data.

3.3 Data collection

In this part, the data collection methods will be described and the interviewees are presented. In addition, the companies whose data was collected from digital platforms (websites), will be presented by company name and description of their services.

Literature review

A narrative literature review was used to get a first impression of the topic and to understand what areas to focus on. The narrative review in this thesis was conducted in a general setting and in an empirical setting. The general setting involves information needed to understand the phenomena behind DSF and the aggregator function. In the general setting, the areas of transition processes, innovation systems, and intermediaries in transition processes and innovation systems were analyzed. Data gathered in these areas were obtained by using the online platforms Google scholar and Chalmers library. On these platforms, keywords and phrases were used to find relevant articles. Keywords and phrases such as: transition processes, sustainable transitions, challenges in transition processes, innovation systems, challenges in innovation systems, intermediaries, intermediaries in transition processes, and intermediaries in innovation processes, were used to find relevant articles.

The empirical setting of the literature review was also based on data gathered from the online platforms Google scholar and Chalmers library. Keywords and phrases used in this section included: demand side flexibility and households, challenges of delivering flexibility from

households, the aggregator function, the aggregator functions potential in delivering flexibility from households.

Semi-structured interviews

The semi-structured interviews were held with households and aggregators to get a better understanding of challenges associated with households delivering flexibility and how the aggregator function may minimize those challenges. The interviews resulted in collected data that was needed to answer RQ1 and RQ2. As stated, semi-structured interviews enable the interviewer to keep an open mind in order to gain data that is needed to create desired theories and concepts (Bell et al, 2019). This was considered to be the best approach to obtain primary data with enough depth and detail to answer the research questions.

In total, 10 households were interviewed. The interviews were held either in person or with the video communication platforms Zoom and Teams, depending on the wish of the participant. All interviews were recorded, which according to Saunders et al (2009) comes with the benefits of e.g. direct quotes and allowing the interviewer to concentrate on questions and listening. In addition to the recording, one of the two interviewees also wrote down important sayings during the interview. This was done to have a summary of the most important aspects found in each interview, in addition to the recorded material. All participants got information regarding the background of the thesis and what information that was to be collected. The participants were also offered to get the interview questions in advance of the interview session. During the interviews, the participants had the possibility to ask clarifying questions, and all participants were offered the ability to withdraw some or all of the information they provided. The participants' gender, role, and available flexibility resources can be seen in table 6. The interview guide was developed by considering the frame of reference. The same areas found in the theoretical framework (market, infrastructure, institutions, economy & finance) were used to construct themes in the interview guide. The interview guide for the households segment can be seen in appendix A.1.

Table 6: *Households interviewed, their gender, role, and available flexibility resources.*

Household participants	Gender	Role/position of interviewee	Available flexibility resources
Household 1 (H1)	Male	Electrician	Solar PV, heat pump and water heater
Household 2 (H2)	Male	Pensioner	Solar PV and heat pump
Household 3 (H3)	Female	Teacher	Heat pump and water

			heater
Household 4 (H4)	Male	Engineer	Heat pump and water heater
Household 5 (H5)	Male	Construction supervisor	Solar PV, heat pump and water heater
Household 6 (H6)	Female	Consultant	Heat pump and water heater
Household 7 (H7)	Female	Lawyer	Heat pump and water heater
Household 8 (H8)	Male	Engineer	EV charger, solar PV, heat pump and water heater
Household 9 (H9)	Female	Teacher	Heat pump and water heater
Household 10 (10)	Male	Engineer	EV charger, heat pump and water heater

A total of four aggregators were interviewed. The interviews were held either in person or on the video communication platform “Microsoft Teams”. The participants got information in advance of what questions that were to be asked, the background of the thesis, and what information that was planned to be used in the thesis. All the interviews were recorded with permission of the participants. In addition to the recordings, one of the interviewers also wrote down important sayings during the interview, to have a summary of important aspects brought up by the participants. During the interviews, the participants were informed that if they did not want to, or were not able to answer specific questions, they could refrain from answering. In addition, they were informed that the results of their participation were to be sent to them to analyze and give their permission for publication. The participants, position, company name, and company description can be seen in table 7. The interview guide for the aggregator segment was developed by considering the frame of reference. The same areas found in the theoretical framework (market, infrastructure, institutions, economy & finance), were used as main themes in the interview guide. The interview guide for the aggregator segment can be seen in appendix A 2.

Table 7: *Aggregators interviewed, position, company name, and company description.*

Aggregator respondent	Position	Company name	Company description
Lars Skoglund (A1)	CEO	Ntricity	This company works with renewable energy investments, maximizing their value by

			smartly aggregating energy resources to create new revenues and services
Misha Voss Gustavsson (A2)	Business developer	Flowertech	The company increases the available power flexibility by energy storage, EV charging, and solar power
Sofia Päivärinne (A3)	Head of Strategic Development	Myrspoven	Helps the real estate industry to decrease energy consumption by the use of data and AI
Carl-Johan Kokacka (A4)	Energy Engineer	Myrspoven	Helps the real estate industry to decrease energy consumption by the use of data and AI

Exploratory interviews

In addition to the semi-structured interviews held with households and aggregators, exploratory interviews with employees of Göteborg Energi were also conducted. These interviews were held sporadically when the need of expertise in certain areas was found to be necessary. The interviews were both flexible and structured in nature. The flexible interviews were mostly discussions and brainstorming sessions where important sayings and facts were written down. In the structured interviews, questions were brought to the meeting and the answers were written down. The exploratory interviews were not recorded. In table 8, the gender and role of the participants at Göteborg Energi can be seen.

Table 8: Participants interviews, their gender and role at Göteborg Energi

Göteborg Energi participants	Gender	Role
Mariliis Lehtveer	Female	Research and Development Engineer
Henrik Törnsjö,	Male	Research and Development Strategist

Secondary data

In addition to the semi-structured interviews, secondary data from aggregators' digital platforms (websites) was collected. The secondary data was collected from aggregators that work directly towards the household segment. The data found on the digital platforms

(websites) was written down and used in the empirical findings. Company name and company description of the aggregators whose secondary data was used, can be seen in table 9.

Table 9: *Company and company description of aggregators whose secondary data was used.*

Company	Company description
Tibber (A5)	An electricity company with the aim to create a smarter electricity market. Offers technological equipment to smarter control electricity consumption.
Greenly (A6)	An electricity company with the aim to optimize customers' electricity consumption with the help of technological equipment.

3.4 Sampling

Due to the time limit of the master's thesis and the limited number of contacts with knowledge on the topic of DSF, the purposive sampling method was the method of choice when collecting data. The purposive sampling method relies on the author's judgment in finding suitable candidates which often results in saved money and time (Black, 2010). According to Saunders et al (2009), the purposive sampling method does not provide a representative population. However, given that this thesis focuses on DSF which not many individuals have sufficient knowledge about, this was deemed not to be a problem. In this thesis, interviews with households, aggregators, and employees at Göteborg Energi were conducted. In addition, secondary data from aggregators digital platforms was collected.

The term "household" was defined as a single family household with the ability to control the own energy consumption and energy production of different appliances. The households were selected based on the purposive sampling method and the only requirement was that the participants had to have one of the following flexibility resources: solar PV, heat pump, water heater, and EV charger. These flexibility resources were chosen since they are rather common in households, and are potential flexibility resources that can be controlled and offered to flexibility markets. The number of flexibility resources of the households provided an indication of prior knowledge and understanding of the energy system and appliances connected to the area of energy systems. When the participants were chosen, the goal was to have a spread of prior knowledge, which meant to have participants with a varying number of appliances. In the end, six households with two appliances, three households with three appliances, and one

household with four appliances were found. Participants in this segment were found by contacting individuals known to the thesis writers. The participants were either contacted by phone, email, or direct message.

The term “aggregator” was defined as an actor who collects several flexibility resources and offers these to some flexibility market. Examples of markets were Svk frequency regulating markets, SthImflex, and Effekthandel Väst. Aggregators were selected by searching the internet for aggregators that exist and operate in Sweden. The main focus was to find aggregators that directly worked towards the household segment. Since it was difficult to get in contact with aggregators that worked directly towards the household segment, aggregators that had an understanding and could familiarize themselves with the households perspective was also chosen to be appropriate for the thesis. Aggregators were contacted by email, and in the case a phone number was found, they were also contacted by phone.

Aggregators whose digital platforms (websites) were used, were defined in the same way as the interviewed aggregators. These aggregators were selected by searching the internet for aggregators that exist and operate in Sweden, and who have the main focus on the household segment.

“Employees at Göteborg Energi” was defined as individuals working at Göteborg Energi with some knowledge regarding DSF. Individuals in this segment were found either by talking to individuals in the department of Innovation and digitalisation, or by sending emails to individuals proposed by the supervisor at Göteborg Energi.

3.5 Data analysis

To analyze the literature, a thematic analysis was carried out. According to Bell et al (2019) the thematic analysis is suitable for qualitative data and when the main purpose of the method is to find key themes. In addition, Bell et al (2019) state that the method is rather flexible since it can be used to analyze a wide range of qualitative data. When the literature had been analyzed, four general main themes were identified. They were identified by analyzing existing literature regarding transition processes and innovation systems. One framework in particular, the framework presented by Negro et al. (2012), was used as inspiration. In the article by Negro et al. (2012) the areas of market, infrastructure, and institutions were considered to be valuable to this thesis. In addition, economy & finance was also found in much of the relevant literature, and was added to this thesis as well. In the end, the themes of market-, infrastructure-, institution-, and economy & finance were selected as the main themes. These

themes were then used as a benchmark to analyze information in the overall literature review process.

Data from the semi-structured interviews was obtained by recording the meetings with either a built-in recording program in MIcrosoft Teams, or by using a built-in recording program in the cell phone (if the interview took place in person). In addition to the recording, one of the interviewers was also writing down important aspects during the interviews. All interviews were held by both interviewers so that one could focus on the interview and follow-up questions, while the other could focus on writing down important aspects. The recorded interviews were listened to and parts of the data was transcribed. The parts that were transcribed were used for both quotation and to write down important parts which were later used for the empirical findings chapter. After the analysis and transcription of the data, the empirical findings were sorted into themes. The main themes were selected to be the same as the ones found in the literature (market, infrastructure, institutions, economy & finance), since similarities between the literature review and data from interviews could be found. Some sub-themes could also be identified in the interviews with households and aggregators, and were also used to code the data in some of the main themes. The sub-themes were used to further narrow down some of the main themes to bring clarity. In the case sub-themes were not considered to be needed, just the main themes were used to code. Sub-themes found in the household interviews were interest, understanding, incentives, information, clarity and simplicity in technology, impact & integration, comfort, adaptability & control, financial validity & transparency, and investment costs. Sub-themes found in the aggregator interviews were only for the market area. The rest of the main themes were chosen to be the same. The sub-themes in the market area were chosen to be incentives, information, and market conditions.

3.6 Method discussion

In this chapter, the aspects of credibility, transferability, dependability, confirmability, and ethical considerations will be discussed. According to Bell et al. (2019), in qualitative research, it is important to consider the trustworthiness of the study. It is also important to consider the ethical aspects since research participants otherwise may be exposed to harm if e.g. identities are published without permission (Bell et al, 2019).

3.6.1 Trustworthiness

Lincoln and Guba (1985) as cited in Bell et al. (2019), state that it is important to ensure quality of research, which may be done by considering the aspects of credibility, transferability, dependability, and confirmability.

Credibility

Credibility considers the aspect of acceptance of the study and how well the findings correspond to the reality (Bell et al, 2019). To ensure these aspects, the method of triangulation can be used, since it promotes the use of several methods or sources of data to check if all findings are correct (Bell et al, 2019). In this study, a literature review, semi-structured interviews, and exploratory interviews were held, meaning that several methods of data collection were used. In addition, a wide range of literature was reviewed, four aggregators and ten households were interviewed, and several participants were involved in the exploratory interviews, meaning that several sources of information were also used. This indicates that the credibility of the study may be considered to be good.

Transferability

Transferability refers to the generalization degree of the conducted research and if the findings are applicable in other settings than that of the specific research (Bell et al, 2019). One way to ensure transferability is the extensiveness of the sample method and sample size (Bell et al, 2019). In this study, households were interviewed regarding their awareness of their electricity consumption and of the concept of DSF. Since several households were interviewed with different levels of knowledge and understanding of electricity consumption and DSF, it can be considered to be an acceptable sample size. The sample size of the aggregators were four and are considered to be decent. To increase the transferability of this study, a larger sample size would be preferable, especially in the case of the aggregators. However, the findings are considered to be relevant for other areas in the energy sector, meaning that it is still considered as generalizable and therefore includes the aspect of transferability.

Dependability

Dependability refers to the trustworthiness of the research process (Bell et al, 2019). This includes that documentation of all processes in the study has been conducted. In this research, the dependability aspect has been covered since all steps of the study have either been described in this method chapter or in the other chapters. The study has also been peer reviewed in a mid term meeting, both by the examiner and opponents to this study. In addition, continuous meetings every week with the examiner of the study have been conducted. All these aspects have worked towards improving the dependability of the study.

Confirmability

Confirmability is the degree of objectivity that has been taken into account in the research (Bell et al, 2019). Complete objectivity in a research study is impossible to achieve, therefore it is important that the authors have considered the aspect of objectivity throughout the whole

study, to minimize biased research and findings. This aspect has been taken into consideration when candidates were selected for interviews and when the literature for the literature review was selected. An effort in objectivism in the data collection methods, in combination with the reminder of objectivism throughout the whole research, has ensured good confirmability.

3.6.2 Ethical considerations

In all studies it is important to consider the ethical aspects. According to Bell et al. (2019), there are four main areas to consider namely; *avoidance of harm, informed consent, privacy,* and *preventing deception*.

Avoidance of harm includes e.g. harm to participants self-esteem, stress, or harm to future employment (Bell et al, 2019). To avoid these aspects to a certain degree, the AON code of Ethics could be followed. According to the AON code of Ethics, the aspects of anonymity and confidentiality should be agreed upon between the interviewer and the participant, and if the participant does want to be anonymous, this should be accepted (Bell et al, 2019). This aspect was considered in this thesis since all interview subjects were asked whether they wanted to be anonymous or not. All participants were also informed that they could at any time, during or after the interview withdraw their answers. In addition, the results used from the aggregators were sent back to them, to let them check general information and quotations from their answers.

Informed consent relates to the aspect of information. According to Bell et al. (2019) it is important that participants in a research study have enough information to make a decision whether they want to participate or not. In this master's thesis, all participants were informed either by email or in person, what the research was about and what questions we were about to ask. This ensured that all participants informed their consent to contribute.

Privacy refers to the potential harm that may be caused if too much information is conducted or if too many personal questions are asked (Bell et al, 2019). The privacy aspect was respected in the conducted interviews since the interview questions were sent out in advance to the participants, and since it was stated before the interviews began that any question that the participant did not want to answer was completely fine.

Deception in research studies means that the research is presented as something it is not (Bell et al, 2019). During this master's thesis, deception has been prevented by stating to participants what the research was about, what questions that were to be asked, and what

answers that were expected to be used in the empirical findings. In addition, information in the literature review was selected and cited correctly, so that future researchers can easily find the source.

4. Empirical findings

This chapter will present and outline the results from the data collection and will be organized in accordance with the themes brought up in chapter 3.4. The household perspective is divided into the main themes of market, infrastructure, institutions, and economy & finance. The main themes are in turn divided into the sub-themes of interest, understanding, incentives, information, clarity and simplicity in technology, impact & integration, comfort, adaptability & control, financial validity & transparency, and investment costs. The aggregator perspective is divided into the main themes of market, infrastructure, institutions, and economy & finance. The main theme of market is in turn divided into the sub-themes of incentives, information, and market conditions. The household perspective will be described with data gathered from interviews while the aggregator perspective will be presented with data from both interviews and digital platforms.

4.1 Household perspective

In this section the household perspective will be laid out. The data and main themes found in the interviews will be described and concretized with quotes and statements from participants.

4.1.1 Market

In this section, the empirical findings regarding the market aspect will be laid out. The areas of interest, understanding, incentives and information will be covered through the households' perspective.

Interest

Most households interviewed had some interest about their electricity consumption besides only looking at their electrical bill (H1, H2, H5, H6, H8, H10). Participants who displayed a smaller interest for their energy consumption, who only looked at e.g. their monthly/quarterly invoice, did so due to a lack of incentives or capability, stating that they did not see any major economic benefit in engaging with their electricity use (H4, H7) or that they did feel that they had the technical capability or knowledge to effectively engage in their energy consumption (H3, H9).

"I'm not so interested in my energy consumption, as I don't see any financial incentives for it right now" - H7

"I feel that i cannot, in a meaningful way, affect the energy consumption of my household" -

H4

On the other hand, participants that showed great interest in their electricity use generally displayed more pickiness around what information around their consumption they wanted to know and how it should be conveyed (H2, H8, H10). Though, the overall interest from interviewees to engage in their energy consumpition came from economic reasons and only occasionally in combination with a genuine technical interest.

"As bit of a nerd, I would like to know what happens in all the steps and processes" - H8

The preexisting awareness of DSF was low with only two participants knowing about it before the interview (H8, H10) though the interest in the concept of DSF was still high among interviewees after they were made aware of its existence, workings and benefits. Even the interviewees that had stated to not have any significant engagement in their electricity consumption still expressed an interest for DSF (H3, H4, H9). The interest generally came from hearing about the economic incentives of DSF as opposed to a technical interest. Only one interviewee clearly expressed a lower interest for DSF as they worried about the loss of control over their own system which they perceived as potentially increasing overall hassle too much in relation to potential economic gains (H5).

"I'm not that engaged in my electricity consumption for the start, but if it [DSF] could save or make me money i would absolutely be interested" - H3

"I want to know my stuff that is in the house, [But if there would be someone who can control better [from an economic perspective] than you can do yourself, do you feel that in that case it would be easier to take that step [to connect equipment to the flexibility market] ?] Then you at least start to consider it" - H5

Understanding

Almost all interviewees showed interest towards DSF after getting a shorter explanation around its workings and incentives. Though preexisting knowledge and understanding around it was low, most participants did not know what DSF was when asked about it. The few interviewees that actually had preexisting knowledge about it had so due to their current work setting (H8, H10) while the other majority needed a proper introduction to the subject of DSF before it could be discussed more deeply.

On the other hand, the understanding of the own household and its consumption was more widespread among interviewees. Interview participants who demonstrated a greater

comprehension of their personal consumption (H1, H2, H5, H6, H8, H10) had acquired this understanding through the use of various apps and meters within their households. Their motivation stemmed from either their interest in topics related to economy and energy or their prior investments in equipment such as solar panels or electric vehicles. In addition to this, participants, regardless of preexisting knowledge or interest, were interested in becoming more technically familiar with their own electricity production and DSF in the future as long as the incentives were there. However, interest varied between participants, with some indicating that they would consider it only if it proved time efficient (H4, H5, H6, H7), while others expressed a need for extensive guidance due to their limited basic knowledge (H3, H7, H9). On the other hand, some participants showed a strong desire to acquire more in-depth knowledge about DSF and energy consumption, as they perceived it as both intellectually and technically rewarding (H1, H2, H8, H10).

"[Why do you feel positive about becoming more technically aware of your electricity use and DSF?] If you have more control and can influence your finances, absolutely, but at the same time I don't want it to affect my comfort and that I have to keep track of it all the time" - H7

"[How do you feel about becoming more technically familiar with your own electricity system and the general technical developments in demand side flexibility in order to participate in the demand side flexibility market?] Great, more than happy, more information, I love it" - H2

Incentives

Participants showed interest in becoming or already had a previous interest in their own consumption and/or in the concept of DSF services. The main incentive that participants expressed for both of these was generally linked to some form of financial gain.

"In my professional life I have always been interested in electricity plus there is a financial incentive [to get involved in your electricity use]" - H2

"I would consider offering my heat pump [to a flexibility market] as long as I get financial compensation for it" - H6

Interviewees reacted positively to how participation in a DSF service could provide potential financial benefits both in terms of savings and/or a form of premium. However, one interviewee (H8) regarded the primary motivation for engaging in flexibility as the environmental and sustainability advantages. Nonetheless, H8 expressed the desire to avoid financial losses and emphasized the importance of at least breaking even. Even though the overwhelming number

of interviewees saw the economic incentive as the most crucial one, a lot of them also considered environmental incentives as a nice "bonus" that came with DSF (H1, H2, H5, H7, H8, H10). In addition, some of the participants, after being made aware of DSF, saw it as a form of collective action contributing to the stabilization of the grid, which they also saw as an incentive to start delivering DSF, even if it came second to the economic incentive (H4, H5, H8, H10).

"I understand that this can be needed [DSF] to be able to build renewable energy at a faster level, absolutely that you want to support it [But it's not the first thing you think of when it comes to incentives for you?] no, it's financial" - H1

"[Would you consider allowing your heat pump to be part of the demand side flexibility market?] Sure [And why can you imagine that?] Well, it's to, one, optimize my electricity consumption and price, and two, to help and support the electricity grid" - H10

Information

When asked about what information interviewees needed before they felt comfortable making decisions around their general energy systems or specific DSF solution several aspects were brought up. The main informational concerns with DSF were around comfort, control, simplicity, adaptability, economical model and technical aspects. People with more interest and knowledge around their energy consumption were generally also more interested in information around technical aspects (e.g. how things are controlled and how it works), adaptability and specifics of the economics in relation to their particular system (H1, H2, H8, H10).

"[What kind of information would have been important for you to know in these information sheets or videos?] in that case, that you can design your own contract yourself, your terms and conditions [...] it should be clear on what you gain from this what we gain from this, transparency plain and simple" - H1

Interviewees' with more casual or low interest were generally more concerned with information around simplicity, comfort and broader economic questions, such as how DSF will affect their ability to regulate temperature, if it would mean that they can't shower when they want to, what monetary compensation they could gain from this, potential lock-in effects caused by contracts, or need for technical commitment.

"I would probably like to know what can go wrong, if you can press the wrong button and suddenly the electricity bill is much higher [...]. You want it so that when the contract is over, someone calls and gets in touch so that it is clear that you are not stuck in something that is expensive and that you have difficulty getting out of" - H9

"I would like to know how it would affect the comfort of my home, how will it affect my indoor temperature for example? And what would I gain in compensation for that?" - H6

Another informational aspect brought up during the interviews was the concept of sharing information and integrity. Interviewees felt no barriers towards sharing information around their households' consumption behavior to a third-party actor as long as the information shared was relevant towards the function of the service. Barriers would arise if information was collected that were not necessarily relevant to the service or if the information was later sold on to other actors for other purposes, a level of transparency was therefore necessary in this regard.

Another aspect of information is how participants want to receive the information. When asked about what kind of way they wanted to receive information (Information pamphlet, website, social media, home visit, video) the response was rather mixed. Most respondents preferred either pamphlets, video or website/social media as first means of contact and were often reluctant towards home visits as a first option. Some interviewees did not prefer social media / websites as they perceived these sources as already being clogged up with so much other information (H9, H4). Though if they were to be interested by the first information source a phone call or home visit was often seen as a viable option in order to discuss further about specifics around their household. However, one of the participants (H10) expressed a preference for more interactive informational sources from the start, such as home visits, as they allow for more dynamic information and go beyond simple standard solutions which was something requested by H10.

4.1.2 Infrastructure

In this section, the empirical findings regarding the infrastructure aspect will be laid out. The areas of technological clarity and simplicity as well as impact and integration will be covered through the households' perspective.

Clarity and Simplicity in Technology

Several participants had some form of technology to monitor and track their electricity consumption (H1, H2, H5, H6, H8, H10). A few of them were relatively new to the technology

as they started controlling their electricity use as a reaction to the recent rise in electricity prices (H1, H5, H6,). In general, participants who tracked their electricity consumption expressed no major difficulties in doing so. However, several attendees advocated for an increased level of standardization and improved integration across the board. This would facilitate the monitoring and management of household appliances and equipment through a single platform (H5, H8, H10).

"Many different apps with several different ways [...] it can be a bit cumbersome. I like to have all the energy-related things in the same place so that you just have an overall view [...] so everything about energy in the household is in the same place" - H8

Households expressed needs of clarity and simplicity if they were to further engage with DSF solutions. When asked what they meant by this, some households expressed a need for clarity and simplicity when it came to technology around their energy systems. When they elaborated on this some households requested simple installation and operation where the equipment "should just work" and not require that much engagement or invested time (H1, H4, H5, H6, H7). Other households wanted to have a very simple interface and engagement with the technology where there was very little room for potential errors that would lead to negative effects upon the household's comfort or economy (H3, H9). Having easy access to support if something were to go wrong or if there was something that they did not understand was also an important aspect voiced by some households (H3, H5, H7, H9).

"If it's very simple [the technology], there are very few reasons not to get involved at least a little bit. [So if it's a bit too time-consuming or complicated, you'd rather abstain?] Yes, absolutely, unless the [financial] benefit outweighs the work" - H4

Impact and Integration

During interviews regarding DSF, several participants expressed concerns about the potential physical effects that it could have on their appliances and equipment at home (H2, H8, H9, H10). These concerns were particularly focused on the impact of frequent on/off switching and non-continuous control on various appliances and equipment, including heat pumps and electric vehicles (EVs). Participants had concerns about the potential for reduced lifespan or loss of proper functioning of their appliances and equipment and many felt that they wanted more information around this aspect before committing to the program. They wanted to understand the potential risks associated with frequent on/off switching and non-continuous control, and to know what steps that would be taken to mitigate any negative impacts.

“The safety, that it will not be damaged, that its lifespan will not be affected to any great extent” - H8

"As far as the heat pump is concerned, it works best when it is not working hysterically, there should not be an on/off switch on the heat pump" - H2

Technical adaptability was another aspect that interviewees brought up in the different interviews. Depending on if the interviewee were more or less involved in their own energy consumption and already had installed equipment or instruments such as smart meter, EV charger, solar panels or monitoring apps, they displayed different requirements on the aspect of adaptability. Interviewees with both a clear understanding and interest in their own consumption or/and DSF (H2, H8, H10) were more picky about how potential flexibility assets of their home are to be connected, controlled and integrated with each other. They wanted to know more about how the service could be adapted to their specific technical and lifestyle context, if all their appliances/equipment could be connected and controlled in a single solution (H8) and if it could be adapted to more complex price structures such as power tariffs (H10). There were also some worries about how optimally appliances/equipment could be controlled and monitored and if it was worth it in relation to doing it manually themselves (H2, H5).

“I have these gadgets, what would it look like for me if I subscribe to your service? Can they control all of them or is it just the car? So you know what you can connect or not.” - H8

“Not only that it is a standard gadget but also that it can be put in to a context - H10
“I'd rather do it myself, I don't like relying on somebody else” - H5

4.1.3 Institution

In this section, the empirical findings regarding the institution aspect will be laid out. The areas of soft institutions will be covered through the households’ perspective which includes aspects of comfort, adaptability and control. Hard institutional aspects were not brought up by households therefore it is not included.

Comfort

Comfort, as described by the participants, encompasses several factors that collectively contribute to their satisfaction with their living environment. These factors may include, but are not limited to, the stability of indoor climate, the predictability of daily routines, and the ability to use household resources. As a result, comfort was an essential element for homeowners

to consider when evaluating the potential benefits and drawbacks of integrating various DSF resources into their homes.

"[What would be the biggest barriers for you to start contributing with flexibility?] that it would seriously limit my own consumption of electricity" - H4

As the participants discussed their willingness to offer certain flexibility resources available in their homes, it became clear that some resources were more strongly associated with comfort concerns. For instance, when considering the use of their heat pump as a resource, interviewees expressed concerns about fluctuations in indoor temperature that could potentially disrupt their sense of comfort (H1, H2, H3, H4, H5, H6, H7, H9, H10). Likewise, connecting their water heater to the DSF solution raised concerns about the possible impact on their daily routines, such as showering and washing (H1, H3, H4, H5, H6, H8, H9).

"If i'm at home want to have a certain temperature and not deviate from that in any significant way" - H6

Similarly, electric vehicle (EV) owners expressed apprehension about potential inconveniences that may arise from the integration of their EV into the DSF solution (H8, H10). Concerns included not having the vehicle fully charged and ready for spontaneous outings or even for their daily commute to work. In contrast, participants considered solar PV systems to be less intrusive to their daily lives and comfort. The reason behind this perception is that relinquishing control over their solar PV systems does not have a direct impact on their daily routines and home environment resulting in fewer expressed barriers to comfort for this specific resource (H1, H2, H5, H8).

"It's all about what charge you have on the battery, for example, it must never be allowed to go below 60% [...] We drive the car a little differently, we don't go to work at 7:30 every morning but it's here [The EV] and you need it sometimes and then you may need it at fairly short notice" - H10

Adaptability & Control

Participants voiced concerns regarding the compatibility of DSF solutions with their personal behaviors and comfort requirements, such as maintaining a desired home temperature or enjoying comfortable showers. Therefore, all interviewees considered adaptation of the DSF service to their schedules as crucial, particularly emphasizing the need for enabling prompt adjustments in unforeseen circumstances that necessitated access to or control over specific equipment. This adaptability factor was closely intertwined with their desire for control and predictability in the resource utilization process (H1, H3, H9, H10). Control-related concerns

revolved around the extent of manual control retained over appliances and equipment, the ability to regain control when needed, and the overall transparency of the system (how and when things will be under DSF control). The interviewees generally demonstrated understanding regarding potential additional costs associated with regaining control, as long as the cost structure and process were transparent. In summary, both adaptability and control emerged as interconnected priorities for the participants when considering DSF solutions.

"If I'm having a party or something similar, I may not want to stand at 19 degrees, then I want to be able to change the temperature for a while" - H9

"If I'm sick at home, I don't want to have to freeze, I want to be able to start the heat pump regardless" - H1

4.1.4 Economy and finance

In this section, the empirical findings regarding economy and finance will be laid out. The areas of financial validity, business models, and investment costs will be covered through the households' perspective.

Financial validity and transparency

Almost all participants saw the economic part of the DSF offer as the most crucial incentive for them to participate in the service. As DSF can bring upon a level of discomfort, participants were very clear that this needs to be adequately compensated for in terms of transparency but mainly economically. Even the interviewee who was more interested in the environmental and stability incentives had requirements upon the economic model and that it should at least break even (H8).

"If you are going to freeze, you have to make something from it" - H2

Some interviewees were also interested in knowing further specifics around the DSF business model (H1, H2, H4, H8, H10). They requested a level of transparency in order to see how their equipment was used (in an economic sense) and what part of the generated monetary value comes back to them. It was important to establish a level of trust in order to know that the proposed deal is fair and that there are no hidden agendas.

"I would like to know what financial share I will get in case of any flex purchases on, for example, local flex markets" - H8

Furthermore, some participants also worried about potential lock-in effects which could result in them being tied to a specific provider and limit their ability to switch or terminate the contract if they are not satisfied with the quality or economic benefits of the service (H1,H3, H9). To address these concerns, participants again requested a high level of transparency around the terms and conditions of the potential agreements they may enter into. Additionally, participants also requested flexibility in the form of trial periods or short notice periods (H3, H9).

"Before I enter a contract I must first ensure that I don't get stuck in it, that I can leave it on a reasonable time basis. I would also like to have some sort of trial period just to get a feeling for its practical implication and actual economic benefit" - H3

Investment costs

Another aspect discussed with participants was the issue of investment costs. When asked about what kind of initial investments the interviewees would be willing to make in relation to their current understanding and interest in DSF, most participants felt that it was wise to start with lower investment levels as most of them still had very little knowledge of the topic, its economic benefits and potential pay-back time (H1, H3, H4, H5, H6, H7, H9). Others had a hard time answering the question due to them feeling uncertain about the long term economic gain of DSF (H2, H10). One participant was comfortable in making larger investments, but that was mostly connected to them already having made previously large such investments in their energy system and that these could make money in other ways besides the potential income of DSF (e.g. battery for solar PV) (H8). In table 10, a summary of challenges expressed by the households in the four systemic areas can be seen.

Table 10: *Summary of challenges expressed by households in the systemic areas.*

Area	Challenges
Market	Limited awareness of DSF
	Limited understanding of DSF
	Some level of varying interest in DSF and personal electricity consumption depending on the household
	Environmental and stabilization aspect seen as a bonus while economic is the main incentive
	The necessity for transparent, ample, easy-to-understand, and varied information, as well as diverse communication avenues

Infrastructure	Need for standardization and integration of appliances under one platform or solution
	Need for simplified technology and clarity in installation and operation
	Concerns about wear and tear damage of connected equipment
	Interest of becoming more technically aware of DSF and personal energy systems varied among participants
	Worries about how optimal the DSF service could control or adapt equipment and appliances
Institutions	Concerns regarding the compatibility of DSF solutions with personal behavior and comfort requirements
	Retaining transparency and control in the DSF system
	Being able to Customize DSF services to personal needs and behavior
	Some resources are more prone to comfort barriers than others
Economy & finance	Economic incentives as primary motivators
	Worries about lock-in effects, bad contracts, and trial periods
	Adequate compensation for time and comfort loss
	Concerns about transparency, what share of the economic pot they are receiving
	High initial investment costs and uncertain business models

4.2 Aggregator perspective

In this section, the aggregator perspective will be laid out. The main information will originate from interviews held with participants working in companies delivering flexibility services. The participants' position and company description can be seen in table 7. Information obtained from the interviews will be described and quotes will be used to emphasize certain areas of interest. Some information has been conducted from aggregators digital platforms (website), and the companies and company description can be seen in table 9.

The aggregators are active in delivering flexibility from different flexibility resources such as batteries, solar PVs, and EV chargers. The interviewed aggregators, respondents A1, A2, A3, and A4, state that they work with different customers such as households, electricity providers, commercial property owners, and industrial clients. Respondent A1 works directly towards the household segment while respondents A2, A3, and A4 state that they are not working directly towards households today, but have information and understanding about the segment that is still applicable to this thesis. Information from A5 & A6 was collected from their digital platforms (website), and both are considered to mainly focus on households.

4.2.1 Market

In this section, the empirical findings regarding the market aspect will be laid out. The areas of incentives, information, and market conditions will be covered through the aggregators' perspective.

Incentives

In the case of the household segment, the respondents state a couple of incentives that are important as of today, and what they think will be important in the future. All respondents (A1, A2, A3, A4) state that the economic aspect is one of the most important factors when it comes to households, and that it will be equally important in the future. If the economic compensation is too small, it will not be as attractive to contribute with flexibility. A2 states that the economic incentive is important, while A1 states that it is the second strongest incentive among households.

"Customers want to gain a good return on the investment, otherwise is it not attractive to start with it" - A2

"They [households] have to get an economic compensation to start contributing with flexibility" - A3

Although all respondents (A1, A2, A3, A4) consider the economic incentive to be one of the most important incentives when it comes to households and DSF, the compensation is often quite low. A3 and A4 state that the low compensation for residential customers is one of the largest criticisms of DSF today.

"This is the big criticism today, there are not much money to earn today as a flexibility provider" - A3

It is not only the economic incentive that is considered to be important. According to A1, the main incentive for households to start delivering flexibility is to feel that they contribute to the greater good, whether it is socially, environmentally, or economically. A3 further states that households have become more environmentally conscious in the last couple of years, and are therefore more willing to allow their indoor climate to be affected compared to before, to facilitate the transition to electrification.

"The acceptance has increased to deviate from the regular comfort [...] They [households] have an increased understanding of this [environment aspect]" - A3

To fulfill the incentives that are important to households, the electricity provider may come into play (A1). A1 brings up the example of an electricity provider that has a solution where households can choose how socially, environmentally, or economically oriented they want to be with their flexibility contribution. This can e.g. be households that want to produce electricity with their own solar PVs for their own household, even though it is more economically beneficial to sell the excess amount (they want to focus on their own environmental impact rather than maximizing the economic compensation). To meet the economic needs of households, electricity providers may reduce the electricity bill with a flexibility compensation, or offer discounts on e.g. charging of EVs through wallboxes (A1).

"Then you [households] can get a flexibility compensation that will be like a discount on your electricity bill [...] other services may include that you get a discount on your charging fee" - A1

The aggregator function in this case, has the potential to collaborate with electricity providers to come up with solutions and infrastructure that allows households to get the incentives that are important to them (A1).

A4 adds to this subject by stating that the economical compensation of the different DSF systems is dependent on the engagement and investments of grid owners and energy producers. The more money they put into the system the more economic gain it could also potentially yield. If there is a lack of economic initiative in some flexibility markets, aggregators may control and manage for other price patterns such as spot prices (A4).

"Those who put money into this system [flexibility] are network owners and energy producers, so depending on how much they want to put into this, I think they are the ones who will determine how much you can [earn], otherwise you [aggregators] will steer according to other price patterns such as the spot price market." - A4

“Those who want to buy the power are not really willing to pay for it at the moment. The tests that have been carried out, have been during times when it has not been so [pause] extreme. This is one reason for low prices. What can you say, there has not been close to chaos yet really, it has not hit the wall. I believe the day they really need to buy [flexibility], that's when the price will go up” - A4

Looking at the websites of A5 and A6, it is clearly displayed that cost reductions are to be gained by using their services. They state that their customers are to reduce their costs by using energy when it is at the cheapest price. In addition to the economic incentive, both A5 and A6 state that by using their services, customers are also contributing to a more sustainable world with a more effective energy management. Lastly, both A5 and A6 portray their services to be easy to switch to and use. When transitioned to their service, customers may connect compatible equipment to their app which can display further information regarding e.g. current prices, use, and production.

Information

According to the aggregators (A1, A4), sufficient information is also important when it comes to households and DSF. The processes to start delivering flexibility can be complex and difficult for households, and as of today it is often households with great technical interest that have some knowledge about the concept of DSF and how it works (A1). Households that are not interested in the technical aspect of DSF are often lacking knowledge and information, and need help in navigating the area. According to A1 and A4, this is where the aggregator function has the opportunity to bring expertise and information to help households understand what DSF is and to help them make decisions that fit their needs. A1 states that this will probably be even more important in the future when the mass market gets interested in DSF.

"Gothenburg Energy [Electricity electricity supplier and producer] is an expert on the grid and its production, but to analyze specific behavior for these customers [households], then it might be good with an intermediary like us" - A4

A5 and A6 both display information regarding services and equipment on their websites. They display for example information regarding how to become a customer, how to lower costs regarding electricity consumption, and physical equipment (e.g. heat pumps and EV chargers) that is needed to start with some of their services. A5 displays information in text on their website, while A6 has text and video-format to display information.

To succeed in delivering information to households, the aggregator function may use several ways or tools. This can e.g. be done by displaying flexibility services on websites, launching marketing campaigns, conducting meet and greet with households, using industry magazines such as "Villa-ägarna", or in person communication with customers, to provide information (A1). It is not only the ways and tools of providing information that are important, it is also important to act as a trustable source of information. According to A1, simpleness, transparency, and openness are important aspects in order to gain trust from households. It is important to gain trust and at the same time be on the same wavelength, to not make the households feel uncomfortable. A2 also speaks about building a strong brand that communicates trustworthiness towards the customers. A2 states that they do this by directly communicating with interested customers and showing how they actively participate and develop solutions for flexibility markets.

"*You have to be transparent towards them [households] to get them to join. You also have to make it simple, you have to show simple business cases that are easy to motivate and to show how everything works*" - A1

"We own it ourselves [the solutions], we have "skin in the game", we don't just optimize others [Is this something you communicate with customers?] I've mentioned it a few times." - A2

According to A1, transparency is especially important when it comes to households with a great technical interest. This is since they are the ones that know a bit more about equipment and DSF overall, and are therefore more likely to judge the process of delivering flexibility. In this case, it is important as an aggregator to bring as much information as possible and be transparent, to avoid misunderstandings (A1).

Market conditions

A3 and A4 state that as of today, markets for households are not well established. SthImflex and Effekthandel Väst are markets that exist and are options for aggregators to operate in, but they are not optimal for households since they do not cover all geographical areas in Sweden making it hard for households in areas without a market to understand how to participate (A3, A4). Even if a household could find someone that would accept their flexibility, there is no, in A4's opinion, easy nor standardized way to connect appliances and equipment of households (A4). However, A4 also recognizes that in the future, aggregators are likely to play an important role in the connection process by communicating information and, in a way, acting as the face of DSF to gather interest and manage the connection of households to the market (A4). A3 further states that they have not had any discussions with households about entering these markets due to the lack of well-established markets for households.

"When it comes to DSF, it is required that a platform exist to operate in [...] there is a lack of platforms in this area, they do not exist everywhere [...] we have not had discussions with households regarding flexibility since the opportunity has not been there" - A3

In addition, A3 states that the local markets have their own standards making it difficult for actors such as grid owners or households to participate as different geographical areas have different standards, requiring different adaptations. A3 states that the aggregator function could aid in developing more global platforms with single standards which in turn lower the entry barrier for participation and creates a robustness for which a stronger economic model also can be developed upon.

A3 also mentions that, especially a couple of years ago, households could almost be a bit suspicious regarding DSF since initiatives came from the grid operators. In this case the aggregator function had, or still has, the opportunity to be a neutral third party that also works in favor of household terms and conditions (A3).

4.2.2 Infrastructure

In this section, the empirical findings regarding the infrastructure perspective will be laid out. Infrastructure mainly focuses on the technological aspect associated with DSF.

According to A1, one challenge with households regarding infrastructure and DSF can be found in existing technological equipment. Some equipment is not made to help households provide flexibility. This can for example be an inverter with the function of reporting the

production from solar PV's so that the owner can see how much that has been produced. This type of equipment is in some cases not optimal or even applicable to use when households are to start delivering flexibility (A1). A4 also states that some equipment is not optimal to use when it comes to households and DSF. A4 brings up the example of a dishwasher without an already integrated control system not being economically justifiable to control, since it would require new controlling equipment and someone to install it. A3 further states that when it comes to households, the technical equipment that exists today, is not as advanced compared to the equipment found in e.g. the commercial properties. Equipment such as sensors and building management systems to collect and optimize energy consumption is not as developed in the household market compared to the ones found for commercial properties. According to A3, the less developed household segment may be a result of lower demand from customers, and since sensors and building management systems come with an initial investment cost, which may hinder households to buy the equipment. This makes it harder for aggregators to operate in the household market.

"The challenge is to get the technology developers to understand that more has to be done [regarding equipment]. If customers [households] are to make money more has to be done"

- A1

"I have not the best understanding regarding households, but in general, this is a segment where you are behind [...] you don't have the same technical systems in smaller households compared to commercial properties [...] they [households] might not have a control system"

- A3

A2 also expresses some technical challenges connected to households. A2 states that problems could arise in aspects such as response time, communication, coordination of large numbers of smaller resources, software updates, or changed requirements from Svk.

"A lot of technical yidder, everything from response times to availability, routers that don't work with communication, do 10000 batteries respond in one second in an aggregated portfolio when they are so different? [Geographically]" - A2

One way to minimize the technological challenges associated with DSF, is for the aggregator function to start collaborating or coordinating technology developers to bring forward solutions that are suitable for households, so that the households may start contributing with flexibility and earn money from it (A1). The aggregator can also act as a technological developer themselves and seek to create their own innovative solution (A2).

"We are working directly with technology developers [...] we try to coordinate with them to create this opportunity for households" - A1

"[Do you come up with new solutions as well, is that what you work with in terms of R&D?] Yes, we are an innovative startup as well [...] We are working to make an interface easier to use so that we can bid in [to flexibility markets] - A2

Another technological aspect that is important when it comes to DSF is digitalization. According to A3, digitalization of processes connected to DSF is a prerequisite to be able to make it work efficiently, and is something that the aggregator function can provide expertise about. Digitalization may include aspects such as equipment for control and data analysis to make reactive and proactive decisions regarding flexibility resources (A3).

"This is a prerequisite, digitalization is a prerequisite for us to fix this [provide flexibility]"
- A3

When it comes to infrastructure, it is also important that households feel that it is simple to navigate through the equipment and interfaces. At the moment, households often buy the cheapest equipment in each category, e.g. in the EV charger category (A1). According to A1, the equipment is not that much of a problem, but the interface poses a bigger challenge. Households generally want to see all their connected units (such as EV charger, battery, inverter) in the same place, e.g. via one app (A1). With several producers of equipment, often consisting of different interfaces, the comfort and ease of use for households will be negatively affected. According to A1, in this case a third-party actor, e.g. an electricity provider, has the opportunity to create a common platform for households that is easy to use. This can be done via an app where the possibility to connect different flexibility resources exists. The aggregator function has in this case the opportunity to help establish the infrastructure and a solution that is needed to make it easier for households to buy and install the equipment needed to start delivering flexibility. As an example A5 collaborates with installation companies to perform the installation process. Households just have to enter their ZIP code online, and after the equipment has been bought, the installation company will contact the household to book an appointment for the installation.

A4 also states that the interface aspect is important for households, they want to have the same interface for all their appliances. A4 states that standardization of the interface would make everything easier for the households, but this will be hard to achieve since companies

have different interfaces on their appliances and will probably not change that. In this case, the aggregator function could possibly collaborate with producers of equipment with control systems, to integrate the same infrastructure, benefitting the households (A4).

"I think it is hard for us to affect a producer of equipment if we don't make some sort of collaboration [...] we could go to them and say that we want to make a collaboration but as for now, it will not generate as much business compared to workload " - A4

A4 also states that the aggregator function has the possibility to be specialized in automation and to control flexibility resources in a better way compared to electricity providers. Aggregators are often better in controlling flexibility resources on demands that customers, such as households, have.

"We have better understanding in automation and to build up the parts that are needed to control properties on the private persons' terms, I think we have an advantage there compared to the electricity companies. We have better knowledge in this area" - A4

4.2.3 Institutions

In this section, the empirical findings regarding institutions will be laid out. Institutions mainly focus on laws and regulations that are associated with DSF.

According to A1, A3, and A4 the laws and regulations that exist today do not affect the aggregator function significantly in their ability to get households to start delivering flexibility. A3 states that whether the flexibility resource comes from households or other actors, it is a flexibility resource that is going to be delivered, and both work fine to deliver on local markets. The only challenge would be if the flexibility resource, e.g. households, is to be delivered to Svenska Kraftnäts frequency regulating market since it requires a prequalification (A3). Though, A2 states that they handle this kind of prequalification processes for their customers and makes sure that the customer system conforms to standards and regulations necessary for participation. A1 talks about similar support as A2 and states that they as aggregators can help customers navigate through the hard institutional complexity of the electrical market and DSF due to their expertise and experience in the area. A4 also states that it is no problem to deliver flexibility to the local flexibility markets, but that it is harder to deliver flexibility resources to the frequency regulating markets since they require a much faster response time.

A1 states that the laws and regulations work completely fine, and when the function of the balance responsible party (BRP) and the balancing service provider (BSP) in Sweden has been updated to be more similar to that of the European regulations, it will be even easier to act as an aggregator.

“In future regulations regarding the balancing service provider (BSP) and everything that is related to that has come into play, things will become even easier. But today it is still going very well” - A1

Regarding regulations and laws in Sweden, A1 and A3 feel that the aggregator function has the opportunity to communicate and express thoughts to the ones responsible for developing the regulations and laws. A1 states that the opportunity to communicate and express ideas with e.g. Energimarknadsinspektionen exists. Energimarknadsinspektionenin in turn may bring up the ideas to the Swedish parliament which institutes the laws. The aggregator function has the opportunity to be involved in discussions regarding DSF and express ideas on the subject which may be listened to by the ones developing and instituting laws (A1).

"Energimarknadsinspektionen are the ones that come with suggestions to the Swedish parliament. They [Energimarknadsinspektionen] listens very much [...] you get listened to when you come and say that I’m [the aggregator function] thinking about this and I’m wondering about this, and we think that this would improve that and this would disimprove that" - A1

Another function the aggregator role has, is that they are the ones that have understanding about laws and regulation connected to DSF (A1, A2, A3, A4). Households don’t have to get involved with regulations and laws and according to A1 and A3, they should not have to get involved either. A4 further states that it would probably be too much information for households to take in. A4 states that they work with this as their full-time job, and it would require too much time for households to understand everything.

“No, they [households] *don’t have to get involved* [regarding Laws and regulations]*”* - A1

“We are the ones that are looking at that [Laws and regulations], it would be too much for a household, I think that the aggregator function has to take that role” - A4

According to A3, another challenge with laws and regulations is that many of them are under development at the moment. This means that some of the consequences have not emerged

yet, making it harder to navigate through them and completely understand them. From the household perspective, this environment becomes very complex and hard to understand. With easier overall legislation, households' overall understanding could be improved (A3).

"[Clearer legislation from the legislation makers would make it more clear for households as well?] Yes, definitely" - A3

In addition to handling hard institutional aspects, soft institutional factors such as comfort and simplicity are also considered to be important when it comes to households and DSF (A1, A2, A3, A4). The households do not have the time to understand everything in detail, nor do they want to put in the effort that may be required. According to A3 and A4 it is important to create low thresholds to get households to start contributing with flexibility so that high volumes of flexibility resources may be generated. Households want everything related to flexibility to work as smoothly as possible and, ideally, they only want to accept the terms of getting started with DSF and then let it run without any problems (A1). Since DSF can be seen as a rather new phenomena, especially in regards to households, the focus will probably be even more on problem free solutions in the future when the mass market has been reached (A1).

"[Household perspective] This sounds really nice, I can buy it if it works, I want to press "Yes", then I just want it to work" - A1

According to A1, for households to obtain comfort and simplicity, it is important to have the right technology from the beginning. By having the right technology from the beginning, households will reduce the risk of having technology that is not compatible or optimal when it comes to delivering flexibility. This can e.g. be batteries, electrical vehicle chargers, or inverters that are obsolete or not compatible with delivering flexibility. In this case, the aggregator role has the opportunity in helping households to select the necessary technology to start delivering flexibility and to act as a trustable source in providing this expertise. The aggregator function has the potential in pinpointing households in the right direction regarding equipment and brand, so that they are future-proof in this aspect.

"*We can pinpoint them [households] in the right direction [...] look at these brands of inverters or batteries, because then you will be future-proof*" - A1

A4 further states that the aggregator function can better adapt to requirements and needs of customers compared to established utilities by controlling and scheduling flexibility resources with respect to the households' behavior. By being able to offer a standard solution with the

option of tweaking several parameters, more tailored services can be created in order to conform to aspects of adaptability, comfort and control (A4). By being able to offer a standard solution with the option of tweaking several parameters, aggregators can create more tailored services adapted towards the customers individual needs (A4).

4.2.4 Economy and finance

In this section, the empirical findings regarding the economy will be laid out. Economy mainly focuses on the economic aspect of DSF and households. The areas of economic compensation and initial investments will be covered.

One challenge for households is the initial investment cost that is required to start delivering flexibility. According to A3, it is a challenge for households to start with flexibility since they have to pay for it themselves. When personal finance comes into the picture, it will be a greater challenge to start with DSF if there is no clear return on the investment within a short period of time. A1 also thinks that initial investment costs are a challenge when it comes to households, but says that it depends on the kind of equipment. According to A1 most households don't consider initial investment costs related to wallboxes and EV charging as a problem since they already have an EV and the capital needed. However, in the case of batteries, households find it challenging since they are expensive and hard to understand how the return on investment will be. In regard to batteries, households do ask about leasing or installment agreements (A1). In Sweden, at the moment, it is not of interest for the aggregator function to contribute with this kind of leasing or installment agreements, households have to fund this in other ways (A1).

"As a household owner, it is regarding your private finances which always indicates that it is a greater challenge to overcome, to make that investment from your own pocket if you don't see a clear return on investment within a short period of time" - A3

Both A5 and A6 offer cost optimization by managing the usage of certain equipment and appliances in customers' households. This can for instance be EV-chargers, heat pumps, and solar PV. The optimization is done against the spot price on the market which makes it possible to use electricity when it's cheap and avoid expensive power peaks. The optimization is algorithmically based which means that is an automatic process that the household doesn't need to manually control. To use the aggregators' services, A5 has a monthly fee in addition to the costs related to electricity consumption, and A6 has a monthly fee, or discounted yearly fee (compared to the monthly fee), in addition to the costs related to electricity consumption.

A5 offers a reduced cost on some equipment if you are a customer of A5, and the cost of the equipment can be seen on the website. A5 also displays information on which equipment is applicable with “ROT-avdrag” and “50% off green technology”. A6 displays equipment on their website but costs are not visible for all products.

At the moment A6 offers, according to them, the cheapest EV charging wallbox to existing or new customers. This is done via a collaboration with another company working in the EV charging wallbox segment. In addition to this, A6 also has a collaboration with a payment company and offers flexible payment options of invoice. In table 11, a summary of the supportive functions expressed by the interviewed aggregators can be found.

Table 11: *Supportive functions the aggregator function may perform.*

Area	Supportive functions
Market	Collaborate with electricity providers to come up with infrastructure and solutions to fulfill incentives demanded by households
	Bring expertise and information in a simple way to help households understand what DSF is and to help them make decisions that fit their needs
	Display information regarding how to become a customer, how to lower costs regarding electricity consumption, and physical equipment needed to start with DSF
	Display information with several tools or ways e.g. websites (with text and video), marketing campaigns, meet and greet with households, industry magazines, and in person communication
	Be transparent and simple with households to avoid misunderstandings, and create trustworthiness by showing that they are actively participating in developing solutions for flexibility markets
	Act as the face of DSF to gather interest and manage the connection of households to the market
	Possibility to develop global platforms with single standards which in turn lowers the entry barrier for participation and creates a robustness for which a stronger economic model also can be developed upon
	Be a neutral third party that works more in favor of households' terms and conditions
Infrastructure	Collaborating or coordinating technology developers to bring forward solutions that are suitable for households
	Act as a technological developer themselves and seek to create their own innovative solutions for households

	Help with equipment for control and data analysis to make reactive and proactive decisions regarding flexibility resources
	Help establish a solution that is needed to gather interfaces in one place for households
	Collaborate with producers of equipment with control systems to integrate the same infrastructure, benefitting the households
	Collaborate with installation companies to make it easier for households to buy and install equipment associated with DSF
	Specialized in automation and controlling flexibility resources from demands of households
Institutions	Aggregators may handle pre qualification processes for households to participate in frequency regulating markets and ensure compliance with standards and regulations
	Aggregators can express their thoughts and ideas to regulatory authorities like Energimarknadsinspektionen, potentially influencing the development of laws and regulations
	Aggregators can manage the complex laws and regulations related to DSF, ensuring households do not need to get involved with them
	Create simplicity and comfort for households by recommending the right technology from the beginning
	Offer standard solution with the option of tweaking several parameters to offer a tailored service for households that fit their needs
Economy & finance	Aggregators manage appliance usage to reduce energy costs by optimizing against market spot prices
	Aggregators may offer reduced costs on certain equipment for existing or new customers
	Aggregators may provide flexible payment options through collaborations with payment companies

5. Analysis

In this part of the thesis, an analysis of the data collected from the interviews with households and aggregators will be presented in order to answer the research questions. The analysis process will be carried out by comparing the results from the households against the literature reviewed, to point out similarities and differences. The empirical data from aggregators will be similar compared to its literature counterpart. Furthermore, the analyzed data from households and aggregators will then be evaluated against each other in order to highlight the areas of where the aggregator function is able to support households in the DSF adoption process.

5.1 What challenges are associated with households delivering flexibility?

The importance of resolving and handling issues around systemic factors such as market, infrastructure, institutions, and economy & finance in transitions processes have been rigorously profiled in existing research (Negro et al., 2012; Andersson & Jacobsson, 2000; Bergek et al., 2005; Carlsson & Jacobsson, 1997; Woolthuis, 2005; Mignon & Bergek, 2015; Mignon, 2016; Yaqoot et al., 2015). Looking at our empirical results, it is evident that the challenges found to be associated with households further reinforce this view and show that these systemic factors also play an important role in households' perception of DSF.

5.1.1 Market

The innovation system literature talks extensively about the importance for innovations to have a market to operate on. Such markets may need to be developed and creatively carved out from smaller, nurturing, and bridging markets which can be a challenging process (Negro et al., 2012; Andersson & Jacobsson, 2000, Bergek et al., 2005). With regard to DSF and households, the literature states that the household market is constrained by the fact that most markets require larger bid sizes and that it is complex to gather many smaller resources at the appropriate size, which has led to the household market still being at an early stage (Zagerholm, 2021; Wohlfahrt 2019; D'Ettorre et al, 2022). The empirical findings showed that households had limited awareness of the existence of DSF. This can be contributed towards the difficulties of forming household markets or lack of effective marketing, limiting its commercialization progress. The literature does not specifically highlight the issue of lack of awareness, possibly due to the assumption that the complexities in establishing and scaling up household markets are considered more immediate challenges.

The absence of both knowledge and interest in DSF and its technical and economical workings among households has been recognized and addressed in previous studies (Hennlock et al, 2023; D'Ettorre et al, 2022). Empirical evidence partly aligns with the existing literature, underscoring the widespread lack of comprehension of DSF amongst households. It was clear that most households had a minimal understanding of DSF and necessitated guidance and information before it could be discussed further. However, when it came to the interest aspect, the empirical studies indicated a general interest in DSF and personal energy consumption among households. Notably though, despite the general interest, the level of enthusiasm still varies among households, presenting a challenge. The interest was primarily because of the potential financial benefits. Furthermore, most households showed openness to becoming more technically engaged, provided they received sufficient informational and financial support during the process. This result contrasts somewhat with the prevailing literature but aligns with the innovation system literature in the sense that it emphasizes the importance of building relationships and markets that can support the end customer (Woolthuis, 2005; Carlsson & Jacobsson, 1997; Bergek et al., 2005). The increased level of interest may also be linked to the rising energy prices which have made households more conscious of their energy consumption and its costs.

Established research on DSF and households showed a reluctance to seek information on DSF as households generally prioritized their time on other things (Hennlock et al., 2023). This is also supported by the empirical data where several factors related to households' informational needs were identified, with transparency, adequacy, simplicity and diversity of information being key aspects. The data suggest that households often require certain information because their fundamental understanding of DSF and occasionally their own energy systems is limited. Though to develop these knowledge and information bases many households expressed a need for guidance and support indicating that they do not feel confident or interested enough to seek it out on their own. This once again connects back to the innovation system literature and the importance of avoiding weak relationships that can't provide the requested information to customers for establishing appropriate knowledge bases and favorable environments for fostering adoption (Yaqoot et al, 2016; Mignon, 2016; Woolthuis, 2005).

The challenges that the DSF literature raises primarily revolve around the lack of knowledge and engagement, rather than focus on the type of knowledge requested and how to provide it. In contrast, the empirical data revealed households' needs for transparent, straightforward, and diverse range of information about infrastructural and soft institutional aspects, delivered through their preferred media channels, such as websites and phone calls. The requirement

for varied information comes from households' different levels of preexisting knowledge and interest regarding their own energy consumption. This factor should be considered, as it can determine the nature and extent of the information sought out by different households.

Incentives for households to start contribution with DSF has in the literature largely been attributed to economic incentives, stating that its absence would result in major barriers for adoption (D'Ettorre et al., 2022; Ponnaganti et al., 2018). This outlook can also be seen in the empirical findings where almost all households expressed a clear focus on the economic incentive as the most important one. An aspect where the empirical finding deviated from the DSF literature was on the importance of other incentives such as environmental and grid stabilization. Even though these types of incentives were mainly seen as convenient bonuses in the empirical findings, for one household it was the most central aspect. This indicates that households are a heterogeneous group of which motivations behind participating can be mostly seen as economic but may also include other incentives that need to be taken into consideration for acquiring adoption. This type of reasoning aligns with the diagnostic market approach proposed by Berg et al. (2005) that aims to, among other things, establish customer profiles. Understanding one's customer base is essential to effectively tailor incentive programs that spark interest and foster broad adoption.

5.1.2 Infrastructure

Based on the empirical findings, households displayed challenges of potential difficulties in installing and operating the DSF equipment and expressed needs of simplicity and clarity. This corresponds well with the DSF literature which discusses barriers of complexity regarding equipment with installing and maintaining, steep learning curves, and sufficient technical assistance (Ponnaganti et al. 2018; D'Ettorre et al. 2022). This overlap illustrates that necessary steps need to be taken towards supporting households in understanding and navigating the technological landscape of DSF. Examining the innovation system research it is clear that being able to rely on the network for technical recommendation proves to be a vital component in this case (Mignon & Bergek, 2015).

The challenge of developing and propagating technical standards for DSF to avoid potential technological lock-in effects and promote flexibility is discussed in the theoretical framework (Good et al., 2017). By observing the result from the households, they also expressed challenges in wanting to be able to connect/integrate the household into a single DSF solution, in order to simplify and streamline the management, installation, and monitoring of the service. This in turn also led to expressed needs for standardization. The overlapping empirical data and literature on DSF puts further emphasis on something that the innovation and transition

research also touched upon in terms of being able to integrate new technologies and digital tools with already established and existing systems (Henriette et al., 2016; Cho et al., 2021; Maksimenko et al., 2021). On the other hand, the concern for future technical lock-in effects and interoperability issues was not clearly voiced by households, its importance nonetheless remains and its absence in the empirical data may be linked to factors of households lacking the knowledge or understanding to properly voice all their concerns and needs (Bergek et al., 2005).

To acquire a significant adoption rate of an innovation, customers and stakeholders must feel confident in the quality of the DSF infrastructure and its standards (Good et al., 2017). The empirical data showed some concerns regarding this aspect as participants displayed worries of how optimally the DSF service could control or adapt equipment and appliances. Participants brought up concerns regarding the process of integrating all their equipment and determining the efficiency of automated DSF control compared to their traditional manual methods. The empirical findings dived into this concern further than the DSF literature, where some households also had worries regarding wear and tear damage of connected equipment. Addressing these valid concerns is critical for the successful implementation and widespread adoption of DSF systems. It becomes crucial for DSF service providers to not only ensure seamless integration and efficient control of appliances but also to provide robust guarantees regarding their safe operation and longevity.

5.1.3 Institution

Hard institutional challenges such as “stop and go”-policies, attention shifts from policy makers, and misalignment between the ones instituting the laws on different levels, are aspects that the DSF and innovations system literature have covered (Negro et al, 2012; Langedahl et al, 2019; Jacobsson & Bergek, 2004; Markard & Stadelmann, 2009). Looking at the empirical findings, households did not express any direct concerns with hard institutions. This indicates that households are simply not aware or concerned with the underlying regulations and policies under which DSF conforms to and they expect that this kind of regulatory management will be handled by the service provider or other actors. This reveals an interesting contrast between the macro-level policymaking and the micro-level household experience. It suggests that the complexity of regulatory structures, while crucial for the implementation and operation of DSF, are largely invisible to the end-user. This highlights what has previously been discussed by IS scholars (yaqoot et al., 2016), a need for navigating these complex hard institutional aspects and to ensure that policy changes or inconsistencies do not negatively affect the consumer experience and creates a favorable environment for diffusion and adoption. This is particularly important in this case, as the empirical data reveals

extensive concerns among households regarding potential increases in inconvenience (e.g., time, technical, comfort) if they choose to adopt DSF solutions.

IS scholars also put emphasis on taking soft institutional factors in consideration when introducing new innovations (Mignon, 2016; Negro et al., 2012). Both the DSF literature (Negro et al., 2012; Hennlock et al., 2023) and the empirical findings cohere to this notion and has identified soft institutional barriers such as attitude, comfort, control and adaptability. While the DSF literature provides a good understanding of the significance of comfort and control, the empirical findings delve deep into these aspects, offering a comprehensive and detailed examination. The empirical data underscores the need for DSF solutions to be compatible with personal behavior and comfort requirements, emphasizing the individual's preference for familiar environments. It also highlights the importance of retaining transparency and control within the DSF system, reinforcing that perceived control enhances system acceptance. The capacity to tailor DSF services not only to align with individual lifestyles, but also to swiftly adapt to unforeseen or planned scenarios, is identified as crucial for broader adoption. This underscores the criticality in being able to offer adaptability.

Furthermore, the empirical data adds nuance to the DSF literature's interpretation of comfort and control demands by showing that these factors vary across different types of equipment and households (e.g. heat pump, EV charger or Solar PV). It suggests that there exists some degree of flexibility or "leeway". This flexibility indicates that the impact of these soft institutional factors might be mitigated or enhanced depending on the specific household or equipment, underscoring the need for a more context-specific understanding and solution for these challenges.

5.1.4 Economy & finance

The findings of this study largely mirror those found in the existing research on economics & finance in relation to DSF. The established DSF research, together with the empirical data, reinforces the central role of economic considerations in driving households' decisions (D'Ettorre et al., 2022; Ponnaganti et al., 2018). Several households in our interviews voiced concerns about the necessity for suitable compensation corresponding with the investment of their time and comfort. These concerns echo the issues raised by Cardoso et al. (2020) and D'Ettorre et al. (2022), wherein households express apprehensions about the cost benefits of DSF being inadequate.

The business case for DSF is not only affected by uncertainties around its business model but also other potential costs in terms of acquiring, installing and maintaining equipment

connected to DSF (D'Ettorre et al., 2022). Interviewed households also gave their views on the subject of investment costs. A good number suggested a preference for small initial investments, citing their limited grasp of DSF. A handful, uncertain about the long-term profitability of DSF, were unable to commit to a clear statement, wanting more information. In contrast, one participant was open to larger investments. This range of opinions underscores the existing worries around the financial uncertainty of DSF and the costs tied to its associated equipment. Another interesting observation in regards to this is that both the IS and DSF literature voiced the importance of being able to provide stable financial support to reduce customers' initial uncertainties around the business model and investment costs (Mignon & Bergek, 2015; Yaqoot et al., 2016). This kind of request for support could not be clearly found in empirical data. This illustrates that customer uncertainties surrounding the business case also stem from a lack of knowledge and information and thus emphasizing the importance of effective communication and education about DSF and potential support structures. This aligns with the findings of Pablo Chaves Ávila et al. (2019) and Woolthuis (2005), underlining the crucial role of information accessibility in shaping customer perceptions and decision-making processes.

Our Empirical findings identified that households required a high level of transparency in the economic process. Importance of transparency was also echoed in the DSF literature, emphasizing the importance of providing clarity in aspects that customers felt uneasy or unknowledgeable about (Pablo Chaves Ávila et al., 2019). The empirical data provides further information towards the understanding of the households' worries, highlighting that their concerns are primarily rooted in the lack of transparency about their share in the economic model, and in apprehensions about lock-in effects and unfavorable contracts. A few interviewees also requested trial periods which is something they believed could help alleviate these concerns by providing an opportunity to experience the terms of the contract first-hand before making a long-term commitment. This view on trial periods suggests a desire for more direct involvement in the economic process and a chance to navigate the complexities of the system with a safety net in place. All these concerns reflect a strong need for clarity, transparency, and a participatory approach in economic engagements.

5.1.5 Summary of the challenges associated with households

Reviewing the analysis and observing the differences and similarities between the empirical framework and the empirical data, a new table can be created to display the challenges associated with households delivering DSF. Table 12 provides a comprehensive overview of the challenges that need to be addressed when it comes to DSF and households, and takes into consideration both established research and our findings from the interviewed

households. The challenges have been numbered to enable matching with aggregators support functions in chapter 5.3.

Table 12: *Challenges of households related to DSF in the areas of market, infrastructure, institutions, and economy & finance.*

Area	Challenges
Market	1. Limited awareness and understanding of DSF - In need of guidance and support
	2. Lack of a mature or established market for households
	3. Some level of varying interest in DSF and personal electricity consumption depending on the household
	4. Need for an effective and transparent information dissemination strategy that respects privacy, caters to varied pre-existing knowledge levels, and offers necessary support through various channels
	5. Challenges in creating a universally appealing incentive system for DSF adoption - balance focus on economic incentives with other incentives
Infrastructure	6. Complexity in installing and operating DSF service - need for simplicity and adequate technical assistance.
	7. Need for standardized, integrated DSF solutions that simplify management and enhance system flexibility while mitigating potential lock-in effects.
	8. Adoption of DSF infrastructure raises concerns about the quality of automated control, the integration process of equipment, and potential wear and tear damage.
Institutions	9. Lack of awareness and concern about the underlying regulations and policies governing the DSF
	10. Concerns about potential increases in inconvenience (e.g., time, technical issues, comfort) associated with adopting DSF solutions
	11. Need for a level retaining transparency and control, and offering adaptability to individual lifestyles and unforeseen scenarios.
Economy & finance	12. Uncertainty and concern regarding the financial viability of DSF, including investment costs and profitability.

	13. Strong need for clarity, transparency, and customer participation in the economic process of DSF, including clear communication, accessible information.
	14. Need for options like trial periods to address concerns about contracts and lock-in effects.

5.2 Analyzing the roles and functions of Intermediaries and Aggregators

In this chapter, an analysis of the theoretical framework and empirical findings regarding the aggregator function and intermediary function will be presented. The theoretical framework includes both the intermediary function and the aggregator function, while the empirical setting includes the aggregator function. Similarities and differences will be discussed to get a better understanding of the current supportive function of the aggregator role.

5.2.1 Market

The aggregator literature states that a key function of the role is to accumulate small flexibility resources and bring them to the market creating financial benefits for prosumers (Ponds, et al., 2018; EI, 2016). However, given the rather young nature of the aggregator role and the household market, the specifics of this process remain somewhat unclear. Current empirical data suggests that household integration is mainly achieved through a strategy of price optimization, where electricity usage is adjusted in response to spot prices. Other ways of connecting households to flexibility markets such as Svenska Kraftnäts frequency market or Effekthandel Väst are, according to our findings, either not yet viable or not optimal for households to operate in. This means that aggregators today are somewhat limited in their offering towards households until the market structure evolves to better accommodate small-scale prosumers. However, one aggregator stated in the empirical findings that the possibility of developing a more optimal, global, market for households exists, but this has not yet been fully actualized.

In the empirical findings, the aggregator function voiced the ability to collaborate with several stakeholders such as electricity providers, technical developers, households, and governments in favor of the household segment. This aspect was also found in literature regarding the aggregator function where the possibility to connect households with DNOs exist, and where collaboration with governments, policy makers, and established utilities to promote changes in favor of e.g. households can be seen (Good et al., 2017; EI, 2021a, EI,

2021b; Langendahl et al., 2019). The empirical data paints a clearer picture of the specific objectives of these collaborations, suggesting that they typically aim to meet the households' desires for both financial and environmental benefits in the market, or provide solutions for comfort and adaptability needs. This kind of process has a connection to the intermediary literature and the function of connecting and transferring information between different actors (Howells, 2006; Van Lente et al, 2003). Given this, it can be said that the aggregator function, underscored in both empirical findings and the literature, can serve as an important intermediary within the energy sector. Their collaborative efforts with various stakeholders aim to align with household desires and needs. Thus, the aggregator's role is crucial in creating a favorable environment that encourages adoption.

Another important aspect is regarding information and how information is delivered. Aggregator literature echoes the importance of conveying information since it can increase the confidence in DSF among households (EI, 2016; Langendahl et al., 2019). The empirical findings resonate with this notion and the aggregators state that bringing expertise and information to households is important to make households understand what DSF is and to help them make decisions regarding DSF that relates to their needs and worries. The empirical data further adds to the aggregator literature by putting a lot of emphasis on informational transparency and building trustworthiness to avoid misunderstandings and displaying a unified front committed to collective progress and mutual benefits. In this case, both the aggregator literature and the empirical findings solidify the aggregator's role as an intermediary which assumes the responsibilities of effectively disseminating information, establishing trustworthy channels of communication, and translating information between various actors (Howells, 2006; Rai & Robinson, 2013; Kivimaa et al, 2019).

The role of the intermediary function extends to potentially reducing communication costs between actors not directly linked to each other (Kivimaa et al, 2019), an aspect that is not significantly highlighted in either the empirical findings or the aggregator literature. Instead, the empirical findings lean more towards realizing the needs of households to encourage their participation into DSF. The aggregators don't explicitly state the reduction of communication costs between actors as one of their primary informational focuses. This oversight could potentially be attributed to the relative novelty of the aggregator function within the context of DSF as compared to intermediaries in other domains. As a result, the emphasis on cost reduction between actors may not have emerged as a focus point just yet.

Furthermore, the empirical data reveals that one aggregator saw the aggregator function working as a more neutral third party that can be seen to also advocate for the household

segment. This need arises as initiatives primarily originate from grid operators, which could potentially raise suspicions among households when considering the adoption of DSF. Observing the empirical findings, this reasoning can be somewhat connected to functions such as aggregators' role in engaging and recruiting households or their role in mediating with DNOs for households (Langendahl et al., 2019). Though the neutrality factor is not something heavily echoed in the theoretical framework about aggregators, it instead connects well with the intermediary research and its perspective on trustworthiness (Howells, 2006; Rogers, 1962; Rai & Robinson, 2013). It's possible that the aggregator literature doesn't underscore the aspect of neutrality and trustworthiness as heavily because it's a relatively new function, with its primary focus being on the technical and operational aspects of aggregators' roles. Additionally, the role of the aggregator, being a more neutral third party, might have been perceived as implicit or taken for granted. The research landscape of aggregators is still evolving, and as such, nuances such as these might gain more recognition and emphasis in the future.

The theoretical and empirical findings concerning the informational responsibility of aggregators largely agree upon the importance of being able to provide a diverse range of information (e.g, technological, soft/hard institutional and economical) (EI, 2016, Langendahl et al., 2019). While intermediary and aggregator theory confirms the importance of information provision, it doesn't delve into the specifics of how this information is delivered to households. In contrast, the empirical evidence sheds light on this area bringing forth various methods of communication that may be of importance such as websites, marketing campaigns, personal interactions with households, industry magazines, and word-of-mouth. This difference might be attributable to the dynamic and evolving nature of the aggregator role within the energy sector. As the empirical evidence suggests, it appears that the aggregator function is increasingly recognizing the need to diversify their communication strategies, thus adapting to the unique requirements of the households.

5.2.2 Infrastructure

According to Kivimaa et al. (2020), in the area of infrastructure, the intermediary function has the opportunity to e.g. connect technology suppliers with technology adopters. The theory (Good et al., 2017; EI, 2021a), and empirical findings regarding the aggregator function do bring up the possibility to connect or coordinate between different actors, but have more focus on collaboration. In the established literature it is said that the aggregator function may collaborate and form partnerships with technology firms in order to develop technological capabilities suitable for DSF (Langendahl et al., 2019), and according to the interviews with

the aggregators, the possibility to collaborate with technology developers to either bring forward technological solutions or interfaces that is well suited for households, exists. In this case, the aggregator function could e.g. work with electricity suppliers to create infrastructure to a common platform for households, with an easy-to-use multi-appliance interface. It could also be to collaborate with different equipment providers to integrate one interface for all appliances, making it easier for households to connect and navigate through appliances of the connected providers. The emphasis on collaboration instead of coordination, as in the intermediary literature, may originate from the aggregator function desiring to be more involved and have an active role in the process regarding DSF compared to what is standard in intermediary theory. Due to the aggregator's deep expertise and knowledge of DSF and related technology, they probably see the potential to contribute more effectively through collaboration rather than merely acting as a link between actors. It may also be because of the lack of markets for households to operate in, where the aggregator function observes that they have the opportunity and responsibility to drive the development.

In addition to collaborating with technology suppliers, the aggregator function may also bring forward its own technological solutions. This aspect is not brought up in the established theory regarding intermediaries or aggregators. The reason for this may be that the aggregator wants to offer households tailor-made solutions, which may be more difficult to do in collaboration with other companies, or that the aggregator wants to have ownership of its own development.

Another important role the aggregator function has is to control the flexibility resources of households. Aggregator literature brings up that they may control flexibility resources of households in a way that fulfills their needs (Ponds, et al., 2018; EI, 2016). This is also brought up in the empirical findings where the aggregators' state that they are efficient in controlling flexibility resources, more so than the electricity companies, since they tend to have better knowledge in the area. As both theory and empirical findings bring up the aggregator function's possibility in controlling flexibility resources, an opportunity arises for the aggregator to both act as a marketer for DSF as well as an technological implementer, where they both acquire and fulfills the needs of the households.

To succeed in controlling the flexibility resources, it was found in the empirical data that the aggregator function may help with selecting equipment that is suitable to control the flexibility resources in an efficient way. With the right equipment, reactive and proactive decisions can be made regarding the available flexibility resources. These findings imply that the aggregator function has the potential to help with the right equipment to make households start delivering flexibility on their own terms and conditions. This type of control was not addressed in the

established theory of the intermediary function, which may be due to the fact that automation and control have accelerated in recent years, meaning that the aggregator function is quite advanced in this area compared to the general intermediary function. When comparing the literature of the intermediary function and the empirical findings of the aggregator function, it could be identified that the aggregator function seems to be more technical in nature compared to the traditional intermediary function.

The established theory regarding intermediaries also brings up the possibility for intermediaries to connect the right skills with the right resources (Kivimaa et al., 2019). This resonates well with the empirical findings regarding the aggregator function's possibility to collaborate with installation companies to offer an easy process for households to buy and install equipment related to DSF. The aggregator function's possibility in connecting the right skills (e.g. installation companies) with the right resources (e.g. households) was not emphasized in the established theory. However, in the theory regarding the aggregator function, it is stated that collaboration with e.g. electricity providers, technical developers, and governments exist (Good et al., 2017; EI, 2021a, EI, 2021b, Langendahl et al., 2019) which could be seen as a sort of connection of the right skills with the right resources, to help households with overall DSF aspects.

5.2.3 Institutions

Institution can refer to policies and regulation but may also refer to more soft aspects such as standards and values (Negro et al, 2012). In our established theory regarding intermediaries, it was found that the intermediary function has the possibility to propose policy goals to involved stakeholders, and has the possibility to connect vision of the future with specific demands on actors or networks (Kivimaa et al, 2020; Kivimaa et al, 2019). The established literature and our empirical data both bring up the importance of policies. As an example, it was found in the empirical data and aggregator literature that aggregators have the possibility of interacting with institutions (e.g. Energimarknadsinspektionen) with the aim of developing and influencing policies and laws (EI, 2021b). This is possible since institutions may convey new proposals, influenced by discussions and expertise from aggregators, to the policy makers. In addition, both the established literature (Eid et al, 2015; Crespo del Granado et al, 2023) and empirical findings regarding the aggregator function bring up that they are the ones that takes the responsibility to interpret and understand laws and regulations regarding DSF, thus relieving households of this aspect. Since aggregators often have the opportunity to work closely with households and have a lot of expertise on DSF, their input can contribute to necessary policy refinements. Thereby contributing to a more efficient process than if only policy makers with limited DSF exposure were solely responsible for driving this area forward.

Both the aggregator literature (Ponds, et al., 2018; EI, 2016) and empirical findings highlight the aggregator's role in linking households to markets. Yet, the empirical data suggest it might be challenging for households to contribute flexible resources to certain markets such as Svk's frequency regulating markets in Sweden due to the large bidding sizes and fast response times. This insight about the regulating markets was highlighted by most aggregators, who also proposed that they could assist actors with flexibility resources in pre-qualification for these markets. Hence, the aggregators can convey clear information about which markets are accessible for households and how they can provide pre-qualification support. By clarifying uncertainties about market existence, pre-qualification requirements, and households' eligibility for markets, the path towards adoption of DSF among households becomes approachable.

Another aspect brought up by the interviewed aggregators is that it is important for households to have the correct technology from the beginning. By providing information and directives regarding what technology is needed to start delivering flexibility, households will have more future-proof appliances which in turn may increase the long-term simplicity and comfort of starting with DSF (soft institutional aspects). This aligns with the intermediary literature by having a strong connection to the function of proposing technology goals and connecting technology suppliers with technology adopters (Kivimaa et al, 2020). The empirical findings bring up the importance of the aggregator function doing so in an early stage since it will increase chances of appliances working in the future as well. This implies that it is important that the aggregator function, which has expertise and knowledge of the technical aspect, is involved at an early stage with the households, to avoid future problems.

To further analyze the comfort aspect, both the theory (Ponds, et al., 2018; EI, 2016) and empirical findings bring up the aggregator function's possibility in offering tailored control of households' flexibility resources that suit their needs. In the interviews it is for example stated that the aggregator function may develop standard solutions for control, where the households have the possibility to tweak parameters (of indoor climate) to fit their specific needs. This is something that is not brought up in the established theory regarding the intermediary function, and is another indication that the aggregator function is more technical in nature compared to intermediaries in other settings.

5.2.4 Economy and finance

The empirical findings show that the aggregation function currently provides economic incentives to households, mainly through cost savings by optimizing against market spot prices. This is in line with the established aggregator literature in the sense that it is consistent with the price-based program typically used to motivate consumer participation (Golmohamadi, 2022). Additionally, it ties in with some of the fundamental functions of an intermediary, which in this case is to enhance the rate of adoption and facilitate information transfer between parties (Kivimaa et al, 2020; Rai & Robinson, 2013; Howells, 2006). In this scenario, the aggregator delivers market price data to households, facilitating informed consumption. On the other hand, aggregators did not clearly articulate use of incentive based programs which was brought up by the aggregator literature (Golmohamadi, 2022). The results of the interviewed aggregators did not give any clear indications of what kind of economic model they presented to households. This is partly due to them not concentrating on the household segment or that it is still in development. A possible reason for the price-based model being the dominant option at the moment may be attributed towards it being easier to understand and administer for both the aggregator and households. The simplicity of a price-based model allows households to understand the economic incentives at play and enables aggregators to implement it in a less complicated way. The transparency provided by a price-based model also creates a sense of trust, which can lead to greater participation by households and ultimately increase the growth of the service. However, the seeming lack of diversity in the incentive programs and the absence of clear economic models for households suggests that there is considerable room for innovation in this area.

The intermediary role plays an important part in establishing bridges between actors for communication and collaboration (Howells, 2006). This kind of bridge building is also present in the empirical data where aggregators may provide flexible payment options through collaborations with payment companies. The result also reflected possibilities for aggregators to offer reduced costs on certain equipment for existing or new customers. This kind of explicit aid with investment costs was not something that the aggregator literature clearly stated. Though on a general level one could find connections between the result and literature in the sense that the aggregator may communicate and collaborate with stakeholders to benefit the customer (Good et al., 2017; EI, 2021a; EI, 2021b; Langendahl et al., 2019). It's important to note that the empirical data did not provide a clear consensus on how to financially support customers. One aggregator suggested that providing financial assistance may not be within the aggregator's scope, implying that households might need to seek this help elsewhere.

5.2.5 Summary of the aggregator's supportive functions

Reviewing the analysis and observing the differences and similarities between the empirical framework and the empirical data, we can construct a new table. This table will visually represent the present outspoken supportive ability of the aggregator function. Table 13 provides an overview of the supportive function that aggregators currently may bring, and has taken into consideration both established research and our findings from the interviewed aggregators. Table 13 is a revised table where similarities between and within the established literature and empirical findings have been merged to create more holistic points. Important identified differences have also been considered and added to the table.

Table 13: *Supportive functions of the aggregator function considering established literature and empirical findings.*

Area	Supportive functions
Market	Collaborate with electricity providers to come up with infrastructure and solutions to fulfill incentives demanded by households
	Display and bring forth demanded information to households, through several channels, and in a transparent and simple way to create trustworthiness and facilitate for decision making
	Act as the face of DSF, and work in favor of households' terms and conditions to gather interest and manage the connection of households to the market
Infrastructure	Collaborate with technology providers/developers or develop own technology that is suitable for households
	Help to establish solutions that gather all interfaces in one place, or collaborate with producers of equipment to integrate the same infrastructure
	Brings expertise and equipment for control and use this to control households appliances in an effective and safe way
	Collaborate with installation companies to simplify the process of buying and installing equipment for households
Institutions	Manage the complex laws and regulations related to DSF and thereby relieving households of this responsibility, and also have the potential to influence the development of hard institutions by sharing their insights with regulatory authorities
	Recommend the right technology from the beginning to households to create comfort and simplicity
	Offer a standard solution with the option of tweaking several parameters to offer a tailored service for households that fit their needs

Economy & finance	Aggregators may manage flexibility appliances to reduce energy costs by optimizing against the market spot price
	Aggregators can alleviate financial hurdles by offering reduced costs on equipment for new and existing customers, and providing flexible payment options through collaborations with payment companies

5.3 How may the aggregator function support households in delivering flexibility?

In this chapter, the identified challenges of households in chapter 5.1 will be analyzed together with the supportive functions of the aggregator function identified in chapter 5.2. Where possible, the supportive function will be connected to the identified households' challenges with the intention of answering the second research question.

The identification process for uncovering both supportive measures and potential gaps primarily involved linking identified challenges within the systemic areas to corresponding supportive measures within the same area. However, it wasn't limited to this straightforward mapping, there were instances where we discovered supportive measures in different systemic areas that proved relevant across multiple themes. This process of pairing challenges with supportive measures was grounded in an analysis of both established literature and our empirical data. However, we should acknowledge that this pairing process, while methodical, could be influenced by our individual interpretations. In other words, the process of associating systemic challenges with supportive measures doesn't just depend on a mechanical correlation; it also involves our personal interpretations of the data and literature. Therefore, while we've strived to maintain objectivity, our analyses may still bear the imprint of our individual perspectives. This isn't necessarily a drawback, but rather a reminder of the complexity of such an analysis process.

5.3.1 Supportive Measures in relation to Market Challenges

In the market aspect, it was found that households have challenges in the form of limited understanding (Hennlock et al, 2023) and awareness of DSF. To support households in this aspect, the aggregator function has e.g. expertise and information regarding DSF which they can bring to households in a simple way to help them understand what DSF is and what decisions they should take to fulfill their needs. Aggregators may display needed information of costs and equipment, and may display it through different channels such as websites,

marketing campaigns, meet and greet with households, and industry magazines. By the aggregator displaying and communicating the information in a transparent and simple way, the overall awareness and understanding could increase. However, the empirical findings were very clear in that households lacked awareness and understanding of DSF. This indicates that the aggregator function is currently lacking in its supportive function in this aspect and may therefore miss out on potential interest from households.

Information and transparency are not only functions the aggregator function may use to increase awareness and understanding, but are also aspects that the literature (Pablo Chaves Ávila et al., 2019; Hennlock et al, 2023) and households stress as necessary for overall participation with DSF. Households stress the need for an effective and transparent information dissemination strategy that respects privacy, caters to varied pre-existing knowledge levels, and offers necessary support through various channels. In this area, the aggregator function shows the opportunity to support by displaying information regarding e.g. how to become a customer, how to lower costs regarding electricity consumption, and physical equipment needed to start with DSF. As stated before, the aggregator function may display this information with several tools or ways. And by being transparent and keeping it simple with households, and showing them that they (aggregators) are actively participating in developing solutions for flexibility markets, a higher degree of trustworthiness may be achieved.

Lack of a mature or established market for households was also found to be a challenge (D'Ettorre et al, 2022). In this case, the aggregator function has the opportunity to act as the face of DSF to gather interest and awareness and manage the connection of households to the market. One of the aggregators in the empirical findings also stated that there is an opportunity to develop global platforms with single standards which in turn lowers the entry barrier for participation in markets and creates a robustness for which a stronger economic model also can be developed upon. By increasing the interest of households to participate with DSF, and at the same time manage the connection to markets with preferably global platforms with single standards, the establishment of markets towards the household segment could be improved. Though as of today the aggregator function is somewhat limited in its ability to realize such a platform as no such platform is yet to be widely established.

Another challenge with households is the varying interest in their own electricity consumption, and in DSF overall. The process of sparking interest or handling different interest levels is a challenging task as it involves a very broad spectrum of actions such as increasing awareness, providing incentives and benefits or offering simple and adaptable solutions, to not scare

households away with too much added hassle or discomfort. Neither the empirical findings or the literature has shown that single aggregators are able to take this type of all-around role to stimulate interest and manage the broad spectrum of required actions. Instead, it necessitates the aid and coordination of multiple stakeholders, including energy providers, government bodies, educational institutions, and technology companies.

The last challenge in the market aspect is the need to create a universally appealing incentive system for DSF adoption to balance focus on economic incentives with other incentives that households want. In this case, the aggregator function has the possibility of collaborating with electricity providers to come up with infrastructure and solutions to fulfill incentives demanded by the households. According to one aggregator, solutions also exist where households may choose what incentive (socially, environmentally, or economically) they want to focus on when contributing with flexibility. Other than this example, no solution where households can choose between incentives were found in the established literature or in the empirical findings. Since the incentives are important for households to start delivering flexibility, and since needed incentives vary between households, more solutions to solve this divide should be looked into by the aggregators. By offering more solutions where households may choose between incentives as they want, would be beneficial.

5.3.2 Supportive Measures in relation to Infrastructure challenges

It was found that one of the main challenges in the infrastructure aspect was perceived to be the complexity and hassle of installing and operating the DSF service, for which simplicity and support was requested. Both the literature (Langendahl et al., 2019) and the empirical findings state that aggregators have the opportunity to support households in this aspect by collaborating, coordinating or forming partnerships with technology developers and equipment/appliance manufacturers to develop solutions or/and by developing solutions themselves. These collaborative and internal actions can be tailored to the needs of households and encourage the development and adoption of user-friendly systems. Aggregators can also extend cooperation to installation companies to make it easier for households to purchase and install equipment. This challenge may also be alleviated by softer aspects such as continuous support and information flow of which the aggregator role can be instrumental, where both the literature (Ponds, et al., 2018; EI, 2016) and empirical data supports its ability to provide assistance and effective communication to households.

Households expressed needs of standardized and adaptable solutions that could be adapted to their present appliances/equipment and work as a single, easy to manage, integrated solution/interface. This kind of request may be a tall order to fully adhere to as a service

provider, but our findings around the aggregator function indicates that their ability to, as stated above, both develop themselves and collaborate with technical developers makes them well equipped to face this challenge. One aggregator brought up the possibility to collaborate with producers of equipment with control systems to integrate the same interface and thereby promote standardization and integrated solutions. Another aggregator also brought up the possibility to collaborate with energy companies to create a common platform, like an app, that flexibility resources can be connected to, promoting more standardized and single interfaces. The promotion of standardization also mitigates the risk of technical lock-in effects which might otherwise be present if aggregators and equipment suppliers all have their own solutions.

The final infrastructure challenge is the concerns expressed by households regarding the quality of the automatic control and the integration of the equipment and possible damage to equipment due to wear and tear. One aggregator stated that they can support households in this aspect by leveraging their expertise in digitalization, which is a crucial aspect of efficient DSF operation. This expertise could be used to optimize the control and data analysis of household equipment, thus addressing concerns about automatic control quality and potential equipment damage. Furthermore, as stated by another aggregator, they are often better at controlling flexibility resources in a way that meets households' needs, with a superior technological understanding of automation and developing necessary controls that better suit households, thus potentially mitigating the concerns over quality of equipment integration.

5.3.3 Supportive Measures in relation to Institutions challenges

One challenge found regarding households is the lack of awareness and concern about the underlying regulations and policies governing DSF. This concern may hinder the adoption of DSF by households, and is therefore an important aspect for the aggregator function to cover. According to our findings, one of the most predominant roles the aggregator function has in regards to this aspect is to manage the complex laws and regulations related to DSF, ensuring households do not need to get involved with them. According to the empirical findings, most aggregators state that households don’t have to get involved with regulations and laws at all, since that is their responsibility. This means that the aggregator function mitigates this concern by taking full responsibility to understand and coordinate around hard institutional aspects.

Another concern stated by households is the potential increase in inconvenience (e.g., time, technical issues, comfort) associated with adopting DSF. According to the empirical findings, households find e.g. comfort and simplicity as important and don’t want these aspects to get affected to an extensive degree. To support households in this soft institutional aspect, the

aggregator function has some abilities in doing so. One example is the aggregator function's ability to use their knowledge and expertise connected to technology for DSF, and use this knowledge and expertise to recommend the right technology from the beginning. If households have the right technology from the beginning, their equipment can be future-proof and less problems in regard to delivering flexibility will occur both in current time and in the future, increasing overall comfort and simplicity. Another possibility the aggregator function has is to offer a standard solution with the option of tweaking several parameters to offer a tailored service for households that fit their needs. Such a solution supports households in their adaptability needs while signaling that they are retaining a sense of control over their own comfort and energy system.

The last institutional challenge relates to the desire to maintain transparency, control, and adaptability to unique lifestyles and unpredictable situations. Aggregators making use of similar support strategies as mentioned above could provide customers with a solution that permits customization of certain parameters, thereby offering a tailored service to households. This approach would improve adaptability, and unpredictable circumstances could be better managed by permitting households to define control parameters. Another way aggregators could enhance transparency, control, and adaptability, is by proposing ideas to entities such as "Energimarknadsinspektionen". Here, the aggregators could offer valuable insights about the household sector and its needs, aiming to sway the evolution of laws and regulations in households' favor. This form of support could provide more long-term assistance in meeting household needs.

5.3.4 Supportive Measures in relation to economy and finance challenges

One of the main challenges is the uncertainty and concern about the economic viability of DSF. Households expressed concerns about profitability and investment costs in relation to the impact on their time and convenience. Existing literature suggests that different business models, including price-based and incentive-based programs, can encourage prosumers to get involved (Golmohamadi, 2022). However, our empirical data currently indicate a more constrained approach, with mainly price-based programs available to customers. This indicates that aggregators are still having difficulty in how to address the uncertainty and financial concerns surrounding households. At present, the primary economic incentives being offered are through price-based programs. This poses a limitation as it does not fully address the range of household concerns about the economic viability of DSF and limits the offering available to households. In terms of reducing initial investment costs, the empirical data indicated that the aggregator function can offer reduced costs for certain equipment for

existing or new customers, as well as offer flexible payment options through cooperation with payment companies.

Another concern raised by households is that there is a strong need for clarity, transparency and participation in the financial process of DSF, including clear communication, available information and options such as trial periods to address concerns about contracts and lock-in effects. In this aspect, the close relationship of aggregators with customers can be exploited, and the aspect of acting as a more neutral and transparent informational partner should be leveraged to alleviate some of the initial concerns and provide better understanding and engagement with the process. On a general level, aggregators can help with these kinds of fears and issues, though more concrete solutions like trial periods were not brought up by either the literature or empirical data suggesting that this is an under-explored area, which could potentially benefit from further consideration.

5.3.5 Summary of how the aggregator function may support households in delivering flexibility

In table 14, the challenges of households found in chapter 5.1, table 12, are connected with the supportive functions the aggregator function possesses which can be seen in chapter 5.2, table 13. As can be seen, challenge 3 and 14 expressed by the households are not covered directly by any supportive function offered by the aggregator, meaning that these aspects are important to consider in the future. The "*" indicates that the challenge does have connected support functions but that these are lacking in its ability to properly mitigate the challenge. These challenges are 1, 2, and 12, and are also important to consider in the future. This indicates that household challenges 1, 2, 3, 12, and 14, are either not supported, or are lacking in support by the aggregator function.

Table 14: *Households challenges and connected supportive functions of the aggregator.*

Challenges households	Supportive functions aggregator
Market **(5)**	Collaborate with electricity providers to come up with infrastructure and solutions to fulfill incentives demanded by households
(1*), (4), (6), (8) (13)	Display and bring forth demanded information to households, through several channels, and in a transparent and simple way to create trustworthiness and facilitate for decision making
(2*)	Act as the face of DSF, and work in favor of households' terms and conditions to gather interest and manage the connection of households to the

	market
Infrastructure **(6), (7)**	Collaborate with technology providers/developers or develop own technology that is suitable for households
(6), (7)	Help to establish solutions that gather all interfaces in one place, or collaborate with producers of equipment to integrate the same infrastructure
(8)	Bring expertise and equipment for control and use this to control households' appliances in an effective and safe way
(6)	Collaborate with installation companies to simplify the process of buying and installing equipment for households
Institutions **(9), (11)**	Manage the complex laws and regulations related to DSF and thereby relieving households of this responsibility, and also have the potential to influence the development of hard institutions by sharing their insights with regulatory authorities
(10)	Recommend the right technology from the beginning to households to create comfort and simplicity
(10), (11)	Offer a standard solution with the option of tweaking several parameters to offer a tailored service for households that fit their needs
Economy & finance **(12*)**	Aggregators may manage flexibility appliances to reduce energy costs by optimizing against the market spot price
(12*)	Aggregators can alleviate financial hurdles by offering reduced costs on equipment for new and existing customers, and providing flexible payment options through collaborations with payment companies

6. Discussion

In this chapter, we discuss key findings from the analysis of the challenges and perspectives of households and aggregators in the context of DSF. We explore unique and common challenges from the household perspective, and the role of aggregators in supporting households, noting the gaps that need to be addressed. Finally, we discuss what implications this will have on actors such as policy makers and established utilities but also society as a whole and discuss potential areas for future research.

6.1 Household perspective

The analysis presented several household challenges within the context of DSF. The areas (market, infrastructure, institution, and economy & finance) of which the data from various theoretical and empirical perspectives were sorted from, provided a nuanced and broad understanding of different challenges. The key findings of the thesis regarding households can be illustrated through the themes of incentives, awareness, understanding, interest, information, simplicity, comfort, control, adaptability, transparency, costs, and financial rewards. Within these themes households expressed similar needs but there were also irregularities and variation between them. These kinds of irregularities arose as a result of for example differences among households in terms of technological literacy, attitude, socio economic status, cultural perspectives, geographical location, or access to necessary infrastructure. Key irregularities could for example be seen in that households displayed different interest levels, comfort requirements, or informational needs. These individual discrepancies have a profound influence on the engagement and effectiveness of DSF strategies at the household level, emphasizing the need for a diverse and adaptive strategic approach when interacting with households as a segment. While this thesis recognizes the unique needs and challenges that households face as individual units, it is also important to note the common problems and challenges that they share as a collective segment. In this thesis, key common challenges have generally been linked to aspects such as adaptability, adequate financial compensation, quality infrastructure, simplicity, support, and transparency.

What was also evident, regardless of the area concerned, was the need for efficient information flow and communication. This need is being reinforced by the lack of an established and mature household market (D'Ettorre et al., 2022), which leads to a lack of awareness and understanding that gives rise to uncertainties that need to be answered or clarified. Even though the empirical data displayed a general lack of awareness and understanding for DSF among households, the general interest for it was high when being

informed of its potential economic and sustainability benefits. From this point of view it could be argued that households as a collective have a heightened interest for their energy consumption at large and are more open towards services revolving around it. However, it is equally clear that sufficient incentives, support and information must be provided if households at large are to be willing to participate in initiatives to significantly change their energy consumption patterns.

For policymakers, this understanding of the household segment is relevant when designing and applying rules that best support the adoption of DSF in households. It is suggested that policymakers should consider both the common and unique challenges faced by households when considering their rules and regulations on how to provide meaningful incentives, ensure fair financial compensation, promote high-quality infrastructure, and establish robust communication channels to increase awareness and understanding of DSF. As a society this may mean pushing more attention and resources towards personal energy consumption as a whole in order to promote broad environmental care and a more democratic energy system with fair distribution of benefits. Established utilities can also play an important role here by adapting their strategies and operations to effectively cater to a more decentralized and active consumer segment. To elaborate, this could mean adjusting pricing models, developing user-friendly interfaces for DSF technologies, and rethinking customer engagement strategies. This transition represents an opportunity for utilities to play a crucial role in driving sustainable energy practices and developing a more transparent and fair energy system.

Future research

Taking the above paragraphs in consideration, areas of future research can be identified. Firstly, we recommend performing a case study on households that aims to fully connect them to a DSF market. This research would aim to validate and test the challenge that the literature and our empirical data brought forward - providing insight into the overlap between theoretical and practical contexts. This case study would allow for real world exploration of DSF application and how households respond and interact with such systems. Furthermore, studies regarding the impact of aspects such as technological literacy, socio-economic status, cultural perspectives, and geographical locations on DSF adoption needs further exploration as it could provide insight into how to tailor DSF strategies to address variations and ensure inclusivity. Lastly, future research should also look deeper into each of the four systemic areas (market, infrastructure, institution and economy & finance) separately to get a more profound understanding of the challenges found in each category and how they impact households' perception of DSF.

6.2 Aggregator perspective

This study shows that the aggregator function can be an effective actor in helping households to deliver flexibility. The empirical findings and the theoretical framework have shown that incentives, information, market conditions, infrastructure, institutions, and economy & finance are areas where the aggregator function has the potential to support households in delivering flexibility. Many of the challenges that households expressed to be of importance, were found to be supported by the aggregator function. Some of these were e.g. information sharing, collaboration with different stakeholders to promote households' needs, help with equipment and control systems associated with DSF, take care of all regulatory aspects, and help in reducing overall costs. However, not all of the challenges stated by the households were found to be directly or fully supported. These kinds of gaps were observed in aspects such as lack of understanding and awareness of DSF which could be attributed to lack of established market as well as ineffective communication of information, lack of concrete efforts like trial periods to alleviate worries of bad contracts or lock-in effects, or lack of diversified offerings beyond price-based programs to address the broad range of household concerns about the economic viability. Therefore, while the current aggregator function exhibits considerable potential, there is a need for strategic developments to better address these identified gaps and fully realize its role in supporting households and harnessing their interest.

Furthermore, it could be argued that our findings provide an overview over the degree of adaptiveness and diversity that must be incorporated into DSF service strategies in order to effectively cater to the multitude of unique household challenges. The varying degrees of technological literacy, differing attitudes, varied interest levels, different socio-economic statuses, contrasting cultural perspectives, and unequal access to necessary infrastructure, collectively suggest that a universal approach towards households is currently not viable for effective DSF engagement and implementation by the aggregator function. However, the thesis also indicates that it is still crucial to work towards more standardized and universal approaches in certain aspects of the DSF service as it could aid in the work towards wider acceptance, simplicity and improved interoperability. This contributes to enabling more scalable DSF strategies for households where the aggregator function is considering the diverse needs of households as well as the common objectives of DSF integration. This thesis therefore highlights the importance of seeking balance, where aggregators face nuanced tasks that can make it difficult for them to position themselves firmly and make it easy to miss certain aspects, as evidenced by the already existing gaps in support that this thesis has identified.

Another finding regarding the aggregation function is the diversity among themselves. Many of the aggregators had different solutions, collaborated with different actors, and were often very technical in nature. In the theory it was found that the aggregator function may collaborate with technology developers (Langendahl et al., 2019), and in the empirical findings it was found that the aggregator function may collaborate with installation companies, payment companies, and policy makers, to further develop solutions for DSF. This indicates that the aggregator function is trying to fulfill the needs of households without taking ownership and responsibility for all aspects. In addition, the technical nature of the aggregator function may come from the fact that the overall DSF business is technical, since adequate equipment and data management is needed to effectively deliver flexibility to the existing markets. Different solutions were often offered by the aggregators, which may be a result of trying to diversify themselves from other actors in the business. The above aspects of solutions, collaboration, and technical nature, combined with the fact that household markets are not well established, may be the reason why a uniform approach does not currently seem optimal for the aggregator function. Instead, it could be argued that the aggregators as of today, complement each other in different aspects, in the end covering many of the diversified needs of households. Whether or not this approach is optimal in terms of aggregators' support to households in providing flexibility, or whether the aggregator should take a more holistic approach and cover all the different needs of the household segment, needs to be further investigated.

Implications of the aggregator function in a holistic societal perspective should also be discussed. Their ability to support households in delivering flexibility may speed up the amount of available flexibility on the market, which in turn can help in speeding up the transition to more renewable energy sources. The aggregator function therefore may have the opportunity to affect society in the overall transition to renewable energy sources therefore help with the goal of reaching 100% renewable power system in 2040 in Sweden (IRENA, 2020). Another implication of the aggregator function is regarding its relation to established utilities. Established utilities, such as energy providers, may see the aggregator function as a potential partner or as a competitor, since energy providers also have the opportunity to act as an aggregator. Energy providers already have established platforms and customer bases with built up trust, and could take advantage of that. This may further accelerate the significance and competitive nature of the role, which may increase the development of equipment and knowledge to be more suitable for households.

Future research

For future research, it would be valuable to study the aggregator function and its potential to cover all varying needs of the household segment. It would be beneficial to understand

whether the aggregator function should continue to be specialized in certain areas and offer different solutions, collaborate with different actors and still be technical in nature; or whether the aggregator function should focus on capturing all the varying needs of the household segment, eventually offering complete and matching services. Another area of interest would be whether established utilities, such as energy providers, should consider the role as an aggregator since they have the customer base and knowledge around the market, or if they should collaborate and use the services of already established aggregators. We believe that these two factors would help in understanding the future role of the aggregator function and how the aggregators should think regarding their business model of the household segment. In addition, it would also be of interest to properly validate the claims of the aggregator function's supportive abilities mentioned in this report. This requires evaluating the functionality and efficiency of these abilities in various practical, real-life, scenarios and use-cases. Comparing the insights from this process with the initially claimed abilities from this thesis, the accuracy of these claims can be better validated.

7. Conclusion

The aim of this thesis was to understand what challenges exist in households delivering flexibility, and what the aggregator function may do to support households in their challenges. To understand the aim of the thesis, two research questions were established. Namely: (1) What challenges are associated with households delivering flexibility, and (2) How may the aggregator function support households when delivering flexibility?

For RQ1, the analysis shows that several challenges exist and can be structured under the four systemic areas of market, infrastructure, institutions, and economy & finance. Within these core areas further themes were identified such as incentives, awareness, understanding, interest, information, simplicity, comfort, control, adaptability, transparency, costs, and financial rewards. Some of the main challenges connected to these themes are lacking DSF market for households, lack of awareness and understanding of DSF, the need for guidance and support to address knowledge gaps, the need to simplify and standardize to reduce infrastructure complexity, challenges of adapting DSF solutions to suit individual households, concerns of how DSF affect control and comfort, and uncertainty about the economic viability of DSF. For RQ2, it was found that the aggregator function has several ways of supporting households in delivering flexibility. The study showed that the aggregator function may support households in the four systemic areas of market, infrastructure, institutions, and economy & finance. Important supportive measures that the aggregator function could perform in these areas were information sharing, bring knowledge and expertise around DSF, collaboration with different stakeholders to promote households' needs, help with equipment and control systems associated with DSF to reduce complexity and increase adaptability, take care of all regulatory aspects, and help in reducing overall costs.

In our discussion chapter, we reflected on, and examined the implications of our findings in relation to theory. From that it was concluded that the outcome of this thesis has contributed towards theory by providing a more detailed and extensive insight into the challenges of households and how this relates to the current supportive abilities of the aggregator function, providing a form of status report. In addition, five main gaps between households' challenges and the aggregator's ability to provide support were identified. The first gap was connected to issues related to the differing needs and interests among households, which calls for customized solutions. However, these households also share many concerns, suggesting the need for more uniform or standardized solutions. This balance in providing supportive solutions is yet to be fully realized by aggregators as indicated by their diverse focuses and the gaps

found in support. The second gap was found to be regarding the challenge of limited markets for households to participate in. The aggregator function possesses the ability to connect households to some markets, but seems to lack the ability to develop suitable markets and to connect households to all markets. The third gap was identified in households' initial lack of awareness and understanding of DSF. When told about DSF in general, households' expressed an interest even though their awareness and understanding was low. This indicates that aggregators do not bring sufficient support in the initial phase, and may miss out on potential interest from households to start with DSF. The fourth and fifth gaps were found in the aggregator's inability to fully support households in their economic uncertainties both in terms of not being able to provide a diverse range of economic benefits, or in alleviating contract and lock-in-effects concerns with concrete efforts such as trial-periods.

In addition to these contributions, tables are presented that bring together the literature and empirical findings on both household challenges and the supporting functions of aggregators. Another table bringing together the identified challenges of households with the identified support functions of aggregators has also been constructed to provide a clear overview of the ability of aggregators to support households. Together, these tables can serve as valuable tools for future researchers and provide a clearer overview of households' current challenges and the aggregator function's supportive abilities, providing a basis for further investigations.

Implications

Policymakers need to consider household-specific challenges to encourage DSF adoption through fair incentives, quality infrastructure, and strong communication. Focusing more resources on individual energy consumption can promote environmental responsibility and democratize the energy system. Utilities can support this by rethinking strategies to support DSF, promoting sustainable energy practices and a more transparent energy system.

The aggregator function in a societal context may contribute to the transition towards renewable energy sources by supporting households in delivering flexibility and increasing market availability. This role could help Sweden achieve its goal of a 100% renewable power system by 2040, as per the IRENA 2020 report. However, the aggregator function might also disrupt existing utilities as energy providers might view aggregators either as potential partners or competitors. These energy providers could also adopt the aggregator role, and in doing so, leveraging their established platforms and trust with customers. This dynamic could introduce competition and drive the development of more household-suited equipment and knowledge, contributing to growth of market share.

Recommendations for future research

Future research should include case studies aiming to fully connect households to a DSF market in order to validate our findings and understand practical challenges more deeply. Additionally, studies should explore how factors such as technological literacy and socio-economic status impact DSF adoption to ensure better, more inclusive strategies. In addition to this, we also recommend looking further into the challenges in each of the four systemic areas (market, infrastructure, institutions, and economy & finance) separately to get a more profound understanding of each category. Future research should also explore the aggregator function's ability to meet diverse household needs and whether it should specialize or offer comprehensive services. Another area to investigate is whether established utilities should take on the aggregator role due to their customer base and market knowledge, or collaborate with existing aggregators. Additionally, it would be useful to validate the claims of aggregator supportive abilities in real-life scenarios to ascertain their functionality and efficiency.

References

Andersson, B. A., & Jacobsson, S. (2000). *Monitoring and assessing technology choice: the case of solar cells*. Energy Policy, 28(14), 1037-1049.

Bell, E., Bryman, A., Harley, B. (2019). *Business Research Methods*, Fifth Edition. Oxford: Oxford University Press.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2005). *Analyzing the dynamics and functionality of sectoral innovation systems - a manual*. In: DRUID tenth anniversary summer conference 2005, Copenhagen.

Black, K. (2010). *Business Statistics For Contemporary Decision Making 6th edition*.

Butler, C. D. (2018). *Climate change, health and existential risks to civilization: A comprehensive review (1989–2013)*. International journal of environmental research and public health, 15(10), 2266.

Böris, K., & Berg, M. (2020). *A Review of Drivers and Barriers for Demand Side Flexibility: The perspective of electric grid customers.*

Cambridge Dictionary. (n.d). *Intermediary.* https://dictionary.cambridge.org/dictionary/english/intermediary

Cardoso, C. A., Torriti, J., & Lorincz, M. (2020). *Making demand side response happen: A review of barriers in commercial and public organisations*. Energy Research & Social Science, 64, 101443.

Carlsson, B., Jacobsson, S., Holmén, M., & Rickne, A. (2002). *Innovation systems: analytical and methodological issues.* Research policy, 31(2), 233-245.

Carlsson, B., & Jacobsson, S. (1997). *In search of useful public policies—key lessons and issues for policy makers.* Technological systems and industrial dynamics, 299-315.

Cho, W., Fan, M., Yoo, B., & Zhang, H. (2021). *Special issue on digital transformation: challenges and opportunities*. Information Systems and e-Business Management, 19(2), 387-388.

D'Ettorre, F., Banaei, M., Ebrahimy, R., Pourmousavi, S. A., Blomgren, E. M. V., Kowalski, J., ... & Madsen, H. (2022). *Exploiting demand-side flexibility: State-of-the-art, open issues and social perspective*. Renewable and Sustainable Energy Reviews, 165, 112605.

Eid, C., Codani, P., Chen, Y., Perez, Y., & Hakvoort, R. (2015). *Aggregation of demand side flexibility in a smart grid: A review for European market design*. In 2015 12th International Conference on the European Energy Market (EEM) (pp. 1-5). IEEE.

Energiföretagen. (2021). *Energiföretagens syn på EU-förslag om oberoende aggregatorer.* https://www.energiforetagen.se/medlemsnyheter/2021/juni/energiforetagens-syn-pa-eu-forslag-om-oberoende-aggregatorer/

Energimarknadsinspektionen (EI). (2021a). *Oberoende aggregatorer: Förslag till nya regler för att genomföra elmarknadsdirektivet - I enlighet med NordREGs förslag* (Ei R2021:03). https://www.regeringen.se/contentassets/5ed60f0bb7284e6482e3cb79997aca76/energimarknadsinspektionens-rapport/

Energimarknadsinspektionen (EI). (2021b). *Årlig sammanställning av hinder för efterfrågeflexibilitet — sammanfattning av workshop 20 oktober 2021*. https://www.ei.se/om-oss/nyheter/2021/2021-11-03-arlig-sammanstallning-av-hinder-for-efterfrageflexibilitet---sammanfattning-av-workshop-20-oktober-2021

Energimarknadsinspektionen (EI). (2016). *Åtgärder för ökad efterfrågeflexibilitet i det svenska elsystemet (Ei R2016:15).* https://ei.se/download/18.d4c49f01764cbd606218b36/1608307256769/%C3%85tg%C3%A4rder-f%C3%B6r-%C3%B6kad-efterfr%C3%A5geflexibilitet-i-det-svenska-elsystemet-Ei-R2016-15.pdff

Energimarknadsinspektionen (EI). (2022). *Tjänster för efterfrågeflexibilitet - Sammanställning av tekniska krav och andra villkor för tillhandahållandet av tjänster i form av ändrad elanvändning* (Ei R2022:15). https://ei.se/download/18.4baa100518529b2af5e2359/1671717105011/Tj%C3%A4nster-f%C3%B6r-efterfr%C3%A5geflexibilitet-Ei%20R2022-15.pdf

Energimarknadsbyrån. (2023). *Normal elförbrukning och elkostnad för villa.* https://www.energimarknadsbyran.se/el/dina-avtal-och-kostnader/elkostnader/elforbrukning/normal-elforbrukning-och-elkostnad-for-villa/

Energimyndigheten. (2022). *Årliga energibalanser.* *https://app.powerbi.com/view?r=eyJrIjoiNjk1YzgwOWQtMTNiZS00ZjE2LTkyZGUtMjhmM2M3OWEyNzdiIiwidCI6IjVjMTk0OGIzLWE5ODYtNDg1MC04M2YyLTQ2NTk2NWMzNmNhMSIsImMiOjh9&pageName=ReportSection*

European Commission, Directorate-General for Energy, Antretter, M., Klobasa, M., Kühnbach, M. (2022). *Digitalisation of energy flexibility*. Publications Office of the European Union.

European Commission. (2023). *Register of Commission expert groups and other similar entities*. https://ec.europa.eu/transparency/expert-groups-register/screen/expert-groups/consult?lang=en&do=groupDetail.groupDetail&groupID=2892

European Union. (2019). *Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (02019L0944-20220623)*. Publications Office of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02019L0944-20220623

Fouquet, R., & Pearson, P. J. (2012). *Past and prospective energy transitions: Insights from history*. Energy policy, 50, 1-7.

Färegård, S., & Miletic, M. (2021). *A Swedish Perspective on Aggregators and Local Flexibility Markets: Considerations and barriers for aggregators and SthlmFlex together with their potential to manage grid congestions in Stockholm.*

Geels, F. W., & Kemp, R. (2006). *Transitions, transformations and reproduction: dynamics in socio-technical systems.* In Flexibility and stability in the innovating economy (pp. 227-256). Oxford University Press.

Golmohamadi, H. (2022). *Demand-Side Flexibility in Power Systems: A Survey of Residential, Industrial, Commercial, and Agricultural Sectors.* Sustainability, 14(13), 7916.
Government Offices of Sweden. (2020). *Sweden's long-term strategy for reducing greenhouse gas emissions.*
https://unfccc.int/sites/default/files/resource/LTS1_Sweden.pdf

Good, N., Ellis, K. A., & Mancarella, P. (2017). *Review and classification of barriers and enablers of demand response in the smart grid*. Renewable and Sustainable Energy Reviews, 72, 57-72.

Granado, P. C. D., Rajasekharan, J., Pandiyan, S. V., Tomasgard, A., Kara, G., Farahmand, H., & Jaehnert, S. (2023). *Flexibility Characterization, Aggregation, and Market Design Trends with a High Share of Renewables: a Review*. Current Sustainable/Renewable Energy Reports, 10(1), 12-21.

Göteborg Energi. (n.d). *Effekthandel Väst – en lokal marknad för effektflexibilitet.*
https://www.goteborgenergi.se/foretag/vara-nat/elnat/effekthandel-vast

Hammam, J. (2016). *Potentialen för en aggregatoraktör att förmedla energitjänster i det svenska elnätet: Möjligheter att tillvarata elöverskott från solcells-och energilagringssystem i flerbostadshus*.

Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. (2007). *Functions of innovation systems: A new approach for analysing technological change*. Technological forecasting and social change, 74(4), 413-432.

Hennlock, M., Karlsson, A.,Nilsson, A., Grahn, D., & Fransson, N. (2023). *Konsumentperspektiv på efterfrågeflexibilitet* (Report U). IVL Svenska Miljöinstitutet.
https://ei.se/download/18.4ed2158a18722d7df785bc9/1680686319221/Konsultrapport-Konsumentperspektiv-p%C3%A5-efterfr%C3%A5geflexibilitet-IVL.pdf

Henriette, E., Feki, M., & Boughzala, I. (2016). *Digital transformation challenges*.

Howells, J. (2006). *Intermediation and the role of intermediaries in innovation*. Research policy, 35(5), 715-728.

Howells, J., & Thomas, E. (2022). *Innovation search: the role of innovation intermediaries in the search process*. R&D Management, 52(5), 992-1008.

Hölscher, K., Wittmayer, J. M., & Loorbach, D. (2018). *Transition versus transformation: What's the difference?*. Environmental innovation and societal transitions, 27, 1-3.
IEA. (2019). *Energy Policies of IEA Countries: Sweden 2019 Review, IEA, Paris.* https://www.iea.org/reports/energy-policies-of-iea-countries-sweden-2019-review

IRENA. (2020). *Innovative solutions for 100% renewable power in Sweden (ISBN 978-92-9260-169-0)*. International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/publications/2020/Jan/Innovative-solutions-for-100-percent-renewable-power-in-Sweden

Jacobsson, S., & Bergek, A. (2004). *Transforming the energy sector: the evolution of technological systems in renewable energy technology*. Industrial and corporate change, 13(5), 815-849.

Kerscher, S., & Arboleya, P. (2022). *The key role of aggregators in the energy transition under the latest European regulatory framework*. International Journal of Electrical Power & Energy Systems, 134, 107361.

Kivimaa, P., Boon, W., Hyysalo, S., & Klerkx, L. (2019). *Towards a typology of intermediaries in sustainability transitions: A systematic review and a research agenda*. Research Policy, 48(4), 1062-1075.

Kivimaa, P., Bergek, A., Matschoss, K., & van Lente, H. (2020). *Intermediaries in accelerating transitions: Introduction to the special issue*. Environmental innovation and societal transitions, 36, 372-377.

Langendahl, P. A., Roby, H., Potter, S., & Cook, M. (2019). *Smoothing peaks and troughs: Intermediary practices to promote demand side response in smart grids*. Energy Research & Social Science, 58, 101277.

Maksimenko, I., Vashko, T., & Zdrestova-Zakharenkova, S. (2021). *Digital transformation and its challenges to the strategic management system*. In SHS Web of Conferences (Vol. 106, p. 01035). EDP Sciences.

Markard, J., Stadelmann, M., & Truffer, B. (2009). *Prospective analysis of technological innovation systems: Identifying technological and organizational development options for biogas in Switzerland*. Research policy, 38(4), 655-667.

Markard, J., Raven, R., & Truffer, B. (2012). *Sustainability transitions: An emerging field of research and its prospects*. Research policy, 41(6), 955-967.

Markard, J., Geels, F. W., & Raven, R. (2020). *Challenges in the acceleration of sustainability transitions*. Environmental Research Letters, 15(8), 081001.

Marr, B. (2023). *Permacrisis: Resilience Emerges As Key Focus For Digital Transformation In 2023*. https://www.forbes.com/sites/bernardmarr/2023/02/03/permacrisis-resilience-emerges-as-key-focus-for-digital-transformation-in-2023/?sh=7d761df9541d

Mignon, I., & Bergek, A. (2016). *System-and actor-level challenges for diffusion of renewable electricity technologies: an international comparison*. Journal of Cleaner Production, 128, 105-115.

Mignon, I. (2016). *Inducing large-scale diffusion of innovation: An integrated actor-and system-level approach (Vol. 1777)*. Linköping University Electronic Press.

Negro, S. O., Alkemade, F., & Hekkert, M. P. (2012). *Why does renewable energy diffuse so slowly? A review of innovation system problems*. Renewable and sustainable energy reviews, 16(6), 3836-3846.

NordPool. (2020a). *Day-ahead market.* https://www.nordpoolgroup.com/en/the-power-market/Day-ahead-market/

NordPool. (2020b). *Intraday market.* https://www.nordpoolgroup.com/en/the-power-market/Intraday-market/

Olgyay, V., Coan, S., Webster, B., & Livingood, W. (2020). *Connected Communities: A Multi-Building Energy Management Approach (No. NREL/TP-5500-75528)*. National Renewable Energy Lab.(NREL), Golden, CO (United States).

Pablo Chaves Ávila, J., Morell Dameta, N., Glennung, K., Starborg, K., & Nilsson, M. (2020). *User and Customer-engagement plan: validated plan for users' recruitment and operation of the cascading funds (D1.2).* https://private.coordinet-project.eu//files/documentos/5d724145adae8Coordinet_Deliverable_1.2.pdf

Ponnaganti, P., Pillai, J. R., & Bak-Jensen, B. (2018). *Opportunities and challenges of demand response in active distribution networks*. Wiley Interdisciplinary Reviews: Energy and Environment, 7(1), e271.

Ponds, K. T., Arefi, A., Sayigh, A., & Ledwich, G. (2018). *Aggregator of demand response for renewable integration and customer engagement: Strengths, weaknesses, opportunities, and threats*. Energies, 11(9), 2391.

Rai, V., & Robinson, S. A. (2013). *Effective information channels for reducing costs of environmentally-friendly technologies: evidence from residential PV markets*. Environmental Research Letters, 8(1), 014044.

Ritchie. H., Roser, M., and Rosado, P. (2022). *Energy*. https://ourworldindata.org/energy

Robinson, J. (2023). *Market*. https://www.britannica.com/topic/market

Rogers, E.M. (1962). *Diffusion of Innovations*. The Free Press, New York.

Sáez. A., Heer. H., Fiorini. L., Castillo. M.M and Slot. T. (2022). *Demand-side flexibility: Quantification of benefits in the EU*. https://www.dnv.com/news/demand-side-flexibility-quantification-of-benefits-in-the-eu-232343

Sandwall, J., & Eriksson, M. (2014). *Möjligheter och hinder för aggregerad förbrukningsflexibilitet som en produkt på reglerkraftmarknaden.* (Dissertation, Uppsala Universitet). Publikationer från Uppsala universitet. http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-231337

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students*. Pearson education.

Smil, V. (2010). *Energy Transitions: History, Requirements, Prospects.* Santa Barbara: Praeger/ABC CLIO.

Solomon, B. D., & Krishna, K. (2011). *The coming sustainable energy transition: History, strategies, and outlook*. Energy Policy, 39(11), 7422-7431.

Sovacool, B. K. (2016). *How long will it take? Conceptualizing the temporal dynamics of energy transitions*. Energy research & social science, 13, 202-215.

Statistiska Central Byrån (SCB). (2022). *Elproduktion och förbrukning i Sverige*. https://www.scb.se/hitta-statistik/sverige-i-siffror/miljo/elektricitet-i-sverige/

Svenska Kraftnät. (2023). *sthlmflex.* https://www.svk.se/sthlmflex

Svenska Kraftnät. (2021). *Balansering av kraftsystemet.* https://www.svk.se/om-kraftsystemet/om-systemansvaret/balansering-av-kraftsystemet

UNDP. (2021). *What are the socio-economic impacts of an energy transition?*. https://www.undp.org/eurasia/blog/what-are-socio-economic-impacts-energy-transition

Van Lente, H., Hekkert, M., Smits, R., & Van Waveren, B. A. S. (2003). *Roles of systemic intermediaries in transition processes*. International journal of Innovation management, 7(03), 247-279.

Wohlfarth, K., Klobasa, M., & Eßer, A. (2019). *Setting course for demand response in the service sector*. Energy Efficiency, 12, 327-341.

Woolthuis, R. K., Lankhuizen, M., & Gilsing, V. (2005). *A system failure framework for innovation policy design*. Technovation, 25(6), 609-619.
Yaqoot, M., Diwan, P., & Kandpal, T. C. (2016). *Review of barriers to the dissemination of decentralized renewable energy systems*. Renewable and Sustainable Energy Reviews, 58, 477-490.

Yin, S., Ai, Q., Li, Z., Zhang, Y., & Lu, T. (2020). *Energy management for aggregate prosumers in a virtual power plant: A robust Stackelberg game approach*. International Journal of Electrical Power & Energy Systems, 117, 105605.

Zagerholm, D., Ackeby, S and Wiig C., (2021). *Digitalisering för efterfrågeflexibilitet (Rapportnummer: 2021:737)*. Energiforsk. https://energiforsk.se/program/elnatens-hallbara-teknikutveckling-och-digitalisering/rapporter/digitalisering-for-efterfrageflexibilitet-2021-737/

Appendix A

A1. Interview guide households

Intro

Hur insatt är du i din egen elanvändning?

i. **OM JA**

a. Hur har du koll på det?
b. Varför har du koll på det?
c. Tycker du det är svårt att hålla koll på det?
d. Varför tycker du att det är svårt?
e. Hur hade man kunnat underlätta?

i. **OM NEJ**

f. Hur kommer det sig att du valt att inte engagera dig i din elanvändning?
g. Vad hade behövts för att du skulle bli mer intresserad?

Teknik

Har du tidigare använt någon teknologi/tjänst för att hålla koll på din elanvändning eller elproduktion?

i. **OM JA**

a. Vad har du använt?
b. Hur hjälpte det dig?
c. Vilka svårigheter finns med det?
d. Hur hade dessa svårigheter kunnat minimeras?

i. **OM NEJ**

e. Varför inte?
f. Vad skulle behövas för att du skulle vilja börja använda någon teknik för att hålla koll på din elanvändning och elproduktion?

Information

a. Om det fanns information som skulle hjälpa dig att använda en teknik eller tjänst för att hålla koll på din elförbrukning, vilken information skulle du i så fall behöva?
b. Nästa fråga handlar om olika alternativ att få information på och vad du tycker om de olika alternativen t.ex: Skriftligt informationsblad, informationsfilmer, hembesök, sociala medier, hemsidor.

Skulle det hjälpa med skriftligt informationsblad, informationsfilmer, hembesök, sociala medier, hemsidor, varför/varför inte?

Efterfrågeflexibilitet

Har du koll på vad efterfrågeflexibilitet är? Om nej, ha en kortare genomgång.

Har du någon av dessa flexibilitetsresurser hemma: varmvattenberedare, uppvärmning/nedkylningssystem, solceller, laddstation för elbil?

En av efterfrågeflexibilitetresurserna är varmvattenberedare, uppvärmning/nedkylningssystem, solceller, laddstation för elbil.
Hade du kunnat tänka dig att låta din varmvattenberedare, uppvärmning/nedkylningssystem, solceller, laddstation för elbil vara med i efterfrågeflexibilitetsmarknaden?

OM JA:
a. Varför kan du tänka dig det?
b. Innan du börjar bidra med flexibilitet från denna produkt, vad hade du behövt för information?
c. Vilka incitament är viktiga för dig för att du ska vilja bidra med flexibiliteten från denna produkt?
d. Vilka hinder ser du med att bidra med flexibilitet från denna produkt?
e. Hur hade man kunnat underlätta dessa hinder för dig?

OM NEJ:
a. Varför kan du inte tänka dig det?
b. Vad hade behövts för att du skulle kunna tänka dig att bidra med flexibilitet från denna produkt?

Ekonomi

Fråga: *Skulle du vara villig att investera i utrustning för flexibilitet på efterfrågesidan och i så fall, vilken prisklass skulle du vara bekväm att starta i och* ***varför?*** *(t.ex om du är bekväm med max 7000 kr, varför är du det och varför väljer du att stanna där?)*

a. 800 kr (T.ex Smart mätare eller styrenhet för varmvattenberedare)

b. 7000 kr (T.ex Elbilsladdare)

c. 25 000 kr (T.ex anpassad värmepump

d. 50 000 kr (T.ex Batteri till solceller)

Avslut

a. Hur känner du inför att bli mer tekniskt insatt i din egen elproduktion och den allmänna tekniska utvecklingen inom efterfrågeflexibilitet för att vara med i efterfrågeflexibilitesmarknaden?
b. Hur känner du inför att dela med dig av information kring din elanvändning i syfte att bidra med efterfrågeflexibilitet?
c. Vilka är de viktigaste aspekterna för dig för att du skulle vilja börja bidra med flexibilitet?
d. Vilka är de största barriärerna för att du ska börja bidra med flexibilitet?

A2. Interview guide aggregators

Intro

- Hur väl känner du till begreppet efterfrågeflexibilitet?
- Hur skulle du definiera efterfrågeflexibilitet?
- Vad erbjuderna ni för produkt/tjänst som bidrar med flexibilitet?
    - Erbjuds detta till hushåll? om inte, varför?

Marknad

- Vad efterfrågas av kunder i dagsläget och hur väl kan ni matcha efterfrågan?
- Vad tror du kommer efterfrågas av kunder framöver? Vilka svårigheter kommer detta att medföra?
    - Hur kan ni som aggregator minimera dessa svårigheter?
- Hur arbetar ni med att nå ut med information till era kunder?
    - Finns det några svårigheter kopplat till detta?
- Vilka problem stöter ni på när ni har samtal med kunder?
    - Hur arbetar ni för att få era kunder att känna att de kan se er som en pålitlig informationskälla?
    - Efterfrågas annan information än den som är tillgänglig?
- Hur ser engagemanget och intresset ut från kunder att bidra med flexibilitet?
- Vilket ansvar ser ni att en aggregator ska ta för att få kunder att bidra med flexibilitet?
    - Vilket ansvar bör andra aktörer ta?
- Hur hjälper ni till att koordinera mellan aktörer idag? (t.ex DSO och prosumer)
- Vad ser ni som de största barriärerna med efterfrågeflexibilitet kopplat till hushåll?

Infrastruktur

- Hur ser ni på den tekniska utvecklingen och dess inverkan på aggregatorrollen, vilka utmaningar och möjligheter ser ni där? (Smarta elmätare, kontrollsystem, energilagringsteknik)
- Är utrustningen som aggregatorer erbjuder till marknaden standardiserad eller inte?
- Är det viktigt för kunderna att ha samma sorts utrustning/gränssnitt?
    - Vilka problem/möjligheter ser ni med detta?
- Hur mycket är ni med och påverkar utvecklingen av utrustning och infrastruktur som används bland kunderna?
    - Ser ni er som spridare av teknologiska lösningar?

Ekonomi

- Vilka incitament ser du att kunder värdesätter mest?
- Får era kunder någon ekonomisk kompensation för deras anslutning till er tjänst? (Mer än att ni kan hjälpa dem att minska kostnader)
- Hur reagerar kunder på de ekonomiska incitament ni framför?
- Finns det barriärer när det kommer till initiala investeringskostnader för kunderna?
    - Försöker ni minimera dessa barriärer på något sätt?

Lagar och regulationer

- Hur påverkar dagens regelverk era möjligheter att aggregera energiresurser och bidra med flexibilitet?
- Vilka lagar eller regulationer ser ni som de största barriärerna till att leverera flexibilitet från kunder?
  - Hur arbetar ni för att minimera dessa?
- Vilka regulationer eller lagar bör ändras eller instiftas för att ni mer effektivt ska kunna leverera flexibilitet från kunder?
- Behöver kunden själv involvera sig i lagar och regulationer vid anslutning till er tjänst?
  - Är ni med och hjälper era kunder att förstå lagar/regulationer som finns just nu