Innovative Demand Side Management Solutions

Exploring Incentives and Barriers for Demand Side Management Solutions at Shared Charging Infrastructure Sites for Heavyweight Vehicles

Master's thesis in Management and Economics of Innovation, and Quality and Operations Management

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Abstract

A major part of the decarbonization efforts of society is related to the energy and transport sectors. The energy sector is undergoing a transition to renewable sources and at the same time Swedish electricity consumption is expected to double by 2045, resulting in two challenges. First, there is a problematic, daily and seasonal, mismatch between supply and demand due to intermittent renewable energy sources and fluctuating demand. Second, the required expansion and reinforcement of the grid is costly and may not be completed in time. When electrifying public transport, involved actors need to adopt new ways of working to address these future challenges in the energy system. Extending from the DREEMER-project, which includes stakeholders in public transportation and shared charging infrastructure, the thesis investigates the necessary incentives and potential barriers for actors to take a more active role in supporting the local electricity grid at bus charging sites. Furthermore, the thesis explores potential demand side management solutions and what measures actors could take to increase participation in the local energy system. The study began with a pre-study, followed by interviews with DREEMER-actors who recommended additional respondents. This led to another round of interviews with a technical focus. Simultaneously, a literature review on sharing economy concepts and technical solutions was conducted. Financial returns are identified as a necessary incentive, while environmental and social incentives are also recognized as important. The results highlight four main barriers that need to be overcome: lack of existing business models, regulatory barriers, uncertainty, and lack of knowledge. The potential of demand side management solutions is discussed in relation to the identified incentives and barriers.

Keywords: demand side management, charging infrastructure, sharing economy, business model, heavyweight transport, electrification, sustainable development

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Amanda Styff & Sara Thorell, Gothenburg, January 2024

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

BESS	Battery Energy Storage Systems
DSM	Demand Side Management
ESS	Energy Storage Systems
EV	Electric Vehicle
PV	Photo Voltaic
V2G	Vehicle to Grid
V2X	Vehicle to Everything

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1. Introduction

In light of the climate crisis, our society urgently needs to adapt and prioritize sustainable development. To mitigate climate change the EU has put forward the European Green Deal, with the ultimate aim of reducing CO_2-emissions to at least 55 percent below 1990 levels by 2030, and reaching net zero emissions by 2050 (European Commission, 2021). A major part of the emissions is related to energy and transport. Therefore the EU is pursuing initiatives and policies that promote the transition to renewable energy systems, improve energy efficiency, and encourage sustainable transport (European Commission, 2021). Sweden has set the net-zero emissions goal to 2045, with at least 85 percent of the reduction targeted within the country (Energimyndigheten, n.d.).

The electrification plays a crucial role in decarbonizing society and creates the necessary conditions for innovation and sustainable development (Energimyndigheten, n.d.). However, the expected rise in electricity consumption also poses some challenges. A high-level scenario for Swedish electricity consumption in 2045 is estimated at 310 TWh, from approximately 145 TWh in 2022 (Sweco, 2022; Svenska Kraftnät, 2021b). Additionally, the cost of renewing the existing grid and increasing capacity is estimated at 668 billion SEK (Sweco, 2022). Svenska Kraftnät (2021b) points out that the demand might become even higher due to recent developments, such as industrial electrification. The substantial cost of reinforcing and expanding the capacity of the grid underscores the need for strategic planning and optimizing resource allocation.

In Gothenburg, the second largest city of Sweden, there is an ongoing initiative called ElectriCity that aims to drive the transition towards electrified travel and transport (ElectriCity, n.d.-b). Extending from ElectriCity, the project DREEMER aims to investigate how different modes of transportation can share charging infrastructure and power supply efficiently without overloading the electrical grid, thereby facilitating the transition to an electrified transportation system (ElectriCity, n.d.-a). Expanding and building charging infrastructure that ensures both availability and efficient resource utilization constitutes a substantial challenge and sharing between multiple actors could be a solution. The project is a collaboration between key stakeholders including ABB E-Mobility, Chalmers Tekniska Högskola, Göteborg Energi, Göteborgs Stad, Keolis, Lindholmen Science Park, Renova, Transdev, Volvo Group and Västtrafik (ElectriCity, n.d.-a).

Currently, the electricity market and the power system are characterized by changing conditions. Power systems are experiencing rapid evolution, as competitive markets have been developed to foster effective use of generation and network resources (O'Connell et al., 2014). Energy efficiency measures, on-site generation technologies, Demand side management and storage systems, when combined with new business models, are argued by Tronchin, Manfren, and Nastasi (2018) to be factors reshaping energy infrastructure and the energy market. Ensuring grid stability in power systems with a significant share of intermittent renewable energy sources often requires the utilization of expensive and carbon-intensive reserve capacity (O'Connell et al., 2014). The transition to a greater share of renewable energy sources is necessary for a drastic reduction in carbon emissions, but the intermittent nature of these leads to a mismatch between inflexible production and inelastic demand (Tronchin, Manfren, & Nastasi, 2018).

To overcome the challenge of combining increased electrification with a larger share of renewable energy sources, demand side management (DSM) offers a potential solution. It is a cost-effective tool to manage electricity networks and balance supply and demand (Williams et al., 2023). With DSM electricity demand can be increased during periods of excess supply, thereby promoting the use of renewable energy sources and facilitating integration of renewable generation into the power system. Furthermore, by reducing peak demand to remain within infrastructure limits, the lifetime of components can be extended, and distribution costs reduced. DSM consists of various strategies to modify the level or pattern of electricity consumption (Williams et al., 2023), and is gaining popularity as technology and regulations develop (Behrangrad, 2015). DSM activities can be categorized into either energy efficiency or demand response, with the latter including more business model options (Behrangrad, 2015). Demand response refers to electricity demand being intentionally adjusted; either decreased, increased or shifted; to accommodate constraints such as supply (Williams et al., 2023). These measures are respectively known as peak shaving, valley filling and load shifting.

1.1 Aim and Research Questions

In a future scenario with shared charging infrastructure for heavy-weight transport, the municipal energy company of Gothenburg anticipates that there will be a need to reduce peak load locally at times of high demand. Extending from the DREEMER-project, the thesis will investigate what necessary incentives and potential barriers exist for actors to take a more active role in supporting the local electricity grid at bus charging sites. Further, the thesis investigates potential demand side management solutions and what measures actors could take to increase participation in the local energy system.

RQ1: What incentives are necessary and what barriers hinder actors to increase participation in the local energy system?

RQ2: What demand side management solutions could actors implement at bus charging sites?

2. The Swedish Energy System

Sweden normally consumes 135 to 145 TWh of electricity every year, while 150 to 165 TWH is being produced, resulting in a net surplus of electricity for export (Energiföretagen, 2023). 61 percent of the electricity produced in Sweden during 2022 came from renewable sources including 41 percent from hydro, one percent from solar, and 19 percent from wind power (Statistiska Centralbyrån, 2023). The remaining production consisted of 29 percent from nuclear power and 10 percent from non-renewable co-generation. There is an interplay among these energy sources, wherein non-weather-dependent sources such as hydroelectric, nuclear, and biomass power balance the variability of weather-dependent energy sources like wind and solar (Energiföretagen, 2023).

The Swedish Power Grid consists of the transmission grid, distribution grids and international connections (Svenska Kraftnät, 2022). Svenska Kraftnät is the transmission system operator (TSO) and manages the transmission grid that distributes electricity from north to south of Sweden, and to other countries. They are responsible for assuring reliable delivery of effect and energy, and maintaining balance in the grid. The transmission grid transports large amount of electricity from the big electricity producers to the regional distribution grids. The voltage in the transmission grid is 400 or 220 kV.

The distribution grids consist of regional and local grids and is managed by distribution system operators (DSOs) (Svenska Kraftnät, 2022). The distribution grid transports the electricity from the transmission grid to the local grid, delivering electricity to end customers. Large electricity users and mid-sized electricity producers are also connected to the regional grid, which is owned by the major power grid companies and usually have a voltage of 130 kV. Smaller and very small energy producers that for example sell back excess electricity from solar panels can also be connected to the local grid. The local grids are geographically delimited with voltage from 40 kV that is reduced to 230 V when it reaches households. The local grids are owned by many different power grid companies. In Gothenburg the regional grid is owned by Vattenfall and Ellevio, while the local grid is owned by the City of Gothenburg via Göteborg Energi (Göteborg Energi, n.d.-b). Electricity consumers in Sweden need two contracts, one with an electricity producing company and another with the electricity grid company that owns the grid where their residence or company is located (Energimarknadsinspektionen, 2023).

2.1 Flexibility Market

The flexibility market is where actors capable of temporarily reducing their electricity consumption or increasing their electricity production can sell that capacity as a flexibility service (Svenska Kraftnät, 2021c). It is a solution to local capacity shortages within the energy grid, which might otherwise hinder actors from having their electricity needs met (Svenska Kraftnät, 2021c). Flexibility within the electricity grids enables a more efficient utilization of available capacity, which is increasingly important as electrification is growing and as more intermittent renewable energy sources are integrated. Svenska Kraftnät (2023a) point out that flexibility service will play a vital role as consumption and production patterns change and energy-intensive industries are connected to the grid. They believe that efforts of reinforcing the grid, digitalization and new market solutions will not be enough to build a robust energy system. Flexibility gives the electricity system an increased ability to handle variations in production, demand, and grid availability, and is becoming increasingly important as consumption and production patterns change and new electricity-intensive industries and businesses are connected to the grid.

2.2 Ancillary Services

For the electricity transmission to function, the grid frequency must be continuously kept within a certain range around the nominal frequency, which implies that electricity generation must consistently correspond to the consumption levels (Svenska Kraftnät, 2021a). In the Nordics the power system is balanced against a frequency of 50Hz. In order to maintain the frequency, the TSO has several stabilizing resources and ancillary services. Currently in Sweden there are five types of stabilizing resources including Frequency Containment Reserves (FCR) and Frequency Restoration Reserves (FRR) (Svenska Kraftnät, 2023d). The FCR serves as the initial response to grid disturbances, and if the deviation persists the FRR will be activated to restore the frequency to 50 Hz. Disturbances can arise from technical faults, disconnection of production and consumption or random variations (Svenska Kraftnät, 2021a). Hence these services are critical in order to ensure a reliable and robust power system, both on national and regional level. The compensation for providing these ancillary services is determined based on a pre-specified price (Svenska Kraftnät, 2023c).

2.3 Spot Market

The price for electricity is determined by supply and demand on the day-ahead market, also known as the spot market (Svenska Kraftnät, 2023b). Market participants include power generators, energy traders and larger industrial consumers. The trading takes place on a common European platform provided by either Nord Pool or EPEX Spot, where bids and offers are matched against each other to set an equilibrium price for every hour of the next day (Svenska Kraftnät, 2023b). Consequently, the price for electricity might vary significantly throughout the day depending on factors such as weather or demand patterns.

3. Methods

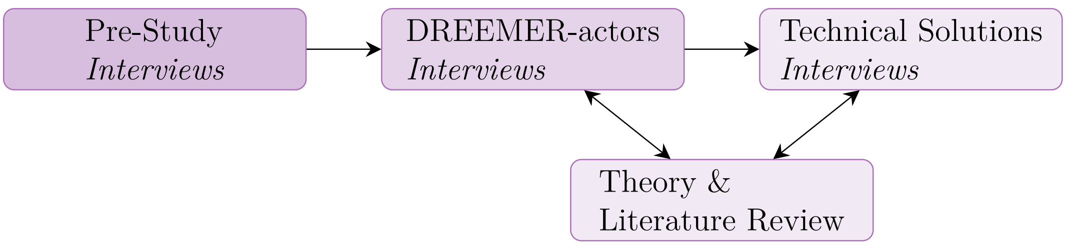
3.1 Research Strategy

The research strategy employed in this study follows a qualitative approach, emphasizing words and images over quantification in the collection and analysis of data (Bell, Bryman, & Harley, 2018). In qualitative research the relationship between theory and research typically follows an inductive approach (Bell, Bryman, & Harley, 2018). This process generally involves weaving back and forth between data and theory, making it an iterative approach of data collection and theory development. Adopting an iterative process involves shaping both theory and data collection in response to the development of the other, making it an appropriate approach for exploring and evaluating innovative DSM solutions.

3.2 Research Design

Prior to conducting the main research, a preliminary study was carried out to acquire a deeper understanding of the DREEMER-project and to gain general knowledge about the electricity market and grid. The main study was conducted in two phases, as illustrated in Figure 3.1. The primary focus of the first phase is on the first research question, studying the incentives and barriers for a higher level of involvement in the energy system at the DREEMER-sites.

Figure 3.1: *An overview of the data collection phases.*



The second phase of data collection involved interviews with a focus on the second research question, studying technical solutions. A literature study was conducted simultaneously as the second phase of interviews, gathering additional information about the sharing economy and technical solutions. The data collection was conducted concurrently as theory, result, analysis, and discussion were developed.

3.2.1 Case Study

Göteborg Energi is an energy company owned by the City of Gothenburg that provides and develops energy and city fiber. The local grid in Gothenburg is owned by Göteborg Energi (Göteborg Energi, n.d.-b). To meet the increasing demand for electricity as transportation and industry is electrified in Gothenburg, it is crucial to reinforce the transmission grid and regional distribution grid (Göteborg Energi, 2023). However, the ongoing expansion of the grid will not be completed in time to meet the increasing demand. The position for Göteborg Energi is therefore that new approaches are needed to enable the ongoing electrification (Göteborg Energi, 2023).

The DREEMER-project has selected four charging sites to be used in the project's testing. One is located in the city centre of Gothenburg, near the central station. Two additional sites, Bäckebol and Partille, are located 5-10 km outside the city centre in areas with shops, industries, parking lots and residential areas. The final site is Lysekil, a small town located 140 km north of Gothenburg with proximity to a ferry, parking lots, residential areas and industries. The relevant DREEMER-actors included in the study, along with their company and roles in DREEMER, are described in Table 3.1.

Table 3.1: Description of the roles in DREEMER.

Company	**Role in DREEMER**
ABB	Provides technical solutions for charging
Göteborg Energi	Municipal energy company and grid owner
Lindholmen Science Park	Project coordination
Keolis	Transport operator
Renova	Municipal waste management company
Göteborgs Stad	Urban development
Transdev	Transport operator
Volvo Buses	Development and production of electric buses
Västtrafik	Regional public transport procurer

3.3 Data Collection

During the pre-study, interviews with industry and academic experts were conducted, visualized in Table 3.2. For these interviews, an unstructured approach was employed. Unstructured interviews tend to be very similar in character to a conversation (Bell, Bryman, & Harley, 2018). At the start of each interview, the topic of the thesis was introduced. Thereafter, following the definition from Bell, Bryman, and Harley (2018) of unstructured interviews, the respondents answered freely, with the interviewers responding to interesting points. During the interviews with parties involved in the DREEMER-project, information about current and future regional bus-charging sites was collected. Study visits were conducted to the sites Partille and Terminal G. This was done to enable an informed decision regarding how to include the sites in the study, and to obtain a better understanding of the surrounding conditions at the sites.

Table 3.2: Description of respondents from interviews held during the pre-study.

Company	**Title**	**Topics**
Lindholmen Science Park	Project coordinators	DREEMER-project Shared charging prerequisites Public transport operations
Göteborg Energi	Flexibility strategist	Flexibility services Ancillary services
Chalmers University	Researcher of electrical distribution systems	Electrical distribution systems The Swedish electricity grid

The insights gained from the preliminary research were imperative when formulating templates of relevant interview questions. During the preliminary study, a theoretical framework focused on the electricity system in Sweden was developed, featured in Chapter 2, in order to deepen the understanding of the Swedish energy system and power grid.

3.3.1 Interviews

When preparing for qualitative interviews, Bell, Bryman, and Harley (2018) suggest exploring what is puzzling about the subject or research questions. Before each interview, a brainstorming session was conducted to explore what information or topics could be gained from the respondent. As suggested by Bell, Bryman, and Harley (2018), interview questions were formulated from the topics to ensure relevance, while avoiding making them too specific or leading.

At the start of each interview, respondents were asked for their approval to record the interview. They were informed that the recording would be deleted after the publication of the thesis, and only their job title and organization would be featured, as presented in Table 3.3 & 3.5. Bell, Bryman, and Harley (2018) describe several reasons for why recording and transcribing the interviews when conducting research is desirable. Firstly, recording interviews allows the researcher to capture all that is said, but also how it is said, which makes it less likely that the data will suffer from the researcher's limitation of memory or personal biases. It also allows for more thorough and repeated examination of the data. Secondly, the interviewer should stay alert and follow up on interesting points and valuable insights, which is difficult if the interviewer has to focus on taking accurate and sufficient notes. Lastly, recording and transcribing opens up the possibility for other researchers to scrutinize the data and evaluate the analysis. However, recording can disconcert the participants, and consequently they may refrain from discussing certain topics (Bell, Bryman, & Harley, 2018). A software tool was used to transcribe the interviews. The majority of the interviews were conducted in person but in cases when this was not feasible due to geographical distances, interviews were held on Teams.

The sampling method used in this report is called snowball sampling, and is described by Bell, Bryman, and Harley (2018) as an approach were a small group of people relevant to the research is used to establish contacts with others. At the end of the DREEMER-interviews, the respondents were asked for other individuals or actors to include in the data collection. This led to another round of interviews with a focus on technical solutions and the feasibility of these.

3.3.1.1 Phase 1: DREEMER

After the preliminary study, semi-structured interviews were conducted as part of the main study. The semi-structured approach allows the researcher to be more flexible, for example with the order of the questions asked (Bell, Bryman, & Harley, 2018). This format also allows for exploring topics of interest more in depth by asking follow up questions, and the openness allows for concepts and theories to naturally emerge from the data. The first interviews were conducted with the actors involved in the DREEMER-project. For Keolis there were two interviewees because the first respondent did not have knowledge on certain topics. Therefore they suggested a second respondent in order to acquire the complementary information. The respondents are presented in Table 3.3.

Table 3.3: Description of respondents from the DREEMER-project.

Company	Designation	Title
ABB	Respondent 1	Sales Manager E-mobility
Göteborg Energi	Respondent 2	Strategy Advisor
Keolis	Respondent 3_a	Contract Manager
Keolis	Respondent 3_b	Electrical Power Engineer
Renova	Respondent 4	Development Strategist
Göteborgs Stad	Respondent 5	Electrification Manager
Transdev	Respondent 6	Development & Innovation Manager
Volvo Buses	Respondent 7	Electromobility Manager
Västtrafik	Respondent 8	Electrification Strategist

The interviews were structured based on the topics outlined in Table 3.4. Questions were either added or excluded from the topics to align with the specific purpose of each interview.

Table 3.4: Topics for interviews held with the DREEMER-actors.

Topics	Aquired data
Intro	Respondent's role and background
DREEMER	The organization's role, expectations and challenges related to the project
Electrification of heavyweight vehicles	Vision and driving force for electrification Challenges related to electrification of heavyweight vehicles
The future charging site	Vision for ownership and potential users
Demand side solutions	Ideas and incentives for demand side management
Prediction	Desirable future scenario

Respondents were presented with three cases of sites with different geographical and size-related conditions, for them to be able to base thoughts and examples on. The cases are shown in Figure 3.2. The respondents were relatively familiar with these three sites since they are part of the DREEMER-project. However, the case descriptions were generic enough to allow the features of each site to be applicable to other locations too. The sites Partille and Bäckebol were presented as one, because of their similar characteristics. Respondents were then encouraged to refer to these cases when providing their responses.

Figure 3.2: *Site cases as presented to respondents.*

Site 1: Terminal G
Central location
Several bus routes
Several charging poles

Site 2: Partille
Outside city center
Several bus routes
Several charging poles

Site 3: Lysekil
Outside city center
End station
Few charging poles

3.3.1.2 Phase 2: Technical Solutions

Following the DREEMER-interviews, a second round of semi-structured interviews were initiated with focus on technical solutions. Table 3.5 shows the company name and the role of the interviewee.

Table 3.5: Description of respondents from interviews with a technical focus.

Company	Designation	Title
Ambidex	Respondent 9	Co-founder & business developer
GENAB	Respondent 10	Strategy manager
Göteborg Energi	Respondent 11	Sustainability manager
Göteborg Energi	Respondent 12	R&D Project manager
Lindholmen Science Park	Respondent 13	Project coordinator
Parkering Göteborg	Respondent 14	Product owner
PowerCell	Respondent 15	Sustainability Officer

Table 3.6 shows the acquired data from each interview. Companies and respondents were chosen based on recommendations from DREEMER-respondents. Additionally, Ambidex was chosen to cover the perspective of a company with an aggregator role. PowerCell was included in order to learn more about applications of hydrogen fuel cells and hydrogen storage, since the topic was discussed both in the literature and by DREEMER-respondents. Attempts were made to get in contact with Bataryloop and Northvolt in order to acquire additional knowledge of BESS, but the attempts were unsuccessful. However, there is a substantial amount of literature on the topic.

Table 3.6: Interview topics for interviews with focus on technical solutions.

Company	**Aquired data**
Ambidex	Aggregation & balancing services potential
GENAB	Grid perspective
Göteborg Energi	Sustainability perspective
Göteborg Energi	Commercialization perspective
Lindholmen Science Park	V2G potential
Parkering Göteborg	V2G potential
PowerCell	Hydrogen potential

3.3.2 Literature Review

A literature review was conducted simultaneously with the second phase of the interviews, and was divided into two focus areas in line with RQ1 and RQ2. Scopus and Google Scholar were used to search for material on the relevant topics. The studied literature associated with RQ1 focused on the concept of the sharing economy and its underpinning theories, in order to understand incentives and barriers to participating in a sharing economy business model. What DREEMER is investigating, sharing charging infrastructure between multiple actors, is an example of a sharing economy business model in a B2B context. The theory could later be applied in the analysis to understand what factors could encourage or inhibit actors to take a more active role in the local electricity system.

Key words included: sharing economy, business model, incentives, barriers, B2B, charging infrastructure, technology-organization-environment framework, self-determination theory, reciprocal altruism

For RQ2 the literature focused on possible technical solutions to supporting the electricity grid, and previous studies on application of such solutions. Given the relatively limited previous research about DSM solutions in a commercial setting, the literature review was conducted to gain additional information about the solutions generated from the interviews.

Key words included: demand side management, peak shaving, vehicle-to-grid, V2G, V2X, energy storage systems, battery, next-gen batteries energy storage, NAs Batteries energy storage, second-life batteries, hydrogen energy storage system, hydrogen storage microgrid, charging infrastructure, electric buses, solar panels

3.4 Data Analysis

To structure the analysis and discussion in Chapter 7, a workshop was held where the authors identified key findings from literature and interviews. The findings were written on post-it notes and then grouped into different themes. The most logical structure decided upon was to divide the analysis and discussion into the identified incentives and barriers. From the data collection, the incentives for increased participation in the energy system were identified as economic, environmental, and social. Correspondingly, the barriers were identified as the absence of fitting business models, the crucial role of policy and regulation, uncertainty related to DSM investments and charging availability, and the lack of knowledge of electricity systems and markets. Furthermore, the DSM solutions from Chapter 5 and 6 are analyzed and discussed in relation to the identified incentives and barriers. Implementation of DSM solutions is seen as an extension of sharing charging infrastructure.

4. The Sharing Economy

Emerging in the late 2000s, the "Sharing Economy" embodies collaborative consumption of goods and services, through the activities of sharing, exchanging and renting instead of traditional ownership (Puschmann & Alt, 2016). This business model typically reduces the cost of accessing products or services by maximizing the utilization of idle assets. For example, the average car is only used 4 to 8 percent of the time (Kumar, Lahiri, & Dogan, 2018). A higher occupancy increases efficiency, although it comes at the expense of reduced lifetime which should be considered as a cost. The sharing economy has been increasingly adopted as digital technologies have developed and focus on environmental and social sustainability has grown. However, there are some concerns regarding this business model, especially in B2B contexts. Rana et al. (2023) point at some underlying issues. For example, there is critique that sharing is a social exchange where no return is expected, which goes against the market-mediated sharing economy business model. In their study, Chatterjee et al. (2023) find that firms wanting to adopt a sharing business model should only do so after carefully considering if the benefits outweigh the risks.

4.1 Theoretical Foundation of the Sharing Economy

Several theories can be applied to explain the aspects of the sharing economy. This study chooses to integrate the Technology-Organization-Environment framework as well as self-determination theory and reciprocal altruism, since they were deemed suitable for B2B contexts. These theories could be argued to constitute the foundation for understanding the incentives and barriers to participating in the sharing economy.

4.1.1 Technology-Organization-Environment Framework

The Technology-Organization-Environment framework describes how the three elements in the title present opportunities or constraints for innovation. The first aspect of Technology-Organization-Environment framework is the technological context, e.g. relevant technologies within and outside of the firm (Chuah et al., 2021). Innovations that exist but are not yet adopted by the firm will still have an impact in terms of paving the way of what is possible (Baker, 2012). The second aspect is the organizational context, e.g. internal characteristics and resources of the firm, including communication processes, organizational structure and firm size. These characteristics can either promote or inhibit innovation activities (Baker, 2012). The third aspect of the framework, the environmental context, focuses on the environment in which the firm operates. It includes regulation, industry structure and technology service providers. Baker (2012) describes how for example the competitive environment stipulates the rate of adoption, where intense competition will drive innovation. Further, regulation and policy instruments could either promote or inhibit innovation.

4.1.2 Self-determination

Kumar, Lahiri, and Dogan (2018) describe how self-determination theory explores different levels of intrinsic and extrinsic motivations, and illustrate how it influences the willingness to participate in the sharing economy. They imply that extrinsic motivation entail the financial benefit received for the provided service, while intrinsic motivations include enjoyment, networking or socialization. Deci and Ryan (2013) define self-determination as the capacity to choose and to have those choices. They contend that individuals are intrinsically motivated when they feel capable and self-determined, driven by personal interest and enjoyment. They further suggest that to be truly intrinsically motivated the individual should feel free from any pressure such as compensation or contingencies. Conversely, extrinsic motivations are driven by external rewards or pressure.

4.1.3 Reciprocal Altruism

The theory of reciprocal altruism, state that humans seek mutual benefits when cooperating with a second party (Chuah et al., 2021). One may act in a way that is beneficial for the other, but will expect that the act is reciprocated in the future, resulting in mutual benefits. If one party, in a business partnership context, continuously acts in a way that benefits the other but the other does not reciprocate, perceived imbalance could threaten the relationship (Chuah et al., 2021).

4.2 Incentives

Several factors that incentivize participation in the sharing economy were identified in the existing literature. Drawing upon the presented theories these factors can be explained.

4.2.1 Financial Benefits

Economic benefits constitute one of the major reasons to participate in the sharing economy. It presents an opportunity for consumers to purchase access to goods at lower prices, avoiding unnecessary investment costs (Muñoz & Cohen, 2017). Additionally, owners of idle assets can get a new revenue stream. Hence, Chuah et al. (2021) argue that there is potential to decrease costs and increase revenue, ultimately improving business performance. These are considered extrinsic motivations for collaborative consumption. Moreover, sharing under-utilized resources to promote efficient utilization imply benefits of economies of scale.

4.2.2 Sustainability Gains

Muñoz and Cohen (2017) claim that the sharing economy facilitates sustainable development. It can be seen as a tool for tackling problems of overconsumption and income inequality. Sharing idle assets increases efficiency and decrease overall costs, while reducing the need for additional resources. Chuah et al. (2021) emphasize that sustainability can be a driver for participation in collaborative consumption. It could be an intrinsic benefit in the form of brand reputation, adding intangible value to the firm.

4.2.3 Social Benefits

Chuah et al. (2021) stress the importance of inter-business relationships and argue that a significant factor for participation in the sharing economy is social connection benefits. In a B2B context sharing assets could improve relationships with other firms. A stronger bond between firms could promote trust and consequently increase predictability of another firms behaviour and reduce the risk of opportunistic acts (Chuah et al., 2021).

Another social benefit builds on the theory of reciprocal altruism. Chatterjee et al. (2023) argue the importance of reciprocal advantage as a motivating factor. In the sharing economy actors commonly participate in reciprocal exchange since many sharing platforms use bidirectional review systems.

4.3 Barriers

Actors also face several barriers to participating in the sharing economy. Some of the major challenges are outlined below.

4.3.1 Risk

Compared to traditional markets, the sharing economy has more associated risks (Kumar, Lahiri, & Dogan, 2018). Chuah et al. (2021) discuss perceived risks in terms of monetary, performance and physical risks related to the sharing economy. Perceived risk is defined as the feeling of uncertainty related to potential negative outcomes from using a product or service, and is an inhibitory factor for collaborative consumption (Featherman & Pavlou, 2003). Monetary risk refers to the perception that renting assets from a sharing economy actor would be more costly than from traditional leasing companies (Chuah et al., 2021). Performance risk refers to that the product or service might malfunction, or fail to comply with what was agreed upon. Lastly, physical risk refers to possible damage or loss of assets.

4.3.2 The Role of Trust

Trust is identified as a determinant of relationship quality, and defined as the willingness to rely on an exchange partner (Moorman, Zaltman, & Deshpande, 1992). Tham, Lim, and Vieceli (2023) highlight the importance of trust in the sharing economy, and argue that trust factors facilitate mutual confidence between consumers and producers. Chuah et al. (2021) conclude that the main challenge of B2B in the sharing economy is that it entails sharing assets between firms who are competitors. Trust towards each other can be difficult to achieve for competing firms. Hence, the lack thereof constitutes a major barrier for the establishment of a sharing economy business model. However, Melander and Wallström (2023) found that firms that are competitors in one field can be collaborators in other areas, for example by sharing charging infrastructure to reach a common environmental goal. They also point to that trust between actors is important in order for competing firms to collaborate.

4.3.3 Policy and Regulation

A significant challenge in supporting the shared economy as a business model is the lack of a regulatory framework, since the sharing economy is not compatible with traditional business laws and government policies (Chuah et al., 2021). Liu and Chen (2020) argue that the sharing economy is reshaping markets and has potential to promote sustainable development and improve social welfare, but it demands a new form of regulatory thinking. For example, the sharing model could be suitable for energy storage systems due to high initial costs and low utilization rates. When studied by Yong et al. (2023), regulations, policies, and industry standards are identified as the most important barriers for shared energy storage. Environmentally sustainable solutions typically comes from firms, but governments have the ability to incentivize development of green innovations (Melander & Wallström, 2023).

4.3.4 Data and Intellectual Property Misuse

Rana et al. (2023) see digital platforms of the sharing economy as an enabler of trust between the parties involved. However, information sharing facilitated by such platforms, can also lead to some adverse consequences where one actor uses data from another actor for their own benefit (Chatterjee et al., 2023). Chatterjee et al. (2023) describe the risk of a firm benefiting from another firm's intellectual property without consent. It could have negative effects on the relationship and the cooperation.

4.3.5 Lack of Top Management Support

Chuah et al. (2021) indicate that top management support has considerable influence on weighing the pros and cons for participation in the sharing economy. Chatterjee et al. (2023) agree and argue that leadership support in digital technologies in the sharing economy is of outmost importance.

5. Review of Technical Solutions

Energy storage systems will become more important in maintaining balance in the power grid, given the increasing integration of intermittent renewable energy sources (Farivar et al., 2023). Battery energy storage systems technology is growing rapidly as a result of declining prices and improved quality. The foreseeable increase in dumped EV batteries leads to a massive rise in second-life batteries being used to recover the initial material costs. To achieve 100 percent sustainability, Farivar et al. (2023) argue that hydrogen will play a major role in storing the massive amount of energy required to handle seasonal demand and energy production. Further, it is argued that technologies that add flexibility in generation and consumption can reduce dependency on energy storage systems in a cost-efficient way.

5.1 Combined Solution Approach

In a study based on two cases in Stockholm's inner city, Lopez De Briñas Gorosabel, Xylia, and Silveira (2022) present a framework for assessment of the construction of electric bus charging stations in an urban environment. The authors point out that a major issue related to charging sites in city-centres is connecting them to the power grid, due to the large impact they have on grid capacity. Some studies suggest possible ways of relieving the pressure on the electric grid and overcoming the capacity constraints by combining different technical solutions. Majumder et al. (2019) analyze the solution to use high capacity batteries combined with solar PV generation to build an electric bus network without putting an additional burden on the distribution grid. They prove that such a system can be feasible, using locally generated energy and energy storage to reduce the reliance on the local grid and allowing for the system to discharge energy to the grid to offset peak demand. In another study, Karmaker et al. (2018) propose an EV charging station using PV modules and biogas generators coupled with batteries as energy storage, to reduce the impact on the power grid. They demonstrate the economic and environmental benefits of integrating multiple renewable energy sources for EV charging infrastructure.

5.2 Ownership Dynamics

Lopez De Briñas Gorosabel, Xylia, and Silveira (2022) argue that no electrification project will become reality if stakeholders cannot come together and work towards a common goal. Electrification of public transport involves multiple stakeholders with different interests and it is essential that they can align on how the project is planned and performed in order to ensure delivery. The authors explain that one of the main issues discussed in the existing literature is ownership of the charging infrastructure. Based on how the public transport network is managed, different stakeholders might have an interest in owning the infrastructure. In cases where the municipality manages the public transport the Public Transport Authority (PTA) is the logical owner but the grid operator might also have an interest in owning. If the public traffic is procured by the PTA, operators could potentially have an interest in owning the infrastructure. However, the lifetime of charging infrastructure is commonly longer than procured contracts which might make it complicated for the operator. Lopez De Briñas Gorosabel, Xylia, and Silveira (2022) further suggest that when the public traffic is procured, the PTA could set requirements to drive the transition towards an electrified transport sector.

In their study, Melander and Wallström (2023), investigate how business actors could potentially share charging infrastructure. They show that there are both economic and environmental benefits with different types of sharing models, proving that it could provide new revenue streams, enable cost sharing, reduce investment costs, increase utilization and reduce material usage. For the owner there will be a new revenue income by renting out, and the users who share will receive cheaper charging options. They further argue that for actors to come together and make a shared investment in charging infrastructure there must be good relationships in place. Another option could be to use an intermediary, a third-party owner, who could enable coordination (Melander & Wallström, 2023). Such a solution might make it easier for firms to join, reducing the cost of investment and allowing for greater flexibility. Melander and Wallström (2023) conclude that there must be both economic and environmental incentives for horizontal collaborations to prosper. Barriers for implementation include lack of trust and coordination issues since sharing charging infrastructure requires consistent data sharing and prioritization of who charges first.

5.3 Energy Storage Systems

Energy storage systems (ESS) is a critical factor in decarbonizing the power sector and can serve a wide range of purposes that can be divided into grid services and market services. Ahcin, Berg, and Petersen (2019) explain grid services as ways of tackling grid issues, such as voltage regulation, avoiding congestion or local frequency control. Market services are defined as not necessarily addressing grid-related challenges, for instance load shifting, energy arbitrage, primary frequency control or self-consumption of solar energy.

5.3.1 Battery Energy Storage Systems

Battery Energy Storage Systems (BESS) consist of one or more rechargeable batteries able to store energy from variable sources and discharge at a different time. It has some considerable advantages in terms of cost-effectiveness, high efficiency, fast response time and scalability (Hesse et al., 2017). In their study Kucevic et al. (2021) focus on the potential of combined operation strategies for BESS at various industrial costumers. BESS offer a solution to balancing the grid and providing back-up power. Hesse et al. (2017) suggest that implementing a BESS can be economically desirable for large-scale electricity consumers such as manufacturing firms, since it allows them to directly reduce their own electricity bill, or generate new revenue streams through energy arbitrage.

5.3.1.1 Lithium-ion Batteries

Rechargeable lithium-ion batteries is the most investigated and commercially established electro-chemical energy storage technology (Vineeth et al., 2022). The characteristics of lithium makes it one of the best anodes enabling high energy and high voltage (Vineeth et al., 2022). With decreasing cost of lithium-ion batteries, they are becoming an increasingly attractive way of reducing peak power (Kucevic et al., 2021). However, the limited availability of raw materials, particularly cobalt, and the high cost of recycling lithium-ion batteries components present challenges. If not recycled correctly it can result in adverse environmental consequences (Vineeth et al., 2022).

5.3.1.2 Second-Life Batteries

Second-life batteries from EVs usually hold 70-80 percent of the original capacity, which means there is potential to use them for other applications (Hu et al., 2022; Deng et al., 2021). Further, storage of renewable energy is described as a massive market for second life batteries (Hu et al., 2022). Secondary use of batteries can significantly reduce investment cost. Using an example with retired lithium-ion phosphate batteries, investment cost can be reduced by 94 percent (Deng et al., 2021).

Centralized charging stations, as studied by Deng et al. (2021), is a promising use for retired EV batteries. At these charging stations, second-life batteries are grouped together to draw power for charging bus-batteries. Simulation of the system, involving second-life batteries integrated with photovoltaic solar power sources, showed a reduction in energy purchase costs and a smoother charging load profile. Additionally, optimizing the charging/discharging cycles of the second-life batteries can extend their lifetime and maximize their utilization.

5.3.1.3 Next-Gen Batteries

Vineeth et al. (2022) mention several alternatives to lithium-ion batteries in the future and argue that there will most likely not be a monopoly on battery technology but rather several technologies with different advantages and limitations. Furthermore, sodium-based batteries are argued to be advantageous since they share comparable properties with lithium and sodium is highly available. The cost of sodium is only 4 percent of that of lithium. Sodium is the second-lightest metal after lithium, but lithium has a much larger discharge capacity value (Vineeth et al., 2022). When used with sulfur in Na-S batteries, the cost is further reduced while electrochemical characteristics are improved.

In November 2023, the Swedish company Northvolt announced their development of their sodium-ion battery for cost-efficient and sustainable energy storage systems, with "best-in-class" energy density of 160 Wh/kg (Northvolt, 2023). The battery is produced with minerals that are abundant on the global market, and will provide energy storage with longer duration and at a lower cost.

5.3.2 Hydrogen Energy Storage System

Technology for hydrogen storage is described by Farivar et al. (2023) as significant for reaching 100 percent energy sustainability. Hydrogen can be stored in gaseous, liquid or solid state (Rusman & Dahari, 2016). Hydrogen ESS involves three steps; generation, storage and utilization of hydrogen (Rusman & Dahari, 2016). The energy density of hydrogen is about three times higher than for petrolium (Rusman & Dahari, 2016) and it is suitable for long-term seasonal energy storage use (Kharel & Shabani, 2018). Furthermore, hydrogen has the highest energy content by weight, can be renewable, and when used in fuel cells, water is the only byproduct (Moradi & Groth, 2019). Further, Moradi and Groth (2019) argue for safety and reliability of hydrogen infrastructure to be a necessary condition for realisation of hydrogen energy, especially since hydrogen, like many other fuels, is flammable.

5.3.3 Vehicle to Grid

Vehicle to grid (V2G), using reverse power flow technology, can transform EVs into an ESS in the power grid and is expected to have a major impact on the stability and operation of the grid in the future (Farivar et al., 2023). The multi-purpose and multi-user utilization of an energy storage system can reduce costs, which is the biggest obstacle to the use of ESS (Iba, 2022). Further, the multi-purpose use of batteries is described as a new key factor in the coming era. Khezri, Steen, and Tuan (2022) explain how an increasing number of EVs is essential for the decarbonization but at the same time it will bring new challenges to power systems in terms of energy supply and capacity issues. Utilizing the discharging capability of EVs could be a supportive option for the grid operators. Khezri, Steen, and Tuan (2022) further describe the main functions of V2G as reactive power compensation, voltage regulation, energy arbitrage and frequency control, and emphasize the importance of aggregators since high power is needed for grid services.

Farivar et al. (2023) argue that the main drawback of V2G is battery performance degradation, leading to a reduction in range and performance of EVs. However, it is suggested that this may change in the near future as battery quality is improved. Further, Khezri, Steen, and Tuan (2022) argue that a potential measure to overcome the technical barrier of battery degradation is to develop smart charging and discharging methods that will consider battery degradation and make the best decision for discharging the EVs.

5.4 Solar Panels

Solar panels are increasingly common on commercial buildings. The intermittent nature of renewable energy sources cause a challenge of matching energy generation and consumption (Fam et al., 2023). To match supplied energy with demand in a commercial building, solar panels must be connected to an energy storage system, of which batteries and hydrogen storage system are the most promising (Mendecka, Tribioli, & Cozzolino, 2020).

5.5 Micro Producers and Aggregators

Electricity systems are moving towards a larger degree of decentralization with higher share of renewable energy sources. Distributed energy resources (DERs) are generally small-scale energy generation or storage devices such as rooftop PVs (Burger et al., 2017). A micro producer of electricity can, during periods of over production, sell the excess electricity back to the grid. This surplus electricity is typically traded at the spot price, which is in the range of a few Swedish ören either above or below the initial purchase price (Göteborg Energi, n.d.-a). Additionally, there is a tax reduction of 60 ören for every kWh of electricity sold and an opportunity to seek further compensation from the electricity grid provider. In order for the DERs to be able to provide their electricity services at scale, an aggregator is needed to group their output and act as a single entity when engaging in the electricity market (Burger et al., 2017). Offering aggregator services in different areas can reduce the need for electricity production, thereby creating a more socioeconomically and environmentally friendly electricity system (Energimarknadsinspektionen, 2021).

6. Results

The initial sections of the results are mostly based on interviews held in the first phase of data collection with the DREEMER-actors. The data have been organized into different themes and are presented in Sections 6.1 to 6.5. Thereafter, data from interviews conducted in the second phase of data collection, with a technical focus, are presented in Sections 6.6 to 6.8, with each section based on responses from only one respondent.

6.1 The Future Challenges in the Energy System

Respondent 12 addresses the future of flexibility services by presenting the predicted increase from about 140 TWh annually to around 300 TWh in 2040-2045, that is planned to be realized through the use of intermittent power sources such as wind and solar. Due to the intermittent characteristics of these sources, flexible solutions are essential to keep the balance in the electricity system. Furthermore, they argue that as intermittent production rises, so does the demand for flexibility. The flexibility supply in relation to demand is a balance that will determine the price.

> *The demand for flexibility and the total supply of flexible capacity at different points in time — because this extends over time — how will it look? It's intriguing, but the need for flexibility should reasonably increase significantly given the amount of intermittent production we plan to have.* – Respondent 12

Respondent 10 believes that with the current production mix, in the next 5 years, the batteries installed in years 4 and 5 will have much less financial potential. If there are substantial investments in nuclear power, making the system less dependent on weather conditions, the potential for batteries would decrease. In that case, mainly local power balancing would remain, which might not be as lucrative. However, if the energy system increasingly relies on intermittent sources, there would be more fluctuations and volatility, potentially maintaining good earning opportunities in the future.

In a scenario with shared charging infrastructure for heavyweight vehicles, respondents identify a major challenge in power availability and the planning of power distribution between actors. Respondent 2 emphasizes peak demand as the main challenge, especially during cold winter days. Respondent 6 stresses the difficulties with local variations and the challenge of making accurate predictions to ensure a certain power supply. Furthermore, Respondent 2 highlights the differences in challenges across the three sites. Site one may encounter problems related to peak loads since many actors will share the available power. Site three may face issues related to having a weaker grid, that might need reinforcement. Site two might have similar challenges, but reinforcing the grid there should be easier.

Respondent 12 argues that translating a traditional business into an electrified one and expecting it to run as usual might be challenging. While it might work sometimes, it may not be successful every time. If a new facility has been built, the connection has easily been resolved within a few months over the past 100 years. However, it might not be that easy in the future.

When it comes to encouraging actors to become more active in the energy market, Respondent 10 believes it will become more natural over time. There will be a capacity shortage that will force actors to engage. If you have specific needs, you will have to be part of the solution. Additionally, they highlight that there are many actors willing to assist with technical solutions, making it a matter of recognizing needs, seeking help, and paying for it.

Respondent 2 states that they will use conditional agreements with all new customers requiring more than one megawatt. Respondent 11 explains a scenario where, if a factory would be offered a conditional agreement guaranteeing their needed capacity 95 percent of the time, the factory would then assess its options. They might choose to invest in a BESS to reduce vulnerability and potentially earn money by providing flexibility services. Respondent 8 has considered this scenario and how it would affect their business:

> *Also, I think it's very smart with conditional agreements as they have started with. There are those who oppose it, but I think it is okay if we lose power for a bit. It will happen so few times in a year, and we won't even talk about an hour, maybe just in minutes, half an hour, twice a year.* – Respondent 8

6.2 Attitude Towards Active Engagement in the Energy Market

Respondents demonstrated different levels of knowledge and attitudes towards the transition towards electrification and DSM solutions. On one hand, some actors appear better prepared and more willing to adopt an active role in the local electricity grid. Respondent 1, 6 and 7 emphasize technological advancements, asserting that it will play a crucial role in bringing diverse actors together.

> *We come from the technical side and believe that most problems can be solved. The challenge today lies mostly in peoples' heads. That is why it is important for us to show that it is possible, just as DREEMER and other projects have done.* – Respondent 1

Respondent 6 argues similarly and believes that all actors have the capacity to extend operations beyond their core business activities to generate positive societal outcomes. They think that industrial actors will likely invest to a larger extent in their own energy production, such as PV systems, to contribute and become less dependent on the current energy system. Further, they claim that actors, in general, will want to be more engaged and assume an active role in the energy system in the future. Respondent 1 emphasizes the importance of accepting the new and realizing that the future will be different but not worse. They express that actors need to adapt and that it will be financially beneficial to do so in the long term.

On the other hand, some respondents hold a more skeptical view and show greater reluctance towards change. Respondent 8 explains that they would need to develop or acquire new competence in order to adopt a more active role in the electricity grid. Consequently there is an unwillingness to explore beyond their core business.

> *We are very good at driving public transportation and planning it, and we need fuel for that. So we buy it. We have no refineries.*
> – Respondent 8

Respondent 3_a shares a similar line of reasoning, stating that there are things they could contribute with, but underscores that it must be specified in the procurement. Otherwise, they will prioritize their core business activities. Respondents with a more skeptical outlook still demonstrate a positive view on different examples of DSM solutions but stress that it is outside of their field, and that someone else should be responsible for that. Respondent 3_b says that they are looking into having some kind of payment solution for actors who would like to use their charging infrastructure. However, they emphasize that there is currently no such solution and that they prioritize their own operations.

> *So we've definitely looked at how and if we can help in the future, but right now we can't. We're not going to get on that train really. We don't have that knowledge.* – Respondent 3_b

Respondent 3_a emphasizes that as a traffic operator, their responsibility is to provide well-functioning public transport that aligns with the requirements in the procurement. They are unwilling to consider DSM solutions if there is a risk of jeopardizing their ability to deliver their service as agreed upon.

> *We need to 100% ensure the delivery of public transport to the citizens of Gothenburg every day. Everything that comes in from outside and can interfere with that delivery poses a risk to us and that risk is that we will not be able to carry out the traffic to the quality that has been procured and that we want to deliver.* – Respondent 3_a

A general observation is that those who demonstrate a higher level of understanding of the energy sector and its future challenges, tend to have a more positive attitude towards shared charging infrastructure and DSM solutions. Correspondingly, those who demonstrate less knowledge tend to have a more reluctant attitude. For example, Respondent 6 and 3 have similar roles as transport operators, but Respondent 6 shows a higher level of understanding than Respondent 3_a, while also showing greater openness to sharing infrastructure and presenting more ideas for how to support the energy system. Respondent 12 believes that there is a need for education about the energy system:

> *There is generally an incredibly extensive need for education and information about the electrical system as a whole. It has gone from being completely uninteresting a few years ago when people just paid a cheap electricity bill and no one cared because there was no need to think further, to now, where everyone needs to understand electricity markets, hourly rates, flexibility, etc. No one knows anything because no one has had to know anything.* – Respondent 12

6.3 Prerequisites for Active Engagement in the Energy Market

For any DSM alternative to be feasible, Respondent 6 stresses the importance of implementing technical development standards and business rules. With these in place, actors can develop the capacity needed to support the grid. Almost all respondents argue that business models need to be defined. Respondent 10 and 12 state that there are some formal obstacles to shared charging infrastructure in the legislation, but Respondent 12 believes they are about to be resolved. Furthermore, Respondent 12 suggests there must be planning and communication regarding when and how much to charge.

Respondent 10 argues that ElectriCity is a great example of how to progress from an idea to a commercial solution. Respondent 12 shares similar ideas and believes Lindholmen Science Park could be a driving force for shared DSM solutions, to get funding for a demonstration to prove its feasibility. Respondent 10 believes that an actor could get the task to show that it is possible, and once showed, other actors will likely follow. Respondent 12 emphasizes that it is difficult for actors to imagine a solution they don't know about.

> *It's hard to wish for something that you're not aware exists.*
> – Respondent 12

Respondent 2 believes that collaboration between different actors will increase, but only as a result of the increasing demand for electricity coupled with an insufficient power supply. Respondent 8 describes the current collaboration between different transport operators as well functioning and provides an example from a recent event where a charging pole was on fire. In this situation other transport operators supported them with their charging infrastructure resulting in no disturbances in the public transport.

All respondents think that financial incentives are essential. Respondent 1 argues that there must be some form of compensation model and costs reduction. Respondent 4 suggests that an actor agreeing to charge back to the grid could get a better price when they charge themselves. Respondent 2 and 7 mention the importance of accounting for the depreciation of batteries. Without financial incentives Respondent 6 believes it is necessary that the public transport procurer sets requirements in the procurements. Respondent 12 also believes that the financial aspect is the foundation for actors to participate. Several respondents express concern that the high financial returns on flexibility services right now, may not be long-lived as the market matures.

Respondent 2 and 3_a believe that contributing to society and sustainable development could incentivize some actors. Respondent 2 suggests that actors with strong local ties could see significant value in contributing to society and the environment.

> *If you want to take social responsibility, have a strong local anchoring of your business, and want to be involved in developing society, that can also be a driving force to be involved.* – Respondent 2

Respondent 11 think that the sustainability aspect of sharing assets and participating in DSM solutions that are beneficial for society and environment is an important incentive but not enough on its own.

> *A challenge in the transition is to find solutions that people perceive as economically profitable, but also as environmentally and socially attractive.* – Respondent 11

6.4 Potential Investors in Demand Side Management Solutions

The interviewed actors have different suggestions on who could own the charging infrastructure and who could invest in DSM solutions. Several parties are suggested as potential owners of the future charging infrastructure. Respondents 1 and 7 propose a third party with a charging station business model to be the owner. Respondent 7 additionally suggests transport operators as potential owners. Respondent 3_b explains that they, as a transport operator, aim at owning all charging infrastructure they need. This strategy allows them to control and optimize operations to be cost and time efficient. Should the procurement contract expire they would have the option to sell the infrastructure to the next transport operator or to the public transport procurer, or they could bring it to a new site. Respondent 2 prefers to not have an individual actor in the project as the owner. Instead, they suggest a jointly owned company or a third party. Respondents 4, 5, 6 and 8 all consider the public transport procurer to be the most suitable owner of infrastructure.

Regarding who should make investments in DSM solutions in connection to the charging sites Respondent 2 suggests a future third party with a DSM solution as a business model as a potential investor. Respondent 4 shares similar thoughts and suggests the company Circle K as a potential partner. The energy company is proposed to be the investor by Respondent 5, 7 and 8. Regarding potential investors, Respondent 8 argues that it is the grid owner's responsibility to provide the demanded capacity.

> *I hold the position that if I require a specific power or capacity, if I want electricity to this location, is it not the responsibility of the grid owner to provide me with it?* – Respondent 8

However, Respondent 11 does not see an opportunity for the energy company to invest in, for example, an energy storage solution.

> *It is difficult to see a business opportunity in investing in battery storage ourselves. I believe that there will be other companies. Companies that can calculate in different ways and have other incentives.*
> – Respondent 11

Respondent 2 has a "never say never" attitude regarding the possibility for them to do DSM investments at a client. Respondent 6 argues that investments with a long technical lifespan should be made by the public, either the public transport procurer or the city. According to Respondent 1, the most reasonable investor in DSM solutions is the actor with a contract with the energy company. This actor could be the owner of either the land, the charging infrastructure or the property. Respondent 2 consider the property owner to be a potential investor.

6.5 Proposed Strategies for Demand Side Management

Respondent 1 and 7 emphasize that an easy way of decreasing peak load is to reduce the own energy consumption. Respondent 7 says that the solution is favorable since you don't need to have any batteries. Respondent 1 explains that it is a standard way of reducing the load today, where actors agree to use less energy for a certain time.

> *It is a natural demand side management solution to just reduce consumption.* – Respondent 1

Several respondents have proposed DSM solutions aimed at reducing local peak load, with most of them suggesting energy storage in the form of batteries. Respondent 2 argues for leveraging batteries to minimize expenses by avoiding exceeding a specified power tariff and suggests charging back to the grid when surplus power is available. Both respondent 7 and 8 highlight the beneficial use of second-life batteries, such as those from used electric vehicles. Respondent 1 further develops this idea and suggests that batteries in parked vehicles could also serve as local energy storage for peak shaving.

Respondent 1 recognizes that batteries in parked vehicles, left unused for some time, constitute an untapped resource of energy. Respondent 3_b on the other hand, holds that V2G for buses is difficult since they don't want to risk having insufficiently charged batteries for their own fleet. Respondent 4 points out that as batteries for EVs improve and the range extends, EV-owners would be more open to the opportunity of V2G. They suggest that the batteries in waste trucks could be utilized for peak shaving during specified times in the future. Additionally, Respondent 4 speculates about the potential use of hydrogen instead of batteries for energy storage.

When discussing the potential of V2G solutions using bus batteries Respondent 8 says that it could be a possibility for them during certain times. They suggest that they, as public transport procurer, could demand V2G capabilities in the procurement, presenting an opportunity for a new revenue stream for traffic operators, insinuating their interest.

Another point mentioned by the majority of respondents is the importance of digitalization and the implementation of a system for shared charging infrastructure and smart charging. Respondents 6 and 7 see the potential for smart charging for both public transport and EVs to even out demand over a longer period of time. Respondent 1 describes a desirable future scenario:

> *I believe there is a lot of digitalization so that there is full control over how large the availability is. It is completely open, and it is more than just buses being charged there. They have found economic incentives, so when it is not fully utilized, it can be active on marketplaces. In other words, simple, yet very smooth.* – Respondent 2

Photovoltaic power systems is mentioned by the majority of respondents as a solution with great potential as a DSM application. Respondent 8 says that they always install solar panels on the roofs of their depots and transportation hubs to decrease costs and load on the grid. Utilizing PV systems generally seems to be an intuitive approach to reducing peak load. However, Respondent 12 points out that on cold winter days the energy supply from solar does not correspond to the demand in Sweden.

Respondent 2 mentions that critical operations, such as hospitals and livestock facilities, often have a backup power system for emergencies, equipped with their own power source. Furthermore, they suggest that this could be a possibility for bus charging sites, in order to ensure a functional public transportation system at all times. Respondent 8 notes the vulnerability in the power system and highlights electricity hubs as potential terror targets. Additionally, they discuss the importance of public transportation in times of crisis for transporting wounded or troops, as seen during the pandemic when people were transported between hospitals.

6.6 Public Vehicle to Grid

This section is based on interviews with Respondent 13, the project coordinators of the PEPP-project.

Volvo Cars initiated a collaboration called Gothenburg Green City Zone, inspired by ElelctriCity, with the aim of moving faster towards a fossil-free transport system. The project involves a partnership with Göteborg Stad, RISE, and others. The Public EV Power Pilots (PEPP) project is part of the initiative, involving 13 stakeholders to explore the potential of electric vehicles when stationary, given that they are parked approximately 95 percent of the time.

> *The message from the energy companies is that there will be a total surplus of capacity from the cars. It will be more than what is needed or can be handled within the electrical system.* – Respondent 13

Currently, the plan is to test 12 cars and additionally there are plans to scale up the next round to 100-200 cars, and for another round involving many more after that. The intention is to examine how charging infrastructure, business models, technology, and regulations, will function not only in private settings but also in public.

> *The challenge with bidirectional charging is the highly complex system perspective. Many actors need to fit into this system, and it requires technical, market-based, and regulatory support. Therefore, testing is necessary.* – Respondent 13

A barrier mentioned is how to motivate the user to plug in the cable if the battery is already sufficiently or fully charged. Especially in public spaces, as electricity is often cheaper at home. Additionally, the question of whether car owners would want to wear out their batteries arises. However, this depends on who owns the car, if its their own, leased or someone else's, and whether the vehicle company provides a battery performance warranty.

There is also a need to figure out where in the system mobile energy storage provides the most benefit. It might be to support the grid, balance power or be used in micro-grid solutions. When parked outside facilities with high power demand, such as the new battery factory in Gothenburg, cars might be used to balance both power grid and energy supply. The factory might be able to buy cheaper electricity from the cars parked outside than from the grid.

Another barrier is connected to whether vehicles would be charged and discharged on grids with different owners.

> *This market is a bit immature now. It hasn't really kicked off yet with regulations, and such. The electricity market is designed for things that are stationary, that remain in one place. It doesn't have wheels to move between different grids, so dealing with this becomes a challenge. I am completely convinced that this will be resolved. It is not rocket science.* – Respondent 13

There is also some speculation on how long the relatively high reward for local and national flexibility services will last.

Furthermore, PEPP is investigating the roles the different actors will have. The energy company, in this case Göteborg Energi, can adopt multiple roles. As a grid owner, they can manage the bidirectional charging connection, business transaction and control thereof. A parking company could serve as an aggregator, and a property owner might also act as an aggregator, bringing benefits to both the property owner and tenant.

6.6.1 Public Parking V2G Opportunities

This section is based on interviews with Respondent 14, a product owner at the municipal parking company.

The municipal parking company in Gothenburg provides 600 charging points in the city, used for public parking, monthly rental for workspace parking, or residential parking. They have a system connected to the charging that enables customers to pay for charging and parking in the same system, in line with current business decisions.

To enable V2G, standards and business models need to be set. As of now, Respondent 14's experience is that it is quite exploratory and experimental. Another barrier is the willingness of their customers to lend out their battery to either sell electricity or assist with load balancing. The respondent also argues that with integrated systems, they should consider where in the value chain they will find themselves.

> *Also regarding business models, how does that work? Is this something we do just for the grid? Who is going to make money here? It's still a factor in the whole thing.* – Respondent 14

Respondent 14 describes that V2G can be integrated locally to support the grid and reduce peaks, and perhaps in combination with solar panels. They are not looking at strategically placing parking lots according to the need in the grid.

The incentives for Göteborg Parkering are not yet clear, according to Respondent 14. Business models need to be figured out, but incentives also include helping the city with climate adaptations.

> *Maybe it's not the best financially for us, but it's necessary in a modern city. However, when the day comes for things like this, one might look beyond their own finances as the main priority.* – Respondent 14

Furthermore, the respondent presents a newsletter from Energimyndigheten, stating that history tends to repeat itself. Evidently, V2G was first discussed in the early 1900s. A crisis creates problems that theoretically can be solved using V2X, but the problem is often resolved in another way, leading to a decreased interest in V2X. A difference today, as described by Respondent 14, is the momentum in the development of electric vehicles. However, the respondent finds it interesting that these ideas have existed in California since the early twentieth century and also during the electric crisis in 2000.

6.7 The Function of Hydrogen in the Future Energy System

This section is based on interviews with Respondent 15, a sustainability officer at a hydrogen fuel cell company.

Respondent 15 believes it is clear that the world must transition away from fossil fuels. They consider hydrogen a strong candidate for hard-to-abate industries such as the transport sector, shipping, and aircraft, as well as stationary applications like off-grid or supporting the grid as an energy buffer. Respondent 15 also believes there will be a lot more overproduction of electricity as more renewable energy sources are used, and that hydrogen will be able to store it until the demand is higher than supply. Furthermore, hydrogen enables decentralized and independent energy systems, allowing anyone with solar or wind power to produce their own hydrogen gas instead of depending on oil and gas.

> *If you were to charge many buses simultaneously or if you want to charge them quickly, it would require a large amount of power from the electrical grid. In such cases, one could balance it out with hydrogen, for example. But one might also consider having a location that serves both as a peak-shaving site and as a charging site for trucks or buses. This way, it functions as both a charging site and a contributor to peak shaving for the grid.* – Respondent 15

Respondent 15 believes that batteries will be best suited for some applications, while hydrogen for others. Hydrogen is explained to have high energy density, while batteries have high power density. Furthermore, hydrogen is considered more suitable when the energy needs to be stored for an extended period, such as several days, weeks, or even months, while batteries are more suitable for shorter durations, such as a few hours or a day. Using batteries for longer durations would require large and expensive storage systems. For short-term storage batteries are preferred since they have a higher round-trip efficiency, with 80-90 percent of the original energy retrievable after storage. When storing in form of hydrogen, electricity is run through an electrolyzer, retaining about 60 percent of the energy. After storage, it runs through the fuel cell, resulting in 40-50 percent being retained from the original amount.

> *Some people talk about batteries and hydrogen as competitors, which I don't see. I view them more as complements in a sustainable energy system, and that's the latest at COP28 now.* – Respondent 15

Respondent 15 believes barriers to the use of hydrogen and fuel cells include a lack of understanding, since it is perceived as a new and untested technology, even though it is not. Furthermore, high volumes are needed to achieve economies of scale, enabling a reduction in production costs. Currently, hydrogen remains more expensive than fossil technology and batteries. Regarding infrastructure, there are plans in the EU to build a hydrogen pipeline network and projects within Sweden to produce hydrogen from wind power. Respondent 15 expects exciting developments by 2030.

6.8 The Purpose and Benefits of Aggregation

This section is based on interviews with Respondent 9, a co-founder and business developer at an aggregation software company.

The role of an aggregator is to gather and manage several sources of energy that can be used as demand response or frequency balancing. Respondent 9 and their start-up take on a role as an aggregator with the business idea of using refrigeration systems of supermarkets to balance the electricity grid. The business idea is supported by the Swedish Energy Agency, who made contributions to the funding of the project. The company is developing a software solution that makes it possible to aggregate and manage refrigeration systems to support the national grid. Respondent 9 explains that the response from the supermarkets has exceeded expectations, and that the demand is huge. The supermarkets are economically compensated by Svenska Kraftnät for the service provided which gives them a new revenue stream.

> *If we manage to get everything perfect, then a fairly large store could make maybe two hundred thousand (SEK) a year.* – Respondent 9

Other than economic incentives Respondent 9 points out environmental benefits and contributing to strengthening the Swedish power grid by increasing resilience, as motivations for participation cited by supermarkets.

> *The money can increase margins. But the best thing is when you help balance electricity production in this way. Then we can manage the fluctuations in electricity production much better, which is due to renewable energy. Then we can implement more renewable energy, which contributes to a sustainable transition. It is also good for the supermarket's brand.* – Respondent 9

To reach the minimum energy supply requested by Svenska Kraftnät 2-3 supermarkets must be aggregated. Respondent 9 explains that from a technical perspective, the different stores don't have to be close to each other, but from a legal perspective it can be more difficult depending on if there are multiple grid operators.

7. Analysis and Discussion

The data collection process revealed incentives and barriers associated with the first research question. This section examines these aspects in detail, exploring their connections to the identified DSM solutions, to address the second research question.

7.1 Incentives

From the interviews, it is clear that appropriate financial compensation mechanisms will be required to incentivize actors to provide support to the local electricity grid. Some actors mention environmental and social benefits as secondary incentives. These factors are also discussed in the literature as incentives for participating in a sharing economy business model (Kumar, Lahiri, & Dogan, 2018). Figure 7.1 displays the key takeaways from the incentives section.

Figure 7.1: *Key takeaways from the identified incentives.*

Financial
Crucial incentive
New revenue stream
Reduced costs
DSM solutions with varying financial barriers

Environmental
Complementary incentive
Competitive advantage
The role of the procurer
DSM solutions offer several sustainability benefits

Social
Complementary incentive
Mutual benefits
Importance of collaboration and coordination
Value in contributing to society

7.1.1 Financial

All respondents agree that financial incentives are essential and form the foundation for investments in DSM solutions. Also in the literature economic incentives is identified as the most important motivational factor for participating in a shared economy business model. By sharing under-utilized resources high investment costs can be avoided, owners can receive a new revenue stream through renting, and users can receive lower costs (Muñoz & Cohen, 2017). Respondent 1 emphasizes the need for some form of compensation or reduced cost for actors to engage. Respondent 12 also argues for the importance of financial incentives and concludes that without it, investments in DSM solutions at charging sites would not be possible. They believe that other incentives can be complementary but that they cannot substitute financial incentives. However, a prevailing concern among respondents is the long-term sustainability of financial returns on flexibility services as the market matures.

By participating in a flexibility market, charging sites can earn money by either increasing or decreasing their energy consumption (Svenska Kraftnät, 2021a), without having to make large investments in ESS. Furthermore, investments in BESS can reduce electricity bills or generate new revenue through energy arbitrage, making it economically desirable for large-scale electricity consumers (Hesse et al., 2017). Respondent 1 also argues for actors to increase their involvement in the energy market, since it would be financially beneficial for them. Utilizing reverse power flow technology, V2G, vehicles can assume the role of ESS, thereby reducing the cost, which is the primary obstacle to investments in ESS (Iba, 2022). Using second-life batteries also has cost advantage, as it can reduce the initial cost by up to 94 percent (Deng et al., 2021). Sharing the initial cost among actors in DREEMER will further reduce cost and risk. Another method to reduce cost-associated risk further is to lease batteries or, as proposed by Respondent 2 and 4, let a third party handle DSM solutions. As argued by Vineeth et al. (2022), the cost of next-generation batteries is expected to be significantly lower than that of lithium batteries used today. According to Respondent 15, hydrogen is currently a more expensive alternative than batteries, since higher volumes are needed to achieve economies of scale in production.

7.1.2 Environmental

Sharing of infrastructure can lead to sustainability gains by reducing the need for additional resources (Muñoz & Cohen, 2017). Sharing charging infrastructure with integrated DSM solutions would increase utilization and resource efficiency. Respondent 2 and 3_a believe that supporting sustainable development could serve as an incentive for some actors to engage in DSM. In the extension, this can be connected to marketing, as sustainability efforts have the potential to enhance brand value. This is argued by Respondent 9, who highlights both the environmental impact of contributing to the balancing of the grid and the positive impact it has on their customers' brand value. Respondent 10 also stresses that actors could get a significant differentiation advantage from being more sustainable. Environmental awareness and increasing demand for more sustainable products and services make sustainability an important competitive advantage. However, most respondents think that sustainability reasons solely is not enough to make actors participate in DSM solutions. Melander and Wallström (2023) also argue that there must be both economic and environmental incentives for horizontal collaborations to prosper.

Both transport operators stress the impact of the procurer. Respondent 3_a and

6 say it must be specified in the procurement for them to contribute with DSM solutions if there are no financial incentives. On the other hand, according to Respondent 8, the procurer argues that it is the grid owner's responsibility and role to provide the demanded capacity. The municipal parking company, as mentioned by Respondent 14, is incentivized to facilitate climate adaptations in the city, looking beyond financial priorities. Considering that the transport procurer is also a public company, they could explore similar incentives, enabling or pushing transport operators to take an active role in the energy system through specified requirements in procurement contracts.

There are multiple environmental benefits related to the discussed DSM solutions. Aggregator services can reduce the load on the grid and reduce the need for electricity production (Energimarknadsinspektionen, 2021), fostering a more environmentally sustainable electricity system. Furthermore, it can help balance the fluctuation in production, consequently promoting increased integration of renewable energy sources. An advantage of ESS is their ability to balance the grid, enabling a higher utilization of energy from intermittent renewable sources (Farivar et al., 2023), thus reducing the mismatch between supply and demand, which is necessary for a drastic reduction of carbon emissions (Tronchin, Manfren, & Nastasi, 2018). Hydrogen, as explained by Respondent 15, is suitable for energy storage over longer periods, such as several weeks or even months. This enables the storage of energy from intermittent sources to be used at a different time, helping to balance the mismatch between supply and demand. For example, solar power produced during the summer season could be stored for use during the darker season. By having second-life EV batteries, which still usually retain 70-80 percent of their capacity (Hu et al., 2022; Deng et al., 2021), the batteries' lifetime can be extended with more efficient resource utilization. Through the use of V2G technology EVs can be transformed into ESS, utilizing the current capabilities to a higher extent. Vehicles at charging sites, such as those parked outside public transport peak hours or tourist buses parked for some time, can be utilized to balance the grid.

7.1.3 Social

From a social perspective, by sharing charging infrastructure and investing in DSM solutions, the common resources can be better utilized. Respondent 6 argues that actors can engage outside their core business to generate positive societal outcomes. Collaboration between competitors can be both challenging and beneficial. The main challenge in the B2B sharing economy is sharing assets among competitors (Chuah et al., 2021). Respondent 8 has a different experience, describing a situation where one transport operator faced a crisis that was successfully managed thanks to the willingness of other transport operators to help. Building stronger connections with each other can be advantageous in such critical situations, as it is easier and more effective to seek help from a competitor you already know. From a societal perspective, this collaborative approach resulted in an uninterrupted public transport. It shows that actors can collaborate on certain areas while competing in others, much in line with the reasoning of Melander and Wallström (2023).

Gothenburg has the advantage of an already well-established collaborative network among the actors involved in ElectriCity and DREEMER, which might lower the threshold for expanding collaboration, even between competing firms. The DREEMER-respondents all say that the collaboration in the project is working well and that there is a clear common goal. Sharing assets and costs, and perhaps jointly investing in DSM solutions could be a future step for this collaboration, and benefit all parties involved, but strong relationships and trust are essential for actors to participate. Lopez De Briñas Gorosabel, Xylia, and Silveira (2022) hold that no electrification project will be realized without coordination and collaboration between stakeholders. Chuah et al. (2021) argue that a strong bond between firms could promote trust, which facilitates mutual confidence (Tham, Lim, & Vieceli, 2023). Melander and Wallström (2023) found that actors that are competitors can also collaborate, for example to reach a common environmental goal.

Respondent 2 and 3_a believe that contributing to society and sustainable development could incentivize some actors. Respondent 2 suggests that actors with strong local ties could see significant value in contributing to society and the environment. Firms that see value in contributing to society would be more willing to share charging infrastructure and invest in DSM solutions. It is therefore an essential aspect to consider when finding suitable actors to involve in such projects.

7.2 Barriers

Business models and regulations are discussed as barriers for higher involvement in the energy market by both Respondents 13 and 14 from the PEPP project, as well as by several respondents from the DREEMER-project. The uncertainty of the future return for providing flexibility services is discussed both by respondents from the energy company and the other actors. This aspect is of high importance since financial incentives are identified as the most important ones. Furthermore, a lack of knowledge is identified as a barrier, since it seems to be related to the attitude towards DSM solutions. Figure 7.2 shows the key takeaways from the identified barriers.

Figure 7.2: *Key takeaways from the identified barriers.*

Business models
Issue of ownership and investor in DSM solutions
Perceived monetary risk of not owning
Roles in the future energy system not yet defined

Policy and regulation
Need for regulatory support
Can foster green innovation
Potential to increase extrinsic motivation

Uncertainty
Concern regarding future financial returns
Perceived risk of shifting focus from core business
Vulnerability of the power system

Knowledge
Affects willingness to participate
Need for knowledge increase with electrification
Individual interest and drive may influence attitude

7.2.1 Absence of Business Models for Shared Charging Infrastructure and Demand Side Management

Several respondents underscore the importance of finding a suitable business model to enable actors to share infrastructure and implement DSM solutions. The development of a business model depends on the ownership of the infrastructure, as it could create a new income for the owner by allowing more actors to use it (Melander & Wallström, 2023). Or if jointly shared, as proposed by Respondent 2, it could enable cheaper charging for the sharing users (Melander & Wallström, 2023). Lopez De Briñas Gorosabel, Xylia, and Silveira (2022) argue that actors involved in public transport electrification need to be aligned to ensure delivery, with ownership of charging sites described as the main issue. The variety of proposed investors for DSM solutions and owners of shared charging sites indicates a lack of alignment on this issue among the DREEMER-actors.

It is widely argued by the respondents for the public transport procurer to own the infrastructure. Respondent 3_b prefers to own it themselves as a transport operator, to maintain control and optimize operations, which can be explained by the perceived monetary risk, assuming it would be more costly to engage in shared economy (Chuah et al., 2021). Lopez De Briñas Gorosabel, Xylia, and Silveira (2022) argues that transport operators might have an interest in ownership, which can be complicated since the infrastructure often outlives the procurement contracts. Respondents

2 and 4 propose a third party to make investments in DSM solutions, Respondents 1, 2, and 7 argue for a third party to also own the charging site. Having a third party that guarantees charging for users might help overcome many barriers, as users need to acquire less knowledge, the third party assumes most of the risk, and solutions related to the business model are figured out by the third party. Melander and Wallström (2023) argue that a third party owner would make the barrier for firms to join lower, as it allows more flexibility and reduces cost of investment.

Several parties hold the position that it is the energy company's responsibility to supply the charging site with the necessary capacity, making them the natural investor in DSM solutions. Respondent 1 believes it should be the actor holding the energy contract. The diversity in proposed potential investors indicates that the roles in the future energy system are not yet defined. Respondent 8 points out that they do not own any refineries and that their role is to drive and plan public transport. This indicates that they desire for their relationship with the energy company to be of a traditional form, similar to their relationships with fuel companies. The roles in the future energy system are also a topic of discussion in the PEPP project according to Respondent 13. The energy company is considered to take on several new roles, and vehicle manufacturers as well as property owners are mentioned as possible aggregators.

7.2.2 The Crucial Role of Policy and Regulation

The importance of policy and regulation has been pointed out by most respondents. A regulatory framework that supports a business model for shared charging infrastructure with DSM solutions is necessary in order to accelerate transition and facilitate implementation. Chuah et al. (2021) argue that suitable regulation is crucial in order to support sharing economy business models, and Yong et al. (2023) claim that policy and regulation are critical barriers for having shared energy storage solutions. Respondents agree on that some form of energy storage at the charging sites will probably be necessary, but for investors to commit the benefits must be made clear. Policymakers have the opportunity to promote innovation and competition by creating favorable regulatory environments for sharing economy business models. Additionally they could amplify the benefits through policy instruments in order to incentvize actors to join. Furthermore, suitable policy could also act to overcome some barriers related to sharing data and intellectual property, potentially with competitors.

The Technology-Organization-Environment framework suggests that regulation and policy instruments can inhibit or promote innovation (Baker, 2012) and Melander and Wallström (2023) point out that governments have the ability to incentivize green innovation through policy. When discussing the future outlook for V2G technology, Respondent 13 emphasizes that the market is immature and suitable regulation is currently lacking. They are however convinced that it will be resolved and stresses that despite being challenging it is not rocket science. Due to the complex nature of bidirectional charging, with a highly complex system perspective, Respondent 13 underscores the need for technical, marked-based and regulatory support, and the importance of testing. Respondent 9 agrees that suitable regulation is lacking and stresses that aggregation that entails multiple grid operators can be difficult from a legal perspective today. Respondent 1 emphasizes the importance of showing what is possible, and firmly believes that the challenge lies mostly in peoples' heads. They are of the opinion that regulation should not be seen as a major barrier. However, it is important to design policy that promotes sustainable development and green innovation.

Policy could potentially be an important tool to provide additional motivation for actors to participate in the electricity market. For actors that have less knowledge and are less forward-thinking, additional incentives that increase extrinsic motivation could be an important factor. Kumar, Lahiri, and Dogan (2018) describe how willingness to participate in the sharing economy is influenced by extrinsic motivation, e.i. the financial benefit received from providing a service. All respondents expressed that financial incentives is the most important factor in getting actors to participate. External rewards for example in the form of subsidization, or pressure in the form of for example ambitious climate goals or carbon pricing, could increase the willingness for more reluctant actors to share charging infrastructure and implement DSM solutions.

7.2.3 Uncertainty Connected to Demand Side Management Investments and Charging Availability

An uncertainty highlighted by most DREEMER-respondents is the concern that the current high financial returns on DSM solutions might not be long-lived. Connected to public V2G, Respondent 13 raises the question of how long the relatively high rewards for flexibility services will last. With an increase in the supply of flexibility services, the returns may decrease. This is contextualized by Respondent 13, who received the message that there will be a surplus of capacity from EVs, more than what is needed or can be managed. There is also a possibility that some DSM solutions will become irrelevant as other technologies develop. Respondent 14 explained how V2G was a hot topic during past electricity crises, but the problem ended up being solved in another way. A significant difference today is the momentum in the transition from fossil fuel vehicles to electric ones, enabling V2G.

Respondents 10 and 12 argue that with the increased use of renewable power sources there will be a higher need for flexibility services to maintain the balance in the electricity system, since the intermittency of these sources lead to a mismatch between supply and demand (Tronchin, Manfren, & Nastasi, 2018). Williams et al. (2023) describe DSM solutions as a cost-effective tool for balancing supply and demand. Respondent 12 further explains that the required annual power will be more than twice as much in 2040-2045 compared to 2023, a point also emphasized by Sweco (2022) and Svenska Kraftnät (2021b), with plans to meet this demand using intermittent sources. Williams et al. (2023) describe DSM solutions as a tool to address challenges associated with increased electrification and a larger share of intermittent energy sources. On the other hand, Respondent 10 argues that substantial investments in nuclear power could make the energy system less dependent on flexibility services, but acknowledges that an energy system relying on intermittent sources is the most common scenario. Therefore, the financial returns of DSM investments depend on the future fluctuations in the energy system and the balance between supply and demand.

Respondent 3_a emphasizes the importance of delivering public transport according to the procurement. Any potential interference is seen as a risk, which can be associated with both perceived physical and performance risks in the context of the sharing economy (Chuah et al., 2021). Compared to traditional markets, the sharing economy has higher associated risks (Kumar, Lahiri, & Dogan, 2018). Physical risk, referring to potential damage or loss of assets (Chuah et al., 2021), may increase with heightened site activity and the involvement of multiple actors, posing risks to both infrastructure and vehicles. Performance risk involves the potential failure to provide the agreed-upon service (Chuah et al., 2021), and may include charging availability concerns, as sharing infrastructure will affect availability. Furthermore, if there is a risk that DSM solutions would jeopardize their core business, Respondent 3_a explains that they are unwilling to consider them.

Respondent 8 emphasizes the vulnerability of the power system, highlighting that electricity hubs are potential terror targets, and underscores the importance of public transportation during times of crisis. Respondent 2 suggests a solution to this by proposing a back-up system to ensure public transport at all times. Respondent 15 argues that hydrogen enables decentralized and independent energy systems, allowing anyone with wind or solar power to produce hydrogen instead of relying on oil or gas. Additionally, hydrogen is explained to be better suited than batteries for energy storage over long periods of time. Furthermore, the trend towards conditional agreements, where needed capacity would not be guaranteed 100 percent of the time, might also necessitate back-up systems. As described by Respondent 11, investing in BESS can reduce vulnerability and potentially generate revenue by providing flexibility services. Respondent 15 argues that ESS investments should serve multiple purposes, supporting both the charging of buses and peak shaving for the grid.

7.2.4 Knowledge Level Determines Attitude Toward Active Engagement in the Energy Market

The respondents demonstrated different levels of knowledge of the energy system, electricity market and associated technologies. Respondents with little insight tended to have a more reluctant approach towards the idea of sharing charging infrastructure and implementing DSM solutions. This indicates the importance of ensuring that actors understand the benefits of participating more and contributing to the electricity system. Respondent 12 explains how there has been little need to know anything about the electricity market, but that is now changing rapidly. They believe that there is a need for information and education on the electricity system in order to bridge the knowledge gap. A better understanding could decrease the perceived risk, which is defined as the feeling of uncertainty related to potential negative outcomes of collaborative consumption (Featherman & Pavlou, 2003). Actors might perceive the risk as greater if they don't have knowledge of the electricity sector. There is an uncertainty in how a potential business model would look like and what role they would assume. As Respondent 12 expressed, it is difficult to wish for something that you are not aware of exists. Respondents with less insight tended to emphasize the importance of promoting their core business activities and were more reluctant towards going beyond that compared to others. Respondents 3_a and 8 stress that a more active involvement in the energy market would fall outside of their core business, requiring new competences.

Furthermore, the level of understanding regarding potential solutions and measures necessary to establish shared charging infrastructure and DSM solutions varied among respondents. The Technology-Organization-Environment framework suggests that the technological context, i.e. relevant technologies inside and outside the firm, is one aspect that determines a firm's willingness to adopt innovation (Chuah et al., 2021). From the interviews it is evident that the more technical firms that act as drivers of innovation, such as Respondent 1 and Respondent 7, demonstrate good knowledge of the electricity system and the future challenges it will face as well as potential solutions. However, Respondent 6 and Respondents 3_a and 3_b show different levels of knowledge and willingness to share infrastructure and adopt DSM solutions, despite having similar businesses as transport operators. Furthermore, despite Respondent 4's fleet not yet operating on electricity Respondent 4's responses consistently reflected a profound understanding of the electricity system and a commitment to shaping the future effectively. In these cases the Organizational aspect, i.e. the internal characteristics and resources of the firm (Baker, 2012), might be more applicable. Factors such as internal characteristics and resources of the firm can either promote or inhibit innovation (Baker, 2012). Chuah et al. (2021) and Chatterjee et al. (2023) argue that top management support is of outmost importance for participation in the sharing economy. Business strategy and firm objectives can encourage sustainable development and the transition to electrification and top management support might be an important factor in getting all actors onboard.

The firms' willingness to participate could also, to some extent, be influenced by individual interest and drive. For example, both Respondent 4 and 7 demonstrated a personal interest in new technology and the future challenges and opportunities of the electricity system, which could be related to personal interest. The different attitudes of Respondents 3_a, 3_b and 6 could also be somewhat explained by individual interest. In these cases a more open attitude towards shared charging infrastructure and DSM solutions might not necessarily be a result of the firms technological context or organizational structure, but rather influenced by individuals in the firm.

8. Conclusions

The conclusions drawn from the findings are presented below. The thesis provides insights into necessary incentives and potential barriers to increased participation in the local energy system, and explores possible DSM solutions. Based on the findings several managerial and policy implications are suggested.

8.1 Theoretical contribution

There are several solutions for engagement in the energy market. Actors can participate in a flexibility market without making any substantial investments by adopting an aggregating role. If an actor decides to invest in a stationary ESS, there are several options. Second-life batteries have cost advantages and environmental benefits as the lifetime of the batteries is extended. Hydrogen ESS are more expensive than BESS, but they have the technical advantage of storing energy for longer periods, to provide energy on cold winter days or in crisis situations. It is also possible to use the ESS in vehicles to charge back to the grid or to support the charging of other vehicles at the site. Different technical solutions should be treated as complementary as they have different advantages. It should also be noted that technical solutions can serve multiple purposes, such as supporting the charging of vehicles at the site and creating a revenue stream by providing flexibility services. When implementing DSM solutions at charging sites the characteristics of the site and its surroundings should be considered in order to determine what DSM solutions are most suitable.

The financial aspect is identified as the most important incentive for investing in DSM solutions. Environmental and social incentives are secondary but recognized nonetheless. Actors would primarily invest for the financial return and appreciate the social and environmental benefits, but they would not invest with the primary goal of obtaining social or environmental benefits and potentially getting financial returns. The implementation of DSM solutions allows for the use of more intermittent energy sources, promoting the green transition. Resources can be better utilized when shared, but this demands a collaborative approach, also among competitors. Benefits of engaging in the energy market also include increased brand value.

The uncertainty of future financial returns for DSM solutions is a highly relevant barrier as it determines the financial incentives. The future demand for DSM solutions depends on several factors, including the use of intermittent resources, whether there are large investments in nuclear power, and the increasing electrification in society. The financial aspect is also connected to business models, who should invest and how to share the profits. Having a third party handling the investment would lower the barrier for firms to join. To support a shared charging business model, a supportive regulatory framework must be set. Another barrier to becoming a more active actor in the energy market is the knowledge level. A general observation is that those with a better understanding of the electricity markets and their future challenges tend to have a more positive view of investments in DSM solutions.

8.2 Managerial implications

The findings of the thesis point to some managerial implications. Knowledge of the energy system, electricity market and associated technologies is deemed to be an important factor that can determine the willingness of actors to participate in shared charging infrastructure and DSM solutions. In light of these findings, it is essential to ensure that actors are educated on the conditions of the electricity system and market, and are well-informed about why they should participate, how they can do that, and what viable solutions exist. As a starting point, the energy company should clearly communicate their demand for DSM solutions. Furthermore, it seems fitting that they would also educate and inform actors of the electricity system and market to bridge the existing knowledge gap, while also highlighting the economic, environmental and social benefits of sharing and contributing to the local electricity grid. If top management have a good understanding of the anticipated capacity challenges of the power grid, how they can contribute, and what benefits they would receive they are likely to be more willing to participate in the market.

Respondents expressed an uncertainty in what their role would be in a future scenario with shared charging infrastructure and a more active participation in the energy market. It should be easy for actors to participate and there should be clear guidelines or defined roles to enable engagement. For example, actors could choose from defined roles that entail different levels of participation. On a first level they might share the charging infrastructure with other actors, increasing resource efficiency and reducing investment costs. A next level might include making a shared investment into the charging infrastructure and integrated DSM solutions such as BESS. Then they could generate new revenue streams by renting out their charging infrastructure to others and by providing flexibility services, and reduce investment costs by sharing assets.

Gothenburg has the advantage of serving as a testbed for several electrification projects. The PEPP-project is an example of an initiative where a collaborative pilot project will demonstrate feasibility, explore future roles, and identify barriers. Lindholmen Science Park could be the driving force to secure financing for the demonstration. If testing shows that DSM solutions are feasible and advantageous for the transport operators or the city in general, it might also encourage the transport procurer to include them in procurements. Furthermore, a pilot project will likely help overcome some of the barriers. If it is demonstrated that there are feasible business models, profitable investments, established regulations and policies, and actors are able to share, it will likely incentivize actors involvement. When tested and proven possible the results should be effectively communicated in order to get more actors to follow.

The importance of coordination and collaboration should not be overlooked. Sharing charging infrastructure between multiple actors and integrating DSM solutions involves many different stakeholders which requires a well-functioning collaboration. The value of closer collaboration between competing actors in DREEMER has been proven, as it enabled an actor to seek help from a competitor in a crisis situation. The actors should consider the benefits of closer collaboration with competitors and other actors.

8.3 Policy implications

The results point to several implications for policymakers. Gothenburg has set ambitious climate goals and the ElectriCity initiative aims to drive the transition towards an electrified transport sector. The DREEMER project can be seen as a first important step towards sharing charging infrastructure between actors. Policymakers should take advantage of the existing willingness to cooperate between key stakeholders and extend the initiative to accelerate the transition and facilitate a large scale implementation. To begin with, collaboration could be extended to focusing on actors that share similar values, perhaps with strong local anchoring or who show commitment to sustainability. A next step could be to include actors that specialize in suitable technical solutions for DSM, who could contribute with their expertise.

Policy measures could help overcome the expressed uncertainty among respondents regarding the immaturity of the market for flexibility services and the future financial returns on investments in DSM solutions. Policymakers should aim to create a regulatory environment that favors shared charging infrastructure and business models for DSM solutions in the local electricity system. For some solutions like V2G and aggregation, suitable regulation is lacking. Financial incentives could encourage participation in sharing business models for charging infrastructure and DSM solutions. Providing guidelines and regulatory clarity would further reduce uncertainty and facilitate coordination and collaboration between stakeholders. Policy should also be designed to facilitate necessary data sharing between actors. Given that respondents are reluctant to participate if it poses a threat to their core business, the transport procurer has an important role and could incentivize transport operators by making stricter requirements in the procurement contracts for public transport.

8.4 Future research and limitations

Based on the study, several recommendations for future research arise. Firstly, exploring the features of a suitable business model would be interesting. This includes understanding the different roles actors would assume and figuring out the ownership dynamics and revenue streams. Secondly, there is a need for data on shared charging systems, with a focus on data sharing and prioritization of charging. Designing a system that meets the needs of key stakeholders is an important aspect.

Thirdly, modeling and testing of shared charging infrastructure with DSM solutions could pave the way for broader adoption, with Gothenburg serving as a suitable test site. Lastly, studying technical solutions in greater detail and evaluating the locations of the charging sites could lead to higher optimization. Charging sites might be strategically placed close to other actors, like industries or parking lots, enabling aggregation and sharing of DSM solutions.

The study is constrained by several limitations. It exclusively focuses on participants and sites in the DREEMER-project. Interviews were mainly conducted with one single respondent from each company, selected based on recommendation of their expertise. Additionally, the personal biases of the respondents should be considered a limitation. For instance, private actors like Ambidex and PowerCell are likely to hold a positive outlook on the future of their technology. The study was also limited to examining the DSM solutions that are most commonly referred to.

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