Electric vehicles' potential to provide flexibility services

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MASTER THESIS

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A case study investigating opportunities and barriers at Axess Logistics

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Abstract

The automotive industry is undergoing an unprecedented transformation, and all actors along the value chain are affected. A company in the midst of this is Axess Logistics, which offers car logistics solutions to general agents and dealers in the Scandinavian market. In times of change, new business opportunities arise, which Axess Logistics wants to identify. An evident trend is the electrification of the vehicle fleet, where the share of electric vehicles among new registered cars is increasing every year, and the growth is forecasted to continue.

When an electric vehicle is parked, its battery can be viewed as an unused resource – particularly since it could contribute to mitigating some of the problems that exist in the electrical grid. Via *vehicle-to-grid* (V2G) technology, the stored energy in the car battery can be fed back into the electrical grid when needed and, hence, constitute a flexibility resource. In the future electricity systems with more intermittent energy sources and increased electricity demand, flexibility resources are regarded as one of the solutions to problems such as power shortage. Today, flexibility is traded in two different markets, namely, Svenska kraftnät's ancillary services market and local flexibility markets.

This study investigates whether Axess Logistics is able to participate in the flexibility markets with the cars they have in storage with respect to the requirements of the markets. Furthermore, external factors that affect Axess Logistics' potential are mapped. Based on the study's data collection, barriers to the implementation of the provision of flexibility services at the company's Malmö facility are identified.

The conclusion is that the cars at Axess Logistics can be used as flexibility resources in flexibility markets. However, there are barriers – e.g. low knowledge of V2G and uncertainties regarding battery health – that need to be overcome before a successful implementation can take place.

Keywords: vehicle-to-grid, electric vehicle, flexibility services, battery storage, barriers to implementation

Sammanfattning

Bilindustrin genomgår en transformation som inte tidigare har skådats och samtliga aktörer längs med värdekedjan påverkas. Ett företag som befinner sig mitt i detta är Axess Logistics som erbjuder billogistiklösningar till generalagenter och återförsäljare på den skandinaviska marknaden. I tider av förändring uppkommer nya affärsmöjligheter, vilka Axess Logistics vill identifiera. En tydlig trend är elektrifieringen av fordonsflottan, där andelen elbilar bland nyregistrerade bilar ökar varje år och tillväxten prognostiseras att fortsätta.

När en elbil står parkerad kan dess batteriet ses som en outnyttjad resurs – särskilt eftersom det skulle kunna bidra till att lindra problem som finns i elnätet. Genom tekniken *vehicle-to-grid* (V2G) kan bilbatteriets lagrade energi matas tillbaka ut på elnätet vid behov och därmed utgöra en flexibilitetsresurs. I framtidens elsystem med en större andel intermittenta energikällor och ett ökat elbehov ses flexibilitetsresurser som en av lösningarna på problem som t.ex. effektbrist. Idag handlas flexibilitet på två olika sorters marknader: Svenska kraftnäts stödtjänstmarknad och lokala flexibilitetmarknader.

Denna studie undersöker huruvida Axess Logistics kan delta på flexibilitetmarknader med de bilar som de lagerhåller med hänsyn till marknadernas olika kravbilder. Dessutom kartläggs externa faktorer som påverkar Axess Logistics potential. Baserat på studiens datainsamling identifieras barriärer till implementeringen av tillhandahållandet av flexibilitetstjänster på företagets anläggning i Malmö.

Slutsatsen är att bilarna hos Axess Logistics kan användas som flexibilitetsresurser på flexibilitetsmarknader. Däremot finns det barriärer – t.ex. låg kunskap om V2G och osäkerheter kring batterihälsa – som behöver övervinnas innan en framgångsrik implementering kan ske.

Nyckelord: vehicle-to-grid, elbil, flexibilitetstjänster, batterilager, barriärer för implementering

Preface

This master thesis has been conducted at the department for Design Sciences at the Faculty of Engineering (LTH) at Lund University in collaboration with Axess Logistics in Malmö. It is the final part of a Master of Science in Industrial Engineering and Management.

Firstly, I would like to thank my supervisors at Axess Logistics, Dimitris Emmanouilidis and Mattias Öhrn, for your support, interest and generosity. Also, thank you, Fredrik Merell and Jonas Löfqvist, for your help with insightful data. Furthermore, I am thankful to the respondents participating in the study. Your knowledge and thoughts have been of great value.

I would also like to express my gratitude to my brilliant supervisor at Lund University. Thank you, Professor Lars Bengtsson, for all your advice, encouraging words and answers to my many questions. I appreciate the time you have devoted to guiding me through the conducting of this study. Lars, you are my academic idol!

Last but certainly not least, thank you mom and dad for your endless love and support – not only during this thesis but also throughout my studies and life in general. I could most definitely not have done it without you.

Lund, May 2022

Celina Gustafsson

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List of acronyms and abbreviations

AC	alternating current
BEV	battery electric vehicle
CO_2	carbon dioxide
DC	direct current
EV	electric vehicle
FCR-D	frequency containment reserve - disturbance
FCR-N	frequency containment reserve - normal
FFR	fast frequency reserve
FSP	flexibility service provider
GIV	grid-integrated vehicles
mFRR	manual frequency restoration reserve
PDI	pre-delivery inspection
PV	photovoltaic
RQ	research question
SOC	state-of-charge
V2G	vehicle-to-grid
VGI	vehicle-grid-integration

Definitions

Flexibility

Ability to adjust supply and demand in the electrical grid in order to achieve an energy balance.

General agent

An importer and distributor of cars. The general agent works as an intermediary between car factories and dealers.

The author

Refers to the author of the thesis, Celina Gustafsson.

The concept

The concept in which Axess Logistics provide flexibility services with electric vehicles.

Vehicle-to-grid (V2G)

The technology that enables that stored energy in an electric car's battery can be fed back into the electrical grid.

1 Introduction

This introductory chapter starts with the context in which the thesis takes place. It continues with a description of the case company Axess Logistics. Thereafter, the purpose, research questions and delimitations are presented. Lastly, the structure of the report is summarised.

1.1 Background

The automotive industry is undergoing an unprecedented transformation responding to sustainability targets, digitalisation and changing customer needs. One example is the electrification of the vehicle fleet, where electric vehicles (EVs) have grown in popularity the recent years. For instance, 45 per cent of the new registered cars were EVs in Sweden in 2021 (Mobility Sweden, 2022). Moreover, the electrification has the potential to reduce greenhouse gas emissions caused by transport, which is an important part in order to reach the Paris agreement goal of limiting the global temperature increase to below 2 degrees Celsius (UNFCCC, 2015).

Although positive for the climate, a growing number of EVs can present challenges for the electrical grid. Uncontrolled charging is estimated to cause significant problems in the distribution system. However, charging strategies optimised for less grid strain can reduce the impact (Steen, Tuan, Carlson & Bertling, 2012). Thus, the increased electricity demand from EVs does not necessarily need to become a problem if the charging is distributed, which could be possible since passenger cars are parked about 95-96 per cent of the time (Kempton & Tomić, 2005; Power Circle, 2021a).

In fact, EVs' batteries present an opportunity to store energy and later feed it back to the grid with *vehicle-to-grid* (V2G) technology. Hence, an EV can provide *flexibility services*, which are services that help balance demand and supply in the electrical grid (LEO, n.d.). In this way, EVs can become a resource instead of a challenge in the power system (Power Circle, 2021a). Furthermore, the utilisation of V2G technology has the potential to contribute to environmental and social benefits, e.g. reducing greenhouse gas emissions from electricity production and enabling a reliable and affordable electrical grid (Mohseni & Brent, n.d.; Turton & Moura, 2008).

The transforming automotive industry does not only affect the car manufacturers and buyers but all actors in the value chain. One of these actors is the company Axess Logistics, which provides car logistics solutions to general agents and dealers in Scandinavia. In the changing market landscape, the company believes that new business opportunities will arise related to the growing number of EVs. In addition, these opportunities may not only be of monetary value but also contribute to a more sustainable society.

1.2 Axess Logistics

Axess Logistics is a car logistics company in the Scandinavian market. The company offers complete and tailored logistics solutions for new import vehicles to general agents and dealers. The logistics solutions include storage, pre-delivery inspection (PDI) and transport (see Figure 1.1). Furthermore, Axess Logistics offers a one-stop concept with complete delivery services without ever moving the vehicles to another location (Axess Logistics, 2022).

Figure 1.1 Axess Logistics' activities in the value chain adapted from Axess Logistics (2022).

Strategically located in the larger ports in Sweden, the company has facilities in Gothenburg, Halmstad, Malmö and Södertälje. In 2021, about 290 000 vehicles passed these facilities.[1] The company is also active in the Norwegian and Danish markets.

[1] Mattias Öhrn, Key account manager at Axess Logistics, interview 16 May 2022.

Axess Logistics regards it as their mission to work for a more sustainable future and create social benefits.[2] For instance, the company has set measurable goals and tracks each vehicle individually to reduce the carbon dioxide (CO_2) impact. In addition, the introduction of EVs has led to the installation of EV charging stations at the company's facilities. Moreover, at the Malmö facility, Axess Logistics has installed solar photovoltaics (PVs) on the roof of a building with a capacity of 500 kW (Axess Logistics, 2022).

As the automotive industry transforms, Axess Logistics wants to identify and map new business opportunities. One evident trend is the growing share of EVs passing their facilities. With V2G technology in the cars, it is estimated that Axess Logistics could offer flexibility to the electrical grid. As a first step, the company therefore wants to investigate the potential of providing flexibility services, which is affected by both internal and external factors.

A new value proposition is seldom introduced in the market without challenges and risks. Acknowledging this fact, Axess Logistics also wants to identify barriers to market diffusion in the investigation of the potential. These barriers can be linked to a variety of areas, e.g. technical, regulatory or commercial barriers. By being aware of the barriers, Axess Logistics can address them proactively.

1.3 Purpose

The purpose of the thesis is to investigate the potential of implementing the provision of flexibility services at Axess Logistics related to V2G. This idea will also be referred to as the concept henceforth. The viability of the concept is affected by several factors, e.g. barriers, and these need to be identified and understood. Moreover, if solutions to overcome the barriers exist, the thesis aims to address them as well.

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[2] Dimitris Emmanouilidis, Production manager at Axess Logistics, interview 16 May 2022.

1.4 Research questions

The purpose of the thesis results in research questions (RQs), which can be seen in Table 1.1.

Table 1.1 The research questions of the thesis.

	What potential does Axess Logistics have to offer flexibility services?	
RQ1	To what extent is Axess Logistics able to provide flexibility?	Chapter 5 & 6
RQ2	Which are the barriers to the implementation of the concept?	Chapter 7

1.5 Delimitations

During the work process of the thesis, the following delimitations have been made:

- The case is limited to the company's Malmö facility.
- The thesis focuses on the stakeholders identified as most important to the concept, which is the reason why other stakeholder groups, e.g. dealers and end customers, were not interviewed.
- The regulatory aspects are discussed from a Swedish perspective if not stated otherwise.
- The case focuses on offering flexibility to external parties, i.e. internal flexibility, such as storing energy to use in own buildings, is not addressed.

1.6 Thesis structure

The structure of the report can be found in Table 1.2, where the chapters are listed and described briefly. It should be mentioned that the findings of the study are divided into several chapters, namely, Chapters 5-7. While the two former present the results from the data collection, Chapter 7 contains an analysis made by the author.

Table 1.2 The structure of the report.

Chapter	*Description*
1. Introduction	Introduces the reader to the background, case company, purpose, research questions and delimitations of the thesis.
2. Methodology	Describes the method design, quality of research and research ethics.
3. Theoretical framework	Presents the theory on which the analysis is based.
4. Market analysis	Describes and maps the conditions in the relevant markets.
5. Potential	Investigates Axess Logistics' capacity to start providing flexibility services.
6. External factors	Addresses external factors affecting the implementation of the concept.
7. Barriers	Based on the data collection, barriers are identified and explicitly listed. Furthermore, the barriers are analysed in the context of the Diffusion of innovations theory.
8. Discussion	The results of the study are discussed and future research areas are recommended.
9. Conclusion	The final chapter presents the conclusions of the study.

2 Methodology

This chapter describes the methodology and research approach used for the thesis. Moreover, the quality of the research and the measures taken to increase it are discussed. Lastly, research ethics is addressed.

2.1 Method design and research approach

Given the purpose and research questions of the thesis, it was determined to conduct a case study to investigate Axess Logistics' potential to offer flexibility services. According to Yin (2018, p. 15), a case study is a suitable method when describing a contemporary phenomenon observed in its real-world context. By focusing on a particular case, in-depth insights can be found that otherwise risk being overlooked in a study with a more general approach (Denscombe, 2010, p. 53). The study was based on both primary and secondary data. Furthermore, the collected data was predominantly qualitative.

The purpose of a qualitative study is not to find the generalisable truth. Rather, the goal is to understand a specific context (Willis, 2007, p. 189). In qualitative research, the phenomenon is not prescribed beforehand. Therefore, data can emerge and change during the study when gaining more understanding of the phenomenon and its surrounding environment (Willis, 2007, p. 202).

With the aim to collect insightful and in-depth data, the sampling strategy was purposive rather than generalisable. In other words, data cases were selected on the basis that they were able to provide information valuable for the analysis and analytical goal (Braun & Clarke, 2013, p. 56).

In qualitative research, one does not need to collect all data before starting the analysis phase (Braun & Clarke, 2013, p. 204). Sometimes, the data analysis can improve the remaining data collection, e.g. new questions may arise when reviewing the gathered data. This flexibility allowed for an iterative way of working as the study could be adapted with respect to changing conditions (Höst, Regnell & Runeson, 2006, p. 34).

A case study can be divided into six phases, namely, planning, designing, preparing, collecting, analysing and sharing (Yin, 2018, p. 1), which are illustrated in Figure 2.1. How each phase was conducted during the study is described in more detail below.

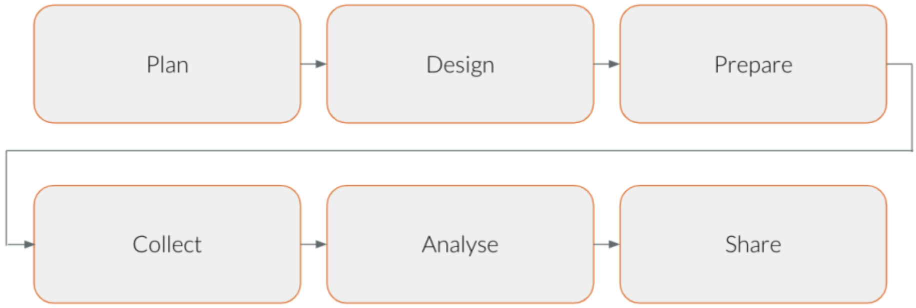

Figure 2.1. The six phases of a case study.

Although presented as a sequence of orderly steps, the method was iterative throughout the study and the phases were overlapping.

2.1.1 Plan

A case study should be planned with the aim of collecting, presenting and analysing data fairly (Yin, 2018, p. 3). In this phase, one identifies what should be studied as well as which research questions to address. Moreover, as important as knowing what to study, delimitations should be clarified early.

Together with the supervisors at Axess Logistics, the problem definition and research questions were formulated. These were also discussed with the supervisor at the university, Lars Bengtsson. The outcome of this phase was a goal document including the purpose and research questions of the study (see Sections 1.3 and 1.4).

2.1.2 Design

The methodology and research approach of the thesis were designed in accordance with the outlined plan, i.e. the goal document. The study followed a structure presented by Yin (2018, p. 1), which can be viewed in Figure 2.1. It was decided to conduct a qualitative and flexible case study. The methodology is described in detail in Chapter 2.

2.1.3 Prepare

Preparation was integral in order to understand the context of the study. It consisted mainly of two elements. Firstly, the supervisors at Axess Logistics provided the author with general knowledge concerning the company and its operations. Secondly, a literature review was conducted, which is a prerequisite for building on existing knowledge and avoiding overlooking already established learnings (Höst, Regnell & Runeson, 2006, p. 59). Database searches were done in LUBsearch and Google Scholar with keywords such as *vehicle-to-grid*, *vehicle electrification* and *flexibility*. In addition to the database searches, a snowballing approach was used, i.e. relevant data were gathered by visiting articles that were cited in already found articles (Sayers, 2007).

Initially, the approach was broad and explorative. Academic journals were prioritised, and the search results were assessed in steps. Firstly, the title and abstract were reviewed. Secondly, the conclusion and result sections were read. If still considered relevant, the article was read completely, and relevant information was extracted.

Given that the thesis addresses areas that change rapidly, the publishing date was taken into consideration. More recent publications were prioritised over older ones. However, a paper was not disqualified directly because of its age, but an assessment of its relevance was made. Due to the lack of existing literature regarding some of the relevant areas, other secondary data were studied as well, e.g. government publications and consultancy reports. Although not peer-reviewed, these sources were found complementary during the preparation phase.

2.1.4 Collect

The main method for collecting primary data was interviews, which is a suitable data collection technique for case studies (Höst, Regnell & Runeson, 2006, p. 34). Interviews are particularly useful when one wants to capture explanations (i.e. hows and whys) and the interviewees' perspectives (Yin, 2018, pp. 118). Interviews were conducted with a variety of respondents, which were divided into 3 respondent groups (see Table 2.1).

Table 2.1 The respondent groups.

	Number of respondents
General agents	2
Industry experts	3
Company representatives	2

The interviews were semi-structured, which means that a set of questions was prepared beforehand. However, the order and formulation of the questions could be adapted to each interview situation (Höst, Regnell & Runeson, 2006, p. 34). This approach allowed the interviewees to speak more broadly and develop their ideas during the interviews (Denscombe, 2010, p. 175). Prior to each interview, an interview guide with open-ended questions was prepared. This type of question is a key factor in qualitative interviews where the researcher wants the interviewees to express themselves in their own words (Denscombe, 2010, p. 165). Furthermore, the respondents were not rushed to come up with quick answers, which allowed them to elaborate on their answers. The approach was to start with a broader scope investigating if the respondents themselves brought up specific subjects during the interviews. If not, more directed questions were asked in order to cover each area in the interview guide. Interviews were conducted both in-person and digitally. Additionally, with consent from the respondent, the interview was recorded.

The main objective of the interviews was to collect data regarding opportunities, challenges and attitudes related to vehicle electrification, V2G, flexibility services and changing customer behaviours. Due to the differing interests of the respondent groups, different interview guides were prepared (see Appendix A & Appendix B).

The interviews are summarised in Table 2.2, and a more detailed description of them can be found in Appendix C. Due to confidentiality reasons, some respondents were anonymised.

Table 2.2 The conducted interviews.

Respondent	*Title*	*Respondent group*
General agent A	Head of logistics	General agent
General agent B	Product and logistics manager	General agent
Ulf Wengeler	CEO, SolarVolt	Industry expert
Maria Edvall	Senior project manager, RISE	Industry expert
Jerry Svedlund	Head of research, CTEK	Industry expert
Mattias Öhrn	Key account manager, Axess Logistics	Company representative
Dimitris Emmanouilidis	Production manager, Axess Logistics	Company representative

In addition to the interviews, a document study was conducted in the collection phase. As a result of gaining more knowledge as the study progressed, more niched searches could be made in the above-mentioned databases. Hence, new keywords were used in the searches, among others, *local flexibility markets, ancillary services* and *battery degradation.* Other sources, e.g. company websites and publications from industry organisations, providing relevant data were also used in order to gather additional information – although with particular consideration of the reliability.

2.1.5 Analyse

When analysing qualitative data, there are three principles that should be acknowledged (Denscombe, 2010, p. 272). Firstly, the analysis is rarely made at a single point in time. Instead, the data collection and data analysis can together be regarded as an evolving process of iterations. Secondly, the analysis is usually taking an inductive approach, working from the specific case and trying to arrive at generalised statements that may apply in broader domains. Thirdly, qualitative data analysis is researcher-centred, i.e. one should recognise that the researcher's values and experiences inevitably influence the analysis (Denscombe, 2010, p. 273).

The data gathered from the interviews were analysed in multiple steps. Immediately after each interview, the first impressions and key takeaways were documented. A more thorough analysis was made shortly afterwards, where the recording was played and the interview was transcribed. The data emerging from the interviews were coded and grouped. In addition, re-readings of the transcripts were made several weeks later. The reason for the latter was to investigate if there was previously overlooked information to be found. In the event of new relevant data, the analysis was complemented with the additional information.

In order to identify barriers to the implementation of flexibility services – and hence answer RQ2 – the data were analysed systematically. Inspired by Gioia, Corley and Hamilton (2012), the data was structured in *1st order concepts*, *2nd order themes* and *aggregate dimensions* (see Figure 2.2). Furthermore, to put the analysis in relation to existing literature is an important part of any analysis (Braun & Clarke, 2013, p. 257). Hence, the resulting aggregate dimensions – each corresponding to a barrier – were discussed in the context of the Diffusion of innovations theory (see more in Chapter 3).

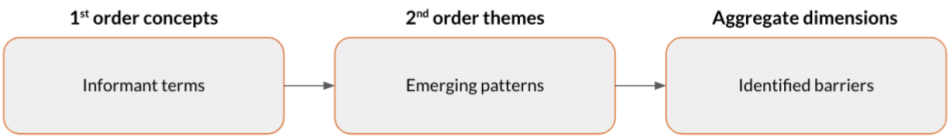

Figure 2.2. An illustration of how the data was analysed.

The systematics of the analysis is further elaborated in the following list:

- 1st order concepts: Initially, the interview transcripts were analysed and attention was given to the words the interviewees chose to express themselves with, i.e. informant terms. The transcripts were coded and informant terms were grouped, which resulted in a number of 1st order concepts.

- 2nd order themes: Secondly, the 1st order concepts were distilled into 2nd order themes. The idea of these themes was to describe emerging patterns explaining the observed phenomena (Gioia, Corley & Hamilton, 2012).

- Aggregate dimensions: Lastly, the 2nd order themes were further transformed into aggregate dimensions. Each aggregate dimension corresponded to a barrier to the implementation of flexibility services at Axess Logistics.

- Diffusion of innovations: According to Rogers (1995, p. 208), an innovation has five attributes that affect to what degree and at what speed it is adopted in the market. These are *relative advantage*, *compatibility*, *complexity*, *trialability* and *observability*. When discussing the barriers from this perspective, possible solutions to overcome them – and thus promote the adoption of the innovation – were found and reflected upon.

As a last step in the analysis phase, the barriers were presented to the supervisors at Axess Logistics in a workshop. The supervisors' input enabled internal validation of the findings.

2.1.6 Share

The results and conclusions of the case study were presented in two ways. Firstly, the thesis was presented orally at a final seminar, where both the examiner at LTH and supervisors from Axess Logistics were present.

Secondly, the study was documented and presented in a written report. The report was critically reviewed by the supervisors at Axess Logistics, the examiner at the university as well as fellow students. The review resulted in feedback that was taken into consideration when revising the report into a final version.

2.2 Quality of research

The credibility of research should not be taken for granted. Denscombe (2010, p. 298) lists four bases on which the credibility can be judged (see Table 2.3).

Table 2.3 The bases for judging the credibility of research (Denscombe, 2010, p. 298).

	Answers the question
Validity	Are the data the right kind for investigating the topic and have they been measured correctly?
Reliability	Would the research instrument produce the same results on different occasions? (Ceteris paribus)
Generalisability	Can the findings of the research be applied to other examples of the phenomenon?
Objectivity	Is the research free from bias?

Validity addresses the connection between the phenomenon one wants to observe and what is actually measured during the study (Höst, Regnell &

Runeson, 2005, p. 42). It can be achieved by collecting data with accuracy and precision (Denscombe, 2010, p. 298). To further ensure validity, triangulation was conducted with internal stakeholders as well as industry experts. The idea of triangulation is to back up conclusions with corroboration from multiple sources (Willis, 2007, p. 219).

High reliability is based on neutrality and replicability in the research method. It can be particularly challenging to achieve in qualitative studies since the researcher is closely linked to the data collection (Denscombe, 2010, p. 299). Braun and Clarke (2013, p. 279) suggest that trustworthiness is a better judging base in qualitative studies since the researcher inevitably influences the research process. To increase the study's reliability, the methodology, data collection and analysis are thoroughly described (Höst, Regnell & Runeson, 2005, p. 41). In addition, the research approach was discussed regularly with the supervisor at the university.

Case studies are, in principle, not regarded as generalisable**.** However, one could argue that if the case is representative in a specific context, it is most likely generalisable in another context with similar conditions. To increase the generalisability, the studied case is described in detail, allowing the reader to understand the context (Höst Regnell & Runeson, 2006, p. 42).

Objectivity should be strived for in order to get outcomes and results that are neutral, i.e. not influenced by the researcher's potential biases. However, since qualitative data are a result of a process of interpretation, no qualitative research is independent of the researcher (Denscombe, 2010, p. 302). Acknowledging this fact, the author has tried to stay neutral throughout the study keeping an open mind. Additionally, the data collection and analysis should meet standards of fairness (Denscombe, 2010, p. 298).

2.3 Research ethics

One should not conduct a case study without consideration of research ethics. This is especially important when the study involves human subjects (Yin, 2018, p. 88). Throughout the study, the goal has been to conduct it with the utmost respect for the privacy of data and people. For instance, all interviewees participated voluntarily and they were asked about their desired level of anonymity as well as permission to record the interviews.

3 Theoretical framework

The analysis of the thesis is based on a theoretical framework, which is presented and explained in this chapter.

3.1 Diffusion of innovations

The diffusion process describes the process where individuals and firms in a society adopt a new technology[3], or replace an existing technology with a newer one (Hall, 2010, p. 459). Rogers (1995, p. 5) defines diffusion as “the process by which an innovation is communicated through certain channels over time among the members of a social system”. Without diffusion, the innovation would not be able to have a social or economic impact. Also, diffusion is an integral part of the innovation process since the spread of the new technology gives rise to learning, imitation and feedback effects (Hall, 2010, pp. 459-460).

The diffusion process is a complex process affected by many interrelated factors. Two of these factors are the characteristics of potential adopters and the properties of the innovation itself. For instance, it has been observed that the rate of adoption differs between innovations (Rogers, 1995, p. 204). Furthermore, it has also been noted that all individuals do not adopt an innovation at the same time (Rogers, 1995, p. 252). Another characteristic of the diffusion process is how it interacts with the innovation process, e.g. learning about the innovation’s use in different environments can generate improvements in the original innovation (Hall, 2010, p. 460).

[3] Not necessarily high-tech, simpler products and services are also included.

3.1.1 Categories of adopters

Based on real-world observations, Rogers (1995, p. 263) states that there are five different categories of adopters in a social system, whose characteristics can be found in Table 3.1. A social system is described as “a set of interrelated units that are engaged in joint problem-solving to accomplish a common goal” (Rogers, 1995, p. 23). Additionally, the norms and structures of communications networks in a social system affect the diffusion process (Rogers, 1995, p. 208). Making these distinctions between categories enables audience segmentation (Rogers, 1995, p. 280).

Table 3.1 The five adopter categories (Rogers, 1995, pp. 263-265).

Type	*Characteristics*
Innovators	• Venturesome • Have substantial financial resources • Ability to understand and apply complex technical knowledge • Able to cope with a high degree of uncertainty • Willing to accept an occasional setback • Gatekeeping role in the diffusion process
Early adopters	• High degree of opinion leadership • Accelerate the diffusion by serving as a role model • Make judicious innovation-decisions in order to maintain the respect from others • Decreases uncertainty related to the innovation
Early majority	• Adopt new ideas just before the average member of a social system • Important link in the diffusion process as they provide interconnectedness in the system's interpersonal networks • Deliberate a while before completely adopting a new idea • Willingness to adopt, but seldom leading
Late majority	• May adopt from increasing network pressures from peers and/or an economic necessity • Approach innovations with scepticism and caution • Do not adopt until most others in the system have done so • The weight of system norms must definitely favour an innovation before the late majority is convinced • The pressure of peers is necessary to motivate adoption • Scarce resources mean that the uncertainty about a new idea must be removed before the late majority feel safe
Laggards	• The last ones to adopt • Near isolates in the social network of their system • Have the past as a point of reference • Decisions are made based on what has been done previously • Interact with others that have traditional values • Suspicious about innovations • Innovation-decision process is lengthy: adoption and use lag far behind awareness-knowledge of a new idea • The resistance may be entirely rational from the laggards' viewpoint due to their limited resources • Must be certain that a new idea will not fail before adopting

3.1.2 Five attributes of an innovation

According to the Diffusion of innovations theory, there are five key attributes – linked to the perception of the innovation – that determine whether an innovation is adopted and at what speed (Rogers, 1995, p. 204). These characteristics are summarised in Table 3.2.

Table 3.2 The five characteristics of an innovation according to Rogers (1995, p. 208).

Attribute	*Description*
Relative advantage	How easy is it to see the advantages of the innovation compared to already existing products or solutions?
Compatibility	Does the innovation align with the needs, experiences and values of the users?
Complexity	How easy is it to understand or use the product?
Trialability	Is it possible to try the innovation before investing in it?
Observability	How easy is it to observe the benefits of the innovation?

Relative advantage is often related to economic profitability, social prestige, decrease in discomfort or other benefits (Rogers, 1995, p. 216). The importance of the different factors can vary between adopter groups. For instance, social prestige is more important to innovators, early adopters and the early majority (Rogers, 1995, p. 214).

Another aspect of relative advantage is the immediacy of the reward. There is a difference between incremental and preventive innovation, where the result of adopting the former is seen at once. Contrasting, the result of the preventive innovation is slower as the reward is delayed or sometimes a non-event (Rogers, 1995, p. 217). To increase the degree of relative advantage, and thus speed up the rate of adoption, incentives and subsidies can be awarded (Rogers, 1995, p. 219). However, incentives do not guarantee the quality of adoption, i.e. whether adopters discontinue their use quickly (Rogers, 1995, p. 221).

Compatibility can exist with sociocultural values and beliefs, previously adopted ideas or client needs for the innovation (Rogers, 1995, p. 224). The more compatible an innovation is, the less behaviour change is required. It is also worth mentioning that compatible innovations can gradually pave the way for less compatible ones (Rogers, 1995, p. 227).

Complexity refers to how relatively difficult an innovation is perceived by the potential adopters. While some innovations are simple to understand and use, others are more unclear in their meaning to adopters. If an innovation is perceived as complex, its rate of adoption can be slowed down significantly (Rogers, 1995, pp. 242-243).

Innovations that can be experimented with on a limited basis are adopted more rapidly in general, as trialability lowers the uncertainty. Furthermore, trialability is more important to earlier adopters than to later ones (Rogers, 1995, p. 243).

Lastly, observability represents to which degree the results of an innovation are visible to others. The more observable results or advantages, the faster the adoption rate. For instance, studies have concluded that a hardware aspect of a technological idea has more observability than a software aspect. Consequently, the latter has a slower rate of adoption (Rogers, 1995, p. 244).

4 Market analysis

This chapter investigates and presents markets and trends relevant to the concept. Thus, findings regarding the automotive industry, electricity market and V2G technology are included.

4.1 The automotive industry

4.1.1 Current challenges

For the automotive industry, the COVID-19 pandemic led to a global semiconductor shortage starting in 2021 (Eisenstein, 2022). This has decreased the production, slowed deliveries and increased prices to the dismay of many customers (Krisher & Chan, 2022).

Additionally, the war in Ukraine has presented a new challenge. Ukraine is a key supplier of wire harness, which is part of a car's electrical system. This supply problem can affect up to 15 per cent of the European automotive production (Trudell & Eckl-Dorna, 2022). As a result, even higher vehicle prices are expected in the nearest future. There are also concerns regarding a potential shortage of vital metals if the export from Russia is stopped (Krisher & Chan, 2022).

The global automotive industry is losing millions of produced and sold cars due to these challenges, and it could continue into 2023 (Eisenstein, 2022). Still, the buyer demand is high but in combination with supply problems, the prices for both new and used vehicles are rising. An industry person says that the automotive industry is in a "raising-price environment, a (production)-constrained environment", which is an unusual situation (Krisher & Chan, 2022).

4.1.2 Are consumers still interested in owning a car?

The introduction of shared mobility services has challenged the traditional private ownership of a car. The concept of sharing vehicles is highly regarded in the circular economy community, which approximates that it could lead to a reduction of 66 million tonnes of CO_2 equivalents annually by 2050 (Ellen MacArthur Foundation, n.d.). It has been proposed that the consumers' relation to the car will transition from owning to accessing (Frazer, 2019). This alternative mindset has led to new companies, e.g. Lynk & Co and Volvo Car Mobility, in the market tapping into this opportunity and offering mobility-as-a-service (Lynk & Co, n.d.; Volvo Car Mobility, n.d.). However, it does not seem like the popularity of ownership has declined. In fact, the opposite seems to have occurred.

The Covid-19 pandemic lowered the interest in shared mobility. Capgemini (2020) states that the pandemic has reversed the ownership trend in younger generations as they show a stronger preference for ownership. Even after the pandemic, consumers located in different regions of the world declare that using their own car is the preferred choice of transport – offering the safest and most convenient alternative (Strategy&, 2021).

The popularity of ownership is observable in Sweden as well. Both the new and the used car markets are growing, demonstrating that customers are highly interested in owning their cars (Kvdbil, n.d.b). Furthermore, when Swedes were asked if they in ten years will own a car, 58 per cent said they would. Only six per cent stated that they would use a car-sharing service. However, younger people show more interest in car-sharing services, which may affect whether the car is privately owned in the future (Kvdbil, 2021).

In addition, this customer behaviour is corroborated by general agents.[4,5] They state that car-sharing may work for people living in apartment buildings. However, they do not believe that car-sharing will replace the traditional private ownership of cars on a large scale. The reason for this is that customers want to own their cars and enjoy the flexibility and freedom to use them whenever they want without risking that a car is not available. Another influencing factor is the price. Today, short-term leasing costs a lot in relation to the value it provides. If the price goes down, it may, however,

[4] General agent A, Head of logistics, interview 16 March 2022.

[5] General agent B, Product and logistics manager, interview 21 March 2022.

become more attractive.[6] Accessibility and price are also brought up as influencing factors in a consumer survey conducted by Strategy& (2021). The importance of the price is acknowledged in existing literature as well, where also the mileage limitation is included as an important factor when choosing to own a car or not (Szamatowicz & Paundra, 2019).

4.1.3 Car fleet electrification

The electrification of passenger cars is evident. EVs made up 45 per cent of the new registered cars in 2021. Thus, almost every second car was chargeable and 19 per cent was fully electric, i.e. battery electric vehicles (BEVs), which can be seen in Figure 4.1. The growth of BEVs was 106 per cent compared to the year before (Mobility Sweden, 2022). In total numbers, this means that almost 300 000 electric passenger cars are in traffic in Sweden, amounting to 6 per cent of the total passenger car fleet (Power Circle, 2022c). In 2030, Power Circle (2021b) estimates that there could be 2.5 million EVs in Sweden 2030.

The forecast for 2022 is that EVs will amount to 60 per cent of the new registered passenger cars, whereas the BEVs stand for 34 per cent (Mobility Sweden, 2022), which is illustrated in Figure 4.1.

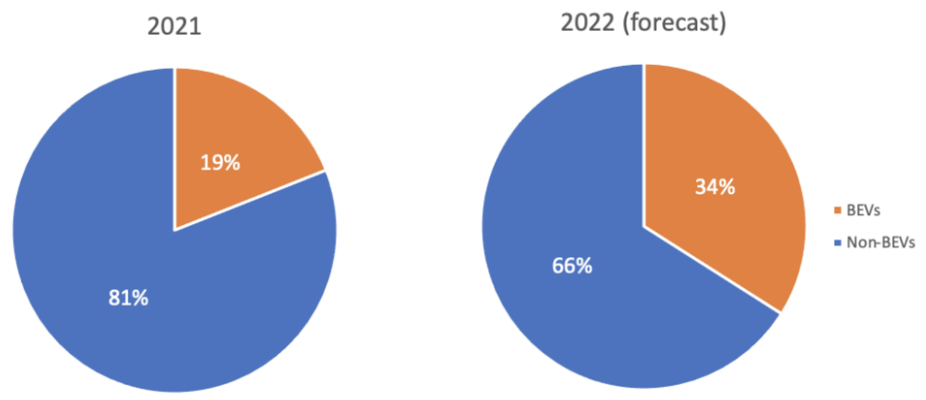

Figure 4.1 The distribution of new registered passenger cars. Note that non-BEVs include EVs that are not fully electric.

Based on Mobility Sweden's historical data of new registered cars (Mobility Sweden, n.d.), Axess Logistics has internally made an approximation of the

[6] General agent A, Head of logistics, interview 16 March 2022.

growth of BEVs (see Figure 4.2). According to the figure, 50 per cent of the new registered cars will be fully electric in 2023. In 2025, the BEVs will account for 90 per cent of the new registrations.

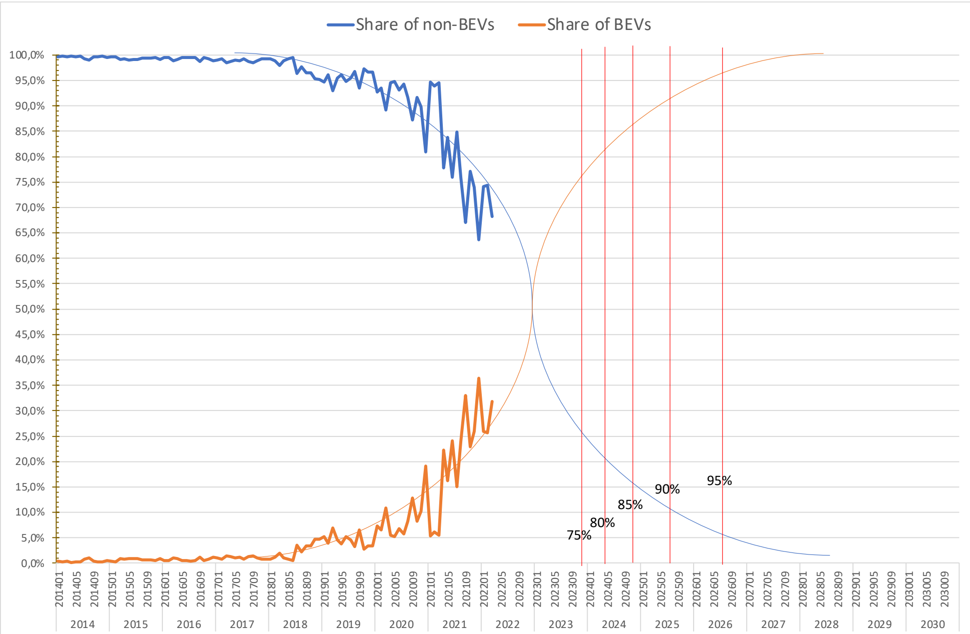

Figure 4.2 An estimation of the growth of BEVs in Sweden.[7]

According to Mobility Sweden (2022), the ongoing growth can be explained by several factors. Firstly, car manufacturers have launched new models that reach more customer segments. Secondly, the prioritisation of producing EVs partly depends on the European Union's emission bans. In addition, the policy instruments in Sweden have contributed to the growth (Mobility Sweden, 2022). In 2018, the Swedish government introduced the Bonus malus system with the objective to catalyse the development of a fossil-free society. A customer buying a new car with low CO_2 emissions receives a bonus, while owners of cars with high CO_2 emissions are penalised with increased vehicle tax (Transportstyrelsen, 2018).

[7] Fredrik Merell, System controller at Axess Logistics, 25 January 2022.

4.2 The electricity market in Sweden

4.2.1 Market design

In Sweden, the power grid is divided into three levels, namely, the national grid, regional grid and local grid. The national grid is managed by the transmission system operator Svenska kraftnät, whose responsibility covers the entire Swedish electricity system (Liikamaa, 2019). More specifically, Svenska kraftnät ensures that the plants of the electricity system work together in an operationally reliable way as well as that the production and import are in balance with the consumption and export (Svenska kraftnät, 2001). When it comes to the regional grids, there are mainly three companies that own and operate them. Moreover, the regional grids are the link between the national grid and the local grids. Lastly, the ownership and operation responsibility of the local grids are distributed between companies with municipal ownership (Liikamaa, 2019).

The production and consumption of power are not distributed evenly in Sweden. While the northern parts produce the most, the largest consumption takes place in the south of Sweden (Energimarknadsinspektionen, n.d.c). Hence, the surplus power has to be transferred long distances to where the demand is (Liikamaa, 2019). Sometimes there is a lack of sufficient transfer capacity, which creates bottlenecks in the electrical grid (Energimarknadsinspektionen, n.d.b). Within the European Union, one of the allowed methods for managing bottlenecks is electricity price areas, also called bidding areas (Energimarknadsinspektionen, n.d.c). Sweden is divided into four areas ranging from SE1 in the north to SE4 in the south (see Figure 4.3). Apart from managing bottlenecks, the bidding areas indicate where grid investments are needed as well as make it more profitable to produce electricity where it is consumed (Konsumenternas Energimarknadsbyrå, 2020).

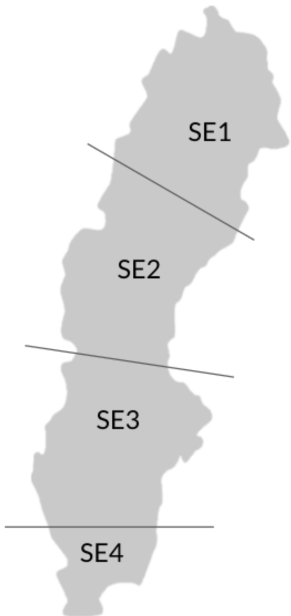

Figure 4.3 The four electricity price areas in Sweden.

The lack of transfer capacity can give rise to another problem, namely, power shortage. Power shortage occurs when there is not sufficient electricity at a certain time at a certain place. For instance, it is not unusual that the demand exceeds the supply during cold mornings in the winter (Eon, 2021). It is estimated that in 2045, Sweden will suffer from significant power shortage if no measures are taken (Power Circle, 2021a). In a scenario with completely renewable electricity production in 2045, Svenska kraftnät (2021e) states that power shortage can occur 900 hours every year, which corresponds to 10 per cent of the year.

4.2.2 Price

The electricity price depends mainly on three parameters: supply, demand and the electrical grid's capacity (Mälarenergi, n.d.). Every hour of the day, the electricity demand is matched against electricity production through auctioning with sell and buy bids. The production facilities with the lowest variable cost, and hence the lowest sell bids, are used first. Gradually, the available sell bids are called-off until the demand is met. The electricity market is using marginal pricing, i.e. the cost of the "last" kWh that is needed to meet the demand sets the spot price (Energimarknadsinspektionen, n.d.c). However, customers with fixed price contracts are not affected by the variable spot price.

When the supply is low relative to the demand, the spot price increases instantly (Mälarenergi, n.d.). Historically, high prices have coincided with high electricity consumption. However, low production due to intermittent energy sources will also cause higher prices in the future (IVA, 2015). Furthermore, the electricity price is affected by other European – especially Nordic – countries' electricity markets. In line with the European Union's energy policy goals, the member states have agreed upon harmonising and integrating national electricity markets. The purpose is to increase the security of supply, contribute to sustainable electricity supply and strengthen the competition in the market, which will benefit the electricity customers of Europe. Among other things, consequences of the harmonisation are more linked transmission infrastructure and increased international trade (Svenska kraftnät, 2021b).

It is worth mentioning that from the customers' perspective, the spot price constitutes only a part of the price. The price that customer pays also includes taxes and additional fees to the electricity supplier (Konsumenternas energimarknadsbyrå, 2022).

4.2.3 Flexibility

Flexibility services could be part of the solution to the above-described challenges in the electrical grid. They can be described as "a range of existing and developing solutions that electricity system users can provide to help balance demand and supply in the electricity network and support its efficient use" (LEO, n.d.).

Flexibility in the electricity consumption is necessary for a functioning system with high electrification in 2045 (Svenska kraftnät, 2021f). In February 2022, the Swedish government presented a national strategy for the future electricity system. The strategy emphasises that flexibility should be built into the system, e.g. possibilities of flexibility should be promoted when electricity-intensive infrastructure is connected to the grid (Infrastrukturdepartementet, 2022).

The main method for creating flexibility in the electricity system has historically been investments in new power lines (Power Circle, 2022b), which still is used (Svenska kraftnät, 2022b). However, the technical development, e.g. digitalisation and forecasting models, has enabled other means of flexibility. The owners of flexibility resources have the ability to regulate the resources' consumption and production based on the demand (Power Circle, 2022b). By creating local markets with flexibility, the problem of lack of capacity in the grid can be relieved (Svenska kraftnät, 2022b). Moreover, flexibility is not only important while new power lines are being built, but it can also lower the need for grid investments (Energimarknadsinspektionen, n.d.a).

Today, it is possible to trade flexibility in two different types of markets. One is the market for ancillary services, and the other is local flexibility markets. Both market types will be described in the following sections.

4.2.3.1 Ancillary services

The transmission system operator Svenska kraftnät procures ancillary services to maintain a stable frequency in the electrical grid. The goal is to have a constant frequency of 50 Hz (Svenska kraftnät, 2022d). To keep the stability, Svenska kraftnät has multiple ancillary services that are ready to be activated if needed. Which service that is activated depends on how much the frequency deviates from 50 Hz. Today, most of the ancillary services are provided by hydropower (Svenska kraftnät, 2020b). Ancillary services can, however, be provided in other ways, e.g. batteries or user flexibility.[8] Therefore, Svenska Kraftnät works to open up the ancillary services market for other technologies and, hence, decrease the dependence on hydropower, which can have hydrological variations (Svenska kraftnät, 2020b).

Certain requirements must be met in order to qualify to place bids in the ancillary services market (see Table 4.1). The quantities of the requirements differ between the services.

[8] Maria Edvall, Senior project manager at RISE, interview 7 April 2022.

Table 4.1 Requirements for Svenska kraftnät's ancillary services (Svenska kraftnät, 2022e).

Requirement	*Explanation*
Size of bid	The provider needs to offer a minimum of power.
Activation time	The time it takes for the provider to respond to the need.
Endurance	The provider needs to be able to offer power during a predetermined period of time.

In addition, the following three criteria must be fulfilled:

- Approved pre-qualifying
- Real-time measurement
- Electronic communication

During the pre-qualifying test, the supplier of the ancillary service must demonstrate that the technical requirements are met for the specific service (Svenska kraftnät, 2021j). Moreover, a company need to be a *balance responsibility party* in order to submit bids to Svenska kraftnät. However, this requirement might change relatively soon as a new role, namely, *balance service provider,* will be introduced in 2022 (Svenska kraftnät, 2021h). If a company wants to participate with flexibility in the ancillary services markets without being a balance responsibility party, it can contract another company that already is such an actor (Svenska kraftnät, 2021a). It should also be mentioned that some ancillary services are purchased just days before activation, while others are purchased on an annual basis (Svenska kraftnät, 2022c).

Furthermore, Svenska kraftnät has certain rules and requirements for resources in the category *energy storage* that provide ancillary services (Svenska kraftnät, 2021d). Batteries are included in this category since they are limited in capacity, i.e. they can only be charged until they are full and discharged until they are empty (Andersen et al., 2019a). For instance, there is a requirement regarding the recovery time, which needs to be taken into consideration when placing bids (Svenska kraftnät, 2021d).

One of the reasons for wanting to be a provider of ancillary services is the economic incentive, which has been demonstrated in several projects (Vattenfall, 2020b, 2022). The remuneration is, in general, based on the parameters available capacity and delivered energy, but the specific remuneration model differs between the services (Svenska kraftnät, 2022c). Svenska kraftnät pays annually in the billion segment (SEK) for ancillary services (Svenska kraftnät, 2021g). The cost of ancillary services is financed by the national grid tariff and the balance responsibility fee. Consequently, higher costs increase the burden on the customer collective. Svenska kraftnät aims to procure necessary capacity from ancillary services as cost-efficient as possible and, at the same time, guarantee operational reliability in the short- and long-term (Svenska kraftnät, 2020b).

4.2.3.2 Local flexibility markets

Local flexibility markets have been created to enable more effective use of the electrical grid during winter seasons (Svenska kraftnät, 2022b). For instance, these markets can help relieve grid congestion by managing bottlenecks (Svenska kraftnät, 2020f). Furthermore, the grid problems vary between locations, e.g. the lack of capacity causes power shortage in Skåne, while the production of wind- and hydro energy needs to be limited due to insufficient grid capacity in the northern parts of Sweden (Svenska kraftnät, 2022b).

In these local flexibility markets, market actors trade flexibility with production or consumption bids (Svenska kraftnät, 2022b). An actor with flexibility resources, also called *flexibility service provider* (FSP), can sell flexibility as a service to other actors in need of power or capacity. Sellers and buyers place bids in the markets, stating the volume, price and time they want to sell or purchase. Today, the buyers are often owners of regional or local electrical grids (Power Circle, 2022b).

To become an FSP, the actor must pre-qualify in the market it wants to participate in. The purpose of the pre-qualification is to ensure that the FSPs are able to provide flexibility in line with the market rules, and it often takes place before the market opens for the season. The flexibility markets have a minimum bid size of 0.1 MW and a minimum delivery time of 60 minutes. However, aggregation (see Section 4.2.4) is allowed in flexibility markets (Power Circle, 2022b).

Today, flexibility markets exist in six different geographical areas, and all are projects in the pilot stage. The marketplace differs between the projects, and a dominant market design with common products and rules is yet to be established (Power Circle, 2022a). Flexibility is mainly sold in two product categories, namely, free bids and availability agreements (see Table 4.2).

Table 4.2 The local flexibility markets' products (Power Circle, 2022b).

Product	***Description***
Free bid	The product is the same in all marketplaces.
Availability agreement	The product is different in the marketplaces. Examples: • FSP offers flexibility between 7 am-8 pm all weekdays of the season • FSP offers a quota volume of flexibility that is distributed during the peak hours of the season • FSP offers flexibility during certain hours the entire season (season flex) • FSP offers flexibility during certain hours the next week (week flex)

The free bids are placed in a continuous market and most of the bids are called-off one day before activation. However, a call-off can take place the same day as the delivery of a bid. From an economic perspective, availability agreements have an advantage since the compensation is based on two parts. Apart from compensation for activation, the FSP is also paid for available capacity regardless of if the bid is activated or not (Power Circle, 2022b).

As a concluding note, providing ancillary services does not exclude the possibility of trading in local flexibility markets – or vice versa. Ancillary services work on a national level to maintain the frequency, while the other markets use flexibility to manage local problems, e.g. congestion and power shortage (Färegård & Miletic, 2021). In some markets, among others, CoordiNet Malmö, free bids that are not called-off can be forwarded to the ancillary service *manual Frequency Restoration Reserve* (mFRR) if the FSP is pre-qualified according to Svenska kraftnät's requirements (Svenska kraftnät, 2022c). Another example of combining the markets is if the FSP offers flexibility during certain hours in a local flexibility market through availability agreements, and then places bids in ancillary services markets during the other hours (Power Circle, 2022a). Being able to participate in several markets leads to better business opportunities for owners of flexibility resources as it increases the possibility of the FSP's bids being called-off (Svenska Kraftnät, 2022b).

4.2.4 Aggregation

Buyers of flexibility prefer relatively large bids, which has resulted in requirements regarding minimum bid sizes in the flexibility markets. On the other hand, far from all owners of flexibility resources reach the required minimum level of available capacity (Power Circle, 2021a). The solution to this discrepancy is aggregation, where multiple smaller bids are aggregated up to the minimum level. The owners of the flexibility resources (e.g. EVs) need to make an agreement with an aggregator, who, in turn, can trade in the market with larger sell bids. Thus, aggregators can help FSPs that are not able to participate in flexibility markets themselves due to a lack of resources (Power Circle, 2022b).

However, several regulations limit what aggregators can offer in the markets. One of the consequences is that a lot of the flexibility that EVs have the potential to offer never enters the flexibility markets as bids (Power Circle, 2021b). Some of the regulations are the following (Power Circle, 2021b; Svenska kraftnät, 2020c, 2020d):

- Some markets do not accept a mix of flexibility resources in the same bid
- Aggregated resources must be located in the same bidding area
- Aggregated resources must share the same balance responsibility party
- Some markets close long before the operating hour, which means that larger marginals are needed
- Aggregators need to have marginals in their bids

The marginals exist to ensure that the sold flexibility can be delivered. However, this shrinks the size of available flexibility (Power Circle, 2021b). In an example, Power Circle (2021a) demonstrates how the aggregation rules of a bid significantly affect the marginal and hence the available flexibility (see Table 4.3).

Table 4.3 An example of how the aggregation rules affect the available flexibility.

	Scenario 1	*Scenario 2*
Number of EVs	10 000	10 000
Number of bids	1	10
Required marginal	10%	40%

If 10 000 EVs are aggregated into one bid, the aggregator needs to have a 10 per cent marginal in order to submit it on the market. However, if the bid is divided into ten smaller bids (e.g. due to market regulations), the marginal will amount up to 40 per cent resulting in significantly less flexibility (Power Circle, 2021a). This is illustrated in Figure 4.4.

Figure 4.4 Illustration of how the marginal is affected by different bid sizes.

Particularly when it comes to EVs as a flexibility resource, aggregation need to be seen from a macro perspective. As EVs have another function of transport, they are not always parked and, hence, available as flexibility resources. Probably, there are always enough cars parked that can be aggregated to make up a bid even if not a specific car will be connected all the time. However, this needs to be measured during a period of time to be sure that a certain power capacity is available continuously.[9]

The aggregator role is relatively new in the market, and the flexibility markets will most probably develop in the future. Besides aggregating bids up to the minimum size, aggregators can also help others that lack competence (Power Circle, 2022b). One of the existing aggregators is Tibber, which has EVs in its pool of flexibility resources and is also pre-qualified for the ancillary service *Frequency Containment Reserve - Normal* (FCR-N) (Nohrstedt, 2020). To ensure that aggregators participate in markets effectively, the European Union has introduced some common rules regarding how aggregators can act in the electricity market (Energimarknadsinspektionen, 2021).

[9] Ulf Wengeler, CEO of SolarVolt, interview 31 March 2022.

4.3 Vehicle-to-grid

4.3.1 The basics

V2G refers to when energy from a vehicle's battery is fed back into the electrical grid (Letendre & Kempton, 2002). There are other terms, such as grid-integrated vehicles (GIV) and vehicle-grid-integration (VGI), that also refer to the technology where EVs are intelligently integrated with the grid (Sovacool, Noel, Axsen & Kempton, 2018). Moreover, the possibility of feeding electricity back into the grid is based on the assumption that cars are parked for a considerable amount of time, where some suggest that the figure is about 95-96 per cent (Kempton & Tomić, 2005; Power Circle, 2021a).

V2G enables different kinds of services, e.g. frequency regulation and congestion mitigation. Andersen et al. (2019b) define a V2G service as "the act of influencing the timing, size and direction of power and energy exchanged between the EV battery and an external load or electric network to provide value not related to transportation".

4.3.2 Potential areas of application

V2G is a promising technology that unites the automotive industry with the electricity market and presents benefits to a diverse mix of stakeholders. For instance, EVs have the potential to contribute to stability in a power system with high integration of renewable energy sources (Andersen et al., 2019b). In a simulation of the future penetration of decentralised and flexible power systems in Europe, Després et al. (2017) found that V2G offers the largest storage potential compared to options such as standalone batteries, pumped hydro and pressed air energy storage.

In a study by Taljegård (2019), it is concluded that EV batteries have the potential to contribute with a large additional power capacity each hour of the year, without doing that at the expense of driving demands. According to the study, the electrical grid services that could be provided are:

- Electricity storage (e.g. peak power shaving, reduced cycling of thermal power plants)
- Power reserve
- Ancillary services (e.g. frequency control)

The services span different functions including intra-day storage and storage between days, which could absorb the intermittency of renewable energy sources (Taljegård, 2019). For instance, the function of the power reserve is to be able to respond quickly to a sudden disruption in the electricity system with capacity, which is difficult to guarantee with variable electricity generation. With a higher share of renewables and variable electricity generation in the system, new ways of providing flexibility services are thus needed (Taljegård, Göransson, Odenberger and Johnsson, 2019).

The multiple functions and possibilities of V2G are documented in research. In a systematic literature review, Sovacool et al. (2018) identify four core areas frequently discussed in V2G research, and these are presented in Table 4.4.

Table 4.4 The four most commonly discussed areas in V2G research (Sovacool et al., 2018).

Area	
Renewable energy storage and integration	• Store intermittent energy • Microgrids and independent grids
Grid stability and ancillary services	• Frequency regulation • Peak shaving • Spinning reserves • Interconnection standards
Battery charging and degradation	• Battery performance • Impacting factors • Inconclusiveness regarding battery wear imposed specifically by V2G
Distribution level services	• Voltage support and power quality • Peak shaving and grid planning • Congestion reduction on the distribution network

Mouli, Kaptein, Bauer and Zeman (2016) corroborate these areas by concluding that V2G has “huge potential for the future to match the EV charging with local renewable energy production, providing grid support and ancillary services and optimizing the cost of charging EV”.

Theoretically, the potential of V2G technology is large. It has been concluded that half of Sweden’s total power need could be met during a short period if 60 per cent of the country’s passenger cars were chargeable and V2G compatible (Power Circle, 2020). In reality, the capacity is limited by how many vehicles that are connected to the electricity system. Furthermore, charging that adapts to the needs of the electricity system could conflict with the users’ needs. To be willing to compromise with their needs, users will probably demand some kind of compensation. For instance, a lower charging cost could be offered if the car is not fully charged directly but instead charged during the night when the electricity demand is lower. Considering the users and the fact that all vehicles seldom will be available at the same time, EVs could still contribute with a considerable amount of capacity (Power Circle, 2021a).

4.3.3 Contribution to sustainable development

Although the V2G domain is well-researched, Sovacool et al. (2018) argue – based on their systematic literature review – that the existing research and results predominantly relate to technical aspects. As a consequence, environmental, social and human elements are neglected in V2G research. Sovacool et al. (2018) therefore suggest areas that would broaden the research and make it more nuanced covering more perspectives. Areas relating to sustainable development benefits – mainly environmental and social – are listed below and a discussion of their implications follows.

- Reduced greenhouse gas emissions
- Reduced air pollution
- Enables higher integration of renewables
- Better water management
- Safer and more resilient grids
- More affordable electricity

The V2G technology can play an important part in greenhouse gas abatement by facilitating a higher integration of renewable and intermittent energy sources, enabling the avoidance of carbon-intensive electricity sources and decarbonising the ancillary service market (Sovacool et al., 2018; Turton & Moura, 2008). However, this benefit is based on the assumption that the additional charging that V2G services may entail is not using electricity produced from fossil fuels (Taiebat & Xu, 2019).

Furthermore, V2G compatible cars can reduce air pollution. Besides the low emissions – if any– when driving, V2G could reduce emissions from the electricity sector. Decreased air pollution would in turn lower the risk of acid rain and particulate matter, which are related to negative health externalities (Sovacool et al., 2018).

The possibility of integrating more renewable energy sources into the electricity production could also enable better water management (Sovacool et al., 2008). Water is considered a scarce natural resource (UN-Water, n.d.)

but is nonetheless used in large amounts in steaming and cooling processes in fossil fuel and nuclear power plants (Sovacool et al., 2008). Thus, if renewables could replace water-intensive power plants in the electricity production, the water consumption would decrease.

Moreover, implementing V2G could help build urban resilience, which is important when facing sustainability challenges and natural disasters. With V2G, the availability of secure energy supplies and the reliability of urban grids could be improved (Sovacool et al., 2018; Turton & Moura, 2008). For instance, charged EVs could provide electricity temporarily during a natural disaster, e.g. flooding (Williams & Kurani, 2007). Moreover, the integration of V2G in the electricity system could also improve resilience in non-disaster situations, e.g. reducing grid congestion and hence increasing grid reliability and efficiency (Lund & Kempton, 2008; Sovacool et al., 2018).

From the perspective of the customer collective**,** the integration of V2G in the electricity system could also potentially lead to more affordable electricity (Mohseni & Brent, 2021). For instance, instead of investing in new power lines, flexibility can be made available from new types of flexibility resources (Power Circle, 2022b). Thus, instead of increasing the grid tariffs due to investments, already existing resources, i.e. EVs can be utilised. In addition, the need of investments in peak power plants, i.e. plants that are needed when high demand occurs but activated few hours of the year, could be lowered. Since the peak power plants are idle the majority of the time, investments in them are relatively inefficient (Turton & Moura, 2008).

4.3.4 Compatibility with vehicles and chargers

In the end of 2019, only 20 000 of 100 000 chargeable vehicles were compatible with the V2G technology in Sweden. Apart from the vehicles, the implementation of V2G requires charger stations that are compatible with V2G (Power Circle, 2020).

Making V2G technology possible requires both hardware and software. Firstly, additional power electronics are needed in the vehicle or in the charging station. When an EV is charged today, the power needs to be converted from alternating current (AC) to direct current (DC), which is done either by the vehicle or the charging station. Conversely, equipment converting DC to AC is needed when discharging the vehicle. Secondly, the V2G software needs to be more complex compared with conventional charging. V2G requires an information exchange between the vehicle and the charging station including, among other things, battery status, electricity agreements, technical parameters, time and location stamps (Power Circle, 2020).

The technical ISO standard 15118 addresses the technical regulations including both hardware and software. This standard is still under development and hence not fully established.[10] It is, however, of great importance that a consistent standard is created since bidirectional charging requires the implementation of ISO 15118 in both the vehicle and the charging station (Power Circle, 2020). It is believed that the standard will accelerate theV2G market (Virta, n.d.).

V2G is currently not possible with AC charging. The onboard chargers of the existing EVs do not support discharging and the communication protocol for AC charging is not compatible with a bidirectional flow of energy (Mouli et al., 2016). Hence, DC is used in the V2G installations existing today.

Technically, it does not matter if the EV is discharged with AC or DC. However, the chosen setup will affect the cost and the need for equipment (Power Circle, 2020). From the car perspective, DC is most optimal. The battery would be connected to a charger station, which converts DC to AC before feeding it back into the grid. In this setup, the power electronics of the charger station are the key component besides the battery. On the other hand, using AC reduces the complexity of the charger station – in its most simple form, it can be a wall outlet. In this case, however, the car needs to have power electronics onboard that can convert DC to AC (Power Circle, 2020).

4.3.5 V2G's impact on battery performance

V2G and its implementation cannot be discussed without a notion about the health and lifespan of the battery. Research in this area is ongoing, and this section will present the different viewpoints. In general, factors such as the temperature, physical age, state-of-charge (SOC), depth of discharge and the number of full discharges affect the health of the battery (Power Circle, 2020). However, the question is whether a car battery used in V2G applications will degrade faster than a battery that is not used for V2G.

[10] Note that the standard 15118-20:2022 was published in the final phase of the study (ISO, 2022).

Research studies have come to different conclusions. On the one hand, Dubarry, Devie and McKenzie (2017) demonstrated that the battery will degrade significantly if V2G is used to maximise the profit. In this context, maximising means "selling as much capacity as possible during one-hour periods where the grid needs it the most" (Uddin, Dubarry & Glick, 2018). On the other hand, Uddin et al. (2017) state that the battery's lifespan can be extended through charging controlled by smart algorithms, which use a battery degradation model to optimise the charging and discharging cycles. Although both these studies' results can be questioned based on their assumptions, simplified simulations, etc. (Uddin, Dubarry & Glick, 2018), they demonstrate the diverse perceptions that exist in the researcher community on this subject.

The hypothesis that a battery's lifespan can be extended is particularly relevant when comparing controlled bidirectional charging to not using the battery at all. For instance, low temperatures in combination with a high SOC affect the battery's lifespan negatively.[11] However, there are many other influencing factors as well. Hence, more studies need to be conducted on this matter in order to get scientific evidence.

4.4 Summary of market potential for V2G

The car fleet electrification is evident as the share of new registered EVs continues to grow every year. In 2022, it is estimated that EVs will account for 60 per cent of the new registrations in Sweden. However, an electrified transport sector will increase the electricity demand. This could present challenges for the electrical grid, which already today is strained on occasions, resulting in, e.g. power shortage. To create more flexibility and solve the problems, investments in new power lines have historically been the measure taken. However, the technology development has opened up for new opportunities, among others, flexibility resources. The characteristics of its battery make the EV a flexibility resource that not only can adapt its consumption but also feed electricity back into the grid.

The flexibility can be offered in two types of markets, which have been created to solve different problems. However, there are certain requirements

[11] Jerry Svedlund, Head of research at CTEK, interview 28 April 2022

that need to be fulfilled to be able to participate in these markets. Given that EVs qualify as a flexibility resource in them, several studies have shown the potential of V2G to support the electrical grid. In addition, V2G is believed to have the potential to contribute to sustainable development by, e.g. reducing greenhouse gas emissions. However, before mass-market establishment of V2G can take place, some parameters need to be clarified, e.g. standardisation and whether the bidirectional flow will have an impact on the battery.

5 Potential

In this chapter, the potential of providing flexibility services at Axess Logistics is investigated. Firstly, the reason why the company is interested in V2G and its possible areas of application is explained. Thereafter, Axess Logistics' capacity is discussed in relation to the existing flexibility markets.

5.1 Willingness

In the transformation and turbulence of the automotive industry, Axess Logistics wants to investigate if new business opportunities arise. In some cases, this could even mean opportunities that are decoupled from their traditional car services. With the growing share of EVs in mind, the V2G technology is highly relevant. A possible agreement could be that the car owners, i.e. the general agents, allow Axess Logistics to use their cars in V2G applications if they, in exchange, e.g. get a discount on the maintenance service. Moreover, Axess Logistics argues that controlled and slow bidirectional charging would not risk degrading the battery. In fact, maintenance charging and discharging is a requirement from car manufacturers if the car is in storage for a longer time period. [12] Also, due to the continuous flow of cars, the EVs' batteries would most probably only be cycled a few times in V2G applications at Axess Logistics. [13]

Combining V2G and the provision of flexibility, Axess Logistics sees an opportunity to contribute to sustainability. Furthermore, by storing energy produced by their solar PVs and participating in flexibility markets, the company would contribute with renewable energy in the electrical grid. As this concept is not the company's core business, it is seen as a learning and growth opportunity. If Axess Logistics would introduce the provision of

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[12] One to three months, depending on the car brand.

[13] Mattias Öhrn, Key account manager at Axess Logistics, interview 16 May 2022.

flexibility services, it would initially be regarded as an investment in knowledge and a way of providing social benefits. Thus, maximising the profit would not be of the highest importance.[14]

5.2 Capacity

Being a provider of flexibility, one has to meet several requirements. For instance, both Svenska kraftnät and local flexibility markets require that flexibility bids are at least the size of 0.1 MW, and another requirement concerns the endurance time (Power Circle, 2022b; Svenska kraftnät, 2022e). To evaluate their capacity, Axess Logistics has created a graph illustrating the available battery storage capacity per day (see Figure 5.1).[15] In addition, the Malmö facility's energy production from the solar PVs is included. The graph is based on both empirical and forecasted values, which will be explained below.

Initially, the following assumptions are made in this section:

- Only BEVs are used to provide flexibility services since their batteries are larger than batteries in hybrid EVs[16]
- BEVs and charging stations are compatible with V2G
- BEVs are parked and connected to charging stations
- V2G does not impact the batteries negatively

Additional assumptions have been made in the graph, and these will be presented in Section 5.2.1.

[14] Dimitris Emmanouilidis, Production manager at Axess Logistics, interview 16 May 2022.

[15] Fredrik Merell, System controller at Axess Logistics, 25 April 2022.

[16] Hybrid EVs are cars that have both an internal combustion engine and an electric motor (Kvdbil, n.d.a).

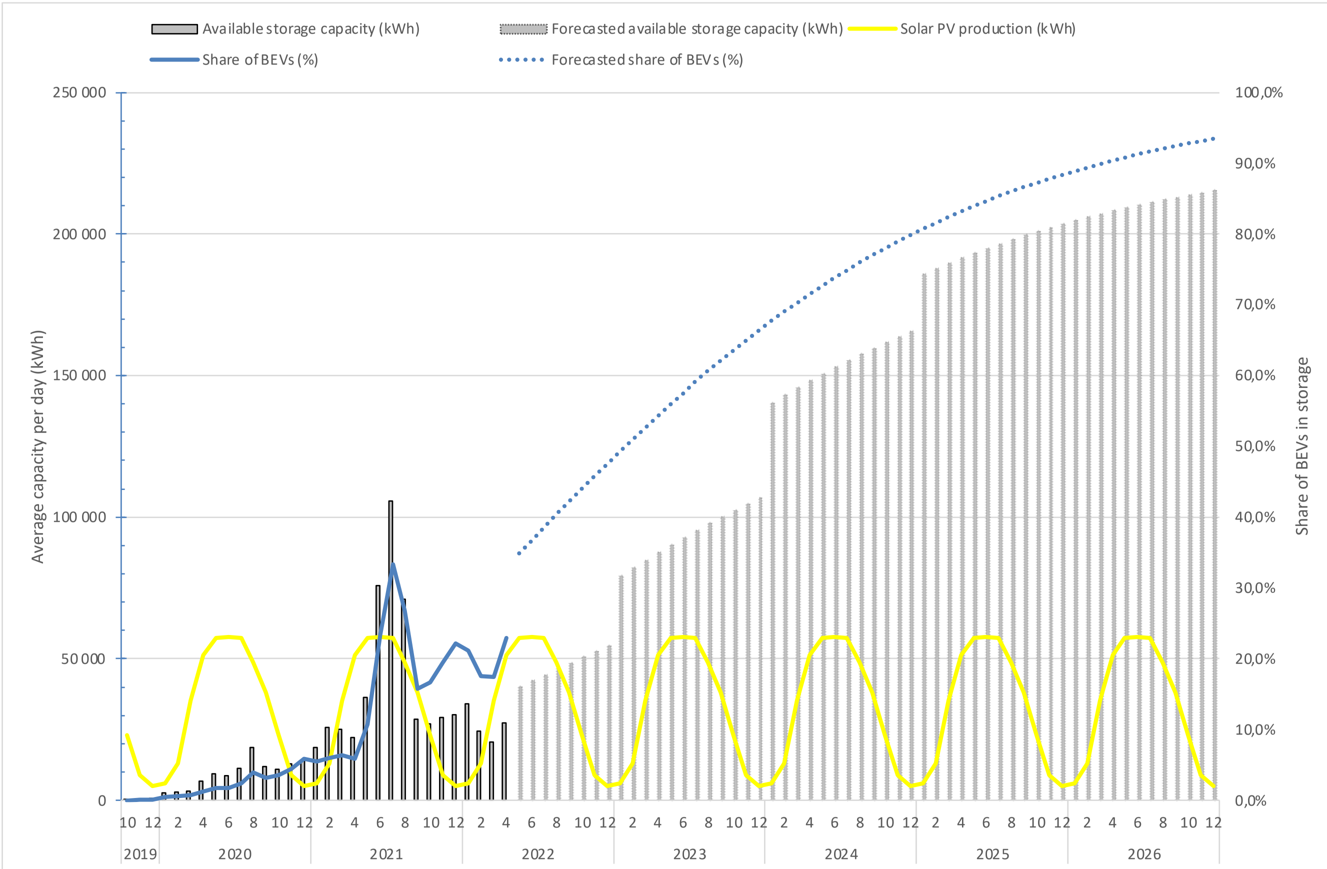

Figure 5.1 The available storage capacity and solar energy production at Axess Logistics.

5.2.1 Explanation of graph

- Yellow line: produced solar energy per day (kWh)
- Dark grey staples: battery storage capacity per day (kWh)
- Blue line: share of BEVs in storage (%)
- Light grey staples: forecasted battery storage capacity per day (kWh)
- Blue dotted line: forecasted share of BEVs in storage (%)

The yellow line represents the daily production of solar energy at Axess Logistics. It can be observed that the production follows a seasonal variation, where the peaks correspond to the summers while the dips represent the winters. Since the installation of the solar panels was done in October 2021, Axess Logistics has not yet a complete year of production data. Hence, the solar energy production has been retrieved from other sources (HemSol, 2021). Furthermore, energy losses occurring, e.g. during charging, are assumed to be 15 per cent[17] and included in the graph.

The blue line indicates the share of BEVs in storage at Axess Logistics historically. Moreover, the dark grey staples represent the battery storage capacity per day, where a BEV historically has had a 57.7 kWh battery on average. However, V2G will only be used in a certain battery cycle interval. It is therefore assumed that 80 per cent of the battery will be available for flexibility services, which means that 46.2 kWh could have been utilised theoretically.

The blue dotted line represents the growing share of BEVs in storage. With data from Mobility Sweden (n.d.), Axess Logistics has forecasted the growth in the coming years (see Figure 4.2). The share of BEVs was multiplied by the forecasted storage volume on an average day (see Table 5.1) to get the total number of BEVs at a given time.

[17] Based on empirical data from Axess Logistics.

Table 5.1 The assumed daily storage volumes in the coming years.[18]

Year	*Volume per day*
2022	2500
2023	3500
2024	4500
2025	5000
2026	5000

Furthermore, the available battery storage capacity of a BEV was assumed to be 45 kWh. By multiplying the number of BEVs and the battery storage capacity of a BEV, the daily total battery capacity was determined, which the light grey staples represent.

It should be mentioned that the forecast of the storage volumes is relatively conservative as the current challenges in the automotive industry are taken into consideration. The storage volume is at historically low levels due to supply chain problems. Earlier, the storage volume has been around 10 000 vehicles.[19] Thus, if the storage volume returns to historical figures, even more battery storage capacity will be available.

The blue line has an interruption due to that there is a difference between the actual share of BEVs in storage and the forecasted share. Due to high buyer demand in combination with supply chain problems, the BEVs are called-off and transported away instantly instead of being stored.[20]

When the yellow line is above the staples, the entire battery storage capacity can be charged by solar energy. Additionally, the rest of the energy can be used in Axess Logistics' buildings or sold directly to the grid. Contrary, i.e. when the yellow line is below the staples, the solar energy production does not cover the battery storage capacity. Thus, if all BEVs are to be charged, external electricity from the grid needs to be purchased. In the graph, it is evident that the battery storage capacity will exceed the produced solar energy in the coming years.

[18] Dimitris Emmanouilidis, Production manager at Axess Logistics, interview 28 March 2022.

[19] Dimitris Emmanouilidis, Production manager at Axess Logistics, interview 28 March 2022.

[20] Mattias Öhrn, Key account manager at Axess Logistics, interview 28 March 2022.

5.2.2 Potential of ancillary services

The ancillary services deemed most relevant to Axess Logistics are *Fast Frequency Reserve* (FFR) and *Frequency Containment Reserve - Disturbance* (FCR-D) due to requirements of smaller bid sizes and shorter endurance.[21] Although only these ancillary services will be investigated in this section, it should be mentioned that Axess Logistics could potentially participate in other ancillary service markets as well.

In a pilot project, the Norwegian system operator Statnett and the aggregator Tibber tested if residential EV charging stations could provide flexibility to the FFR market. The conclusion was that EVs are capable of providing FFR with technical viability (Entsoe, n.d.). Furthermore, a Danish project named Parker concluded that EVs have – through bi-directional power exchange – the ability to perform demanding and advanced grid services, such as FCR, that require a fast, accurate and precise response (Andersen et al., 2019b).

FFR is activated at low levels of rotational energy to manage frequency changes (Svenska kraftnät, 2021i). To restore the frequency, the electricity production needs to increase. In Axess Logistics' case, this means that the BEVs are discharged. For FCR-D, Svenska kraftnät makes a distinction between if the frequency needs to be regulated upwards or downwards, resulting in the two services *FCR-D upp* and *FCR-D ned* (Svenska kraftnät, 2022e). The former raises the frequency through more production[22], e.g. discharging BEVs, while FCR-D ned lowers the frequency by increasing the consumption, e.g. charging BEVs.

Table 5.2 lists the requirements for each of the relevant ancillary services. The activation time requirement is assumed to be met since batteries respond quickly (Andersen et al., 2019a; Vattenfall, 2020a), and is therefore not included as a limiting factor in the calculations below. Other requirements are assumed to be fulfilled as well, e.g. real-time measurement and delivery as a – or via – a balance responsibility party. However, it should be noted that FFR is not yet regulated in the balance responsibility agreement (Svenska kraftnät, 2021i). It is also worth mentioning that the remuneration models for FFR and FCR-D are based on available capacity (Svenska kraftnät, 2022c).

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[21] Maria Edvall, Senior project manager at RISE, interview 7 April 2022.

[22] The frequency can be regulated upwards by stopped charging as well, but that does not include V2G.

Table 5.2 The requirements for FFR and FCR-D (Svenska kraftnät, 2022e).

	FFR	*FCR-D upp*	*FCR-D ned*
Minimum bid size	0.1 MW	0.1 MW	0.1 MW
Endurance	5 or 30 seconds	20 minutes	20 minutes

Assuming a bid size corresponding to the minimum requirement of 0.1 MW and a charging capacity of 11 kW[23] results in a need of 10 BEVs. If the available battery of each BEV is 45 kWh, the total available battery storage is 450 kWh with the assumption that all BEVs are sufficiently charged. This amount of energy exceeds the energy required in the minimum bids for all three ancillary services (see Table 5.3).

Table 5.3 The energy required in the minimum bid sizes.

	FFR	*FCR-D upp*	*FCR-D ned*
Minimum energy amount	0.14 kWh (5 sec) 0.83 kWh (30 sec)	33.3 kWh	33.3 kWh

Besides fulfilling the requirements presented above, one has to take the recovery time into consideration. The provision of FFR needs to be available again in 15 minutes, while an energy storage providing FCR-D needs to have a recovery time within 2 hours (Svenska kraftnät, 2021d, 2022e). For Axess Logistics, this means that the dimensioning of the number of BEVs in the V2G resource pool is important in order to align with the bids placed in the market. For instance, it may be sufficient to have 10 cars for one bid. However, if Axess Logistics want to place more than one bid during a day, parameters, such as charging capacity, need to be taken into account, which may mean that more BEVs are needed. A larger quantity of cars given the same bid size would also mean that less of each BEVs' battery was discharged, reducing the potential risk of battery degradation.

The requirements may, however, soon be changed to make it easier for limited energy reservoirs, e.g. EV batteries, to participate in the FCR-D markets (Svenska kraftnät, 2021c, 2021d). More adapted requirements could present new opportunities and increase the financial liquidity as they open up for more technologies in the market, which in turn will spread the risks and

[23] Average value based on empirical data from Axess Logistics.

increase the effectiveness (Svenska kraftnät, 2021c). These changes will most likely affect the FFR market as well (Svenska kraftnät, 2020a).

Another aspect is how and when the ancillary services are purchased by Svenska kraftnät. FFR are purchased annually, while FCR-D is purchased one to two days in advance (Svenska kraftnät, 2022c). Since Axess Logistics has a continuous flow of cars and is dependent on deliveries, it might be more optimal to choose a service where the bids can be submitted just a few days ahead of delivery. A forecast of available storage capacity made two days before delivery is most likely more accurate than one that is made one year ahead.

Lastly, it is possible to participate with the same flexibility resources in both the FFR and FCR-D markets since they are activated at different frequency levels. However, it is not possible to be called-off for the same capacity in both markets at the same time (Svenska kraftnät, 2020e).

5.2.3 Potential of local flexibility markets

The local flexibility market closest to Axess Logistics in Malmö is CoordiNet Skåne. With the correct dimensioning of EVs, the minimum bid size of 0.1 MW and endurance time of 60 minutes should be reached. The most suitable product is probably free bids as they can be placed continuously during the season and are often called-off one day before activation. This enables Axess Logistics to place bids corresponding to the momentary battery storage capacity, which mitigates the risk of not having sufficient capacity. Availability agreements, on the other hand, require that Axess Logistics can guarantee a quantity of available power over a longer period of time, which can be difficult with varying storage volumes. However, an alternative could be to offer flexibility in availability agreements via an aggregator, which can aggregate more and different types of resources.

One should bear in mind that the local flexibility markets are under development and the market design is not fully established. If a bid has been activated in the pilot markets, it has often been for an educational purpose rather than demand-based (Power Circle, 2022a). In the future, the market requirements will probably be stricter and the products might be changed.[24]

[24] Maria Edvall, Senior project manager at RISE, interview 7 April 2022.

5.2.4 Cost-optimal charging and discharging

The economic viability of V2G is partly dependent on price differences in the electricity market. Axess Logistics' strategy should be to charge at a low price, i.e. directly from the own solar energy production or when the spot price is low. When the electricity is fed back into the grid, it should be at a higher price. For instance, assume that a number of cars were charged by solar energy. This electricity could then be sold in one of the relevant ancillary markets resulting in a remuneration based on available capacity. If the production bid also was activated, there would be an additional revenue stemming from the electricity provided to the energy trading company. Another alternative is to place a free bid in a local flexibility market and be called-off there.

Furthermore, the viability of the ancillary service FCR-D ned should be addressed. In this market, Axess Logistics would participate by placing consumption bids, i.e. the cars would be ready[25] to start charging if the bid was called-off. In other words, Axess Logistics would be remunerated for an activity they would need to do regardless of participation in the ancillary market or not. Note, however, that Axess Logistics still have to pay the electricity supplier for the electricity according to their bilateral contract. Moreover, if the trading is made via a balance responsibility party, this actor demands a fee as well.

To quantify the economic viability, a more detailed analysis on an hourly basis needs to be conducted. It will, however, not be done in this study due to the lack of data (e.g. actual solar production) and confidentiality reasons (e.g. Axess Logistics not wanting to disclose electricity costs) as well as the limited scope of the thesis.

5.3 Summary of Axess Logistics' potential

Axess Logistics has a willingness to investigate new business opportunities. Observing the growing share of BEVs and having knowledge of the V2G technology, the company finds the flexibility markets interesting. In addition,

[25] A bid can be called-off without being activated.

Axess Logistics regards the concept as a possibility to contribute to a more sustainable society.

The potential and viability of participating in the flexibility markets depend on the company's capacity. It could be concluded that Axess Logistics has a sufficient quantity of storage capacity to reach the minimum bid size of the local flexibility market CoordiNet Skåne as well as the most relevant ancillary services, namely, FFR, FCR-D upp and FCR-D ned. However, important aspects to take into consideration when placing bids are, among others, the varying storage volume and the possibility of taking advantage of price differences in the electricity market.

6 External factors

Apart from the internal potential, external factors play a role in the implementation of flexibility services at Axess Logistics. This chapter lists factors that need to be taken into account when developing the concept. However, since the establishment of V2G is in its inception and, hence, there is uncertainty regarding its implementation, the list of factors should not be considered exhaustive.

6.1 General agents

Since Axess Logistics does not own the cars passing the facilities, the possibility of using the EVs in V2G applications is dependent on the general agents' permission. Some of the general agents have been interviewed[26,27], and the collected data are presented in this section.

Although a common concern in the context of V2G, the general agents are not too worried about the potential battery degradation and are, hence, not instantaneously negative towards V2G. One of the general agents says that batteries are fairly durable according to studies he has read. However, it is possible that V2G will affect the warranties.

Another general agent says that the battery type, charging speed, temperature and power are more important than the V2G technology itself. If V2G is implemented correctly with DC and the charging and discharging cycles are relatively slow and controlled, the battery will not degrade significantly. He states that slow DC discharging could be seen as equal to driving the car, which does not harm the battery. The general agent emphasises that the implementation of flexibility services at Axess Logistics would mean that multiple cars are discharged in order to provide flexibility. Hence, it is not a

[26] General agent A, Head of logistics, interview 16 March 2022.

[27] General agent B, Product and logistics manager, interview 21 March 2022.

question of one single car that is charged and discharged over full cycles several times, which lowers the risk of potential battery degradation.

However, whether the battery's lifespan degrades, extends or stays unaffected is not scientifically proven yet. Until more studies are conducted, discussions regarding this matter are mostly based on speculations and hypotheses according to one of the general agents.

Another aspect of V2G and flexibility services is the possibility of stabilising the grid and integrating more renewable energy sources in it. The general agents have a positive attitude towards providing social and environmental benefits. However, it was emphasised that economic incentives are most important.

6.2 Car manufacturers

The V2G compatibility of cars affects Axess Logistics' potential to provide flexibility services. During one of the general agent interviews, it was stated that the willingness to introduce V2G in cars varies among car manufacturers. For instance, some car brands are very conservative and are not willing to implement new and relatively untested technology. They try new technology with "belt and suspenders", which makes the implementation slow. However, other brands want to be perceived as innovative, which makes them more prone to include the latest technology in their cars.[28]

6.3 End customers

End customers were not included as a respondent group due to the study's delimitations. However, their impact on V2G possibilities surfaced during several of the interviews. Although not directly linked to Axess Logistics' potential to offer flexibility services, end customers affect the diffusion rate of the V2G technology. More end customers demanding EVs with V2G possibilities will create a market pull, incentivising car manufacturers to produce and sell V2G compatible cars. The number of V2G compatible cars

[28] General agent B, Product and logistics manager, interview 21 March 2022.

passing Axess Logistics' facilities will have a direct impact on the company's available storage capacity.

The situation of V2G could be described as a chicken-or-egg problem. On the one hand, it is up to the car manufacturers to make their EVs compatible with V2G. On the other hand, the car buyers must be willing to pay for the technology taking into consideration potential earnings and pay-off time.[29] End customers could be reluctant to buy a V2G compatible car if it turns out to be more expensive compared to one without the technology installed. To incentivise them to buy a V2G compatible car, a solution could be subsidies. For instance, the car owner could get additional compensation in the Bonus malus system.[30,31]

General agents and car manufacturers believe that V2G and storage opportunities will become must-have attributes for end customers in some years. Hence, car manufacturers plan to offer V2G compatibility in the future even though few cars are compatible with the technology today. It is believed that the next generation of EVs will have more possibilities to be integrated with buildings as well as the electrical grid. Furthermore, the younger generation of buyers will probably demand functions such as V2G to a larger extent. Although the strongest driving force is often the economic incentives, they may also have other incentives, e.g. wanting to live a more sustainable lifestyle.[32]

Studies point out that the potential cost of battery degradation is a considerable barrier to customer adoption of V2G (Hu, Martinez & Yang, 2017). Even if the customer has the possibility of saving or earning money in V2G applications, the amount might be too small to compensate for the vehicle owner's concern regarding battery degradation and the impact V2G will have on the vehicle's availability. On the other hand, if the owner values sustainability, the environmental benefits of V2G can outweigh the concerns (Wang, Sharkh & Chipperfield, 2016).

[29] Ulf Wengeler, CEO of SolarVolt, interview 31 March 2022.

[30] Ulf Wengeler, CEO of SolarVolt, interview 31 March 2022.

[31] Maria Edvall, Senior project manager at RISE, interview 7 April 2022.

[32] General agent B, Product and logistics manager, interview 21 March 2022.

6.4 Regulations and policy instruments

Power Circle (2020) highlights the importance of how the energy tax and other policy instruments are designed to incentivise V2G. There could be a reason to direct the customers towards the implementation of new technology – in this case, V2G – with financial support and legislation. This was brought up during some of the interviews as well. For instance, additional subsidies could be given to people buying a car or charging box compatible with V2G.

Changes in the Bonus malus system could influence the new sales of EVs. For instance, the relatively low price of private leasing an EV is a result of Bonus Malus.[33] A reduction or removal of the subsidy would most probably decrease the growth rate of EVs. Furthermore, car manufacturers will be affected by coming regulations, which are stricter regarding emissions of new produced cars. This will most probably further increase the share of EVs that are launched in the market.[34]

When V2G is more established, it is possible that the government will introduce more regulations and laws concerning the technology and its applications. A possible regulation could address how and in which quantities companies are allowed to sell electricity from car batteries, which Axess Logistics would have to comply with.[35]

The design of the different flexibility markets is also of importance. For instance, the local flexibility markets are under development, and their products and requirements will affect Axess Logistics' potential to participate in the markets. Another example is that the Nordic countries will introduce a 15-minutes time resolution for settlements and trading in 2023. Among other things, this change will promote the use of flexibility (Svenska kraftnät, 2022a).

[33] General agent B, Product and logistics manager, interview 21 March 2022.

[34] General agent B, Product and logistics manager, interview 21 March 2022.

[35] Mattias Öhrn, Key account manager at Axess Logistics, interview 16 May 2022.

6.5 Summary of external factors

The possibility of providing flexibility services with EVs is dependent on multiple external factors. As few EVs are compatible with V2G today, it is first necessary that car manufacturers start to launch car models with the technology. An incentive for them to do it could be a large end customer demand, creating a market pull. It is believed that the younger generation of buyers will demand additional functions in their cars, such as V2G, which most likely will have an impact on how car manufacturers choose to develop their products.

Given that V2G compatibility is standard in EVs, it is nevertheless not uncomplicated for Axess Logistics to start offering flexibility services. The general agents owning the cars must allow Axess Logistics to use the EV batteries as flexibility resources. Hence, an important parameter is whether V2G will have an impact on the batteries' lifespan.

In addition, existing and future regulations and policy instruments will affect the concept's feasibility. They can either complicate the implementation, e.g. additional taxes decrease the economic viability, or promote it, e.g. less strict market requirements simplify the qualification process for flexibility resources.

7 Barriers

Building on the collected data, a framework consisting of barriers to the implementation of flexibility services at Axess Logistics was developed. These are deemed to affect the adoption rate of the concept. Moreover, the barriers and possible solutions to overcome them are discussed in the context of the Diffusion of innovations theory. Lastly, Axess Logistics' comments and reflections regarding the barriers are presented.

7.1 Framework

In order to identify barriers to the implementation of flexibility services at Axess Logistics, the structuring of the analysis was, as earlier mentioned, inspired by Gioia, Corley and Hamilton (2012). In other words, informant terms were grouped into 1st order concepts. These concepts were reduced into 2nd order themes, which in turn were distilled further into aggregate dimensions that correspond to barriers (see Figure 7.1). The identification and analysis of the barriers were made by the author of the thesis. However, the analysis was based on collected data from the document study and the interviews. Moreover, the author used the Diffusion of innovations theory (described in Chapter 3) to suggest and discuss solutions to overcome the barriers.

Due to the novelty of the V2G technology, it can be difficult to distinguish between general barriers and barriers specific to Axess Logistics. Therefore, the identified barriers will be discussed both in the context of Axess Logistics and on a higher, more overarching level in the coming sections.

Furthermore, the barriers are neither mutually exclusive nor unrelated. Although not visualised in Figure 7.1, there are 1st order concepts that relate to several barriers in one way or another. In the study, however, the 1st order concepts were only linked to the most relevant 2nd order theme. It should also be noted that some of the barriers may be difficult for Axess Logistics to influence, but it is nevertheless of value that the company is aware of them.

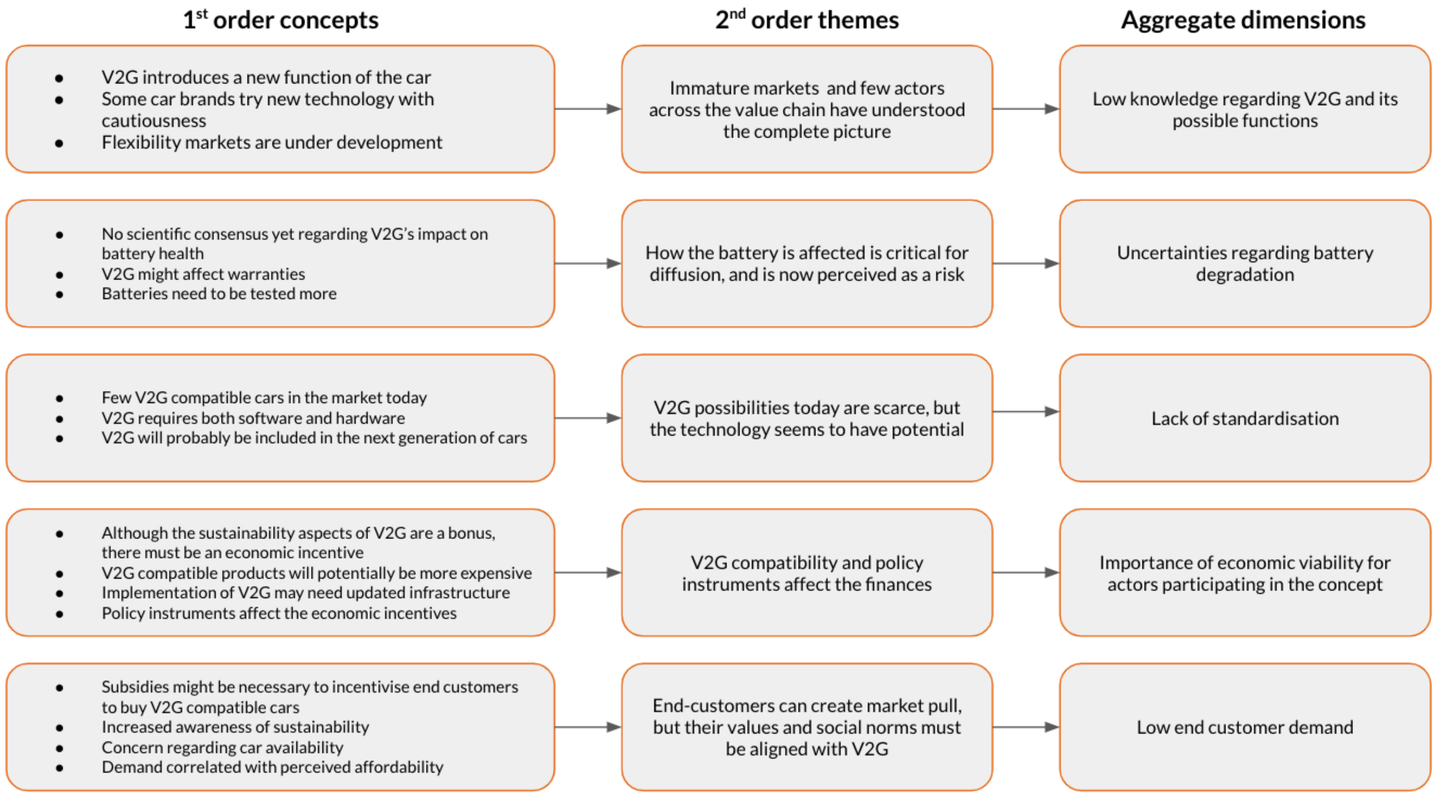

Figure 7.1 The analysis resulted in five aggregate dimensions, which represent barriers to the concept.

7.1.1 Low knowledge regarding V2G and its possible functions

When interviewing different actors across the value chain, it became evident that the knowledge of V2G varies. However, the knowledge is deemed to be relatively low in general. In turn, this knowledge gap – leading to an immature market – constitutes a barrier to diffusion. A possible aspect contributing to the barrier is that V2G redefines the function of the car. From being only a mode of transport, it is now also an energy storage. This new function can make it difficult for customers to compare it relative to something else, in turn making it difficult to observe the relative advantage. How the storage capacity can be utilised, e.g. provision of ancillary services is even more unknown by the actors. Furthermore, using the car as a battery may also conflict with the current social norms and user behaviours.

To mitigate the barrier of low knowledge while V2G diffuses, Axess Logistics could work as a knowledge hub reducing the perceived complexity. This can be done on a theoretical level but also more practical. A first step could be to inform the general agents about the possibility of using the car batteries as flexibility resources. Given that the necessary infrastructure is installed at Axess Logistics' facility, general agents could try out the concept before deciding if they want to adopt it fully. A full-scale V2G installation could also make it possible to observe the relative advantage in reality. Furthermore, Axess Logistics could be intentional in their communication to others, e.g. adapting the quantity and detail-level of the information based on the target group to avoid making the concept more complex to understand than necessary.

In addition, the willingness to try new technologies differs between car manufacturers. Some of them will not introduce V2G in their cars until more knowledge and information regarding the technology exist. However, the strategy could be to target the car manufacturers, and their general agents, that are less risk-averse. Related to Rogers' adopter categories, these could be seen as innovators and early adopters (Rogers, 1995, pp. 263-264).

Apart from the possibility of additional revenues, there are more benefits to V2G. However, those benefits are not always evident, which leads to the discussion of the immediacy of the reward. The avoidance of electrical grid problems with help from flexibility resources is a preventive measure, i.e. the relative advantage is a non-event, which makes it more difficult to observe.

7.1.2 Uncertainties regarding battery degradation

There is one question that needs an answer before V2G can become fully established in the market; whether the bidirectional energy flow will contribute to significant degradation of the battery or not. If V2G turns out to be harmful, it would not be advantageous, but it does not automatically disqualify V2G from market establishment. However, it is a factor that has to be taken into account. For instance, car owners could still accept V2G if the investment could be motivated by revenues from selling flexibility.

It should be emphasised that the batteries of BEVs at Axess Logistics providing flexibility services would probably only be cycled a few times. Also, if Axess Logistics dimensions the concept to include a large pool of cars but does not maximise the available capacity, each battery will individually be cycled less. Furthermore, cars that are in storage for a longer time period must be charged and discharged according to maintenance requirements from the manufacturers. This maintenance charging could be done in combination with the provision of flexibility services. In exchange for that Axess Logistics get to use the battery, the general agents can be compensated, i.e. get a discount on the maintenance service.

General agents expressed that more tests regarding EV batteries and V2G need to be done to get scientific evidence since all they have now is hypotheses. However, general agents might be reluctant to take risks. A way of enabling these tests and pilot projects is that Axess Logistics bears the risk, e.g. financially compensates the general agents if it turns out that V2G causes battery degradation. On the other hand, if V2G turns out to extend the battery's lifespan, the relative advantage would be evident and easy to understand and observe.

7.1.3 Lack of standardisation

As suggested by several respondents, the lack of standardisation is a significant barrier to the establishment of V2G. Few cars today are compatible with V2G, although car manufacturers say they will launch cars with the function within the next few years. A clear standard could potentially catalyse the introduction of V2G by mitigating the perceived risks. For instance, car manufacturers can be afraid of investing in the "wrong" technology, i.e. one that will not be compatible with the future standard. Furthermore, the standard could reduce the complexity of using V2G.

For Axess Logistics, it may be difficult to affect the standard and its design. However, the company should nevertheless stay updated on the ISO 15118 standard. If decisions or investments are made, they should be done with the standard taken into consideration.

This barrier's compatibility – or lack of – is mostly related to technology and not the users' values. Nonetheless, it is of importance that, e.g. communication and control protocols are compatible with each other and do not constitute a barrier to diffusion.

7.1.4 Importance of economic viability for actors participating in the concept

It has become evident that the economic side of V2G cannot be neglected, which may not come as a surprise. However, since V2G can contribute to social and environmental sustainability, one could believe that the economic aspect potentially had less significance. An insight is that all involved actors need to see some kind of financial gain – however, it does not have to be the largest one.

Brought up during the interviews, the legislation and policy instruments will have a direct impact on the economic viability. For instance, regulations and taxes concerning sold electricity from V2G installations will affect the economic incentive to use the technology. Furthermore, the market design of flexibility markets will inevitably determine which actors that can participate and find incentives to invest in the required infrastructure. The markets are still under development, which leads to uncertainties regarding the potential to participate and possible earnings. However, markets still being in a development phase should not only be seen as a disadvantage. With no established market design yet, participating actors have a possibility to influence it, e.g. in pilot projects. Both Svenska kraftnät and the local flexibility markets have stated that they want to make it easier for new flexibility resources to participate and, hence, take input from actors participating or wanting to (Power Circle, 2022a; Svenska kraftnät, 2020b).

Although the demand for flexibility is believed to increase with a more electrified society, the viability of having flexibility resources may decrease over time. Given that the demand stabilises at some point, but more flexibility resources continue to enter the markets will result in a lower price according to the theory of supply and demand. This could mean lower viability and more uncertainty regarding if the bids will be called-off.

One thing that could lower the threshold related to the economic risk for actors participating in the concept is that Axess Logistics can provide an infrastructure including charging stations and solar PVs. General agents could then try the concept without making their own investments in infrastructure.

Another aspect is the possibility of contributing to social benefits through V2G and the provision of flexibility. As Axess Logistics, other actors could find flexibility services as a way to contribute to sustainability – if it is compatible with their values. If the same actors do not regard flexibility services as their core business, the economic profit could be of secondary importance.

7.1.5 Low end customer demand

Customer demand creates a market pull that companies need to cater to – at least if they want to stay relevant and survive in the market. The respondents say that end customers, i.e. the ones that can create a market pull, generally have a low level of awareness and knowledge regarding V2G. If explained, the end customers understand the principles of the technology. However, according to the respondents, it is more difficult for them to understand how it will work in practice due to its complexity. If the end customers do not see the advantage of V2G, they will not demand it in the market leading to a lower number of V2G compatible cars.

Furthermore, it has been suggested that if V2G compatibility increases the price of the car, end customers would be hesitant to buy it as long as they cannot see the added value. Hence, the added value should be communicated in a way that makes it possible for end customers to understand and observe the relative advantage. In addition, more power shortage situations in the future can make the benefits of V2G become evident if a car owner can store electricity in the battery and then feed it back into the own building independent of the electrical grid's status. For others, the possibility of increasing the integration of renewable energy sources, and hence lowering the use of fossil fuels, could be appealing.

A way to get V2G compatible cars to attract attention in the market could be to call them something more than just EVs. Consequently, the V2G function would be more highlighted and noticed. By creating a new segment in the market, it could be easier to reach customers whose social norms and values are compatible with V2G, e.g. people with sustainable lifestyles or others interested in technical innovations. As innovators and early adopters, these customers would be the first ones to adopt V2G compatible cars. According to Rogers (1995, p. 264), they would then contribute to the diffusion in the market. For instance, an innovator's lower electricity cost could be observed, or one could even try the V2G technology at an innovator's house without needing to make own investments.

Furthermore, it has been suggested that the younger generation of buyers will demand cars that are more integrated with their homes. Hence, the V2G technology would be compatible with this demand. Lastly, Rogers (1995, p. 219) acknowledges that subsidies can speed up the diffusion process by increasing the relative advantage. Thus, subsidising cars with V2G compatibility could create a greater end customer demand.

7.2 Workshop

During a workshop, the results of the study were presented to the supervisors[36,37] at Axess Logistics. They were asked to comment and reflect upon the identified barriers. Furthermore, the supervisors were asked to discuss the findings regarding Axess Logistics' potential as well as which implications the study could have for the company in general. The takeaways from the workshop are summarised and presented in this section. By reason of that a new standard, ISO 15118-20:2022, was published in the final phase of the study (ISO, 2022), a short comment regarding it is included as well.

7.2.1 Comments on identified barriers

Axess Logistics agrees with the fact that the knowledge level is low across the value chain. In the industry, V2G has become a buzzword while few actually understand what it means. The supervisors have the perception that many talks about V2G without even knowing if their cars are compatible with the technology or the potential areas of application.

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[36] Dimitris Emmanouilidis, Production manager at Axess Logistics, interview 16 May 2022.

[37] Mattias Öhrn, Key account manager at Axess Logistics, interview 16 May 2022.

The supervisors acknowledge that Axess Logistics too still have a lot to learn in this area. Therefore, seeing the concept as a learning opportunity, they are willing to take help from other actors with more expertise, e.g. aggregators, although it could decrease the profit. Furthermore, Axess Logistics hopes that more actors will see the concept as a learning and growth opportunity instead of only focusing on maximising the profit. However, the company recognises the barrier connected to economic viability.

Axess Logistics had not thought of the possibility of being a knowledge hub but finds the idea interesting. The supervisors state that innovation should be driven by knowledge and facts, not "gut feelings" and hypotheses. Furthermore, they believe that Axess Logistics could be a company that helps to provide others with facts.

Moreover, the supervisors believe that the reason why some people have a negative attitude towards V2G depends on a low knowledge level regarding the technology. If people assume that V2G would mean that the battery is charged and discharged completely several times, their fear of battery degradation is valid. However, that is not how V2G is supposed to work. V2G will use the battery in a predetermined charging interval and discharge at a slow speed. Axess Logistics stresses that it is a requirement in the cars' maintenance plans to discharge slowly, which speaks for that V2G is not detrimental to the battery.

Regulations and policy instruments are acknowledged as highly important and seen as a concern in the industry. One example is how the electricity used to charge EVs will be taxed, as it has been suggested that the cost of driving an EV in the future will be equal to driving a fossil fuel car today. Furthermore, how the flexibility markets develop will affect Axess Logistics' capacity related to market requirements.

Axess Logistics says that they are not sure if it is a market pull that will establish V2G in the market. One of the supervisors believes that car manufacturers will push the technology into the market when they are ready, rather than waiting for end customers to demand it. This statement questions the importance of end customer demand, but since several respondents brought it up, it is still included in the framework of barriers. However, one should take into account that the barrier's importance might be lower than first assumed.

7.2.2 Additional reflections

One of the supervisors suggests a sixth barrier, namely, the varying available battery capacity due to different storage volumes at different times. This additional barrier did, however, not emerge during the data collection, which can be explained by that the interviews had an external focus. Nevertheless, this barrier should be recognised. Even though not explicitly expressed during the workshop, the company seems to prioritise addressing this barrier. Axess Logistics has initiated a research project where they will investigate their available storage capacity on a highly detailed level.

Lastly, when asked about the study's implications for the company in general, the supervisors found the results relevant to all facilities. If a viable concept can be demonstrated in Malmö, it is not unlikely that the other facilities will be interested in doing something similar and therefore start investigating their local conditions.

7.2.3 ISO 15118-20:2022

The publication of ISO 15118-20:2022 necessitates a comment since the lack of standardisation was brought up by several respondents and therefore was identified as a barrier. When asked about the implications of the newly published standard, an industry expert did, however, not believe that it would accelerate the V2G market. The reason is that affected actors have stayed updated – some have even been involved in the development of the standard – and ISO 15118-20:2022 is hence not unfamiliar to them.

However, the general perception that there is a lack of standardisation may remain until the publication has become more known along the entire value chain. Therefore, the (perceived) lack of standardisation is still deemed to constitute a barrier.

7.3 Summary of barriers

Based on the gathered data, five barriers to the implementation of flexibility services at Axess Logistics were identified. These are summarised in Figure 7.2. As a sixth barrier, it was suggested by Axess Logistics to add the varying storage volumes. Although it did not emerge in the data collection, it is added as a barrier.

Figure 7.2 Barriers to the implementation of flexibility services at Axess Logistics.

Furthermore, the barriers were linked to the five attributes of an innovation according to the Diffusion of innovations theory. Based on the attributes, possible solutions to overcome the barriers were suggested (see Table 7.1).

Table 7.1 The attributes of an innovation and suggestions on how to address them.

Attribute	*Suggested solutions*
Relative advantage	• Inform about the added value • Highlight the sustainability aspects of V2G, e.g. the possibility of integrating more renewable energy sources • Inform about what can happen if flexibility resources are not integrated into the electrical grid, e.g. more power shortage situations • Incentivise with subsidies
Compatibility	• Redefine the car to being more than just a mode of transport • Target customers whose values and social norms are aligned with the sustainability and technical aspects of V2G • Inform about flexibility services' compatibility with the maintenance plans of the cars • Stay updated on the standards • Make sure that V2G is a natural part of the more integrated homes and workplaces • Avoid too large customer behaviour changes
Complexity	• Axess Logistics can work as a knowledge hub • Adapt the information to the target audience to avoid unnecessary complexity • Make it easy to use and understand the added value
Trialability	• Before adopting the concept fully, others can try it in Axess Logistics' existing infrastructure • Innovators and early adopters can contribute to creating a greater end customer demand
Observability	• Full-scale installation at Axess Logistics makes it easier to observe the advantages • V2G compatible cars should stand out in the market • Make it easy to observe the V2G function and its benefits

Lastly, it should be noted that the barriers are dependent on each other. In other words, if one barrier is reduced, it can create a ripple effect. For instance, assume that it is scientifically proven that the battery will not degrade faster due to V2G. The financial risk would decrease, and the economic incentive would probably increase. A larger economic incentive could spur the end customer demand. If it was proven that V2G would extend the lifespan of the battery, value chain actors would pay attention to how V2G could be used in their cars, e.g. the provision of flexibility services, and search for more information, which would increase the knowledge level.

8 Discussion

This chapter will discuss the findings and results of the study. In addition, implications and limitations are presented. Lastly, areas that could be researched in the future are suggested.

The purpose of the study was to investigate the company Axess Logistics' potential to offer flexibility services. However, it soon became evident that it was not possible to conduct the study without taking into account external actors. A common theme permeating several of the identified barriers, and the concept in general, is the need for and importance of cooperation between involved actors – some of whom never have collaborated before, e.g. general agents and electrical grid owners. A successful implementation of this concept requires a certain minimum level of resources, and the risks often increase with the size of the investment. However, by sharing the risks with other actors, the individual risk for each party decreases. Risk sharing may be particularly important in industries that are transforming, e.g. the automotive industry.

According to Rogers (1995, p. 227), innovations that are relatively compatible in a social system can pave the way for less compatible ones. This could be applied in the case of EVs and V2G. If V2G had been available in the first EVs, it is possible that the diffusion process had been slowed down due to incompatibility with the general user behaviour. However, now when EVs are adopted in the market, they can thus be a springboard to the diffusion of the V2G technology.

From a sustainability perspective, it should be acknowledged that the best car is the one that is not produced. Hence, V2G will not be the solution to the climate crisis, and there are other areas that would have a more significant impact when trying to mitigate climate changes. However, identifying what one can do and trying to make a positive impact is better than doing nothing. For instance, V2G has the potential to reduce greenhouse gas emissions and air pollution, which will lead to environmental benefits (Sovacool et al., 2018). Moreover, the technology's possibility of creating a reliable and affordable grid contributes to social benefits (Mohseni & Brent, 2021). Thus, it is possible for V2G concepts to play a role in sustainable development.

Even though it was concluded that Axess Logistics could qualify for several flexibility markets, it is not recommended to try all markets at once. Due to the complexity and uncertainties surrounding the concept, it would be wise to not maximise from the start. Instead, the recommendation is to start on a smaller scale, build a viable concept and then scale up. Thus, a suggestion is to start with one of the ancillary services. Another alternative would be to start with the local flexibility market CoordiNet Skåne, preferably in close collaboration with the other participating actors as the market develops and there is a chance to affect the future market design (Power Circle, 2022a).

8.1 Implications

To Axess Logistics' other facilities, the findings of the study are of relevance. Although they do not have solar PVs installed, they can still provide flexibility via the EVs. The possibility of participating in the flexibility markets could even be an argument for investing in more own solar production.

It should be acknowledged that far from all actors have the favourable conditions as Axess Logistics, i.e. a considerable number of EVs that they, in general, can predict and control the movement of. However, other actors with somewhat similar conditions could be inspired – or at least become aware of the opportunity – to participate in flexibility markets. One example is companies with commercial fleets – although the bids would need to be adapted to a probably less predictable available battery storage capacity.

Furthermore, the study has shown that the growing number of EVs and the increased electricity demand will not necessarily become a problem. With V2G technology that combines the automotive industry with the electricity market, EVs can become a valuable resource in the future electricity system. In addition, it has been shown that V2G has the possibility of contributing to a more sustainable future.

8.2 Limitations

One of the shortcomings of the study is the low number of interviewees – even though the sampling strategy was purposive. If it had been possible to conduct more interviews within the respondent groups, more data could have been gathered, potentially resulting in more identified barriers. Another improvement could have been to extend the scope of the study, e.g. including car manufacturers, dealers and end customers in the data collection. Throughout the study, the research questions have guided the author to ensure validity, but more interviews could have increased it further.

Although the respondents did not share the same opinion regarding some subjects, the author has tried to stay neutral. For instance, the different opinions and perspectives brought up have been presented in the study to avoid bias. However, interviewing more respondents had most likely contributed to a broader and more nuanced continuum of opinions and attitudes. The interview questions were documented to increase reliability and asked in a neutral way. However, it is difficult to avoid that the researcher affects the interviewees since the researcher and data collecting technique cannot be separated. The same applies to the analysis, which inevitably is influenced by the researcher's interpretation in qualitative studies (Denscombe, 2010, p. 273).

Furthermore, it should be mentioned that some of the data sources are industry organisations, which may have their own interests as well as partners with commercial interests. However, the author tried to triangulate the data to increase the objectivity. In addition, the interviewed industry experts referred to some of the industry organisations, which were deemed to enhance the credibility.

Given the nature of case studies, the findings and results are not generalisable. This thesis has been carried out at Axess Logistics' Malmö facility. However, since the company's other facilities are relatively similar to the one in Malmö, the study's findings could be argued to be relevant to them.

8.3 Future research

For Axess Logistics specifically, the company could make a more quantitative analysis. With data on actual solar production and costs for, among other things, infrastructure and electricity, it would be possible to state the economic viability in figures. Furthermore, a more detailed analysis should be done regarding the market requirements and how they affect the possibility of placing bids with a varying available storage capacity at Axess

Logistics. This analysis would also give a hint on how the pool of cars needs to be dimensioned.

A more quantitative analysis would enable better interaction with stakeholders. By creating and presenting different scenarios, including both qualitative and quantitative data, they could take a stand on what they would accept in a concept like this and what would make them reluctant to it.

One area that inevitably needs to be further researched is the battery and how its health is affected by different parameters. If it is concluded that V2G will harm the battery, studies investigating how much earnings that are needed to compensate for the degradation could be conducted. For instance, is it possible that customers would accept the shortened lifespan of the battery if they can save or earn money from V2G applications?

Highlighted and requested by Sovacool et al. (2018), V2G research should be broadened to address more environmental, social and human elements. Arguing that there exist research gaps, they state that including more perspectives is necessary for V2G to reach its full potential.

Furthermore, another potential area to study is the interplay between the EVs as flexibility resources and the electrical grid. This area could be studied on different levels – from a general level to a local one, e.g. investigating the specific conditions in the south of Sweden.

9 Conclusion

In this final chapter, the conclusions of the study are presented.

The purpose of the study was to answer the overarching question; *What potential does Axess Logistics have to offer flexibility services?* To investigate the potential, the question was broken down into two sub-questions, namely, RQ1) *To what extent is Axess Logistics able to provide flexibility?* and RQ2) *Which are the barriers to the implementation of the concept?*

When addressing RQ1, a distinction was made between Axess Logistics' internal capacity and external factors that affect the concept's potential. By putting Axess Logistics' battery storage capacity in relation to the requirements in the flexibility markets, it was concluded that the company has the internal capacity to provide flexibility services. In other words, the company has sufficient storage capacity to meet the minimum requirements regarding parameters such as bid size and endurance. Some products in the local flexibility markets and ancillary services were deemed to be more relevant to Axess Logistics taking into account their conditions.

In addition, external factors that will affect to what degree Axess Logistics is able to offer flexibility services were identified and investigated. For instance, it is crucial that the owners of the cars, i.e. the general agents, allow Axess Logistics to use the cars' batteries as flexibility resources. Due to the novelty and low knowledge of V2G, most of the discussions regarding the external factors took place on a conceptual level rather than a tangible one. However, a takeaway from the interviews is that nothing emerged that would make the concept impossible to implement.

In order to answer RQ2, interviews with different respondent groups were conducted in combination with a document study. During the data analysis, the following five barriers could be identified:

- Low knowledge regarding V2G and its possible functions
- Uncertainties regarding battery degradation
- Lack of standardisation
- Importance of economic viability for actors participating in the concept
- Low end customer demand

In a workshop with the supervisors at Axess Logistics, a sixth barrier was acknowledged, namely,

- Varying storage volumes

By analysing the barriers from a Diffusion of innovations perspective, possible solutions to overcome the barriers were found. For instance, Axess Logistics could work as a knowledge hub making the concept simpler to understand and try in order to speed up the diffusion process.

Flexibility resources could be an integral part of the future electricity systems, where the electricity demand is forecasted to grow. The market designs are under development to make it easier for new types of flexibility resources to participate, e.g. EVs with V2G compatibility. An interesting aspect of V2G is the fact that the function of the car needs to be redefined. The ability to store energy in the cars' batteries presents new opportunities to contribute to all three pillars of sustainability: a reliable and affordable electrical grid, more integration of renewable energy sources leading to reduced greenhouse gas emissions and new revenue streams for both companies and private people.

To sum up, using EVs as flexibility resources has potential. However, there exist some barriers that need to be overcome before mass-market establishment can take place. When the automotive industry and electricity market are combined, new business opportunities will present themselves to companies such as Axess Logistics.

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Appendix A Interview guide – General agent

Appendix A presents the interview guide prepared before interviewing general agents.

- Present the thesis and the purpose of the interview
- Ask about the desired level of anonymity
- Ask for consent to record the interview
- Could you please present yourself, your role and the organisation you are working for?

The car

- What function does the car have in the future?
- Do you think that EVs' batteries will be utilised in more applications than transport? If so, how?

V2G

- Do your cars have V2G compatibility?
- What is your attitude towards Axess Logistics using the cars as flexibility resources?
- What is your perception regarding potential battery degradation when using V2G?
- Are you interested in using your cars in V2G applications? If so, why are you interested?

End customer

- How do you think that end customers view the car in the future?
- Are they aware and interested in V2G?

- Do you have any questions to me?
- Is there something else you want to bring up?
- Thank you!

Appendix B Interview guide – Industry expert

This appendix presents the interview guide used during interviews with industry experts. However, it should be noted that not all questions were asked during each interview. Instead, the focus areas and questions were adapted to the expertise of the interviewee. Also, as the interviews were semi-structured, follow-up questions were asked, although they are not included in this interview guide.

- Present the thesis and the purpose of the interview
- Ask about the desired level of anonymity
- Ask for consent to record the interview
- Could you please present yourself, your role and the organisation you are working for?

Flexibility services

- What are flexibility services, and when are they needed?
- Which are the marketplaces for flexibility?
- How can EVs provide flexibility services?

V2G

- How established is V2G?
- What is your perception regarding potential battery degradation when using V2G?
- Do barriers to market establishment of V2G exist? If so, which are the barriers?

The concept

- What are your thoughts on the introduction of flexibility services at Axess Logistics?

- Do you have any questions to me?
- Is there something else you want to bring up?
- Thank you!

Appendix C Interviews

In this appendix, the interviews are described in more detail. Since information from the supervisors was gathered on a regular basis, no specific interview situation is presented.

Respondent	***Title***	***Respondent group***	***Date***	***Communication method***	***Time***
General agent A	Head of logistics	General agent	2022-03-16	In-person	30 minutes
General agent B	Product and logistics manager	General agent	2022-03-21	Digital	1 hour
Ulf Wengeler	SolarVolt, CEO	Industry expert	2022-03-31	Phone	40 minutes
Maria Edvall	Senior project manager, RISE	Industry expert	2022-04-07	Digital	1 hour
Jerry Svedlund	Head of research, CTEK	Industry expert	2022-04-28	Phone	30 minutes
Mattias Öhrn	Key account manager, Axess Logistics	Company representative			
Dimitris Emmanouilidis	Production manager, Axess Logistics	Company representative			