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Driving the Grid: The Role of V2G in Modern Energy Ecosystem

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Abstract

The automotive sector has been rapidly evolving towards more sustainable practices, with electric vehicle (EV) manufacturers consistently innovating to develop the EV of the future. The growing demand for electricity offers numerous opportunities for innovative technologies and services to be introduced; one of them is the Vehicle to Grid (V2G) concept, which explores the possibility to transfer part of the energy stored in the EVs' batteries back to the grid to be used in times of need.

This research aims at investigating how V2G could impact the currently evolving energy ecosystem in Sweden, where automotive industry is now a huge stakeholder. The research explores opportunities and challenges of this technology. In particular, the second part of the paper focuses on possibilities for end-users to benefit from this service.

A review of the previous literature and discussions with eleven experts from various industries reveal that the industry currently lacks a solid business model to market this service. Additionally, the adoption is hindered due to legal and technical factors which are evolving slowly in the Swedish bureaucratic landscape. There must exist a significant end-user incentive for widespread adoption and various environmental aspects are also to be explored extensively. Building on the empirical findings from these interviews, a scenario planning analysis has been carried out to assess potential end-user benefits. The resulting numbers from the four different scenarios show a significant potential for the end-users to generate financial benefit out of this service. However, considering the bigger picture, other factors such as flexibility and ease of use may be the compromise end-users have to make to maximize these benefits. Hence, a balanced approach is recommended.

Considering this analysis, the research presents some suggestions on aspects to consider and improve in order for V2G services to be democratized, such as standardizing charging infrastructures and solving GDPR issues. Future courses of action are also considered in the final section of this paper.

Keywords:

Vehicle-to-Grid; V2G; Electric Vehicles; Energy Sharing; Energy Markets; Energy Distribution Systems; Innovation; Sustainability; Power Grid; Energy Storage; Renewable Energy; Resource Efficiency

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A huge thanks to Per Östling from "First to Know" (https://www.firsttoknow.se/), who has guided, motivated, and mentored us since the time when the project was in the ideation phase. He encouraged us to consider the ecosystem perspective instead of focusing on just the technology itself. Most importantly, the majority of our potential stakeholder interviews were arranged through his professional network.

We would also like to express our gratitude to all the industry experts we have had the opportunity to interview. As we have been running the interviews in parallel to the literature review, it has been nice to form a general understanding of the topic by discussing with professionals and comparing their views to that of the previous researchers.

Finally, we would like to thank each other. Despite the busy schedules and family commitments, we were able to accommodate each other and synergize for maximum efficiency and productivity throughout the project life cycle. Moreover, we both considered each other's strengths and weaknesses and always managed to maintain an equal workload in the process. We have both grown as professionals and friends throughout this period.

(Gothenburg, May 30, 2024)

Ammaar Arshad **Filippo Loi**

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Abbreviations

BEV	Battery-operated Electric Vehicle
B2G	Boat to Grid
CPO	Charging Point Operator
DSO	Distribution System Operator
EV	Electric Vehicle
FCR-D	Frequency Containment Reserve – Disturbances
FCR-N	Frequency Containment Reserve – Normal
FFR	Fast Frequency Reserve
GDPR	General Data Protection Regulation
GWh	GigaWatt Hour
kWh	KiloWatt Hour
MWh	MegaWatt Hour
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle
SCB	Statistics Central-Byran
TSO	Transmission System Operator
UN SDG	United Nations Sustainable Development Goal
V2G	Vehicle to Grid
V2H	Vehicle to House
V2V	Vehicle to Vehilce
V2X	Vehicle to “X” (X refers to everything, e.g Grid, House, Vehicle etc.)
VAT	Value Added Tax

1. Introduction

The energy sector is arguably one of the most strategically important markets at both national and global level, especially considering the recent geopolitical events and environmental concerns. Given the increasing need for more sustainable transportation, the Electric Vehicle (EV) industry has become a huge stakeholder in this sector, which may eventually drive the global transition to greener sources of energy.

1.1. Background

In the last decade, due to favorable policies, environmental goals, an increased reliance on renewable energy sources and a generally positive public opinion, sales of EVs reached new all-time records, with numbers projected to rise even further (Ghatikar & Alam, 2023). The replacement of traditional vehicles with electric ones has proven to have considerable benefits in terms of reduction of carbon emissions; furthermore, the use of EVs could actually be cheaper. This would be true in terms of refueling, with electricity being much more affordable than gas, and the EVs bearing generally lower maintenance costs. Eventually, as more and more Original Equipment Manufacturers (OEMs) shift their production to EVs, initial purchase prices will also decrease, while restrictions on emissions are only meant to rise (Mojumder et al., 2022).

In the context of a general electrification process, EVs could not only be seen as a mere means of transport, but also, thanks to the battery that powers each of them, as an electricity storage. Traditionally an electric car would be plugged into a charging station and charged, with energy flowing unidirectionally from the charger to the vehicle itself.

The concept of Vehicle to Grid (V2G) challenges this assumption. By connecting an EV equipped with a V2G adapter to a bidirectional charging station, energy could flow in both directions. Thus, the car itself could be used to transfer and sell the energy stored in its battery back to the grid when needed. Clearly, in this regard, two of the most important components of this technology are the adapter and the bidirectional charger themselves.

This technology could potentially change the entire energy market, as car manufacturers could become stakeholders in the energy sector, together with energy utilities and other traditional players. Vice versa, the car industry would also be affected, as energy prices and electricity would influence the demand for vehicles. Hence, a new ecosystem, where OEMs and existing stakeholders in the energy sector are suddenly collaborating towards the same goal of de-carbonisation and use of renewable energies, could be created.

It is the aim of this thesis to investigate how the energy ecosystem and its stakeholders will be impacted by V2G technology in the Swedish context. Moreover, given the possibility to sell energy from one's vehicle back to the grid, we will explore what could be the eventual opportunities for private individuals to profit from this system.

1.1.1. Alignment with the UN SDGs

The potential of V2G technologies aligns closely with the United Nations Sustainable Development Goals (SDGs) 7 and 11, particularly the targets 7.a and 11.b. Both these SDGs and targets are explained below:

1. **SDG 7: Affordable and Clean Energy.**

"Target 7.a: By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology" (United Nations, n.d.)

V2G systems enable electric vehicles to store energy to supply back to the grid when needed, especially in darker hours when solar energy is not available. This contributes to the transition towards renewable energy sources by integrating electric vehicles as mobile energy storage units, reducing reliance on fossil fuels.

2. **SDG 11: Sustainable Cities and Communities**

"Target 11.b: By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels" (United Nations, n.d.).

Target 11.b emphasizes the importance of adopting and implementing integrated policies towards climate change mitigation. V2G technologies support this by providing a flexible and resilient energy system capable of responding to fluctuating energy demand and emergencies, thereby increasing urban infrastructure resilience against climate-related disruptions. These technologies are part of innovative solutions that foster sustainable urban development and a cleaner, more sustainable energy future.

1.2. Research Question

The process of developing a research question was, in itself, iterative in nature. We discussed our interest in V2G and talked to different industry experts and academics to assess whether this technology could benefit both industry and academia. We further conducted two pilot interviews with energy consultants and asked them about their view of the topic. All this resulted in some preliminary findings about the research area, which enabled us to develop a preliminary research question presented in the upcoming heading. This original research question was, however, changed at a later stage of the project after receiving feedback and input from the various interviewees.

1.2.1. Proposed Research Question

With all the initial brainstorming and discussion in the preliminary interviews, we initially proposed the following research question:

1. What strategies could EV companies adopt to integrate their products into the evolving European energy markets, such as Vehicle-to-Grid (V2G) services?
2. How would this impact their overall business model and revenue streams?

1.2.2. Revised Research Question

We initiated our literature review and interviews with various stakeholders. During the course of interviews, we asked all respondents about the strategies and business models that could

help the EV companies maximize their benefits from this opportunity. It was soon evident that many of the industry experts and consultants did not have many insights to share on strategies and business models as they considered the technology too new for this discussion. They had different ideas, but they were hesitant to mention the specifics of those business models and strategies. The primary reason is that they did not have much clarity themselves, as this is an evolving discussion within those companies. Secondly, we believe they did not feel comfortable sharing their internal strategies and unique business models publicly before any solid plan of implementation.

This discussion led us to modify our original research question to reason more on the kind of information we had been able to gather during interviews. Based on further retrospection and analysis, the following research questions were formulated.

1. How is the energy ecosystem evolving for different stakeholders upon the advent of V2G (Vehicle-to-Grid) technologies?
2. What opportunities does this provide for end-users to capitalize on this trend?

As evident, the research question consists of two interrelated yet distinct parts. The first one is more focused on the macroscopic view of V2G ecosystem. In particular, it deals with qualitative research, thus a series of interviews with professionala and experts from different industries and organizations.

The second part of the question has been derived from the fact that the majority of our respondents stressed the importance of incentivizing the end-user in financial terms (this concept is further discussed under the heading “Incentivizing the End-User”). Hence, we decided to explore whether there is a significant potential for these individuals to benefit from this technology or not. Due to the lack of a clear understanding of business models and revenue streams, we decided to develop multiple scenarios where end-users may be able to use their car’s battery capacity and profit from fluctuations in the energy market. Hence, this scenario planning framework (dealt with in the fifth chapter) aims at answering this second part of the research question.

1.3. Thesis Disposition

To answer the presented research questions, this thesis will be divided into six chapters. First, after the introduction, a literature review on the main characteristics of the energy market will be introduced. The concept of ecosystem and the different stakeholders present in the energy sector will be discussed, as well as the main opportunities and challenges of V2G. After that, Chapter 3 will present the methodology behind the qualitative and quantitative data collection. Chapter 4 deals with the first part of this analysis, the qualitative data findings from the interview process.

Chapter 5 will present a scenario planning framework, which, as mentioned, will be mainly based on quantitative data, and will address the second part of the research question. This section will also include an introduction to scenario planning techniques and, more in general, everything regarding this analysis. We believe that dedicating one entire chapter to this topic, without introducing it in the literature review nor presenting the assumptions behind the framework in the methodology section, will result in a greater understanding of the model itself. Finally, chapter 6 will present a general discussion and conclusion on the findings from Chapters 4 and 5 in relation to each other and the literature review in Chapter 2 as well as some suggestions for future courses of action for V2G technology to be implemented.

2. Systematic Literature Review

The main focus for this part of data analysis was to analyze relevant research conducted in this domain by other researchers and organizations. Our primary focus in this case has been academic articles published by different researchers from universities and research institutions around the World. Such review provided us a good reference point to utilize what has been discovered previously and expand our knowledge.

The systematic literature review has been conducted using the following search query in SCOPUS, the database system of the University of Gothenburg.

TITLE-ABS-KEY (vehicle-to-grid AND energy AND business) AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "ECON") OR LIMIT-TO (SUBJAREA , "ENER"))

The search query was executed on February 18, 2024, and resulted in 33 results. These were then downloaded in the form of CSV with their abstracts included. The abstracts were reviewed to shortlist 18 out of 33 articles.

This list of 18 articles chosen among the overall 33 results that we got from the above-mentioned query was selected subjectively by us according to the degree of relevance to our topic. As an example, articles focused entirely on technical subject areas of the V2G technology design and engineering were excluded from our analysis.

Another criterion based on which we have selected the papers for this systematic literature review was their relevance with the interviews that we were running at the same time; some of these articles were found after the interviewees mentioned some particular topic, and we thus deemed it necessary to further analyze that area of interest. The articles dealing with the more technical information and characteristics of the electricity market, its functioning, and its main stakeholders were, for example, chosen according to these criteria. This second list of articles was also retrieved from the previously mentioned database, SCOPUS GU.

Finally, one of the interviewees also provided us an article dealing with the possible effects of V2G technology on battery degradation. This article (Bui et al., 2021) was also included in this chapter.

Hence, this section will focus on the systematic review of the previous literature on the development of Electric Vehicles (EV) and, in particular, on the actual state as well as on the challenges and future perspectives of Vehicle to Grid technology (V2G).

The first part of this review will present the definition of the various types of EVs and chargers available on the market, as these are the necessary infrastructure for V2G. Given the aim of this paper, the holistic perspective of ecosystem innovation and an overview of the different stakeholders operating in the market will follow. The challenges and the main hindering factors for the democratization of V2G, including early technology, potential GDPR issues, legal requirements and business model innovation will also be discussed.

2.1. Main Types of EVs

The rapid increase in personal vehicle ownership has caused issues such as environmental pollution and a rise in greenhouse emissions; as a result, car manufacturers have shifted their focus to the production of electric vehicles instead. Hence, in recent years, due to

governmental incentives and policies, both on national and international levels, and a general positive attitude of the general public, EVs have become an essential part of the automotive industry, as shown in Figure 1 (Razmjoo et al., 2022).

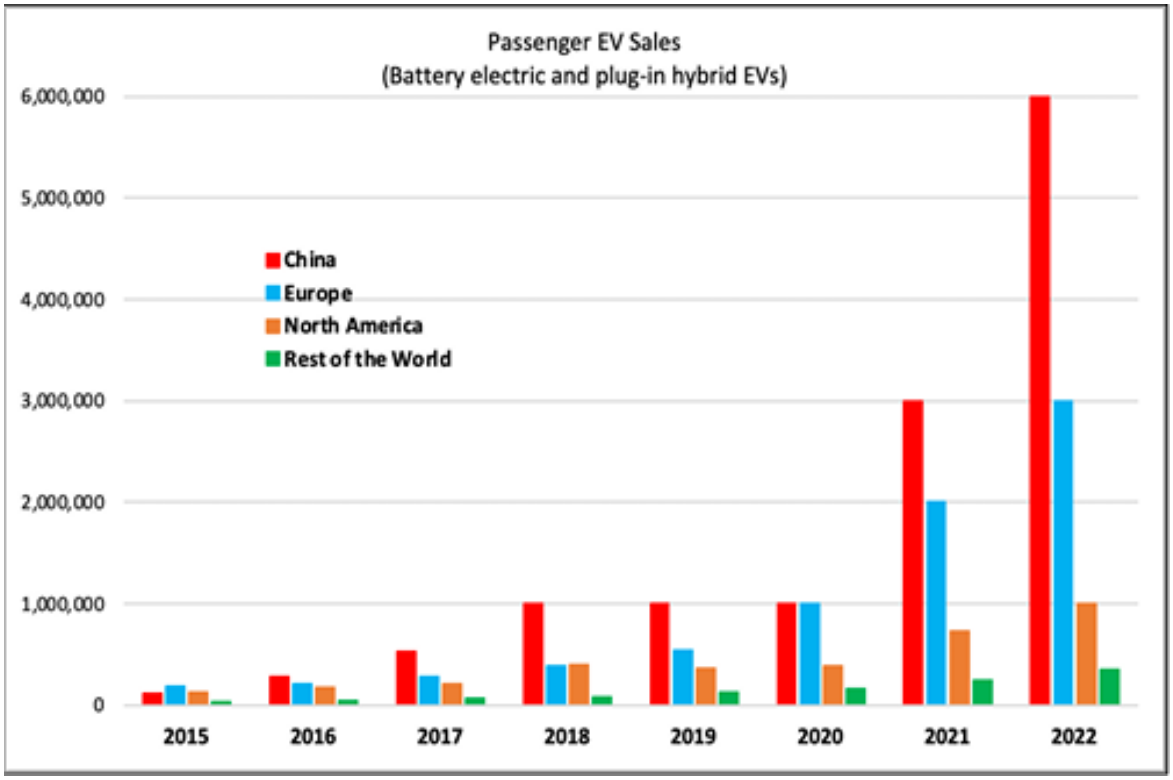

Figure 1 - Passengers EV sales, 2015-2022 - Source: (Razmjoo et al., 2022)

There exist mainly three macro-categories of EVs: fuel cells, which produce electricity directly onboard using a fuel such as hydrogen; battery EVs, which store electricity on a battery onboard and finally; hybrid EVs, which produce electricity onboard using a combustion engine that turns a generator (Kempton & Tomić, 2005).

Fuel cell electric vehicles exploit the recent improvements in fuel cell technology; however, they are affected by the challenge of transporting hydrogen. Once a fuel cell car is connected to a station, the cell onboard is filled with hydrogen and, through a chemical reaction, this is transformed into electricity. These vehicles are generally more efficient than conventional cars with traditional engines because they emit only water vapor and warm air (Razmjoo et al., 2022).

Battery Evs (BEVs), also known as all electric vehicles, are powered completely by electric motors. These are charged through external charging stations or while using automatic braking system of the car while driving.

The third macro category of EVs is the hybrid vehicles, thus cars which exploit both an electric and a traditional internal combustion engine. A standard hybrid vehicle cannot be connected to an external charger to recharge its electric engine; the latter can only be recharged while driving using the traditional engine.

In this sense, the critical technological improvement that has paved the way for the concept of V2G itself has been the introduction of the so-called plug-in-hybrids (PHEVs), thus hybrid vehicles which can also be connected to an external charger (Mojumder et al., 2022).

Historically, these plug-in hybrid vehicles have been charged unidirectionally, thus through a charger transferring electricity from the grid to the vehicle itself. The concept of vehicle-to-grid challenges these assumptions, stating that the vehicle could transfer part of this electricity back to the grid.

2.2. Main Types of Chargers

Electric vehicle charging stations are the most crucial infrastructure for the successful implementation of any electrification project; the lack of chargers is currently one of the main challenges and hindering factors to the adequate development of EVs internationally (Figure 2). Countries like Japan, China, India, and some European nations have now introduced extensive policy frameworks to improve electric charger coverage all over their territory. Furthermore, considerable efforts have been carried out to develop some useful indicators to better understand the overall demand for electricity, such as demand and intensity management for EVs as well as charger's intensity distribution (Mojumder et al., 2022, Razmjoo et al., 2022).

Charging stations are often categorized into the following categories:

- Residential charging stations: these are private chargers or publicly owned stations erected in residential areas where household members can charge their vehicles, prevalently at night.
- Commercial charging stations: include all those chargers erected in public areas such as supermarket parking lots. Users may benefit from these chargers for a fee.
- Fast charging stations: these chargers are more advanced than their traditional counterparts, as they can usually charge up to 80 kms in 10 to 30 minutes, which allows most electric car users to cover their daily routes with ease (Mojumder et al., 2022).

In general, chargers can be either alternating (AC) or direct (DC). Power from the grid is always of AC type, while the power that can be stored in an EV is DC, which means that the power from the grid must in all cases be converted to DC.

To do this, AC chargers need a converter built inside the car, whereas the more modern DC chargers have the converter directly built inside, thus allowing power to flow directly into the car (Razmjoo et al., 2022).

At the moment, there exists no unique international agreement regarding charging stations, as every manufacturer is free to agree to an existing standard or eventually create an ecosystem on their own, as Tesla did. Some examples of agreements in place are the SAE-K17 and the Chinese GB/T20,234, which consider power and the level of electrical energy flow during the charging. The IEC-62196, used in some parts of China and by some European countries, considers the nominal power used during the charging as the main indicator. Apart from that, IEC 61851-1 and IEC 62192-2 are the main standards used worldwide to build and design outlets, connectors, and plugs for EV charging stations (Mojumder et al., 2022).

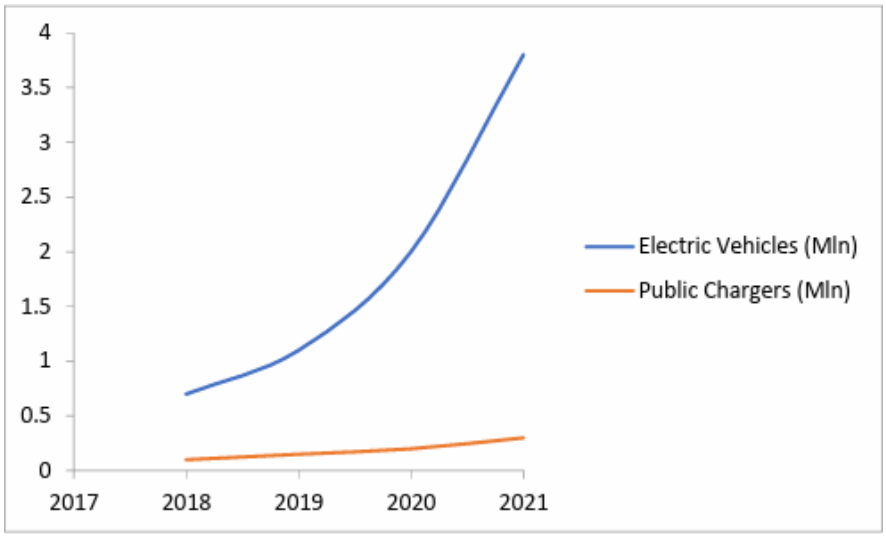

Figure 2 - Number of public chargers relative to the number of Evs - Source: (Razmjoo et al., 2022)

2.3. Ecosystem Innovation

Given that this research aims at presenting the holistic prospective of the V2G World, a theoretical section on ecosystem innovation will follow.

The term ecosystem, in an industrial scenario, refers to the union of different stakeholders located in the same geographical area which, while formerly belonging to different industries and markets, collaborate and share knowledge with each other to develop new products and business models (Neto et al., 2024). This concept of collaboration and information sharing is based on the definition of open innovation by Chesbrough and Appleyard (2007) in their article “Open Innovation and Strategy”. The authors were the first ones to theorize that companies should not try to create and develop every product only with their internal resources and knowledge but that it would be better to collaborate with other firms operating in the same industry to come up with better solutions, faster and cheaper. The role of universities is of particular importance, according to the authors, to share knowledge with the industry to increase the rate of innovation. Being an ecosystem a complex and uncertain environment, the role of the Government is also key, as policies and legislations do affect businesses and society as a whole. In this sense, Neto et al. (2024) mention the so-called “Triple Helix", thus the intercorrelation of firms, universities, and government. As the authors stated, this framework has later been updated to consider civil society and the environment in the picture as well.

Clearly, given the elements of the updated “Quintuple Helix”, every ecosystem has characteristics of its own. Firms, affected by policies and regulation, aim at satisfying the specific markets in which they operate, with different characteristics depending on the geographical region and the society itself. It is thus impossible to come up with a precise definition of ecosystem valid for every business (Neto et al., 2024).

However, according to the literature, there are some common and necessary characteristics for every ecosystem to successfully innovate in terms of products and business models.

Radičić et al. (2018) state that collaboration and positive relationships among the different stakeholders involved are vital for the project to be successful. To support innovation, actors need to be open-minded and actively share knowledge to co-create products. Co-creation entails more than superficial collaboration; rather, it involves investing time and resources to build this relationship over time. This process can surely be done along the value chain but

also, as mentioned, between firms and academic institutions. In this sense, alliance competencies are also needed to initiate and nurture these relationships, as well as governance, to align partners with current organizational goals. Another common denominator to all successful ecosystems is human capital and organizational culture. The capacity to collaborate is inherently a human factor rather than an institutional skill, but it can clearly be incentivized by a positive attitude and organizational culture of the company. Clearly, in an open innovation scenario, the capacity to collaborate and work in teams is actively insisted in the interview process to make sure that each candidate could eventually fit into the culture of the firm (Neto et al., 2024).

2.4. Overview of the Electric Market and its Stakeholders

The electric market works on a day-ahead basis: this means that all the parties involved need to determine/forecast the quantity of electricity they would need for each time slot of the next day as well as the minimum/ maximum price at which they would be willing to buy. The day-ahead market closes at noon, which means that all the bids and asks, with relative quantities needed and prices, must be submitted by that time the day before. Furthermore, agreed prices vary by the hour (Kahlen et al., 2018).

In their study, Román et al. (2011), presented a possible regulatory framework for charging EVs; in particular, they presented the main stakeholders in the electric market, differentiating them between existing actors and potential ones in the V2G scenario.

- Distribution System Operator (DSO): the owner and operator of the distribution grid. Most of them are monopolies and, as distribution is not bound to supply and retail, they can't trade energy. They only provide network services.
- Supplier or Retailer: the actor who sells energy to the final consumers. In markets where distribution and supply are diversified, there are both the DSO and the supplier; the latter is remunerated by the final consumer after having procured the energy and having paid the DSO for its service (energy distribution).
- Independent System Operator (ISO) or Transmission System Operator (TSO): responsible for keeping the system operation secure at the national and regional levels by procuring such services as operational reserves and frequency regulation. A provider of regulation services can be paid in two different ways. A capacity price can be paid to the TSO for its availability to deliver energy when needed, even if no energy is needed to restore balance, or an energy price can be paid for energy actually provided (Andersson et al., 2010).
- Final customers: the agent that requires electricity for end users by purchasing it from the supplier. A final customer is not allowed to resell the same energy to another final customer, but only to the end user (privates).

In their analysis, Román et al. (2011) also consider other possible actors that could participate in the electric market, especially in a V2G scenario:

- The Plug in Hybrid vehicle owner: with V2G technology, every electric vehicle owner could be able to participate actively in the grid. In this sense, the authors differentiate between the type of charging infrastructure; privately owned with private or public access and public charger with public access.
- EV supplier-aggregator: the agent selling electricity to the EV owner. Given that the EV owner will demand freedom and mobility, thus the possibility of charging the vehicle in different locations while remaining with the same aggregator, the EV

supplier contract will not be bound to a single charging outlet or location. In general, they will aggregate multiple vehicles and potentially provide V2G services to the TSO (operational services and V2G will be further discussed later in this paper).

- EV charging point manager (CPM): this actor will buy electricity for personal use (owner of the private property) or resell it to other users under an agreement (owner of the public area where chargers are installed). A CPM could be a residential owner who installs a charger for private use on his/her private property, an office/building owner who installs chargers for private use of its employees/clients, or an EV charging station owner who installs infrastructure for public use.

To this list, in the V2G scenario, Mojumder et al. (2022) also include the actual vehicle manufacturer as an active stakeholder in the grid and overall V2G ecosystem (Figure 3).

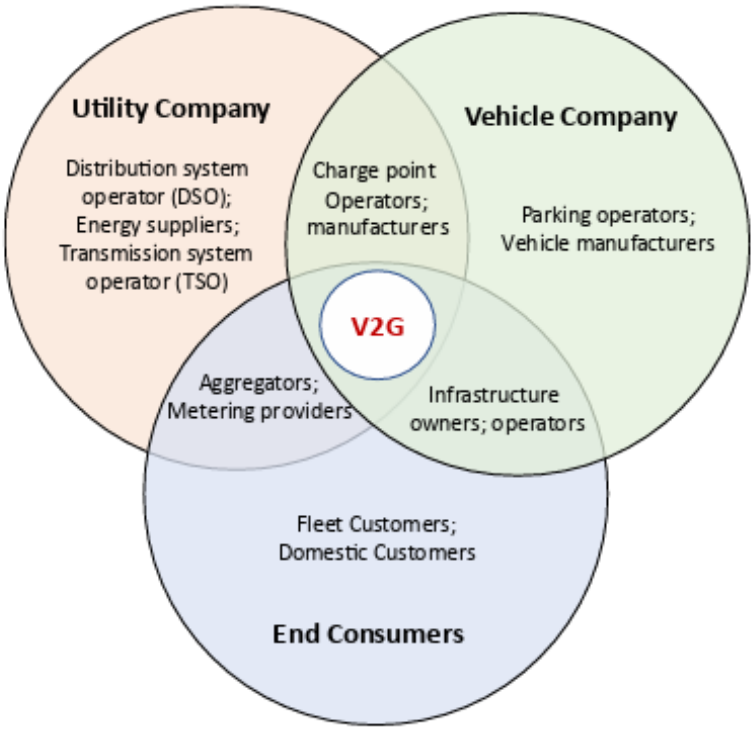

Figure 3 - Stakeholder integration in the V2G ecosystem - Source: Mojumder et al. (2022).

After presenting the main actors in the electric market, current and potential ones, a brief discussion on the different types of services required to maintain a smooth energy supply will follow. The main types of power systems in the overall electric market scenario are categorized as such:

- Baseload power: this represents a significant part of the power generation and runs all the time
- Peak power: this type of power is used only when a peak of electric demand is forecasted, for example, during the warmest days of summer, when households are predicted to increase their use of air conditioning, or during the harsher winter days.
- Spinning reserves: this type of power is used mainly to respond quickly in case of major power failures in the grid, such as when generators are down or when the power suppliers fail to deliver the agreed amount of energy during a particular time slot. This kind of power typically lasts 10 minutes to 1 hour.

- Regulative services (ancillary services): the second type of operational services, after spinning reserves, which are needed to maintain the balance of supply and demand in the grid. They are mainly used to maintain frequency and voltage steadily; they usually last a few minutes at a time, but contrary to spinning reserves, they need to regulate the grid continuously. The generators that provide ancillary services are different from the ones which provide baseload power; these run 24 hours a day and are equipped with automatic systems to respond, within minutes, to sudden increases or decreases in the voltage and frequency, keeping the overall grid balanced by increasing or decreasing the power output (Kempton & Tomić, 2005, Tomić & Kempton, 2007).

In particular, the topic of ancillary services has been extensively dealt with in the literature, as it is considered the major power market where a technology such as V2G could be beneficial. As stated in Kempton & Tomić (2005) and in Andersson et al. (2010), Plug-in Hybrid Vehicles could participate in the grid ancillary services with a function of frequency control, thus maintaining demand and supply of energy stable (the current role of a TSO). In this sense, the role of the aggregator, as previously discussed, will be fundamental to ensure that enough power is delivered in the right location when needed.

In the current electric market, when supply is higher than demand, the frequency will go up, and thus, there is the need to regulate it down. V2G could provide this service by simply charging up the battery of the vehicle. On the other hand, when the demand for electricity is higher than its supply, the overall system frequency will go down, and regulation will need to go up. As in the previous case, if a vehicle is equipped with a bidirectional charger, it could discharge its battery into the grid to provide more energy when needed. This service could also be provided by stopping the charging of some vehicles in the area when regulation is needed (Andersson et al., 2010).

In their studies, Kempton & Tomić (2005 and 2007) analyzed the possible profitability of Plug-in Hybrid Vehicles as power regulators. After studying the possible effect of the previously cited power systems (peak load power, spinning reserves, and regulatory services), they concluded that power regulation could be highly profitable for electric vehicles. In particular, they state that charging up a vehicle when regulation down is needed, when supply is greater than demand, could be more profitable than discharging a vehicle when regulation up is needed.

In a later study, Andersson et al. (2010) consider the previous data and aim, among the rest, to test to what extent it would be possible for PHEVs to participate in the market as regulating power providers in Germany and Sweden. In general, they found that V2G could be profitable in Germany, where prices are higher (at the time of the study, thus from 2008 to 2010) both for capacity and energy for regulating power whereas, according to their simulations and data, this system would not be profitable in Sweden, even under their maximum profitability scenario. Clearly, these data are only indicative of how the state of the electric market was at the time in these two countries but could not be used to make a rightful comparison nowadays, as policies, stakeholders, prices, and the geopolitical scenario are different.

The authors also elaborated a SWOT analysis on the potential of these vehicles as regulating power providers. Among the main strengths found there is the capacity of these vehicles to deliver busters of energy within seconds to the grid, which is the main characteristic of a power regulator. Furthermore, unlike a traditional TSO, the vehicle owners would not need to pay more than the normal cost of charging to leave their cars available to the grid in case of power failure or loss of frequency once the necessary infrastructure has been put in place. An obvious weakness is that, given that the battery storage on the car is limited, there is a

constraints on the length of the period that PHEVs can be used for frequency regulations; in particular, when the battery is full, this car cannot be used to regulate down the frequency (i.e. supply is greater than demand and cars could be charged up to decrease the frequency on the grid). Another challenge would be that one single car, as previously mentioned, would not store enough energy to be able to participate in the grid on its own, but it would rather be necessary to pool together different vehicles at the same time (role of the aggregator). Clearly, the more vehicles that are parked and available in one area, the greater the possibility of aggregating the necessary number of vehicles together. This challenge of aggregating enough cars would be further complicated by the fact that these cars are obviously mobile and not restricted to the area of interest; it is then difficult for the TSO to actually understand the exact number of vehicles available in one area at a specific time and almost impossible to foresee it. On the other hand, as the author points out, even during rush hours, the supermajority of the cars would still be parked and thus be potentially available on the grid.

A major opportunity for this technology would be, according to Andersson et al. (2010), the rise of intermittent power in the grid, thus coming from natural resources; as the latter would not be provided with the same certainly as other traditional forms of energy, given that, for example, wind and Sun conditions change continuously, the need for regulating and frequency services will likely increase. Governments would also play a key role in this sense, as the need to reduce CO2 and the current environmental goals at national and international levels will likely push toward electrification. One way could be to increase the flexibility of the regulating power market, which, as of now, is one of the main challenges, by allowing smaller actors and PHEVs to participate. Another possible limitation would be that, in an electrification scenario, only a small portion of electric vehicles would be sufficient to cover the flexibility needed for frequency adjustments in one area; hence, the participation of too many vehicles could reduce the financial margins per car and thus overcompensate.

Finally, the authors conclude with some future remarks on the feasibility of this technology and the potential conflicts of interest that could arise. The first could potentially be the one between the utility industry and the automotive one when deciding who would need to invest the majority of the budget to build the necessary infrastructure. The latter would, most likely, also need to be standardized, which would leave the original equipment manufacturers the choice, whenever no binding policy would be put in place, to adhere to the standard or to create their own ecosystem, as in the case of Tesla. Finally, a fleet of PHEVs would potentially become a new category of consumer but also a new competitor in the grid (Andersson et al., 2010).

2.5. Opportunities and Challenges of V2G

The following section will build upon the already mentioned literature and present the main opportunities, expectations and challenges for the V2G ecosystem.

2.5.1. Opportunities and Expectations

Scheduled charge and recharge times:

In their comprehensive study on V2G, Mojumder et al. (2022) and Davies et al. (2022) state that the best advantage of such technology is the capacity to schedule recharge and discharge times and thus generate an economic profit for end users. The EV could be plugged in when supply exceeds demand, and then the battery can be charged and, vice versa, discharged at peak times. This is fully in line with the previously presented studies, including the one from

Andersson et al. who, already in 2010, stated that this flexibility, coupled with the capacity to generate short bursts of energy, is the main advantage of this technology.

Renewable energy sources:

As in Mojumder et al. (2022), V2G could actually promote and be complementary to the use of renewable energy sources; the coupled use of the two could improve the efficiency of EV and energy management systems while increasing flexibility in the grid and reduce emissions on the two fronts of mobility and energy solutions. Hence, given the already mentioned intermittence of renewable energies, one could use an EV with a bidirectional charger as a buffer in case the weather is not perfect to gather energy by itself and provide the remaining power needed to the grid. In this scenario, the coupled use of V2G and renewable energy sources could also improve power quality management, especially for microgrids or smart grids.

The authors conclude by confirming the potential financial benefit of operating in the flexibility and ancillary service market, which has already been discussed in the previously mentioned studies (Mojumder et al., 2022).

Future expectations:

Differently from the majority of the literature written on the topic, Sovacool et al. (2019b) do not consider any technical detail nor economic factors in their analysis but rather focus entirely on the consumer perspective of V2G. In particular, they ask themselves how this technology is being promoted and discussed by experts in the Nordic region. The authors have interviewed over 250 professionals in the energy, automotive, and infrastructure industries.

The main vision and opportunity for V2G expressed by respondents was that of a fully electrified society, thus not only considering the presence of EVs on every road but also including some expectations about fast charging infrastructure, adequate mileage per charge, self-charging highways and ubiquitous infrastructure. The latter is also mentioned in Davies et al. (2022), who state that the amount of chargers is expected to increase by ten times by 2030, mainly due to the investments by EV manufacturers. In this scenario, some of these industry experts also foresee the utilization of EVs in closed environments, such as warehouses or even households, given that they would not produce any emissions. This scenario, according to the experts, would be made possible not only by improvements in V2G technology but also, and more in general, by battery and computing innovations. Finally, much in line with the rest of the literature, industry experts in the Nordics foresee a shift towards a more flexible and decentralized electricity market, where smaller actors could participate in the grid. This market would hence be dominated by local stakeholders rather than national monopolies (Sovacool et al., 2019b).

2.5.2. Main Challenges

After having discussed some views on opportunities and expectations on V2G and, more in general, on the spreading of EVs, some of the main challenges that have been raised in previous articles will be considered.

The previously mentioned paper by Davies et al. (2022) sums up the main challenges associated with Evs in the following visualization.

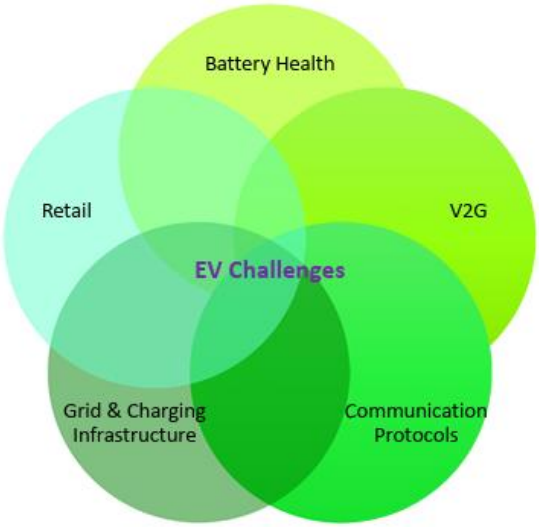

Figure 4 - Main challenges associated with mass introduction of Evs - Source: Davies et al., 2022

Lack of infrastructure

The most prominent challenge, which has already been discussed in this paper, is the current lack of chargers. As mentioned, the authors also state that this issue is meant to be solved by the combined effort of governmental policies and the manufacturers themselves. However, apart from the financial and technological development cost, the authors also mention the challenges in finding enough physical space to build large charging plants, especially in densely populated areas. Limited network connection could be an issue for those areas that are served by a sub-station and do not have access to high voltage. In this context, the authors consider V2G to be a challenge for the development of EVs in itself, as it further increases the requirements and costs for infrastructure (Davies et al., 2022).

Battery degradation

Battery degradation and disposal are two of the main concerns for EVs, as the bidirectional charging of V2G technology could potentially aggravate the issue. Clearly, degradation changes from battery to battery, depending on the technical specifications, the type of charger used, and the owner's driving behavior. For example, rapid charging and, especially, discharging to provide ancillary services could degrade the battery lifetime faster (Mojumder et al., 2022). Furthermore, weather conditions and temperature do affect degradation; in particular, cold weather can reduce battery lifetime. To prevent this, a thermal management system is installed in every battery; however, when the vehicle is not plugged in for several hours, studies have found a permanent degradation, also referred to as calendar loss (figure 6) (Davies et al., 2022).

In their technical study on battery degradation, Bui et al. (2021) developed a degradation model to evaluate battery aging under V2G applications; in particular, they have tested the above-mentioned calendar aging as well as the so-called cycling aging, thus the number of charge cycles that a battery can sustain before degrading. Cold temperatures negatively affected both types of stress factors; the authors also point out that the owner's behavior, thus driving with an aggressive style, also affects the degradation rate.

The issue of cold temperature is also mentioned by the Nordic industry experts interviewed by Sovacool et al. (2019b), who view that as a hindering factor for the spreading of EVs in the Nordics.

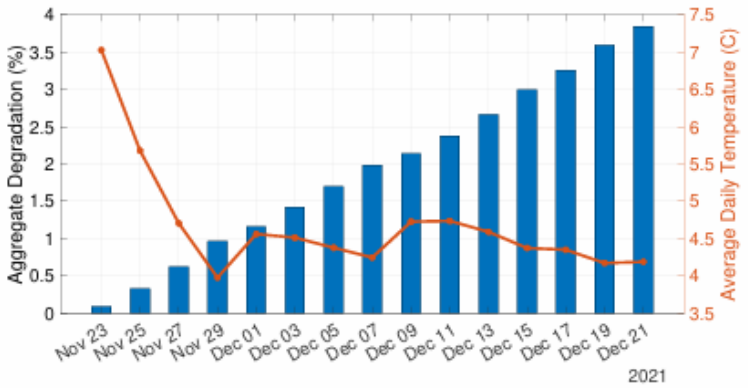

Figure 5 - Percentage of battery degradation of a parked EV in Glasgow, UK - Source: Davies et al., (2022)

Uddin et al. (2018) state that, according to their study and the analysis of previous work, unintelligent use of V2G and profit maximization strategies for the owner are not feasible in the long run due to excessive degradation. A smart grid concept and the implementation of a smart control algorithm to control the battery level and regulate the charge/discharge accordingly would be needed instead.

Lack of standardization

Standardization protocols and communication systems, thus between the vehicles, the aggregator, the TSO and the grid management system are also viewed as one of the main challenges to deal with. As already mentioned, there exists no absolute standard regarding charging infrastructure, which means that, as of now, OEMs can decide to build different connectors and chargers following the general policy guidelines for a specific class of vehicles. The lack of a common standard is seen as an important hindering barrier to the democratization of V2G technology.

Another type of standard is related to the communication systems, which enable, for example, the TSO to know how many V2G- equipped cars are in a certain area at a given time. Another example could be between the grid and the car to know when exactly to stop charging or to start discharging (The Smart Grid by Uddin et al., 2018). In this sense, it would really be a matter of collaboration between energy and utility companies to find a common solution. At the moment, each company uses its own communication system, which entails that it is virtually impossible to reach the openness and flexibility necessary to share all the data needed, thus positions, battery level, and others, to enable V2G technology (Davies et al., 2022). Another advantage of having one single communication system, and, more in general, one single standard, is that manufacturers would be able to exploit an economy of scale to produce all the infrastructure; furthermore, due to a faster learning curve, technological development would be much faster (Mojumder et al., 2022).

GDPR and Cybersecurity

A major potential issue related to interconnected and communicating systems would be GDPR and cybersecurity. The former would need to be addressed by policymakers and, depending on the level of interconnectivity between the vehicle and all the stakeholders involved, different types of agreements on data sharing would need to be drafted. On the other hand, this system potentially opens up cybersecurity concerns, as the linked grid and vehicles may be vulnerable to malware or cyber penetration. In this case, the EVs and the aggregators could be fitted with a secret access key which would protect from breaches in the system, as well as a manual command to authenticate the charging and discharging operation,

much similar to current authentication control for e-commerce (Mojumder et al., 2022, Davies et al., 2022, Sovacool et al., 2019b).

Legal frameworks

Regarding the cybersecurity issue, legal frameworks all around Europe are considered a hindrance to the development and actualization of V2G projects. For example, a study by Zagrajek et al. (2021) analyzed the current legal framework in Poland and concluded that, at the moment, there would be noticeable changes to be made in order to ensure a smooth implementation and avoid possible issues, such as double taxation, while minimizing gray areas in the legal text. Some examples made by the authors are the current lack of a proper definition of a bidirectional charger, which would leave OEMs completely free to create whatever they want (thus the opposite of reaching the previously mentioned common standard) or the lack of a solid market for V2G services.

Retail and business models

Another challenge for the retail world is to create new business models to sell vehicles, which, ultimately, could be used as a source of financial gain. In this scenario, companies should collaborate with utility firms to potentially create a unique package to sell to customers or, as suggested by Davies et al. (2022), to create a sort of servitization business model. An example could be to offer services such as battery boosting softwares to increase the battery performance and lifetime. Training staff and improving technical support could also be lucrative, according to the authors, as the battery is the most important and expensive part of an EV. Hence, they could run some sort of battery certification test, assessing the state of the battery after a certain mileage to give the client an idea of the remaining EV lifetime as well as a potential price to sell it on the secondhand market. More on business model innovation will follow in this section.

Socio-economic injustices

In a different study, Sovacool et al. (2019a) researched what are the types of social injustice that are associated with the use of EVs and V2G technology and if there were any patterns to electrical mobility that were worsening social vulnerabilities. As in the previous study cited in this paper, the authors have run a qualitative analysis by interviewing experts in the sector in the Nordic countries.

The main socio-economic issue that they have found is that electric mobility and, especially, owning an electric vehicle is still something that is restricted to the upper class. In this sense, V2G technology would be seen as something even more elitist, as only a very small percentage of people owning an EV would be able to participate in such a market, at least in the beginning. Furthermore, some interviews have raised concerns regarding policies that back EVs, stating that also these would only favor the elite. An example could be the fact that, once the government of Sweden and Norway, for example, had implemented a series of subsidies to incentivize people to buy EVs, these subsidies were used by the middle-upper class to buy an EV, which would not have been the first household car, only to benefit fiscally from that purchase.

Other issues raised by respondents in this study were the previously mentioned cybersecurity concerns as well as a series of negative externalities caused by the production of electric vehicles. Hence, the manufacturing process and the use of rare Earth raw materials, such as Lithium, the main component of batteries, which may negatively overcompensate for the environmental benefit of the actual use of an EV. Increased water consumption due to greater electrification and battery disposal were also mentioned in this study.

2.6. Business Model Innovation

The challenge to develop innovative business models to bundle and commercialize V2G services creates opportunities for both manufacturing companies and utilities to benefit from these services.

In particular, given that both automakers and energy firms participate in the V2G ecosystem, there is a confluence of interest and the possibility to bundle products differently. Previously, car manufacturers were not used to considering electricity as a factor determining the demand for cars, let alone a potential revenue source. The paper by Costa et al. (2022) explores business model innovation opportunities in this cross-industry scenario.

The introduction of EVs, state the authors, immediately challenged the traditional automaker business model, whereby a centralized manufacturing facility aims at reaching maximum economy of scale before delivering the cars to a series of distributors and resellers. Examples of early business model experimentations were the possibility for a customer who bought an EV to access a traditional car in case he or she needed to go for a longer trip; this was because of the initial challenges and concerns regarding mileage and the possibility to recharge the battery along the way. A current example of business model innovation is the possibility of leasing the battery instead of buying it. In this sense, the customer would have the possibility to lease the battery and buy the car separately and thus change the battery at a lower cost while keeping the car (Costa et al., 2022).

Given the importance of the battery in an EV, the literature has greatly discussed new possible applications for the latter after its use in the car. Once it reaches 85% degradation from its original state, a battery is not usually deemed good enough to fit a car; given the remaining value in it, manufacturers or third parties have the possibility to explore new usages for all of them, potentially creating financial and environmental benefits (Costa et al., 2022). The previously mentioned study by Davies et al. (2022) addresses battery recycling opportunities and suggests that these could be repurposed as storage systems for renewable energy and thus continue to supply the grid.

Given that, as previously discussed, V2G use will, at least in its early phases, increase battery degradation, Agarwal et al. (2014) mention the possibility of creating an incentive scheme for the customer to be able to buy a new battery at a favorable rate with lower maintenance cost, including in the package also parking and charging tariffs. Furthermore, a warranty on the battery offered by the aggregator would be necessary for the customer to use V2G technology without being worried about degrading the battery, within the boundaries of fair use.

The development of charging infrastructure also represents a business opportunity for the vehicle manufacturer, although this would require substantial initial investment cost and collaboration with energy supplies (Costa et al., 2022). In this sense, the authors state that, as of now, vehicle manufacturers had the tendency to take on the leading role as regards possible cross-industry collaborations in the electricity market, rather than the opposite.

3. Methodology

This chapter discusses the complete methodology that has been followed during the course of this project. The strategy and the overall research design are described in detail in the following sections.

3.1. Research Strategy

Business research may follow deductive or inductive strategies. The former indicates the process of researching with the purpose of deducing a hypothesis. Induction, on the other hand, refers to the process of having a hypothesis and then working to find evidence in support or against the hypothesis itself (Bell et al., 2022).

Our primary strategy may not be categorized strictly as deductive or inductive but rather as a combination of both. We started off with a primary hypothesis and built on that by collecting and analyzing primary information from various sources, primarily interviews and previous literature. Hence, we started with an initial hypothesis based on our generic understanding of the topic, and, as we continued to interview industry experts and professionals, we adapted our hypothesis and research question according to the new findings throughout the process. This process has been done with the highest degree of precaution and thought so as not to disrupt the academic research process.

Based on the above description, it also becomes evident that, although we have been changing and improving our research question over the course of the project, we still started with a basic hypothesis in the beginning, thus making the strategy predominantly “inductive” by definition.

3.2. Research Method

Considering the mixed approach between deduction and induction, we could argue that the same applies to the two main research perspectives: quantitative and qualitative. Following the same line of reasoning as above, these two strategies are not mutually exclusive, but they could very well complement each other. Thus, the key goal in this case would be to complement the two methods to enhance each other’s performances (Morgan, 1998).

In this sense, giving equal importance to the two methods will result in a complete dataset, but, given the time and the scope of this paper, we would argue that it would also be impractical. This prioritization approach is also suggested by Morgan (1998), who states that, oftentimes, prioritizing one of the approaches and using the other one to complement it will be enough for the scope of the research and will streamline the methodology. According to the author, the order in which the two methods are presented will mainly depend on the effectiveness and the maximization of the strengths of each of the two. Once again, using both methods simultaneously would be challenging, as it would be more difficult to understand exactly the contributions of the two.

Hence, our project has been mainly qualitative, considering the first part of the research question, which is more related to how the overall ecosystem is evolving with the advent of V2G technologies. We believe that a qualitative approach in this case would have been better suited given that, normally, there would not just be a clear answer or perspective to this question, but it would rather be a mix of different, subjective opinions based on personal experience.

On the other hand, considering the second part of the research, namely the scenario analysis, we believe that a quantitative approach could very well complement the previously obtained data from the interviews by generalizing the respondents' opinions. Hence, the resulting strategy will consist of collecting and analyzing qualitative data and then implementing them with quantitative figures, as depicted in the following visualization (Figure 6).

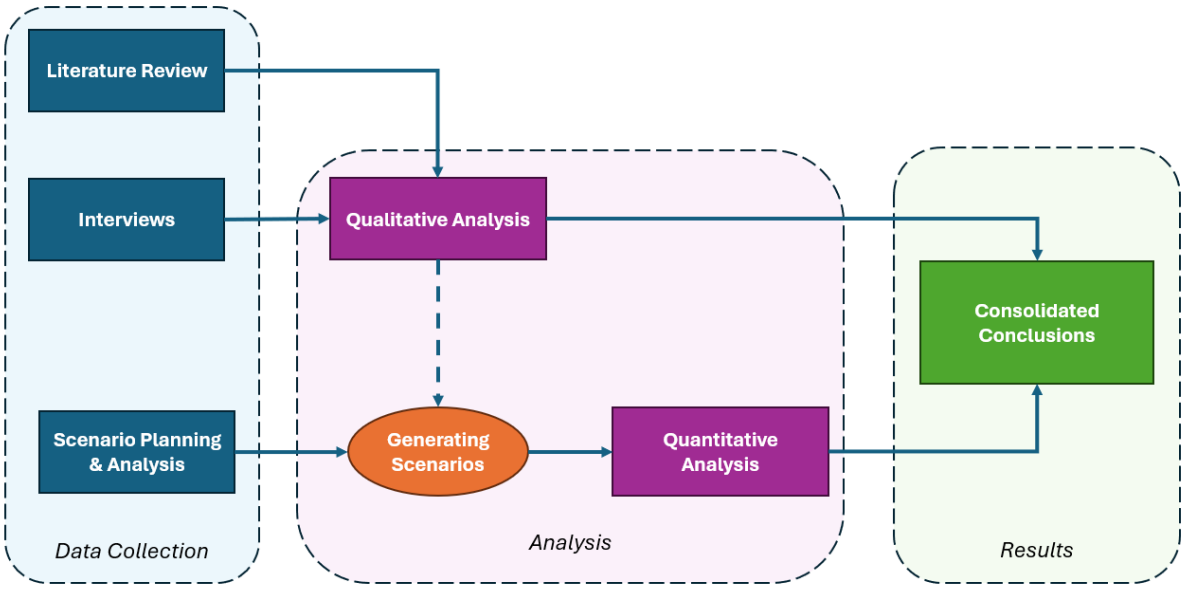

Figure 6 - Adapted convergent parallel design, based on our strategy

3.3. Research Design

Before deep diving into the design that we have chosen to carry out this project, we would briefly mention the criteria upon which business research is normally evaluated focusing mainly on the ones that we believe could be of interest for this type of project.

Bell et al., (2022) argue that the most common criteria to evaluate business research are mainly reliability and validity.

Considering the first one, reliability could be further divided into the sub-criteria of internal, inter-rater, and external reliability. Internal reliability refers to the extent to which the measures to analyze data are applied more or less in a consistent manner throughout the research. Inter-rater reliability considers the degree to which the researchers are able to evaluate more or less the same piece of information in the same way. In this sense, we have discussed and agreed on the interpretation of data, especially for more subjective areas. External reliability, on the other hand, refers to the possibility of the research being carried out by other researchers with the same results. Clearly, considering the subjective opinions of the interviewees, we are less concerned with this last criterion, as for the research to be perfectly replicable, other researchers should interview the same exact people in the same context, time, and place.

Validity is more related to the extent to which the paper really captures and answers the research questions. It is thus important to gather data that could actually be useful to the purpose while being generalizable. In this sense, we have focused on several different

organizations and backgrounds not to restrict our information and thus be biased in one direction only.

Given these evaluation criteria, to carry out this research we have chosen to use a cross-sectional design. This design is particularly adapted to both qualitative and quantitative methods (Bell et al., 2022). By interviewing different people and organizations at the same point in time it is possible to gather a more complete perspective without narrowing down our point of view.

3.4. Data Collection

The data collection includes both primary and secondary data. Primary data were mainly gathered by conducting interviews with different stakeholders within the industry. Secondary data include qualitative and quantitative data published in the existing articles, journals, reports, and other research literature. Both these processes are further explained in the following headings.

3.4.1. Primary Data

The main aim of the thesis is to understand the perspectives of different stakeholders directly or indirectly associated with the V2G ecosystem. Hence, the interview process includes EV manufacturers and energy utility companies as primary stakeholders, and most of the interviewees belong to one of these industries. However, we have taken a broader perspective and included other actors in this ecosystem, including real-estate developers, boat manufacturers, policymakers, and researchers working in this domain. The main focus was to get a holistic understanding of the ecosystem and correlate the findings from all dimensions and all stakeholders at the same time.

3.4.2. Interviews for Primary Data Collection

The interviews were conducted following a semi-structured approach, which provides more flexibility to the interviewee to answer the questions while also keeping the conversation structured and focused on the main subject (Bell et al., 2022). A preliminary interview guide was developed and followed throughout all the interviews (Appendix 1 – Interview Guide). It is pertinent to mention here that the interview guide only lists the main guiding questions.

In general, the interview protocol has been developed according to previous qualitative analyses and explanatory papers on the matter. Namely, according to Gioia et al. (2012), a research questionnaire should focus on the research question, trying to incorporate thorough questions and anticipate possible related issues. This kind of interview should not lead the witness; thus, it should include questions formulated to implicitly guide the respondent in answering in a specific way.

Furthermore, during our interview process, we reviewed and adjusted our questionnaire several times to make sure to include new perspectives as well as, in a sense, try to tailor some questions based on the specific expertise of the interviewee. Given the semi-structured format, more follow-up questions were also improvised and asked based on the specific responses of the subject and depending on the available time during the specific interview. This was done to put at ease the respondent as well as to try to follow the natural flow of the conversation as much as possible (Schoenberger, 1991)

Being close to the respondents may also have some downsides. Namely, one should avoid completely adopting the informants' view and thus losing sense of the bigger picture (Gioia

et al., 2012). In this sense, both of us have reviewed each other's work as regards the interview analysis part as well as the quotes reported in the text. Another possible challenge when conducting more open-ended questions rather than a fully standardized questionnaire is the validity of the overall data. Schoenberger (1991) states that, while a fixed set of questions may be considered more reliable and valid, as it will confirm or deny the same topic under the same point of view, a set of open-ended questions will better grasp the bigger picture.

To be able to gather as much valuable data as possible, we have asked, at the end of our discussions, if the interviewee were to know anyone else from his/her industry as well as in another related field with whom we could have talked. In this sense, as in (Bell et al., 2022), we used the so-called snowball sampling, thus allowing the chosen respondent to further suggest other people to interview.

As regards the sample size, we did not have a specific number of respondents in mind ex-ante. We stopped the interview process when we realized that we had a solid base of data from which we were able to define some clear recurring themes considering the heterogeneity of industries considered.

The following table shows a list of the interview respondents. In the rest of the document, each respondent would be referred to by his/her code mentioned in the table below (e.g R1, R2, etc.). On average, the interview duration ranges between 40 and 60 minutes.

Table 1: List of interviews for the thesis.

Code	**Name**	**Designation**	**Organization**	**Industry**	**Date**	**Mode**
R1	Magnus Hartmann	Business Developer	Gothenburg Energy	Energy	12-2-2024	Online
R2	Henrik Forsgren	Senior Project Manager, R&D	Gothenburg Energy	Energy	12-2-2024	Online
R3	Jens Groot	Chief Engineer (Battery System)	Polestar	Automotive	15-2-2024	Online
R4	Emannuella Wallin	PO Charging and PL V2G	Polestar	Automotive	15-2-2024	On-site
R5	Solveig Ramallo	Business Controller (R&D)	Polestar	Automotive	15-2-2024	On-site
R6	Niklas Lundin	Technology Collaboration Manager	Volvo Penta	Automotive	23-2-2024	Online
R7	Mark Bagley	Academic Researcher	N/A	Academia	5-3-2024	Online
R8	David Steen	Academic Researcher	Chalmers University	Academia	13-3-2024	On-site
R9	Jonnas Tannered	Head of Technical Installations	Örebro Bostäder	Real-Estate	25-3-2024	Online

3.4.3. Other Interviews (before this Thesis)

Prior to the start of this project, we contacted two field experts to ask their view on V2G. This was done in an effort to streamline our research question and understand whether this topic could have been further explored. The interview questionnaire developed at that time was a simpler version of the current questionnaire **(**Appendix 2 – Pilot Interview Guide**).**

The details of people contacted for these pilot interviews are provided in the following table. These interviewees are also referred to as PL1 and PL2 respectively in the interview findings.

Table 2: List of interviews conducted before thesis (pilot interviews)

Code	Name	Designation	Organization	Industry	Date	Mode
PL1	Umar Mukhtar	Energy Consultant	N/A	Energy	23-11-2023	Online
PL2	Qutab Baig	Energy Consultant	N/A	Energy	25-11-2023	Online

3.4.4. Secondary Data for Scenario Planning

The process of interviewing and collecting primary data from a multitude of stakeholders is always time-consuming. Therefore, it is often important to collect additional secondary data in parallel to best utilize the limited time period of your research. Secondary data has multiple advantages, as described by Bell et al. (2022), but the most important ones in our context are the considerations of cost, time and quality.

By cost and time, it is implied that the process of collecting the primary data by the two of us took a lot more effort and time which includes all the efforts of communicating with the potential interviewees and other stakeholders and then waiting for their responses, setting up meetings and then again waiting till the meeting appointment. That time was productively utilized in searching secondary data sources that offer high-quality and credible data from globally recognized sources. These sources include research articles in recognized journals, data reports by the country governments, reports by international bodies and associations, and similar outlets. This data serves as an additional pillar of our research, which allows us to expand our horizons in a considerably limited and shorter period of time.

As mentioned in the introduction, this research includes a scenario planning analysis aimed at answering the second part of our research question. In this sense, the scope, the time frame, and more details regarding the quantitative data used to build the scenario planning framework are presented in the related chapter of this document (chapter 5). In general, we considered statistics related to the growth of the EV sector in Sweden as secondary sources of data to model the framework. The most valuable data sources in this regard were the official databases of Sweden, such as SCB (Statistics Central Byrån) and its associated survey bodies. Additional data was retrieved from the statistics published by international bodies such as the World Bank Data (DataBank), United Nations Statistics Database (UNSTAT), International Energy Agency (IEA), and the European Commission Statistics (Eurostat). In addition to this, the NordPool Database of day-ahead prices proved helpful for scenario modeling as a source of historical electricity prices.

3.5. Data Analysis

The next step after effective data collection is to analyze the data to answer our research questions. The process of data analysis is summarized in the following sub-headings.

3.5.1. Coding and Thematic Analysis

The qualitative data collected during interviews is large and complex in nature, making it time-consuming to analyze. As a first step, the interview recordings were transcribed, and coding was applied to the text. Coding is a process in which the transcript text is categorized into components, which are then assigned individual labels (Bell et al., 2022). This process led to a comprehensive thematic analysis that was carried out in an iterative approach by repeatedly going through the interview transcripts and identifying as well as mapping different themes discussed by the interview subjects. A deductive coding methodology was then applied to identify and assign different codes to the interviews' content.

According to Nowell et al. (2017), the main advantage of thematic analysis is that it is more accessible and easier to carry out, particularly for those not used to research since it does not need any prior knowledge of the subject. The authors state that this method is relatively easy to learn, and it allows the researcher to summarize large amounts of data in an organized way. On the other hand, this methodology is sometimes considered less rigorous than other more researched methods, such as grounded analysis (Nowell et al., 2017).

As an example, the following text was marked and highlighted for two different themes within a single excerpt of an interview: 1) "taxation & legalities" and 2) "technology sharing and standardization". The following text from the interview transcripts of Niklas Lundin was mapped for the two themes as highlighted below:

> *"But of course, there is the regulatory tax that has to be managed. So it's a new area, I know Sweden is moving now to add a sort of legislation revenues from these type of services, how are they taxed and so on. Of course, there are different aspects there and bidirectionality that has to be handled. Insurance is another topic that pops up. If you want to do bidirectional charging, then there must be standards that are trusted. And then there also must be insurance and policies in place. So that the risk will be manageable." Excerpt from the interview of Niklas Lundin, Volvo Penta.*

A similar practice was applied to all other interviews by repeatedly going through the transcripts and identifying new themes and topics within the same text.

3.5.2. Quantitative Analysis

The quantitative data obtained through secondary sources was run through a rigorous quantitative and statistical analysis to identify trends and patterns within the data with the aim of creating a scenario planning framework. Additionally, we utilized the statistics to quantify the expected monetary value end-users could achieve by subscribing to different alternatives for V2G services in the coming years by identifying the current patterns of data. Some forecasting, prediction modeling and assumptions were applied to the data to develop these predictions and outcomes. More details about specific data and assumptions related to scenario planning and analysis will be provided in the fifth chapter.

4. Empirical Findings from the Interviews

The findings from the interviews are summarized in the upcoming headings of this section. We have organized these findings according to the different thematic codes that were identified during our analysis of the interview transcripts.

4.1. Revenue, Business Model and Market Potential

Almost all the interviewees agreed that V2G holds considerable growth and scalability potential in the market if implemented in an efficient manner. However, they also confessed that this business is comparatively new and mostly in the experimental stages, which makes it challenging to identify and assess specific business models and potential revenue streams.

From the perspective of energy companies, R1 and R2 believed that all major stakeholders would be able to benefit from this initiative. Energy companies will not only gain financially but also play a greater role in society, where V2G systems enable them to generate more contracts and interact with a wider range of stakeholders. Automakers will benefit from this opportunity indirectly by being able to sell more cars, more batteries, additional accessories for V2G, and possibly similar new revenue streams. The two respondents stated that the end-user would also profit from this incentive. All these possibilities open new business opportunities for many stakeholders.

R5 stated that, although there appears to be a very strong business case and potential for V2G, Polestar is still trying to figure out the best business model to capitalize on this opportunity. She believed that it is too early to judge how much financial benefit will the stakeholders be able to generate out of this system in the coming years, but that the overall profits will be evenly distributed among the three main stakeholders, namely energy companies, EV manufacturers and end-users.

R5 also suggested that EV companies might consider and experiment two different revenue models; either fixed-term subscription based or a transaction-based model, whereby the company would earn profits based on the total units of energy sold. According to her both these models would have their own advantages and more detailed technical analysis and experimentation would be needed to choose either of them.

R6 shared his views about business models from a boating industry perspective. He believes that revenues and financial benefits of the system should be contained within a few beneficiaries to make it attractive. If benefits were to be distributed to each and every direct or indirect stakeholder, then nobody would make any value out of it. For it to be financially sustainable, only the main stakeholders should be able to gain considerable financial benefits out of this setting. He also suggested that eventually the boat owner or the boat user should be able to gain the most out of this system.

R7 also shared his views about revenue potential from an economic perspective. He stated that these innovations may be challenging to assess initially, as eventual profits will depend on the rate of adoption of the technology itself. Initially, revenues might not be high for early adopters, but as soon as V2G is adopted on a mass scale level, these should increase. The eventual growth of revenues in that regard should be considerable as soon as that “tipping point” is achieved.

> *“Not necessarily at the tip there, but when it begins to take off, when it starts to begin to lift off, then you see all these firms just kind of just spawn and appear, and it can be within a matter of one year. It's quick” R7 (Mark Bagley, Researcher)*

R8 agreed with most of the findings above, especially considering the huge market potential that exists in the future. However, he also shared his thoughts and opinions about how, with the rise in the adoption curve, the overall financial profit margins might diminish for individual users, specifically in the FCR markets (explained further under the heading energy sharing and distribution balancing). This means that, as of now, the demand and supply distribution curves offer huge potential for users to capitalize on this trend, store cheap electricity, and sell off at a time when it is more expensive. As more and more people continue to join this bandwagon the overall curve will likely flatten, reducing the peaks in demand and supply differences and eventually leading to less profit margins for those storing and selling energy using their vehicles. Hence, there seems to be less clarity on how profitable and sustainable these business opportunities remain in the long run. This will largely affect the FCR-D & FCR-N markets, but volumes may not be as large to impact the entire energy trade market.

R8 also shed light on some possible transaction models between grid owners, energy companies and the single EV/fleet owners in terms of various energy sources, paid on a fixed or variable monthly subscription basis, which could guarantee fleet owners continued cash flows. This, however, may oblige them not to use the cars during specific time slots. This model is also explained further in the upcoming heading of "Energy Sharing and Distribution Balancing".

R9 brought a new perspective to this energy-sharing model. He mentioned that a pilot project conducted by his real-estate company implemented a system with a large, fixed battery installed in the dwelling that is connected to the grid for energy reselling. The tenants' vehicles are not connected directly to the grid in this scenario, and they only transfer back their excess capacity to the stationary battery at the dwelling. The real estate company then pays a specific amount to the vehicle owner. On the other hand, it provides this pooled energy to the grid at a different rate, thereby presenting a possibility of a profitable model. This pilot project was implemented at Örebro Bostäder some years back.

> *"In this case, the battery in the car is connected through this charger to our own stationary, larger battery, which is connected to the building and the electrical system." R9 (Jonnas Tannerstad, Örebro Bostäder)*

The above perspective mentioned by R9 provides an additional business opportunity for real estate owners to profit from this V2G initiative. However, R9 also acknowledged that this configuration is too costly for large-scale implementations, which suggests that it would probably be better to project a solution that does not require this additional cental battery.

4.2. Incentivizing the End-User

This appears to be one of the most important factors highlighted by this interview process. Within the context of this study, end-user refers to consumers who use the electric vehicle (including private cars, passenger cars, transportation fleets, or even electric boats etc., assuming the vehicle is capable of bi-directional charging and the infrastructure for that exists). End-user benefit refers to any kind of financial benefit, incentive, or reward that individuals get by connecting their vehicle to the grids.

From the interview process, we can summarize the main kind of benefits mentioned by the respondents:

1. Revenue by selling excess electricity to the grid at a price higher than the cost of charging.
2. Cost savings by utilizing the excess energy stored in the car battery, which the end-user would otherwise have to purchase from grid sources.
3. Possible tax deductions or credit points that the end-user could earn, which eventually could be calculated in terms of financial gains or savings.
4. An improved user experience and ease of use.

These pecuniary benefits, which mainly refer to the financial profit, appear to be the main driving factor for all end-users according to the R7. From a macroeconomic perspective, he stated that the entire business model could not work on a mass scale unless there is a significant financial benefit for the end user. He quoted several case examples of past innovations that were technologically superior to their rivals but that were never preferred to the alternative due to the lack of financial incentive for the end-user to adopt them.

"You also need to have an incentive for people, or companies, or firms, or individuals, or whatever households to adopt it. And if those incentives are not there, it doesn't matter how good the innovation is." R7 (Mark Bagley, Researcher)

R7 also mentioned the importance of financial incentives to overcompensate for the initial investments to adopt V2G, as the existing chargers are not bidirectional. He reaffirms his stance from an accountant perspective, stating that the end-user would invest if they got substantial returns on investment in this situation. R7 also mentioned some personal experiences of various services where he was not willing to switch from his current subscriptions to a new one, despite small financial benefits, just because of the cost and effort required for the switch.

R6 also shared their perspective on the matter and considered the financial benefit of the end-user a core factor in analyzing the entire business model, although he mentioned that this would not be the only one, as multiple factors must be taken into consideration. From the perspective of the boating industry, he admitted that electric boats are currently expensive compared with traditional ones but argued that the former offer a much more luxurious experience, mainly because of less noisy and smoother navigation. He believes that, as more users experience electric boats, they will prefer to switch to this alternative. In this sense, companies are looking into ways of making them more affordable. Such initiatives may also increase the end-user benefit of adopting V2G technologies.

"Yeah, it (financial benefit) has to be shared between just a few players, and otherwise, there won't be any substantial revenue. We believe that in the end, of course, the boat user or boat owner has to benefit." R6 (Niklas Lundin, Volvo Penta)

R4, R5, R6, and R7, as well as PL1 and PL2, also agreed that the overall system is going to work only if it is easy to use for the end user. They suggested that V2G could work if the entire system were like a plug-and-play system, where end users would not have to go through massive installations and modifications of their existing infrastructure.

"It has to be easy. It can't be like you have to call this person, you have to contact that company...it needs to be like a nice setup where you can have one contact, easy, smooth." R5 (Solveig Ramallo, Polestar)

4.3. Flexibility of Use

An important aspect for the end-user, according to R4, R6 and R7, would be flexibility of use. Generally, end-users follow specific time-tables to charge their vehicles, which may be very specific and fixed or, for some others, quite flexible and variable. However, when becoming part of a program to sell energy back to the grid, they might have to plan some specific time slots so that the energy distribution could be scheduled accordingly.

In this sense, states R6, boat owners may have to limit their flexibility in order to be part of the program. They will need to plan their trips accordingly in different days or time slots to make the boat available for V2G purposes during the summer season, when the boat would not be idle most of the time. In this case, they could decide not to take their boat out with a 30-minute notice anymore if that timeslot was originally dedicated to V2G charging. It is then to be investigated how many end-users would be willing to give up their flexibility in return for some financial gains.

> *"You need to know when the battery is available. When the boat is in the water during the summer, you want total flexibility; if you want to use the boat anytime with a 30-minute notice, then you cannot benefit from that (V2G). But if you agree to limit your flexibility and plan your usage, then I could plan to use my boat Friday evening and enter that into some type of calendar. Then you can be part of the ecosystem." R6 (Niklas Lundin, Volvo Penta).*

R7 and PL2 also argued that the system should be designed to provide maximum flexibility for the end-user. Without end-user flexibility embedded in the overall service design, customers might not be willing to be a part of this.

4.4. Energy Sharing and Distribution Balancing

It was discussed in the interview with R3 & R4 that effective management of V2G initiatives will require the vehicles to be grouped together into virtual fleets or car-pools. A single car battery may not provide a significant electric storage potential and it would thus make more sense to manage a group of cars as "Virtual Power Plants (VPP)".

> *"You cannot do that as a single car (share energy to the grid). You need to be connected to an aggregated fleet. And that's what you call a virtual power plant. So, you share it (energy) with the aggregated capacity." R4 (Emmanuella Wallin, Polestar)*

Upon further inquiring whether this would exclude individual car owners, R4 stated that this system would not exclude individual owners, but rather, it would make the service more inclusive for everyone. She also mentioned that becoming a part of a VPP would not require the group of vehicles to be at the same physical location. On the contrary, different groups of cars stationed remotely could operate as one unique connected entity. This would provide greater flexibility for the vehicle's owner.

R6 also indirectly touched upon this topic from the boating perspective. According to him, personal cars may have a lot of connection points from where they could share energy back to the grid. These may include residential, office, or public parking lots. Boats, on the other hand, have a lot more predictability in this sense, as they would only have limited options to connect to the grid. Moreover, they are stationed at one dock or trailer for longer periods (the winter season), potentially making the battery available for charging and discharging during this idle time.

R8 provided some technical details regarding how the battery pool could be valuable in the energy distribution ecosystem for restoration and managing of the electrical frequency (ancillary services). Two possible configurations from a car-pool perspective are listed below:

1. FCR-D[1]: This is the reserve capacity aimed at normalizing the electrical frequency in case of any disturbance in the system (for example, unplanned disruption of a nuclear power plant). A pool of electric car batteries could be used as a backup source in these situations to provide instant power to the grid and normalize any frequency variations.
2. FCR-N[2]: This is also a reserved capacity aimed at normalizing the electrical frequency in the system based on regular time-to-time fluctuations in the system.

These configurations act as fixed reserves to the grid. Usually, the grid owner must pay for the fixed capacity that is reserved at any time to the grid, which means that this system would provide a steady revenue for vehicle owners who make their cars available even if there is no actual need to exchange energy. This revenue will still be based on hourly prices, with less uncertainty and possibly less control of the pool owners. In addition to the FCR, there exist other opportunities in the market, such as the FFR[3] and FRR[4]. These models are similar to the FCR but differ on the basis of larger required volume and complicated technical requirements, rendering them unsuitable for V2G at present.

For real estate agencies, R9 believes that implementing V2G systems would not only be necessary for managing demand in the national grid but also as a contingency and power backup for local and regional energy requirements. As he mentioned in his pilot project, large stationary batteries were installed in certain residential dwellings; he argued that this could act as a power backup in case of blackouts and emergency situations. In this regard, if an area close by was to be cut off from the main grid for some reason, the dwelling would have a local energy backup system to supply that area for some time. R9 also mentioned the security situation with the Russia-Ukraine war and suggested that these backups may be necessary from a strategic perspective.

> "You get several possibilities. One is that you could see the cars as energy storage, you could aggregate and sell services to the local grid. They have a need for certain services. You could also think about the fact that you have several batteries that could provide nearby buildings with energy from a DC grid. We have this situation now with Russia and Ukraine; you have to build things in a more robust way. You have to consider blackouts and emergencies. If you have a blackout in the electrical system, you could use this installation to provide nearby houses with energy." R9 (Jonnas Tannerstad, Örebro Bostäder)

4.5. Policy, Legislation, & Legal Aspects

This is one of the areas that may require considerable efforts to enable effortless and effective inclusion of all stakeholders in the ecosystem. All our respondents agreed that there are

[1] Frequency Containment Reserve – Disturbances (https://www.svk.se/aktorsportalen/bidra-med-reserver/om-olika-reserver/fcr-d-ned/)

[2] Frequency Containment Reserve – Normal (https://www.svk.se/aktorsportalen/bidra-med-reserver/om-olika-reserver/fcr-n/)

[3] Fast Frequency Reserve (https://www.svk.se/aktorsportalen/bidra-med-reserver/om-olika-reserver/ffr/)

[4] Frequency Recovery Reserve (https://www.svk.se/aktorsportalen/bidra-med-reserver/om-olika-reserver/afrr/)

considerable grey areas regarding the legal aspects of bidirectional charging, especially in terms of obligations and taxation.

R1 and R2 stressed that there should be a clear and straightforward policy for the benefit of all stakeholders of the ecosystem. An important factor pointed out by R1 was taxation; in addition to the energy tax, would purchasing and then reselling energy constitute a duplication of VAT applied on the same commodity or not? Or would this be handled differently? These kinds of uncertainties are key from the perspective of end-users and energy infrastructure companies.

R6 argued about the importance of special taxation regulations and insurance policies that would cover the liabilities of different stakeholders in the ecosystem. R5, R7, PL1 and PL2 also mentioned the importance of these legislations, as they would play a vital role in widespread adoption of V2G.

Another uncertainty mentioned by R7 was the possibility of system abuse or misuse by any stakeholder, which may result in negative consequences for the whole ecosystem. He described the example of the "Cobra Problem"[5] to exemplify how this could result in a "Perverse Effect"[6] resulting in more harm than good. Financial benefits may encourage greedy actors to manipulate supply and demand to maximize their profit instead of focusing on the actual goal of balancing and normalizing the distribution curve. Therefore, certain policies must be put in place to ensure that the system is designed to preserve energy and improve distribution without being exploited.

R8 mentioned that there are ongoing discussions regarding policies and legislations and that the academia is working closely with the government to make this a reality. He stated that this is an ongoing process, and it may take some time but believed we are in the right direction.

4.6. Partnerships & Ecosystem

Almost all the interviewees considered the following as the primary stakeholders responsible for driving this ecosystem, which are mapped against their scale of impact in Table 3.

R3 and R4 mentioned that, in addition to the existing relationships between stakeholders, new actors will arise and become a part of the ecosystem. They mentioned "BSPs and BRPs"[7],which will work on the technical aspects regarding the integration of bi-directional charging within the grid.

R5 stated the importance of strategic partnerships not only for the energy ecosystem but also for the organizational goals and objectives of the individual stakeholders. As an example, she mentioned the Polestar Zero[8] project, which aims to make their entire production climate-neutral by 2030. She explained that, without strategic partners, collaborators, and organizations that share the same values, it would be impossible to achieve this goal. She mentioned that the same applies to V2G as, without a shared vision by all parties, the ecosystem would not be able to work effectively. It is necessary that all stakeholders understand the end goal of the V2G initiative and consistently play their part to make it a reality. She also stressed that all stakeholders must understand the bigger picture and the end

[5] https://ourworld.unu.edu/en/systems-thinking-and-the-cobra-effect
[6] https://en.wikipedia.org/wiki/Perverse_incentive#cite_note-siebert3-2
[7] Balancing Service Provider and Balance Responsibe Party (https://www.svk.se/utveckling-av-kraftsystemet/systemansvar--elmarknad/inforande-av-aktorsrollerna-bsp-och-brp/)
[8] https://www.polestar.com/global/sustainability/climate-neutrality/polestar-0-project/

goal of this initiative, which is to make our entire energy system more sustainable and efficient, reducing waste and dependency on non-renewable sources. With this alignment of visions, effective strategies could be developed to accelerate the transition to sustainable energy practices.

"I think that one of the key things is partnerships, not only between EVs (manufacturers) but with others, like electrical companies, the government, and so on. We want to be part of that and connect the different dots for V2G. It's not only the technology development itself here; you need to collaborate with everyone." R5 (Solveig Ramallo, Polestar)

Table 3 - Mapping of different stakeholders based on their scale of impact.

Stakeholders		Scale of Impact		
		Local/Regoinal	National	Global
1	Energy Companies (e.g Gothneburg Energi, Varberg Energi, etc.)	x	x	
2	Grid Onwer (e.g SvanskaKraftnent)	x	x	
3	TSOs & DSOs (Usually owned by Energy Companies)	x		
4	EV Manufacturers		x	x
5	Charging Point Operators (CPOs)	x	x	
6	Municipal Bodies	x		
7	Real-Estate owners and builders	x		
8	Technology Companies (that manufacture charing equipment for EVs.)		x	x
9	Technology standardization bodies/organizations		x	x
10	Taxation Agencies (e.g Skatteverket)	x	x	
11	Vehicle Dealerships	x		
12	Dockyards/Boat Charging Stations	x		

R6 also stressed the same concept. He explained that every new technology that must be implemented on a system level requires interaction between a multitude of stakeholders who need effective partnerships. Upgrading an engine may not require the involvement of different actors other than a few technology providers. V2G, however, is a much more complex system that requires the inclusion of all the stakeholders directly or indirectly affected by this technology. Moreover, the adoption of V2G itself requires all stakeholders to collaborate very closely and effectively.

"We need to know which players will be central to make this work. It is more complex when you look at bidirectional charging than normal charging. You need to have players that are able to handle this additional complexity and make sure that this challenge is taken away from end users, so they don't have to worry about that." R6 (Niklas Lundin, Volvo Penta)

R6 mentioned other stakeholders from the perspective of V2B: boat dealerships and marinas. He mentioned that boats are usually a seasonal hobby that people keep idle in their marinas for the rest of the year. These marinas are important for boats to be part of this ecosystem. In this case, they would have to encourage and incentivize boat owners to adopt V2B. Clearly, these marinas should also be well integrated into the grid and equipped with bidirectional charging. Without the alignment of technology, the whole ecosystem would not work out.

R9 would want the entire system to be as open and transparent as possible for all stakeholders. He believes that building strong partnerships and consensus among all actors would encourage the adoption of policies that are beneficial for the ecosystem first and then for the individual stakeholder. If not, a few companies might be able to build a monopoly to

exploit this technology for their personal gains. This would make large-scale implementation challenging.

> *"We believe to make this in an open way, so you could have one local system operator, or you could change it to another. That will be an important factor in the future. And here, we see that some companies are working in the opposite way; they don't want to make it open. They see this as a business case where they can make a lot of money. We make a lot of effort to have a healthy competition." R9 (Jonnas Tannerstad, Örebro Bostäder)*

4.7. Battery Technology & Excess Capacity Management

Battery technology is one of the major factors that can either accelerate or hinder V2G adoption, according to most of the interviewees. R5 mentioned that there is a significant effort within the industry to make batteries lighter, more sustainable, and long-lasting. Batteries should weigh less and have more capacity while also supporting more charging cycles. She also mentioned that Polestar aims to minimize the use of rare minerals that are actually harmful to the environment after disposal (lithium). R7 also agreed that the widespread adoption of V2G will require a significant improvement in battery technology.

R6 pointed out that the current batteries used in boats have certain qualities that might encourage the adoption of V2G. He explained that some of these, if left idle for long, may face considerable degradation. In that case, it would be more effective to use the battery for V2G when the boat is not in use for an extended period. This would be true especially in the Nordics, where boating is seasonal and boats would be left idle for the whole winter.

Furthermore, R6 emphasized that this is not just limited to seasonal benefits but that it could also work on a weekly or monthly basis if boat owners decide to plan ahead for their trips. In this way, they could decide when they want to take the boat for a ride and share energy the rest of the time. This would enable the boat owner to possibly generate additional financial benefits, which may cover docking and maintenance expenses.

R9 considers batteries to be the most important aspect of V2G technology. He stated that degradation should be researched more in-depth soon to really understand the possible negative aspects. Furthermore, given the current concerns about the actual production and disposal of batteries for the environment, he mentioned his efforts and relationships with two different companies, Scania and Epiroc, to reach commercial agreements for the recycling of their batteries. In this sense, both companies assured R9 of the feasibility of the project, as their batteries would not be deemed fit enough to be used, in the case of Scania, for example, in a truck, but they would be perfectly usable in the dwelling and real estate context. In a way, this could create a circular ecosystem where used batteries could be utilized in V2G instead of being discarded.

4.8. Sustainability & Environment

Almost all the interviewees agreed that widespread implementation of V2G is going to be beneficial in terms of sustainability. All of them mentioned how the need for non-renewable energy power plants would decrease during the night when using energy in cars, which would be charged in the daytime using greener sources (such as solar power, etc.)

R7 talked about different ways to assess the environmental impact of V2G. He proposed, as an example, to track CO2 emissions over time and compare them before and after V2G

implementation. He also suggested regression analyses based on other similar environmental variables that could be linked to this technology. However, he emphasized that these metrics could not be observed in the short term. Instead, these will take years of continuous monitoring. Moreover, there could be the need to study in parallel other variables, such as the overall adoption of EVs instead of fossil-fuel vehicles.

> *"I mean, that's an end result. Keeping in mind, though, that both of these things (V2G adoption and reduction of CO2 emissions) will have a lag effect. So, you know, you couldn't just sort of put this into place and then everyone adopts it and everything is great. And then you look at the numbers and they're not; they haven't fallen. It'll take some years before it falls. You know, old things take time to disappear. And that's something that, for example, politicians would need to be absolutely clear on. And something that often politicians don't really understand." R7 (Mark Bagley, Researcher)*

R9 also shared insights about how we could measure the environmental impact of this initiative. He suggested measuring the energy purchased from non-green sources compared with the amount derived from V2G over the next few years and then following the historical trend to assess the overall positive impact in that regard.

4.9. Hindering Factors for Adoption

Several respondents mentioned possible hindering factors that would negatively affect the adoption and democratization of V2G. R9 stated that the current cost of batteries is one of the most important blockers, as arguably the most important part of this system is prohibitively expensive for most, especially considering larger projects. In this sense, costs will be eventually driven down by the market. The previously discussed concern regarding battery degradation is also one of the major hindering factors at the moment, as pointed out by R4, R6, R7, R8 & R9 on different occasions.

In the context of real estate, the spread of this technology could be significantly influenced by owning the property or, on the other hand, renting one. For the owner, R9 states that adoption will be easier as it will be mostly the decision of the owner himself/herself. On the other hand, living in a dwelling and thus being subject to the decision of the landlord and the real estate will likely be different. In this case, adoption will be more challenging, given the need for common consent and slower bureaucracy.

The latter point, bureaucracy, has been mentioned by several interviewees. R2, R6, and R9, as mentioned, state the need to solve the issue of double taxation. R9 suggested that, more generally, Sweden could be slower than other European countries on the bureaucratic side, but on the other hand, the current challenge of double taxation will be addressed shortly. In April, states R9, 38 lawyers will convene in Stockholm to discuss the matter and hopefully further clarify the issue.

> *"I know these discussions are ongoing. And we have also had a request from the government in Stockholm, which will send 38 lawyers or juridical persons to discuss this next month. So yeah, I know something is going on here." R9 (Jonnas Tannerstad, Örebro Bostäder)*

The current lack of charging and communication standards will also be a challenge to be addressed, states R4. She asserted that, even if the standards are developed, there has to be some way to ensure their adoption by the major stakeholders. Unless they are unanimously

agreed upon and implemented across the board, there will be obstacles to widespread adoption.

> *"It's one thing if it's standardized and one thing if that everyone will apply it right. So the standard, yes, it will be there. But will it be obligatory to implement? No, I don't think so." R4 (Emmanuella Wallin, Polestar)*

A common digital platform to manage all the different sides of the agreements and charging operations will also be needed, according to R6, R7, and R9. The three of them state that it is imperative for the customer to be given the possibility to manage everything simply on one single platform rather than having to change every time. Furthermore, companies should provide these different services as a package to be as easy to use and understand as possible. As quoted before, R7 clearly stated that failing to provide an easy and comprehensive solution to the end user will likely mean failing to democratize this technology.

Another point raised by R9 was the newness of this technology for many stakeholders. He believes that, since this entire concept is new, it would require much deeper knowledge of the whole ecosystem from each stakeholder.

> *"You need to have new knowledge on how to control this whole ecosystem. Cars will be a part of the energy system. That's a new thing. For many companies, it's a new thing for the company (Örebro Bostäder). Here, we have to build a whole area with five building firms together, so that requires new knowledge on how to do it." R9 (Jonas Tannerstad, Örebro Bostäder)*

5. Scenario Planning & Analysis

With the increase in uncertainty and pace of innovation organizations are putting more emphasis on scenario planning techniques. Scenarios, often used together with other types of forecasting techniques and strategic analysis, are a possible description of a future situation. These techniques, based on past data and specific knowledge of the business environment, are used by managers to articulate strategies and reduce uncertainty about the future. In this sense, it is imperative to consider a holistic perspective of the business ecosystem when planning possible futures. In general, scenario planning techniques could be developed for any sort of future, but given their holistic nature, they tend to be more beneficial if a longer time horizon is taken into consideration (Amer et al., 2013).

Porter (1991) divides future scenarios into two macro-categories. Descriptive scenarios present a series of possible alternative events and are subjective in nature. Normative scenarios, on the other hand, are goal-oriented; they try to answer a specific policy and aim to reach a clear target. Another macro differentiation is between the more qualitative models and those that tend to rely more on quantitative data analysis.

In their comprehensive literature review of the topic, Amer et al. (2013) discuss the main schools of thought regarding scenario planning. The intuitive logic school assumes that the manager in charge of defining possible futures must be familiar with the main factors affecting business decisions, thus the economic, political, environmental, social, and resource spheres. In this sense, this school of thought does not use any mathematical model and relies mainly on intuition and previous experience.

Probabilistic modified trends, on the other hand, relies heavily on forecast and on probabilistic modifications of previous trends. This approach combines forecasting analysis with qualitative data to strengthen the insights given by the statistical models.

The authors also mention some other quantitative approaches, which all use previous data and statistical extrapolation, sometimes paired with expert judgments, such as in the case of Trend Impact Analysis or scenarios based on Fuzzy Cognitive Maps (Amer et al., 2013).

In the literature, there is not, as stated by Amer et al. (2013), an agreed number of future scenarios to be developed to make sure that the forecast is as accurate as possible. According to the authors, however, there seems to be a general understanding that the developed scenarios must be neither too few nor too many. Durance and Godet (2010), for example, state that the optimal number of hypotheses lies between 4 and 6; with more hypotheses, the model would not be manageable.

Once these scenarios have been drafted, they need to be analyzed and evaluated. The literature has presented a series of validation criteria including:

- plausibility: the scenarios need to be capable of actually happening
- consistency: there must not be internal conflicts in the hypothesis
- utility: each scenario should contribute something specific to the problem
- novelty: the scenario should add new knowledge to the organization and challenge existent conceptions
- differentiation: the scenarios shall be different and not simple variations of the same hypothesis (Wilson, 1998).

In general, to generate models aimed at reducing uncertainty and guide companies toward the best possible decisions, the literature really emphasizes the importance of consistency in the various developed scenarios (Amer et al., 2013).

5.1. Scenario Planning Framework

While several authors have contributed to the literature by developing their own models, it is not in the interest of this paper to review all of them but rather to introduce the topic in general terms. However, given the importance of following certain steps in order to create possible futures that will be, as stated, consistent with each other, one of the most influential scenario planning frameworks will be reviewed.

In his article "Scenario Planning: A Tool for Strategic Thinking", 1995, Schoemaker describes one, if not the very first, scenario planning framework. The author tries to bridge the gap that existed at the time between academia and practice. According to him, it is key to consider scenario planning, among the other existing planning methods, as the main tool to try to foresee possible futures. In this sense, contingency planning and sensitivity analysis, for example, could be limited to consider the effect of one type of uncertainty or variable at the time, while the main advantage of scenario planning would be its capability to consider the holistic picture (Schoemaker, 1995). In the following framework, the author tries to compensate for the main problem when depicting futures, thus either overpredicting or underpredicting some possible changes. This result can be achieved by considering what is already known and the observed trends, for example, in relation to possible future uncertainties, coming both from within and outside the corporation or the single entity for which this analysis will be run. Hence, this model considers both internal and external stakeholders. To do so, the author presents a 10-step process.

1. **Define the scope:** the first step of his model is to set up the time frame and the overall scope of the analysis. It is key to reflect on what has already happened in the past and try to anticipate similar occurrences as well as taking into consideration factors such as the rate of change of the given technology, possible new policies and product life cycles.

2. **Identify the major stakeholders:** current stakeholders are key to determining possible changes in the business ecosystem, as the power structure between them and their contractual agreements will influence the business model of the company.

3. **Identify basic trends:** current and possible future trends shall be considered when drawing a possible future scenario. Political frameworks and economic, societal and environmental trends shape the demand and supply of goods as much as consumers.

4. **Identify key uncertainties:** much related to trends, it is imperative to consider the industry's basic drivers of change in the foreseeable future.

5. **Construct initial scenario themes:** the initial ideas of the scenarios could now be drafted given the main trends and uncertainties, thus the two most important elements.

6. **Check for consistency and plausibility:** as per the previously mentioned criteria for scenario planning, the plausibility and consistency of the drafted scenarios should be considered. In this sense, are the scenarios consistent with the chosen time frame, the current trends and the power structure of the different participating stakeholders?

7. **Develop learning scenarios:** the earlier drafted scenarios can now be reshaped according to the previous point.

8. **Identify research needs:** as companies know the industry in which they operate but do not master other business environments, this step of the framework gives firms the possibility to analyze what lies outside of their normal knowledge and may affect their current business. This is particularly true when dealing with businesses that operate in more than one industry and thus need to be knowledgeable of several different factors.

9. **Develop quantitative models:** the use of data will strengthen or weaken the drafted learning scenarios. It is thus key to develop some quantitative frameworks to complement the qualitative knowledge accumulated so far.

10. **Evolve towards decision scenarios:** at the end of this iterative process the final scenarios shall be drafted, in accordance with the evaluation criteria and the quantitative data, to support the different conclusions (Schoemaker, 1995).

As said, this framework is not the only one that has been developed in literature; other models, such as the one created by Schwenker and Wulf (2013), are considered popular. The latter, in particular, presents only six steps and further streamlines the previously presented framework. While the majority of the steps are very reminiscent of the work by Schoemaker, the authors seem to focus less on quantitative data to strengthen the previous hypothesis and prefer to create, for each scenario, an ad hoc strategic action plan to make sure that, if needed, the single scenario could actually be put in place. Furthermore, Schwenker and Wulf (2013) present their tool, "the scenario matrix"; using the two most important dimensions, which have been identified in the previous steps, they generate four quadrants that will represent the four different scenarios (Figure 7).

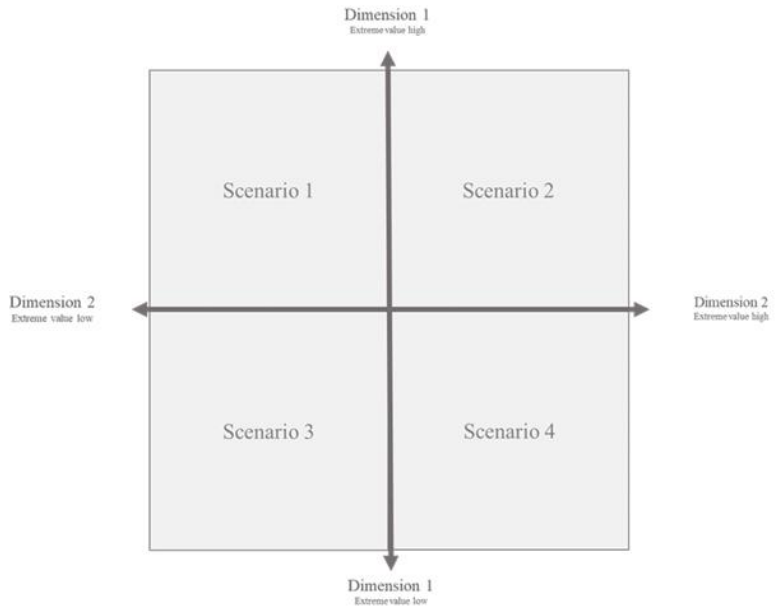

Figure 7 - Scenario planning matrix. Source: Schwenker and Wulf (2013)

Another difference between the 2 frameworks is that Schwenker and Wulf also consider, as their last step, an implementation and monitoring phase.

5.2. Tailored Framework

Given the purpose of this paper, we decided to develop a tailored framework based on the previous examples. In this sense, some steps of the model by Schoemaker were considered redundant and not appropriate to our time frame. Hence, we developed a 6-step framework with the intent of streamlining our research while, as already mentioned, strengthening our interview findings with quantitative data. This framework will not differentiate between initial, learning, and decision scenarios, but it will rather present four possibilities based on the previous scenario matrix model by Schwenker and Wulf (2013). The development factors, key uncertainties and observed trends are the result of the thematic analysis presented earlier in this paper based on the empirical findings from the interview process. Furthermore, the framework will not aim at implementing any of the proposed scenarios.

The tailored framework is presented as follows:

1. **Define the scope:** much like the previously mentioned frameworks, it is key for us to determine the purpose and the time frame of the analysis, defining the stakeholders as well as clarifying the main beneficiary of this analysis.

2. **Identify trends and uncertainties:** this second step is based on the empirical findings resulting from the thematic analysis of the interviews. The main trends, as the most recurring aspects of the V2G technology, will be analyzed for each theme. Furthermore, some related uncertainties will be mentioned for each one of them.

3. **Plausibility and consistency:** the trends and uncertainties will be checked to make sure that they can fit within the time frame and the scope without contrasting with each other.

4. **Quantitative analysis:** in this section, a series of data will be collected to assess and model the scenarios.

5. **Generated scenarios:** This step will be aimed at generating the four resulting futures from the scenario matrix.

6. **Summarizing the outcomes:** finally, a general summary of the analysis will be provided.

The entire process is summarized visually in Figure 8. Each step is further explained in detail in the upcoming sub-headings.

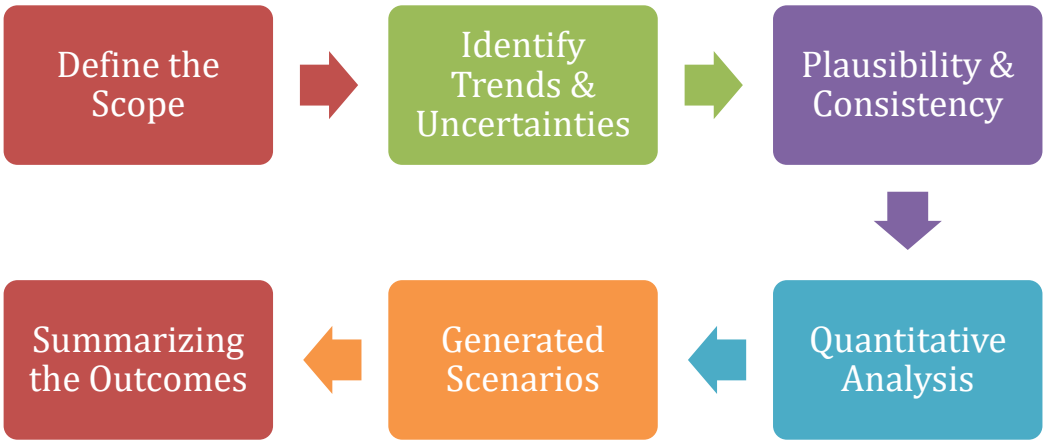

Figure 8 - Tailored process for scenario planning and analysis

5.2.1. **Step 1: Defining the Scope**

The first step of the model is aimed at defining the boundaries of the framework in terms of goals and time frame. Considering the previously cited article by Porter (1991), this model is intended to reach the so-called normative scenarios, thus possible futures which are aimed at answering a specific question rather than just exploring future possibilities. In particular, the main aim of this analysis is to draft four different scenarios for possible business models to be adopted based on a quantitative analysis of V2G.

In this sense, the data gathered during our interview process was key in defining the scope of this model. As already mentioned in the empirical findings section, the majority of the interviewees stated that, in the foreseeable future and with the current prices, V2G technology will not, most likely, represent a huge source of financial income for the companies themselves, thus manufacturers and energy utilities. On the other hand, the respondents were mainly motivated to pursue research and development in this field with consideration of the bigger picture, thus, societal and environmental benefits. However, as noted, for this technology to be accepted and democratized, there should be a financial benefit for the final consumer. This will likely incentivize privates to adopt this system and will thus need to be greater than the switching costs incurred.

Hence, in this model, we will assume different scenarios based on a user case of a private individual living in the Gothenburg area. Sweden is divided into four different regions regarding electricity supplies (SE1, 2, 3, and 4), and prices across these regions vary substantially, with SE1 (the north) being considerably cheaper than the south (SE4). Due to these differences, there would be the need to average the price for the entire country, which, given the two extreme values of the north and south region, would not result in a statistically sound model. For these reasons and for the scope of this model within this paper, we have only considered prices in the area SE3, which includes both Gothenburg and Stockholm. The other assumptions that we have considered are listed below:

- The individual owns an electric battery vehicle capable of V2G technology and a bidirectional charger.

- The BEV has an average battery capacity of 72.2 kWh (*EV Database*, n.d.)
- both the house and the charger are owned by the individual
- the ability to sell electricity back to the grid or to participate in the FCR from home charger exists
- A comprehensive online platform exists so that everything regarding V2G technology can be managed easily and on an individual level

As previously mentioned, the time frame is key to develop consistent scenarios, as planning too far ahead in the future will result in greater uncertainties and possibly inaccurate predictions. In this sense, the EV market in general is rapidly evolving, given governmental incentives for electrification and current environmental concerns. Furthermore, Sweden is one of the leading countries in this sector at the European and international levels. In particular, prices of both vehicles and chargers are meant to decrease in the future due to greater knowledge, research, and development. These factors, coupled with the fact that this framework addresses possible propositions for initial business models, suggest that, for the sake of this analysis, a shorter time frame of five years should be considered. Hence, an overall market potential for the next five years is analyzed under the Step-4. However, it is also important to mention here that the electricity market price is highly volatile and it is difficult to predict prices so far ahead; therefore, the profitability of an individual is calculated for only one year, taking the hourly prices of 2023 as the basis. This is explained further in the upcoming headings.

5.2.2. **Step 2: Identify Trends and Uncertainties**

Drawing from the previous chapter of empirical findings, we consider the main themes that have already been identified and, for each of them, we analyze trends and related uncertainties.

1) Business model and market potential

Trend 1: considerable growth and scalability

In general, respondents agree on the fact that V2G represents an interesting business case for both the automotive and the energy utility industry to have future financial margins as well as the end users.

Uncertainty 1: unclear business models

The main gray area in this sense is the novelty of this technology itself. The interviewees were unanimous in stating that it is still unclear how to market the full potential of V2G in terms of business models and potential revenue streams. Some propositions were a fixed subscription model or a transaction-based model. Furthermore, the division of the eventual profits between the different stakeholders is also unclear.

Uncertainty 2: revenues for the final consumers

While the majority of interviewees stated that, being at the very beginning of the learning and adoption curve, the possible financial margins for the final consumers may be considerable, at least to cover the switching costs, R8 expressed doubts on the feasibility of this model in the long run. The demand for ancillary services might not increase as much as V2G adoption, which means that, without new markets to implement the technology, financial margins for consumers may diminish as supply increases more than demand. This doubt reflects what

Andersson et al. stated in their research in 2010, as previously presented. However, we believe that this kind of uncertainty would be outside of the time frame of this model.

2) End-user incentives

Trend 2: not only environmental benefits

Respondents agree that, for the end user to personally invest and adopt V2G technology, there should be some financial benefit. In this sense, some propositions were tax incentives, energy savings or the possibility to sell energy to third parties. The environmental benefit is believed to play an important role for future adoption as well.

Uncertainty 3: ease of use & simplicity

Not only should the system provide some incentives but it should also be easy and intuitive to use. Respondents have been adamant in stating that, without a common platform, such as an app, where end users could easily manage or simply view the state of their V2G, even the best of the technologies would not be successful, as it would require too much time and effort to be understood.

3) Flexibility of use

Trend 3: a reduction in flexibility may hinder adoption

One important factor for adoption would be trying to avoid reducing day-to-day flexibility for the end user. In this case, customers may value their flexibility more than an eventual small financial gain from this technology.

4) Energy sharing and distribution balancing

Trend 4: need for aggregation

In general, respondents agreed that a single car could not necessarily participate in the grid on its own but that it would rather be necessary to implement what has been referred to as a virtual power plant. Hence, cars would be aggregated virtually by the service provider so that they would be able to share energy with the grid together and at the same time without being forced to stay in the same location.

Uncertainty 4: contractual agreements

It is still unclear how the use of VPPs will be managed contracts-wise.

5) Policies and legislation

Trend 5: need for more defined guidelines

Everyone agreed that more defined laws and regulations are needed in order to clear the current gray areas regarding double taxation, stakeholder participation as well as policies on liabilities and insurance. New regulations to define bidirectional chargers are also needed.

Uncertainty 5: possible stakeholder exploitation of the system

R7 stated that, with the need to implement new regulations, the system could actually be abused by manipulating supply and demand to generate supernormal financial gains instead of focusing on the balance in the grid.

Uncertainty 6: slow bureaucracy

Different stakeholders, R9 in particular, stated that, although Sweden is one of the leaders in the electrification sector, its slow bureaucracy may hinder the democratization of this technology.

6) Business ecosystem

Trend 6: stakeholders alignment

In general, V2G technology will require stakeholders, who are usually used to operating within their own industries, to collaborate with each other. Respondents stated that this cross-industry collaboration will be key for the widespread development of the system and for a faster development of the technology itself. The different stakeholders, mentioned in the respective paragraph in the empirical findings section, will need to collaborate to reach a common goal with the bigger picture in mind, stated different interviewees.

Uncertainty 7: cross-industry collaboration

The power structure, the single stakeholder participation in V2G project and the relative division of the revenues is still a matter of discussion. Furthermore, every project being different and involving more or less actors in the picture, it would be impossible to draft some general guidelines valid for every contract.

7) Technology

Trend 7: batteries and chargers need to be improved

Batteries and chargers are the two most important components of V2G. At the moment, batteries need to be improved in terms of power to weight ratio. Furthermore, newer batteries should tend to minimize harmful components for the environment. Chargers need also to be improved. At the moment, bidirectional chargers are a super minority of the charging infrastructure and are extremely expensive to commercialize as of now.

Uncertainty 8: battery degradation

As already mentioned, battery degradation is one of the most important factors to clarify and improve before a possible V2G democratization. The effects of this technology on batteries have already been researched but they are still not completely clear, as in the case of colder weather conditions. Recycling could be one of the most interesting forms of business model in the foreseeable future, which would alleviate the current environmental issues with production and disposal of batteries.

8) Sustainability and environment

Trend 8: general environmental benefit

All respondents agreed in stating that this technology would have a general positive environmental impact, amid the previously discussed potential issues with the batteries.

5.2.3. Step 3 Plausibility and Consistency

In this section of the framework, the previously presented trends (T) and uncertainties (U) will be briefly discussed and checked for consistency and plausibility against the time frame and the scope of the model.

T1, business growth and future opportunities highly relate to T6; thus, there is a need to co-create, with all the other interested stakeholders, a unique and holistic business ecosystem with the aim of considering the bigger picture and benefit of this technology. The need to create a valid and applicable business model is clearly the first step for the V2G system to be implemented and democratized. Hence, it will most likely be done within the time frame of this model. Clearly, stakeholders alignment and business model innovation are affected by a likely better definition of policies and regulations regarding matters such as chargers, stakeholder power structure and responsibilities within a common project. This may be

negatively affected by the slower Swedish bureaucracy, as noted by some respondents; however, we believe that this clarification of norms will be tackled by the government in the foreseeable future, also given the leading role that the country has taken regarding electrification projects.

This overall discussion of policy and business model will also affect T2, T3, and T4 with their related uncertainties. Once the general guidelines are clearer, we believe that companies will immediately start to draft possible implementations for this technology to be as flexible as possible without thus restricting anyone's daily freedom of movement. This need for flexibility relates to the need for aggregation, T4, which, depending on the contract, may positively or negatively impact the firmer.

One clear aspect taken from the interviews is that U3 will be key for whatever business model prevails, as ease of use may be eventually preferred to a more profitable alternative but more challenging to understand and manage.

The need to further develop the technology (T7) behind V2G and, mainly, batteries, massively affects business models, as prices and thus implementation will mainly depend on that. Battery degradation and recycling (U8) will also play a key role in the overall success of the project, both from a financial and environmental level (T1, T2, and T8). This challenge is currently being addressed. Hence, we believe that substantial improvements in the power-to-weight ratio of the batteries and their disposal/recycling will be accomplished. This could be proved by the already ongoing collaborations between companies to increase the overall product life and recycling of batteries, as R9 mentioned in his interview.

In general, we believe that the presented trends and uncertainties related to the findings from the interview process are aligned with each other and the time frame of this framework as well as the previous literature.

5.2.4. Step 4: Quantitative Analysis

Determining the feasibility and the potential outcomes of different scenarios requires understanding the size of the Swedish market. To get this perspective, the primary data about electric vehicles were taken from multiple official sources, primarily the Statistics Sweden website (scb.se). Additional sources were also accessed. The data are summarized in Table 4.

The original data available on the SCB website shows the total number of cars registered in Sweden from January 2019 till March 2024. The rest of the data was forecasted on a monthly basis till December 2030 using exponential forecasting. The percentages and the total battery capacity are then calculated using the resulting monthly stats from exponential forecasting. The average battery capacity of the BEVs and PHEVs was taken from online sources, namely ev-database.org and adamasintel.com, respectively (EV Database, n.d).

A preliminary analysis of the data shows that approximately 325,000 new cars are forecasted to be registered in 2025 alone. If the trend continues, there will be nearly 2.7 million new electric vehicles matriculated from 2025 to 2030. This means that in the next six years, almost 114 GWh (Giga Watt-Hours) of electrical capacity will be added to the pool of BEVs and PHEVs combined. If we assume that half of these vehicles are equipped with V2G technology, there will be nearly 57 GWh of energy at our disposal. This represents a significant amount of energy and a considerable potential market in the upcoming years.

Table 4 - BEV and PHEV Statistics for Sweden

	Number of Vehicles Registered			% of Vehicles		Average Battery Capacity (kWh)		
Year	***BEV***	***PHEV***	***Total***	***% of BEV***	***% of PHEV***	***BEVs***	***PHEVs***	***Total***
2019	15,795	40,702	56,497	28%	72%	1,138,820	887,304	2,026,123
2020	28,097	94,231	122,328	23%	77%	2,025,794	2,054,236	4,080,030
2021	57,881	136,081	193,962	30%	70%	4,173,220	2,966,566	7,139,786
2022	96,163	162,938	259,101	37%	63%	6,933,352	3,552,048	10,485,401
2023	112,775	174,010	286,785	39%	61%	8,131,078	3,793,418	11,924,496
2024 *	101,518	166,021	267,540	38%	62%	7,319,453	3,619,268	10,938,721
2025 *	125,789	198,915	324,704	39%	61%	9,069,401	4,336,342	13,405,743
2026 *	148,179	228,149	376,328	39%	61%	10,683,689	4,973,648	15,657,337
2027 *	170,568	257,383	427,952	40%	60%	12,297,977	5,610,954	17,908,932
2028 *	192,958	286,617	479,575	40%	60%	13,912,266	6,248,260	20,160,526
2029 *	215,347	315,852	531,199	41%	59%	15,526,554	6,885,566	22,412,120
2030 *	237,737	345,086	582,823	41%	59%	17,140,842	7,522,872	24,663,714

The other important parameter to analyze in this respect is the variation in electricity prices on an hourly, daily, weekly and monthly basis. The data for electricity prices was not readily available on public data sources as most of them show aggregated monthly or daily averages. To be able to model the hourly variations in electrical prices, hourly data were collected from the website of Nordpool Group (nordpoolgroup.com). The data was available for different weeks, and the dataset for the entire year was manually compiled. Unfortunately, more recent data was not available, so the data for the entire year of 2022 was collected into a spreadsheet for analysis and this data is used for all scenarios. A summarized view of the overall trends of electricity prices is shown in Figure 9.

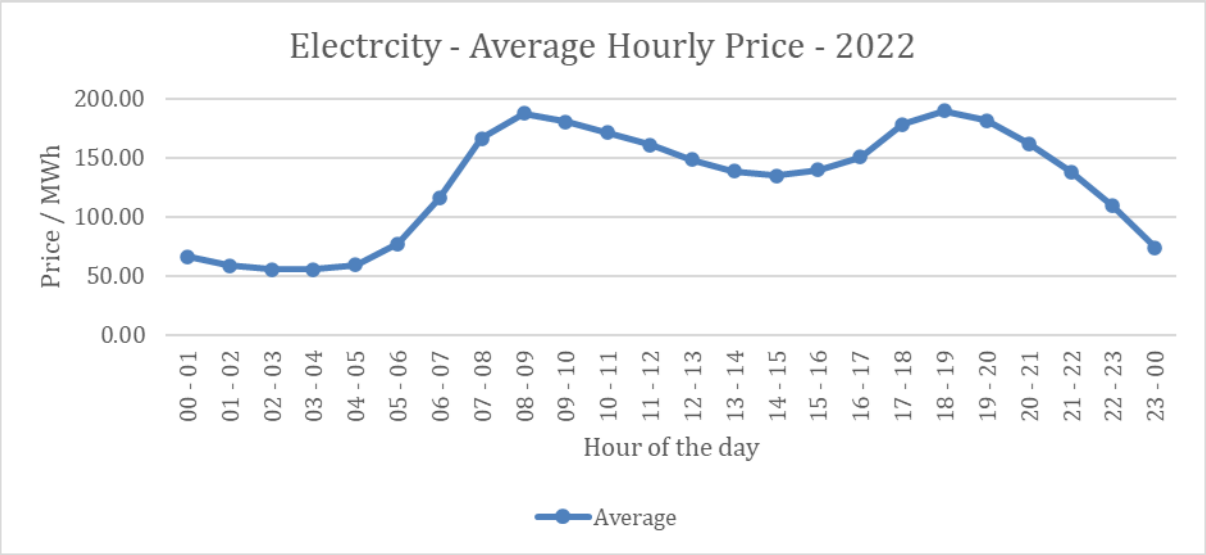

Figure 9 - Average hourly electricity prices in SE-3 region of Sweden over the entire year 2022

It is important to note that the data have a very high amount of deviation on a daily basis and the averages do not really represent the accurate picture. For example, for 20:00 till 21:00, the electricity price went as high as 741 on 25th August and as low as 1.02 on 11th November in the same year.

These hourly and seasonal variations provide a significant opportunity for the V2G users to utilize these variations to their benefit by storing the energy at lower costs and selling back to the grid when the demand is greater, eventually making profit out of it.

5.2.4.1. Basic Assumptions and Constants

The quantitative analysis was based on some key assumptions and constants that had remained consistent and applicable in all the developed scenarios. This would ensure harmony across all the scenarios and would also guarantee that all assumptions are documented and thoroughly calculated. A list of these assumptions is presented in the following table.

The first column in the table represents whether the variable was calculated, assumed, or inserted as an input based on another data source. It must be asserted here that although the assumptions were based on some facts and statistics; for instance the average travel distance of 25 km is taken from the Swedish National Transport Survey (Statistics Sweden, n.d.). Other sources for the input variables are provided in the appendix (Appendix 3 – Basic Calculations and Assumptions for Quantitative Analysis). The table in the appendix also contains additional comments and formulae for the other variables in the table.

Table 5 - Basic assumptions and constants that are applicable to all scenarios.

Type	*Name*	*Description*	*Value*	*Unit*
Commute and Consumption				
Input	c1	Average Travel Distance (Rounded Up)	25	km
Input	c2	Average EV Consumption (Rounded Up)	0.2	kWh/km
Calculated	c3	**Total Power Cosumed for Commute**	**5**	**kWh**
Battery Capacity				
Input	c4	**Average Battery Capacity (BEVs)**	**72.1**	**kWh**
Calculated	c5	**Hourly Charge/Discharge Rate**	**10.30**	**kWh**
Calculated	c6	Battery Capacity (available after Commute)	67.1	kWh
Input	c7	Average energy loss in charge/discharge	10%	
Calculated	c8	Net Battery Capacity (available for trade)	60.39	kWh
Assumed	c9	% of battery saved as backup for emergency	20%	
Calculated	c10	Total Battery power kept as backup	14.42	kWh
Calculated	c11	**Battery Capacity (Intended for trading)**	**45.97**	**kWh**
Lifestyle & Choices				
Input	c12	Average Working Hours, Weekly	38	hr
Calculated	c13	Average Working Hours (Rounded up), per Day (5 working-days per week)	8	hr
Input	c14	Avg time spent Travelling, daily	1	hr
Input	c15	**Average Charging Time (From 0% to 80%)**	**7**	**hr**
Others				
Assumed	c16	VAT for Selling Energy	9%	
Assumed	c17	Other Miscellaneous Charges	5%	
Input	c18	Annual Inflation	4%	

5.2.5. Step 5: Generated Scenarios

The fifth step of the framework aims to present the four generated scenarios based on the previous trend and uncertainty analysis as well as on the quantitative analysis. In particular, the previously presented scenario matrix used by Schwenker and Wulf (2013) will be considered.

The four quadrants representing the scenarios have been split according to two dimensions, taken from the uncertainty and trend step of the framework, which we consider to be the two most important factors based on the interviewees' responses. Namely, all respondents have been unanimous in stating that, in order for V2G technology to be widely adopted, there will be the need to incentivize final users to switch to this system. Financial revenue seems the most effective solution in this sense. Hence, one of the dimensions of this framework considers the possible financial compensation to end-users depending on the different business models proposed.

The other key factor for adoption is flexibility and the related uncertainty. The need to consider electricity hourly spot prices and to account for a sufficient amount of vehicles to share energy with the grid at the same time (with the use of a VPP) could potentially limit the end customers' everyday flexibility and freedom to use their vehicles. At the moment, flexibility could be considered as inversely related to the certainty of making money by V2G service to the grid. For instance, a contract requiring the vehicle to share energy at certain times of the day would diminish the customer's freedom to use their vehicle while increasing the certainty of the V2G energy sharing (and possibly more certain financial benefit in return). The opposite is also true, as with more freedom of vehicle use, it would be more uncertain that the vehicle could be used for V2G at specific hours of the day. As discussed before, the need for aggregation and the possibility of using virtual platforms, which ultimately would not limit anyone's flexibility, could be the solution to this challenge in the long run.

Building on this discussion, the scenario matrix for this framework and the relative profiles/user stories for the different scenarios are presented below:

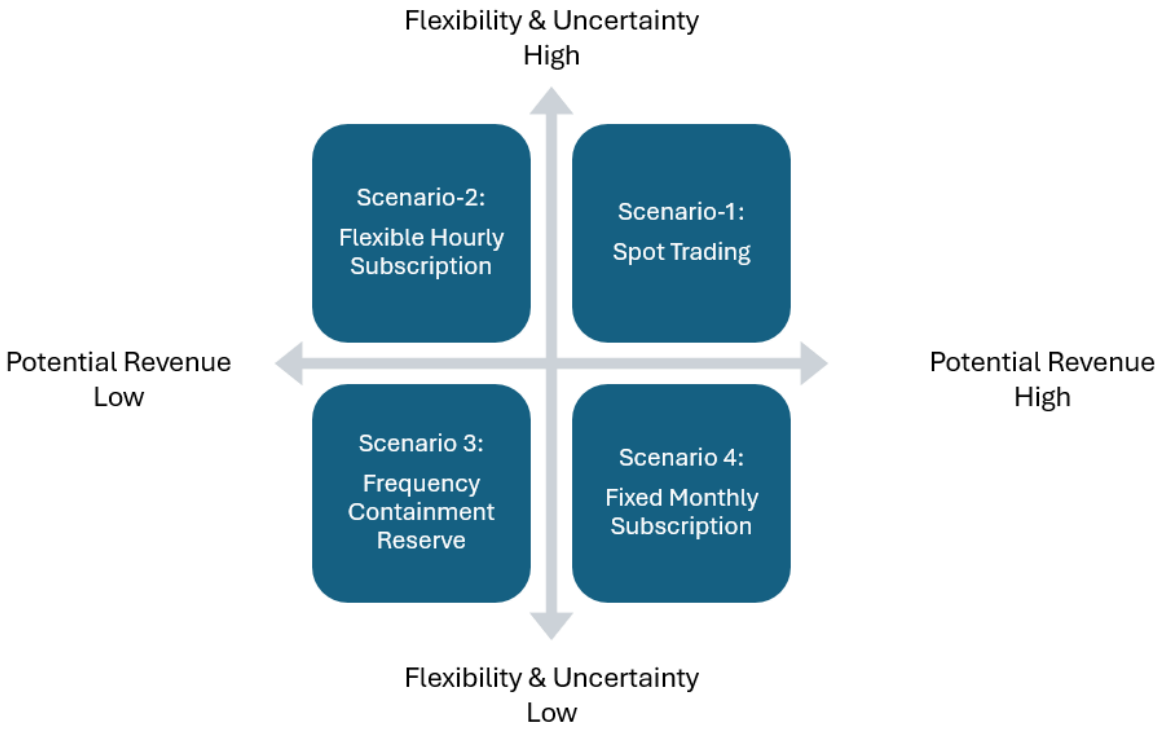

Figure 10 - The scenario planning matrix, tailored model

Scenario 1: *The Maximizer Grid Guru*

This scenario entails maximum flexibility and, potentially, the highest revenue generated from excess electricity capacity sold back to the grid in a manner more similar to spot trading.

In one year, let us suppose an individual in Gothenburg will be able to comfortably sit in his/her home office and select via app, on a daily basis, which hours to charge or discharge the vehicle the day after, based on private schedule and electricity spot prices. In this sense, the end customer would be able to choose an amount of hours, with no minimum or maximum required, in which he or she could charge the car at the lowest possible price on the day after (based on the day ahead prices being available, as they are currently on the NordPool website) as well as selecting the best time to sell back energy to the grid when prices are the highest. When selling to the grid, the customer subscribed to this service will be paid only for the actual energy (in kWh) transferred to the grid through the reverse metered connection. The same model applies to scenarios 2 and 4 as well. For this service, the end user would be able to choose a monthly or yearly subscription, with the possibility of interrupting it anytime with two weeks' notice.

The spot trading case could potentially generate the highest revenue out of the four scenarios while guaranteeing the end user daily flexibility. The calculated outcomes of this scenario are summarized in the following table:

Table 6 - Outcomes of Scenario-1

Scenario-1 (Summary)		
Description	*Value*	Unit
Total Hours in a day	24	hrs
Hours Required for Charging	7	hrs
Hours Required for Commuting	1	hrs
Remaining Hours Available for Discharge	16	hrs
Battery Capacity (Intended for trading)	45.97	kWh
Hourly Charge/Discharge Rate	10.30	kWh
Total Hours Possible for Trading (Rounded)	4	hrs
Results (for 365 days)		
Total Cost of Charging	- 17,521	SEK
Total Revenue from Selling Electricity	36,545	SEK
Net Revenue	**19,024**	**SEK**
VAT for Selling Energy (9%)	1,712	SEK
Other Miscellaneous Charges (5%)	951	SEK
Net Gains/Loss (Annual, Current Year)	**16,361**	**SEK**
Total Discharging Hours	1,482	hrs
Gains/Loss per Hour	11.04	SEK/hr

As evident, the end-user would be able to generate a net profit of around 16,000 SEK annually, which could be a significant amount. In this case, it was assumed that the person is able to charge the car during the seven hours with the lowest price and sell back energy at four hours with the highest price (which is the ideal scenario). The calculations also assumed that the individual is able to do this every single day of the year, making this specific model probably unrealistic.

It is also important to mention here that the total cost of charging in the calculations of all the scenarios includes the cost incurred by travelling in the vehicle for daily use. Hence, the net

gains represent the value generated after the person has paid for all their travelling expenses as well. This represents the additional savings generated from the V2G service which the person would have paid as charging costs otherwise. This also explains why the car is charged for four hours only, but then recharged for almost seven hours everyday. This difference of hours caters for the additional energy spent on travelling and the energy losses.

To subscribe to this service, an individual would not only need to have a remote job, or the possibility to leave the vehicle at home to be able to profit from oscillations in prices throughout the day, but would also need to be capable of understanding spot prices and willing to invest time in choosing charge and discharge hours daily. In this sense, this scenario could be interesting for people who are already knowledgeable about the electricity market and passionate about new technologies, thus the so-called early adopters.

It could be said that the flexibility provided by this service would come as a result of daily management of the service itself, which may not be the best solution for a new customer who just wants an easy and intuitive introduction to this service. The profile for this kind of subscription would then be that of a customer who, given almost complete freedom schedule-wise, would like to maximize revenue in spite of the daily management of the platform. However, given the need to be available all day long, we believe that this subscription would be eventually chosen by a minority of the population and thus would not be the best alternative to fully democratize this technology. Furthermore, the calculations shown before assumed the customer would be trading every day of the year, which, while useful in simplifying the model and assumptions, would be unlikely in a real-life scenario.

Another downside of this subscription would be the excessive charging and discharging of the battery. As mentioned in the literature section, the paper by Uddin et al. (2018) proved how an aggressive use of V2G could be detrimental to the battery in terms of degradation and suggested the use of smart grid systems instead. Spot trading would probably be, in that regard, too extreme to be sustainable in the long term, and the revenue generated by selling energy would be used to replace the battery of the vehicle.

Scenario 2: *Flexibility Pro (Max)*

In this case, an individual would be able to subscribe to the V2G service through the mainstream app and decide, on the day before, some time slots to charge or discharge the car on the day after. The difference between this model and the previously presented spot trading is that, in this case, time slots would not be of a single hour, rather slots would be grouped into 4 or 5 hours each. In this sense, one would be able to select 6-7 hours to charge the vehicle at the most convenient price (in the early afternoon for example) and, vice versa, 4-5 hours to sell back energy in excess, whatever the price and the need for energy in those time slots is. Another difference with respect to the previous scenario is that the individual is assumed to be able to sell back energy only 3 or 4 days a week due to personal schedule. These days, customers can clearly choose freely.

As shown by the calculations in the following table, this would result in no significant financial benefit on a yearly basis. These calculations were made based on randomly chosen hours for charging and discharging on different days of the year. The iterations were run multiple times using the ‘Random’ variable formula in Excel, and each variable rendered either a very small overall financial gain or sometimes even a negative outcome, meaning an overall loss for the end-user.

While less appealing from the financial perspective, this scenario would also be less extreme than the previous one in terms of assumptions and, we believe, more applicable in reality. In essence, there would not be a need to share energy on a daily basis or to stay at home all day

long. For this scenario, on the other hand, we have envisioned an individual who is supposed to still have a flexible personal schedule with the possibility to still spend some considerable time at home due to 2 days a week of remote work, for example. While still needing to dedicate a few minutes a day to choose the time slots, this subscription would be easier to manage than the previous one, not having to go through each hour one by one.

Table 7 - Outcomes of Scenario-2

Scenario-2 (Summary)		
Description	*Value*	Unit
Total Hours in a day	24	hrs
Hours Required for Charging	7	hrs
Hours Required for Commuting	1	hrs
Remaining Hours Available for Discharge	16	hrs
Battery Capacity (Intended for trading)	45.97	kWh
Hourly Charge/Discharge Rate	10.30	kWh
Total Hours Possible for Trading (Rounded D	4	hrs
Results (for 365 days)		
Total Cost of Charging	- 7,005	SEK
Total Revenue from Selling Electricity	7,100	SEK
Net Revenue	**95**	**SEK**
VAT for Selling Energy (9%)	9	SEK
Other Miscellaneous Charges (5%)	5	SEK
Net Gains/Loss (Annual)	**82**	**SEK**
Total Discharging Hours	382	hrs
Gains/Loss per Hour	0.21	SEK/hr

The main downside of this proposition is the lack of financial revenue for the end user, which is considered, according to most interviewees, one of the most important incentives for adoption. As a result, for this subscription to be considered by a potential customer, all the other assumptions for V2G technology need to be satisfied. The price of the infrastructure would drastically need to go down, considering the investments in the charger, for example, and the service itself would need to be absolutely smooth and easy to use. Furthermore, the potential end user would need to be strongly driven by environmental or ideological reasons to face switching costs. Hence, we believe that there could be better alternatives to this type of subscription in the early stages of the adoption of V2G and that this proposal could then be integrated later on in the process and learning curve of this technology.

Scenario 3: *The Opportunistic Reservist*

This model, referred to as frequency containment reserve (disturbance), FCR-D, is aimed at directly answering the need to maintain balance in the grid through ancillary services. Thus, according to some of the literature, a promising application of V2G.

With this type of agreement, mentioned in the interview process by respondent 8, an individual would be guaranteed to be paid for the whole time slot during which the vehicle is connected to the grid, whatever the actual energy shared during those hours. It could then be said that a subscriber would be paid just for being available to the grid. In this case, there would be no minimum nor maximum amount of hours to charge/discharge during the week or month, but it would be at the discretion of the individual to decide. Furthermore, one would be able to make his/her own vehicle available for the next hour with a minimum of a 45-minute notice. Hence, spot prices could also be taken into consideration to maximize revenue.

However, to subscribe to this service, one needs to understand the functioning of the electric market and ancillary services. FCR-D could be downward or upward. The former would be needed when regulation up is necessary, thus when frequency falls under 49.5 hz/hr and needs to be increased. In this case, a fully or partially charged car could be used to transfer energy to the grid. On the other hand, FCR-D downward answers to the opposite issue, thus when frequency is more than 50hz/hr and needs to be decreased. A vehicle on an empty battery would then be made available to the grid to be charged and the frequency would be regulated downwards. The vehicle owner would then need to actively choose to make his/her car available to the grid for regulation up or down, as this process would not be automatic. Thus, one could use the car for one or two days and, when needing to be charged, make it available for FCR-D downward. On the other hand, when not in use, the fully charged vehicle could be used for FCR-D upward.

Another technical requirement for this service to work is the participation of the car in a virtual power plant (VPP). Usually, the minimum energy reserve requirement for FCR-D is 0.1 MW, which is a significantly larger amount than the hourly energy transfer capability of a car (averaged around 10 kW = 0.01 MW). This requires the individual car to be connected to a pool of vehicles in the form of a VPP where a group of cars provide a combined capability of, possibly, a few Mega Watts. In this sense, this specific model is a bit difficult to implement and may require more formalization in the future.

The modeling for this scenario is slightly different than others. We are not making the vehicle charge or discharge the energy continuously. We are just making it available for longer hours, should the grid need to take or release energy in the battery for frequency stabilization.

For this purpose;

- The individual uses the car regularly throughout the week without charging daily. Usually, one could use the vehicle for standard commuting for almost 10 days without charging, based on our basic assumptions.
- After ten days, when there could be nearly 20% of battery left, the user plugs in the car for one night for FCR-D (Downwards). Whenever the frequency goes above the threshold, the battery should be able to take the load from the grid to the battery.
- By the next day, either the battery is almost fully charged or it is still empty. In either case, the car owner can fully charge the battery and the next night make it available for discharge, by bidding on the FCR- D (Upwards) so that whenever the frequency falls below threshold, the car's power could be transferred to the grid.
- In both cases, the car owner gets paid, whether or not there is a charge/discharge.
- Additionally, it is assumed that the car owner has the available flexibility to let the car be on reserve or charge for every 10^{th} and 11^{th} day, and it does not affect their schedule.
- We have also assumed that there is a 50% chance that the car battery may be used for FCR-D or FCR-N and a 50% chance it is not used at all. Hence, it will take a total of 5 hours to fully charge the battery if FCR-D (Down) is activated. With a 50% chance, we convert it to 10 hours, and we assume that at the end of 10 hours, the car battery will be fully charged.
- The car is then put to FCR-D (Up) when the battery is fully charged to make it available for offloading. In this case, with a 50% probability, it is assumed that the car will be offloaded fully in 10 hours.

- In both cases, there may or may not be a need to charge the car fully or partially between the two cycles or at the end of both cycles. For simplicity, we will keep a charging cycle at the end of both FCR-D and up and down cycles. However, we will assume that the car is fully discharged and charged within the FCR-D cycles so the charging cost is not taken into account separately. However, there will still be a gap of 7 hours between the two cycles to make it possible to charge the car fully if required after an FCR (down) cycle.

Other than the connection to the literature, this scenario could potentially be profitable, even if not as the spot trading alternative, for the end customer. This total revenue, while not incredibly high if considered on a yearly basis, could still help one's household financially and represents a good incentive to share energy. Furthermore, while the customer is always expected to choose between upward and downward service, which, at the beginning, could take some time to get used to, we believe that, in the longer run, this choice would not constitute much of a hindering factor for people to subscribe to this service. Management-wise, this alternative could still be easier to use than the spot trading case and, mostly, more implementable in terms of private schedule. The certainty of being paid for the overall number of available hours provided to the grid could also be an element in favor of this approach.

In terms of flexibility, this scenario entails a certain degree of freedom, considering the extremely short notice with which one would be able to make his/her own vehicle available to the grid every hour. It could still be regarded as a bit more complicated than spot trading and flexible hourly subscription given the choice between upward and downward service.

Table 8 Outcomes of Scenario 3

Scenario-3 (Summary)		
Description	*Value*	Unit
Total Hours in a day	24	hrs
Hours Required for Charging	7	hrs
Hours Required for Commuting	1	hrs
Remaining Hours Available for Discharge	16	hrs
Average Battery Capacity (BEV)	72.1	kWh
Average Daily Commute Power	5	kWh
Interval before next FCR-D (Down) cycle	10	Days
Battery power used in interval	50	kWh
Remaining Battery power	22.1	kWh
Charging/Discharging Losses	10%	
Net Remaining Power	19.9	kWh
Battery Capacity (Intended for trading)	45.97	kWh
Hourly Charge/Discharge Rate	10.30	kW
Total Hours Possible for Trading (Rounded Down)	4	hrs
Results (for 365 days)		
Total Revenue from Selling Electricity	467	EUR
Total Revenue from Selling Electricity	**5,440**	**SEK**
VAT for Selling Energy (9%)	490	SEK
Other Miscellaneous Charges (5%)	272	SEK
Gross Revenue (Annual)	**4,678**	**SEK**
Total Hours (FCR)	803	hrs
Gains/Loss per Hour	5.83	SEK/hr

Overall, we believe that this alternative could be regarded as more promising at the moment, as it could represent the right trade-off between revenue for the end user, simplicity of use, and flexibility. Hence, while not as profitable as others, it could be considered a good starting point for this technology to spread out while assuming that new business models and opportunities will be developed along the way. Furthermore, this subscription would not be as aggressive on the battery as spot trading; FCR-D could actually be beneficial in terms of battery degradation, as David Steen mentioned in his interview.

Scenario 4: *The Uptight Scheduler*

This option represents what we consider could be the least amount of flexibility for the service.

In this scenario, an individual would be able to choose some daily time slots, which would then remain fixed for the whole month, evenly distributed from 3 to 7 days a week depending on the agreement. For example, one would choose to discharge the car on Sunday, Monday, Wednesday, and Friday from 17:00 to 21:00 for the whole month. While charging times would not be subject to any restriction, a penalty would be applied if the individual does not make his/her vehicle available to share energy with the grid in the agreed time slots. As in the previous case, there would be different subscription periods and the possibility of withdrawing from the agreement with a month's notice. This would require the end-user to be uptight and strict with their scheduler to make sure their car is available to offload energy for the hours they have committed.

This option would be suitable for those people who do not desire to maximize spot trading and have a fairly fixed schedule. It could also be considered an entry-level subscription; one could try this for a month and then decide to opt for another agreement, for example, depending on the personal schedule and commitment/knowledge of the technology and prices. Running the numbers in our model, we get the following outcomes.

Table 9 - Outcomes of Scenario 4

Scenario-4 (Summary)		
Description	*Value*	Unit
Total Hours in a day	24	hrs
Hours Required for Charging	7	hrs
Hours Required for Commuting	1	hrs
Hours Awayfor Work	8	
Remaining Hours Available for Discharge	8	hrs
Battery Capacity (Intended for trading)	45.97	kWh
Hourly Charge/Discharge Rate	10.30	kWh
Total Hours Possible for Trading (Rounded D	4	hrs
Results (for 365 days)		
Total Cost of Charging	- 16,780	SEK
Total Revenue from Selling Electricity	21,060	SEK
Net Revenue	**4,279**	**SEK**
VAT for Selling Energy (9%)	385	SEK
Other Miscellaneous Charges (5%)	214	SEK
Net Gains/Loss (Annual)	**3,680**	**SEK**
Total Discharging Hours	1,047	hrs
Gains/Loss per Hour	3.51	SEK/hr

A fixed monthly subscription would entail the least amount of flexibility in the contract, but, according to our calculations, it would still potentially result in a yearly revenue comparable to the FCR-D agreement.

Given this lack of flexibility, the end customer who could be interested in subscribing to such a contract is assumed to have a fixed schedule for the whole month, or at least for those days and time slots that he/she would choose to make his/her vehicle available to the grid. In this sense, one might work remotely on certain days of the week and let the car be available only on those days and hours. The advantage of this service is that it would be easy to manage; the end customers would not need to consider spot prices nor think about participating in the upward or downward market. It would just be sufficient to schedule everything once for the month ahead. Clearly, as it would still be unlikely that this individual is able/willing to stay at home all year long, this subscription could be ended whenever with a month's notice. This could be useful, for example, during the summer months when the family has planned a vacation period or during Christmas.

Given the ease of managing this subscription and the relatively less uncertainty, assuming a fairly fixed schedule, we believe that this alternative could be suitable as a sort of entry-level trade-off. Some users may initially have doubts about the V2G system and would thus prefer a low-maintenance, low-commitment option to test it out in the first place and then, eventually, upgrade to other types of services. This could be the case of, for example, a retired couple who do not drive as much as before and spends most of the day at home but does not want to consider a spot trading service. The lower estimated revenue, compared to other alternatives, could still be enough and serve as an incentive given the low management.

5.2.6. Step 6: Summarizing the Outcomes

A quick visual summary of the designed scenarios is presented in the following figure, which is followed by more details and discussion in this sub-heading.

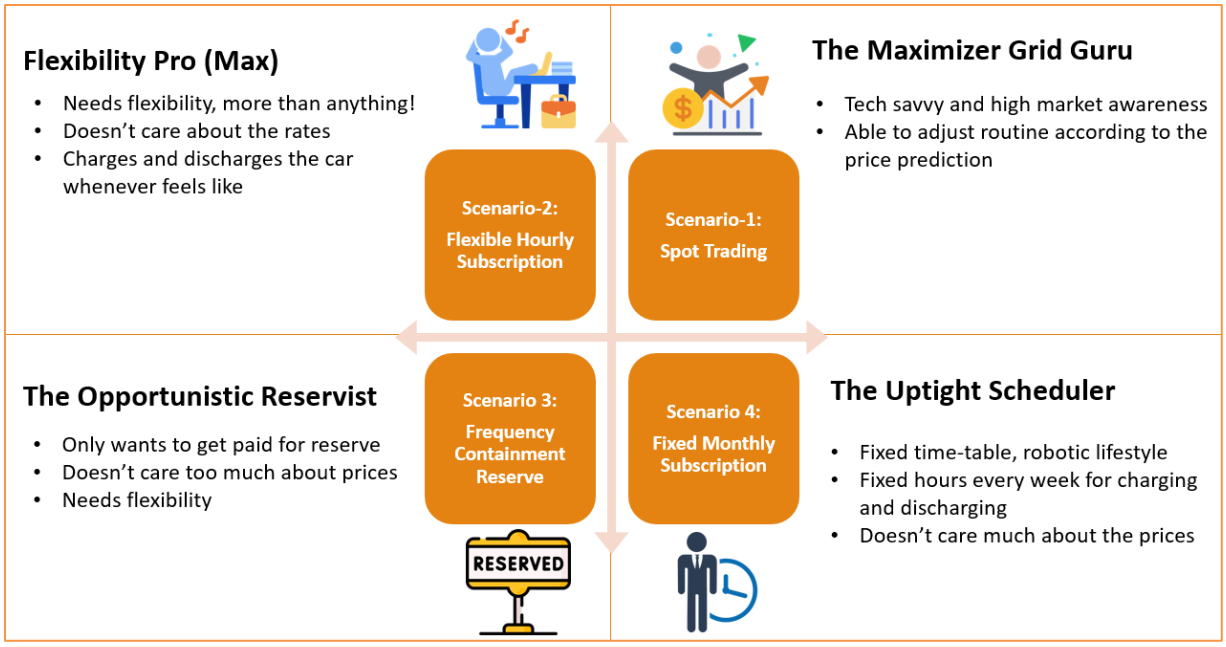

Figure 11 - Summary of all designed scenarios

The following can be the key takeaways from the overall analysis:

1. Scenario-1 provides the highest gains in revenue, yet it deprives the end-user of its flexibility. Moreover, it is based on the best-case scenario, so it is more optimistic in nature rather than realistic.
2. Scenario-2 may provide some minor benefit or a small loss. In any case, there will be no considerable financial gains, therefore, it may not be preferred by the majority.
3. Scenario-3 provides gains almost midway between Scenario-1 and Scenario-2. It does not require excessive daily management and it is considered to be less detrimental for battery health. Hence, this one seems to be somewhat preferred and practicable.
4. Scenario-4 is much closer in numbers to the third scenario and it may also be considered as a feasible solution, as it does not significantly compromise the flexibility of the end-user. People who follow strict work routines might prefer this.

The overall outcomes of all the scenarios are presented together in the following table. To make the results across all the scenarios comparable, we have divided the total gains by the total hours of engagement in the services. This translates the results into an average earning per hour which makes it easier to compare how much gain each scenario generates in one hour.

Table 10 - Summary of the quantitative results

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
	Spot-Trading	**Flexible Hourly Subscription**	**Frequency Containment Reserve**	**Fixed Monthly Subscription**
Net Gains/(Loss) in SEK	16,361	82	4,678	3,680
Total Engagement (hours)	1,482	382	803	1,047
Revenue per Hour (SEK/hr)	**11.04**	**0.21**	**5.83**	**3.51**

In general, these scenarios present several opportunities for end users to capitalize on this service; in particular, the financial benefit generated from these subscriptions could be regarded as the most important one. However, in this model, we have only considered direct revenue, which is actively generated from the sale of energy. As discussed in the empirical findings section, end-user incentives could include other financial benefits, such as tax deductions for people who adopt V2G or discounts on future purchases of car batteries, which we have not considered in this framework. Such additional incentives may still motivate users to participate in, for example, scenario-2 with no direct profit but certain other benefits that offset the cost of this investment.

Another indirect and non-monetary benefit from the spread of V2G technologies would be the improvements of the frequency and balance in the grid. As V2G would mainly act in the ancillary services, society as a whole would benefit from an improved service which would include, for example, better frequency during bad weather conditions, such as storms, or an improved supply of energy to highly populated areas.

Finally, the environmental advantages of this service should not be overlooked, especially when considering V2G technology paired with other forms of sustainable energy. As mentioned in the introduction, V2G aligns with the United Nations SDGs in this regard. However, this reduction in emissions should not be offset by the production and disposal of V2G and EV infrastructures.

6. Discussion & Conclusion

In this chapter, the previously presented tailored framework will be discussed in relation to the literature review and the empirical findings with the aim to reach a general consistency between the three different parts of this paper and to answer the research questions.

6.1. Unveiling Market Opportunities

The quantitative analysis in the previous chapter provides sufficient evidence of the potential of the Swedish market in the coming years. The high-level findings are summarized in the following figure.

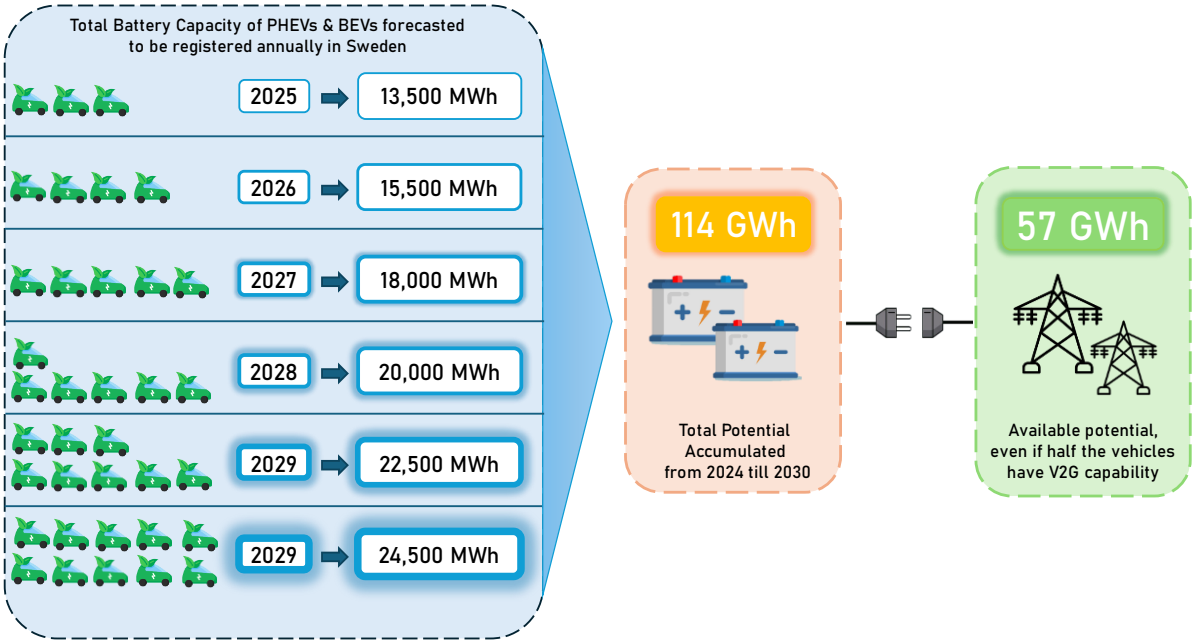

Figure 12 - Summary of overall market potential in terms of accumulated battery capacity in the coming years, based on number of cars registered in Sweden annually.

Given this potential, it would be unwise to let this excess amount of energy rest idle in times when the grid is under-supplied without exploiting vehicle batteries as storage, especially considering the previously mentioned opportunities for end users to capitalize on V2G.

Both the literature and our respondents agree that the main application of this technology would be participation in ancillary services and, at the moment, in no other type of electricity market. In this sense, all our possible scenarios are intended to answer this need, with a particular focus on scenario 3. Our results and our discussions with the interviewees hint towards the fact that scenario 3 is profitable and, overall, more suitable for battery health.

The other common denominator between the literature and our interview process is the current lack of clear, executable business models to market this technology. Clearly, all the mentioned challenges of costs, technological level, and bureaucracy are conductible to business model innovation as they profoundly affect revenue streams, value chains, and the end customers.

6.2. Foundations of Success

Considering our findings from the literature, interviews and the scenarios combined, we believe that there are certain foundations of success which must be embedded in the V2G system. With any of these missing, it might be difficult for end users to benefit from this technology. These foundations are summarized in the following pyramid, with the most important one at the bottom.

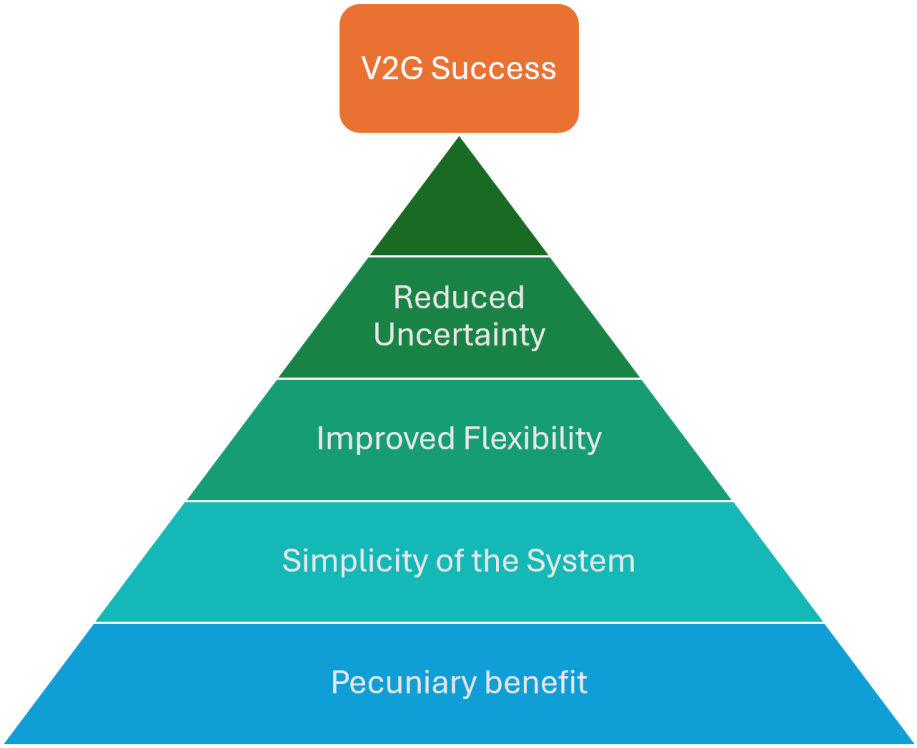

Figure 13 - Hierarchy pyramid for the foundations of success

Each of these foundations is briefly explained below:

1. **Pecuniary Benefit:** This represents the eventual benefit that the end-user would gain for participating in the V2G services. This could be in the form of financial profits, reduced expenses, tax incentives, or similar rewards that may be equivalent to some financial gains. Without these benefits, it is believed that the V2G system may not work out at all.
2. **Simplicity of the System:** As stated by many respondents, the system has to be extremely intuitive for the end-user to adopt it and it should have simple investment requirements for hardware and software. It should be more like a plug-and-play for successful end-user adoption at wider scale.
3. **Improved Flexibility:** Flexibility is key to be preserved for business models to be successful. It is to be kept in mind that the primary purpose of the car for an end-user is to be able to travel from one place to another when needed. The lack of flexibility may undermine this primary motive, and thus, participation in V2G would be very unlikely even if the end-users were promised higher returns.
4. **Reduced Uncertainty:** Although uncertainty is naturally embedded in the energy prices market as a whole, it is necessary for providers to try and reduce it to the maximum extent. This has to be done by developing business models where end-users

could know the minimum financial return they might get by participating in the program as a compensation for a reduction in their flexibility.

6.3. Navigating the Obstacles

Just like the foundations of success in the previous heading, there are certain obstacles that hinder a successful implementation of V2G, which the energy ecosystem is currently evolving towards. These are visualized in the following diagram in the order of their decreasing priority.

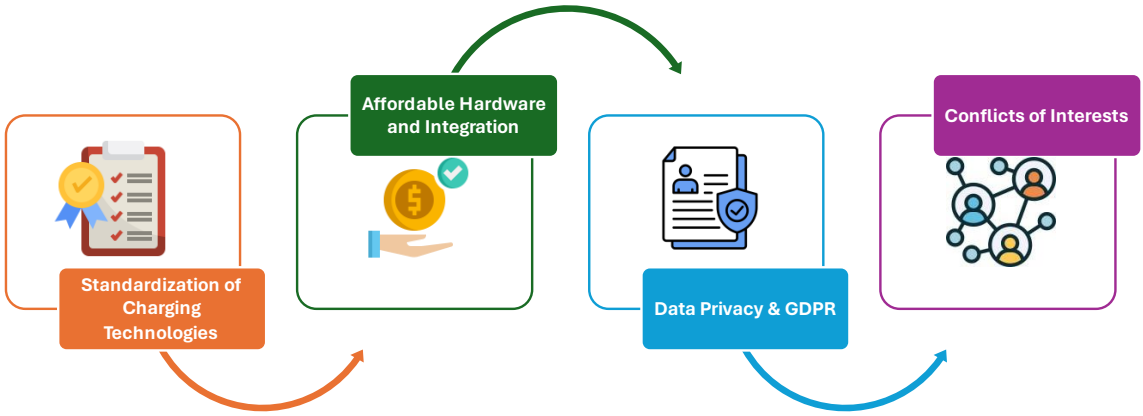

Figure 14 - Summary of obstacles that must be overcome for V2G success

Each of these obstacles is summarized below.

1. **Standardization of Charging Technologies:** As of now, there are undergoing R&D projects aimed at developing new bidirectional charging stations both for domestic and commercial use. It might be one of the biggest obstacles at the moment to align these efforts in a way that standard charging ports are developed and agreed upon first nationally, then on a regional (for example, within EU) or global scale. Without effective standardization, the process may face delays in widespread adoption.
2. **Affordable Hardware and Integration:** In addition to the standardization, the prices of bidirectional charging systems have to be in a nominal range. As assessed in the scenario analysis, there is currently not a significant high potential revenue gain from the service. Therefore, the ROI is low and investing in very expensive chargers might hinder widespread adoption.
3. **Data Privacy and GDPR:** This is another factor that must be thoroughly investigated and followed up by strict data privacy protocols and standards implemented across all stakeholders. The data regarding charging, discharging cycles and electricity usage could potentially reveal certain lifestyle characteristics of the end-users and make them vulnerable; as an example, they could be used to determine the hours when the owner is away from home and potentially be used for a robbery plan.
4. **Conflicts of Interest:** As highlighted by one of the interviewees, some of the stakeholders currently like to work in silos attempting to maximize their own gains. This will be counterproductive for the market, as these actors should prioritize the overall success of the ecosystem and eventual benefit to the environment over their own personal gains. This has also been confirmed by other respondents who believed that, if there are too many beneficiaries of the system, the profits might be too low for possible investment and support.

6.4. Crafting Viable Pathways

In the current evolution process of the energy ecosystem, following figure shows some recommendations for the steps that could be taken for V2G to be successful.

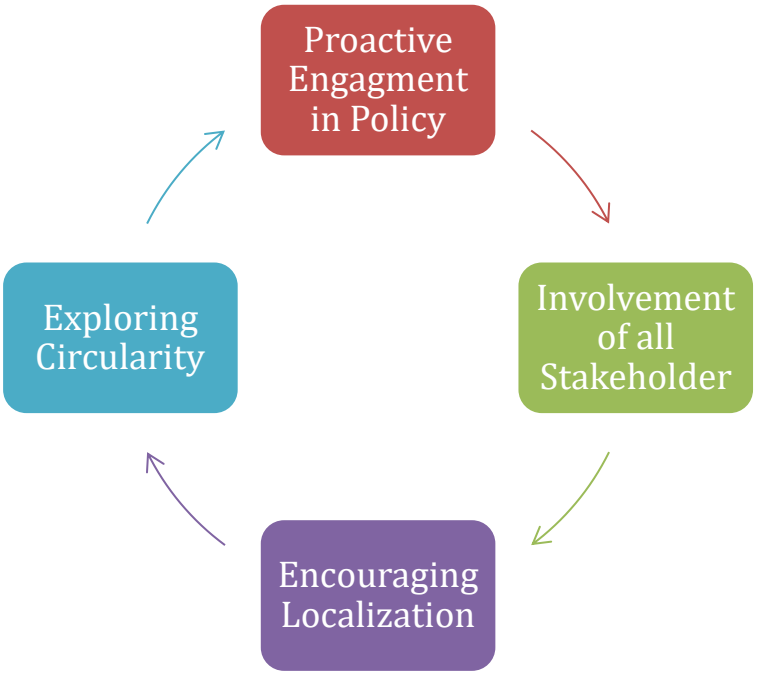

Figure 15 - Recommendations to proceed towards crafting viable pathways for V2G

These recommendations are visualized above in a cyclic process because it is believed that this will be a continuous process which will keep iterating unless V2G becomes mainstream over the next few years. Each step is further explained briefly in the following paragraphs:

1. **Proactive Engagement in Policy and Legislation:** It is encouraging to see the overall efforts towards achieving a unanimous ecosystem for the V2G services. As R8 stated, over 38 lawyers were supposed to convene in Stockholm in April this year and will work together for legislation; such initiatives have the power to mainstream and accelerate V2G adoption by the end users.
2. **Involvement of Additional Stakeholders:** The V2G initiative has to take in wider focus and involve other parties that may have a stake in this. It would include the TSOs, DSOs from the grid perspective, boat manufacturers, dealers, marinas for V2B, heavy transport vehicles for their battery recirculation and even more possible stakeholders who may be able to make this successful. Hence, it is important to step back from just the vehicle perspective and take an ecosystem view to involve other possible stakeholders that can complement the V2G services.
3. **Encouraging Localization and Independence:** The practicality and success of V2G services could also be accelerated if these are implemented on a smaller scale, first locally and then eventually scaled nationally or internationally. The example of Örebro Bostäder stands as a role model of how real-estate developers could generate their own capabilities and rely less on the grid. This shall pave the way for new opportunities locally and may also bypass the complexities and legalities of connecting with the national grids. Another example was quoted by Niklas Lundin, who said that some of the far-off coastal areas have a really high cost of delivering energy through grids. These coastal areas, however, usually have many boats. If these

boats are replaced with V2B ones, those areas could eventually become independent, by storing the solar energy in daytime and using it in the dark. They could also utilize the batteries of the seasonal boats for longer periods of time in the winters.

4. **Exploring Circularity Options:** R9 mentioned their initiatives to plan to use second-hand batteries from heavy trucks and large mining vehicles in their dwellings for energy storage. These batteries, not good for vehicles anymore, are still great for energy storage. Such examples could extend battery life of all vehicles and re-purpose them in small or large-scale energy storage reservoirs in different applications. Circularity was also mentioned by Niklas Lundin, who explained that V2B would not require new boats, but rather that the existing fossil-fuel boats could be converted to electrical ones. This would provide greater flexibility in the boating industry, thus giving second life to existing boats and reducing waste. The literature also suggests some business models related to V2G and recycling, as mentioned, such as the possibility of leasing a battery without changing the car (Costa et al., 2022) or re-purposing it as storage for electricity (Davies et al., 2022).

6.5. Way Forward

As a very young and promising technology, companies are working on business models and scenario planning to try to commercialize it. Firms in the automotive industry such as Volvo and Polestar in the Swedish context, or VW and BMW in the European scenario, for example, are researching more and more on V2G. An example of a currently ongoing V2G prospect which involves automakers and infrastructure companies is the DrossOne V2G parking project, financed by the European Commission's Innovation Fund and carried out by Free To Move e-solutions (a charging station manufacturer and start-up) and Stellantis. This project, based in Turin, Italy, is aimed at demonstrating the feasibility of a large V2G installation and at providing ancillary services to the Italian TSO. The companies are testing this solution in the Stellantis parking spot before eventually shipping their products to car dealerships for commercialization (eSolutions Europe, 2024).

Free To Move is also collaborating with the Politecnico di Milano for research purposes. In this sense, it can be said that, in an open innovation context, partnerships between companies and universities (Chalmers University of Technology or the Politecnico di Milano, to cite two of them) are as important to share knowledge as collaborations along the value chain between energy utilities, local administration and the car industry.

Moreover, we have witnessed efforts to recycle batteries, which are not deemed acceptable anymore for vehicle usage but still have around 85% of their life span. We believe that, in this sense, these business models based on recycling opportunities as well as the coupling of electrification projects with the use of renewable resources (Figure 16), will continue to expand independently of the success of V2G technology, which could be considered only as one piece of the puzzle. As per the literature, some services, for example, FCR-D (downwards), do not even require the bi-directional capability as they only discharge energy from the grid to the car. This will also open the existing pool of ordinary BEVs and PHEVs to be a part of the overall ecosystem.

Hence, it can be said that the overall ecosystem is gradually evolving towards a general collaboration between all the stakeholders involved and that V2G seems to be one of the most important developments in the industry as of now. In this regard, we could soon witness a great rise in the participation in V2G services in the Swedish market as well as globally. There exist certain possibilities for end-users to profit from this trend and this will also

benefit them financially, if an appropriate schedule is followed for FCR-D or energy trading. However, the greatest benefit in this transition will not just be financial but more towards the stabilization of the entire energy grid and, eventually, a greener future.

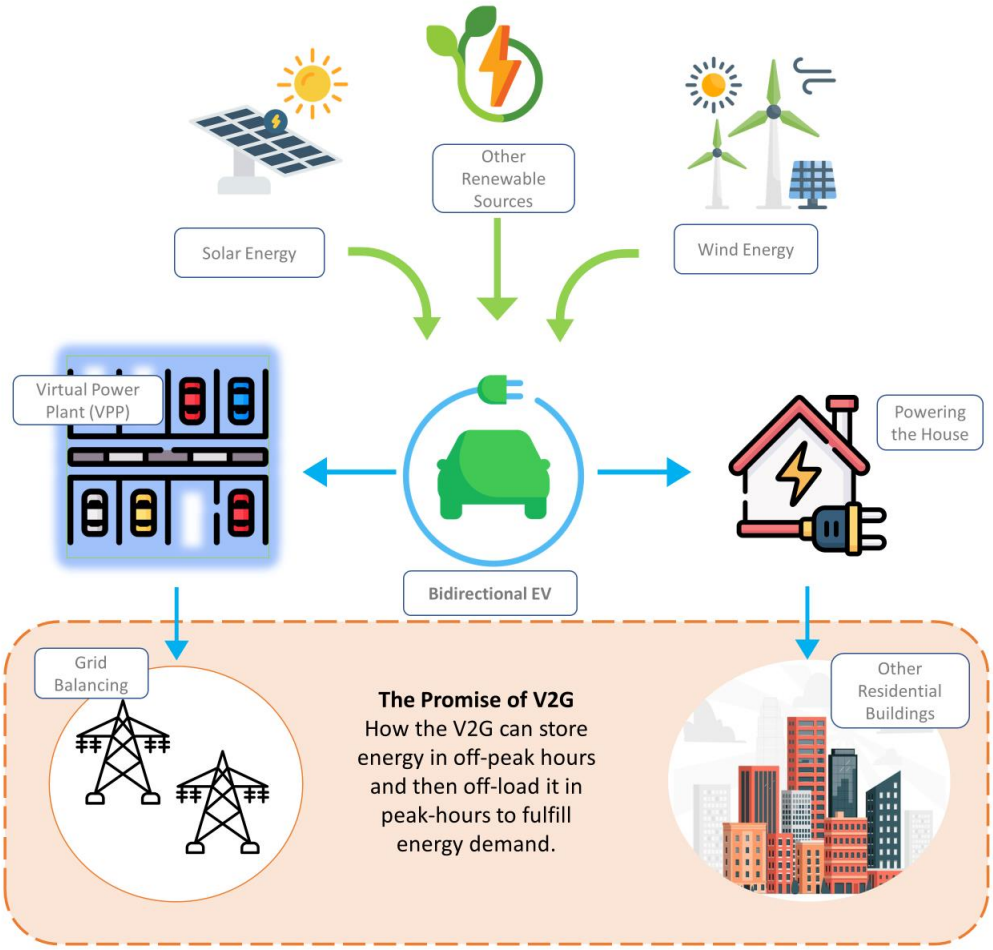

Figure 16 - A proposed visualization of the future V2G powered energy ecosystem.

7. Limitations and Future Research

The conducted research has investigated possible V2G applications, advantages and challenges and it has proposed four different scenarios for applying this technology in the foreseeable future. The latter scenario planning analysis, in particular, has taken into consideration the point of view of the final customer without considering possible futures from other stakeholders' perspectives, namely automakers or energy utilities. One of the reasons for this was, as already mentioned, the lack of data regarding possible revenues deriving from these applications, as well as a general uncertainty regarding what solutions to adopt to democratize this technology. In this sense, possible future research could focus more on the business model perspective, considering the financial benefits deriving from this technology from the firm's point of view. Furthermore, while the interview process has considered a variety of stakeholders, from electrical utilities to battery experts in the automotive sector to the boat industry, the scenario analysis has only considered a user case perspective of a vehicle owner. The decision not to deal with the boat industry nor with dwellings and the landlord's point of view, as discussed by respondents 6 and 9, has been taken considering the overall scope and time frame of this research. When balancing the industry and academic side of this research, it was necessary to restrict the field of analysis to avoid being too superficial and losing track of the project itself. In particular, as pointed out by respondent 6, the use of boats and their time spent idle could be more predictable than cars, making it, on paper, easier to apply business models such as the ones suggested. Furthermore, together with the previously mentioned benefits for batteries, electric boating could also be considered more luxurious and, overall, a more enjoyable experience than traditional boating due to less noise while navigating. However, it is also true that a smaller part of the population could be involved, and this could lead to elitism critiques, which, according to the literature, is a current challenge of V2G and incentives for electrification in general. In this regard, future research, especially focused on the Nordic market, could focus more on the potential impact of V2G on boating (V2B), which could provide environmental and end user benefits.

Other limitations of this analysis are related to the other assumptions presented in step 1 of the tailored framework; namely, only considering SE3 electricity prices from 2022 as basis as well as modelling the scenarios based on average BEVs battery capacity.

Regarding future research, it may also be of interest to focus on the environmental side of V2G as well as on recycling opportunities for batteries. This would not only deal with the challenges related to batteries' production and disposal but also contribute to possible business model innovation as well as cross-industry partnerships and environmental goals.

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9. Appendices

Appendix 1 – Interview Guide

Appendix 2 – Pilot Interview Guide

Appendix 3 – Basic Calculations and Assumptions for Quantitative Analysis

Appendix 4 – Monthly Trend of BEVs and PHEVs Registration

*Appendix 5 – V2G Master Thesis - Ammaar & Filippo - Scenario Modelling - R1_8.xlsx

*Note: Some of the background data files used for data modelling for scenarios are too complex and lengthy to be attached in this report. The main file for scenario analysis is placed on a shared drive and can be accesses at the provided link.

If you have problems accessing this data, or for further information regarding the data model and its working, please contact one of the authors of this document.

9.1. Appendix 1 – Interview Guide

Interview Guide

Research Topic:

"Energy Market Integration: what strategies could EV companies adopt to integrate their products into the evolving European energy markets, such as Vehicle-to-Grid (V2G) services, and how would this impact their overall business model and revenue streams?"

Organizers: Ammaar & Filippo
Program: Master of Innovation & Industrial Management

This interview is being conducted as part of the thesis project being conducted by the students at Masters of Innovation & Industrial Management, at the University of Gothenburg. The thesis will be completed by June 2024 and will be shared with the interviewees if they intend to receive a copy.

Preliminary Questions (Regarding the Interview):

1. Is it okay if we mention the following details regarding this interview in our thesis?
    a. Name
    b. Designation
    c. Organization
    ▪
2. Would it be okay if this interview's audio is recorded?
    ▪ (The audio is recorded just for transcription and analysis purposes; it will not be included in any document and will be destroyed as soon as the thesis is completed.)

General Questions:

1. Could you introduce yourself a bit, slightly explaining your background and tell us what is your current role in the company? (You can also chose to stay anonymous and provide generalized information about yourself)
2. Are you directly or indirectly involved with the implementation of V2G or other network solutions by your organization? If yes, in what capacity?
3. Do you think that V2G solutions offer a potentially strong business case for EV companies, that is worth pursuing in the longer run?

Stakeholders & Ecosystem:

4. In your view, what are the key stakeholders that must be on-board while proposing or implementing any plan for V2G services? Also elaborate a little bit on the roles and contributions of each stakeholder in the overall ecosystem.
5. Who do you think would be the greatest beneficiary of a successful V2G implementation, in terms of financial gains?
6. How feasible would it appear to include public fleets, such as logistic fleet operators, bus companies, and similar, in such energy storage and reselling ecosystem? Do you see a strong business case for them as well?

7. Would there be any clashes or conflicts of interests between the potential stakeholders? If yes, please specify with an example.

Policy and Regulation:

8. Where do you think we stand in the regulatory framework for implementing these systems on a public level?
9. Are there any existing legislations or policies that can accelerate the adoption of such initiatives among the public?
10. What is the greatest challenge in this regard with respect to the legislative framework for such energy reselling systems? Or is there any piece of existing policies which may prohibit widespread adoption of such systems?

End-User Perspective:

11. From your understanding, would end-users be really interested in utilizing the V2G services on a regular basis?
12. What do you think would be their prime motivation? For example, financial benefit, energy savings, or contribution to the environment?
13. Can you think of any main reasons as to why some of the end-users may be reluctant to adopt this technology?

Sustainability & Environment:

14. What is the greatest environmental advantage/treat of implementing and promoting V2G solutions?
    a) How could it be measured?
15. Are there any other aspects of the V2G implementation which may negatively impact the environment?
    a) If yes, how would you recommend mitigating this threat?

Future Predictions:

16. What are the primary hindering factors, at present and possibly in future, which could block V2G widespread adoption?
17. What emerging trends or innovations do you foresee that could further enhance these partnerships and ecosystem building efforts in the V2G arena?
18. Based on your expertise, what strategies or approaches do you believe are crucial for EV companies to adopt when initiating or engaging in these collaborative ventures?
19. Based on what we have been talking about, would you say we have missed some important aspects of the matter? Would you have any suggestions regarding other stakeholders to interview?

9.2. Appendix 2 – Pilot Interview Guide

Main Research question (PILOT):

Energy Market Integration: what strategies could EV companies adopt to integrate their products into the evolving European energy markets, such as Vehicle-to-Grid (V2G) services, and how would this impact their overall business model and revenue streams?

Interview Questions (General):

1. In your view, what are the key advantages or benefits for electric vehicle (EV) companies in forging strategic partnerships with energy utilities and charging infrastructure providers?
2. What are the main hurdles or challenges that EV companies would encounter when trying to collaborate with these stakeholders, and how can these obstacles be overcome to foster successful partnerships?
3. From your experience, how do such collaborations influence or benefit the end consumer's experience with electric vehicles? Are there specific ways consumers perceive or benefit from this ecosystem approach?
4. Could you elaborate on how these collaborations contribute to the environmental sustainability goals of the EV industry? Are there measurable impacts or indicators you've observed?
5. From your perspective, what emerging trends or innovations do you foresee that could further enhance these partnerships and ecosystem building efforts in the EV industry?
6. Based on your expertise, what strategies or approaches do you believe are crucial for EV companies to adopt when initiating or engaging in these collaborative ventures?

9.3. Appendix 3 – Basic Calculations and Assumptions for Quantitative Analysis

Type	*Name*	*Description*	*Value*	*Unit*	*Comments*	*Source*
Commute and Consumption						
Input	c1	Average Travel Distance (Rounded Up)	25	km	*The Swedish National Survey 2022, includes all kinds of travelling on car (work, study, leisure, etc.)*	(Statstics Sweden, n.d.)
Input	c2	Average EV Consumption (Rounded Up)	0.2	kWh/km		(EV Database, n.d.)
Calculated	c3	**Total Power Cosumed for Commute**	**5**	**kWh**	c3=c1*c2	
Battery Capacity						
Input	c4	**Average Battery Capacity (BEVs)**	**72.1**	**kWh**		(EV Database, n.d.)
Calculated	c5	**Hourly Charge/Discharge Rate**	**10.30**	**kWh**	c5=c4/c15	
Calculated	c6	Battery Capacity (available after Commute)	67.1	kWh	c6=c4-c3	
Input	c7	Average energy loss in charge/discharge	10%			(Gareth, 2023)
Calculated	c8	Net Battery Capacity (available for trade)	60.39	kWh	c8=c7-(c7*c8)	
Assumed	c9	% of battery saved as backup for emergency	20%			
Calculated	c10	Total Battery power kept as backup	14.42	kWh	c10=c9*c4	
Calculated	c11	**Battery Capacity (Intended for trading)**	**45.97**	**kWh**	c11=c8-c10	
Lifestyle & Choices						
Input	c12	Average Working Hours, Weekly	38	hr	SCB Labor Force Surveys, based on average hours for the age of 20-66 from 2022 till March 2024.	(Statstics Sweden, n.d.)
Calculated	c13	Average Working Hours (Rounded up), per Day (5 working-days per week)	8	hr	c13=c12/5; based on the assumption of 5 day work-week, rounded up.	
Input	c14	Avg time spent Travelling, daily	1	hr	The Swedish National Survey 2022, by Transport Analysis	(Statstics Sweden, n.d.)
Input	c15	**Average Charging Time (From 0% to 80%)**	**7**	**hr**	Based on Level 2 chargers	(Transportation.gov, n.d.)
Others						
Assumed	c16	VAT for Selling Energy	9%		Yet to be determined by Government	
Assumed	c17	Other Miscellaneous Charges	5%		Additional unforeseen charges	
Input	c18	Annual Inflation	4%		Annaul CPI Inflation from SCB, based on rounded off current inflation rate in March 2024	(Statstics Sweden, n.d.)

9.4. Appendix 4 – Monthly Trend of BEVs and PHEVs Registration

(Next page)

New Registration of Passenger cars (BEV and PHEV)

Record	Year	Month	Date	Electricity	Plug-in hybrid	Electricity + Plug-in Hybrids	% electric cars	% plug-in Hybrids
1	2019	1	01/01/2019	1,103	1,577	**2,680**	41%	59%
2	2019	2	01/02/2019	902	1,900	**2,802**	32%	68%
3	2019	3	01/03/2019	2,107	2,292	**4,399**	48%	52%
4	2019	4	01/04/2019	1,377	1,711	**3,088**	45%	55%
5	2019	5	01/05/2019	1,255	1,655	**2,910**	43%	57%
6	2019	6	01/06/2019	1,692	1,748	**3,440**	49%	51%
7	2019	7	01/07/2019	1,083	1,307	**2,390**	45%	55%
8	2019	8	01/08/2019	971	1,668	**2,639**	37%	63%
9	2019	9	01/09/2019	1,764	1,874	**3,638**	48%	52%
10	2019	10	01/10/2019	848	2,696	**3,544**	24%	76%
11	2019	11	01/11/2019	1,062	3,256	**4,318**	25%	75%
12	2019	12	01/12/2019	1,631	3,223	**4,854**	34%	66%
13	2020	1	01/01/2020	1,268	4,113	**5,381**	24%	76%
14	2020	2	01/02/2020	1,430	4,027	**5,457**	26%	74%
15	2020	3	01/03/2020	3,015	4,753	**7,768**	39%	61%
16	2020	4	01/04/2020	1,049	3,233	**4,282**	24%	76%
17	2020	5	01/05/2020	841	2,591	**3,432**	25%	75%
18	2020	6	01/06/2020	1,706	4,696	**6,402**	27%	73%
19	2020	7	01/07/2020	1,307	5,414	**6,721**	19%	81%
20	2020	8	01/08/2020	2,120	5,301	**7,421**	29%	71%
21	2020	9	01/09/2020	3,678	6,233	**9,911**	37%	63%
22	2020	10	01/10/2020	2,345	7,849	**10,194**	23%	77%
23	2020	11	01/11/2020	2,729	7,590	**10,319**	26%	74%
24	2020	12	01/12/2020	6,609	10,334	**16,943**	39%	61%
25	2021	1	01/01/2021	1,161	5,898	**7,059**	16%	84%
26	2021	2	01/02/2021	1,416	6,598	**8,014**	18%	82%
27	2021	3	01/03/2021	2,625	14,963	**17,588**	15%	85%
28	2021	4	01/04/2021	4,888	4,578	**9,466**	52%	48%
29	2021	5	01/05/2021	3,972	5,558	**9,530**	42%	58%
30	2021	6	01/06/2021	8,706	9,146	**17,852**	49%	51%
31	2021	7	01/07/2021	2,556	3,808	**6,364**	40%	60%
32	2021	8	01/08/2021	4,806	4,561	**9,367**	51%	49%
33	2021	9	01/09/2021	7,486	4,778	**12,264**	61%	39%
34	2021	10	01/10/2021	4,634	5,634	**10,268**	45%	55%
35	2021	11	01/11/2021	5,549	5,979	**11,528**	48%	52%
36	2021	12	01/12/2021	10,082	6,699	**16,781**	60%	40%
37	2022	1	01/01/2022	5,221	5,378	**10,599**	49%	51%
38	2022	2	01/02/2022	5,491	5,509	**11,000**	50%	50%
39	2022	3	01/03/2022	9,254	6,826	**16,080**	58%	42%
40	2022	4	01/04/2022	5,500	5,154	**10,654**	52%	48%
41	2022	5	01/05/2022	6,529	6,146	**12,675**	52%	48%
42	2022	6	01/06/2022	8,365	6,159	**14,524**	58%	42%
43	2022	7	01/07/2022	4,792	4,259	**9,051**	53%	47%
44	2022	8	01/08/2022	5,927	3,668	**9,595**	62%	38%
45	2022	9	01/09/2022	7,871	4,387	**12,258**	64%	36%
46	2022	10	01/10/2022	8,036	5,381	**13,417**	60%	40%
47	2022	11	01/11/2022	10,970	5,660	**16,630**	66%	34%
48	2022	12	01/12/2022	18,207	8,248	**26,455**	69%	31%
49	2023	1	01/01/2023	4,333	3,465	**7,798**	56%	44%
50	2023	2	01/02/2023	6,212	3,864	**10,076**	62%	38%
51	2023	3	01/03/2023	12,644	5,542	**18,186**	70%	30%
52	2023	4	01/04/2023	6,983	4,561	**11,544**	60%	40%
53	2023	5	01/05/2023	11,696	5,991	**17,687**	66%	34%
54	2023	6	01/06/2023	11,005	5,806	**16,811**	65%	35%
55	2023	7	01/07/2023	6,528	3,896	**10,424**	63%	37%
56	2023	8	01/08/2023	9,832	4,575	**14,407**	68%	32%
57	2023	9	01/09/2023	12,552	5,351	**17,903**	70%	30%
58	2023	10	01/10/2023	9,454	5,762	**15,216**	62%	38%
59	2023	11	01/11/2023	10,128	5,321	**15,449**	66%	34%
60	2023	12	01/12/2023	11,408	7,101	**18,509**	62%	38%
61	2024	1	01/01/2024	5,068	4,095	**9,163**	55%	45%
62	2024	2	01/02/2024	5,244	4,500	**9,744**	54%	46%
63	2024	3	01/03/2024	8,381	5,556	**13,937**	60%	40%
64	2024	4	01/04/2024	7,559	5,405	**12,963**	58%	42%
65	2024	5	01/05/2024	9,290	5,452	**14,742**	63%	37%
66	2024	6	01/06/2024	11,478	5,500	**16,978**	68%	32%
67	2024	7	01/07/2024	5,591	5,547	**11,138**	50%	50%
68	2024	8	01/08/2024	7,218	5,595	**12,813**	56%	44%
69	2024	9	01/09/2024	10,564	5,642	**16,206**	65%	35%
70	2024	10	01/10/2024	8,491	5,690	**14,181**	60%	40%
71	2024	11	01/11/2024	10,223	5,737	**15,960**	64%	36%
72	2024	12	01/12/2024	12,411	5,785	**18,196**	68%	32%

73	2025	1	01/01/2025	6,524	5,832	12,356	53%	47%
74	2025	2	01/02/2025	8,151	5,880	14,031	58%	42%
75	2025	3	01/03/2025	11,497	5,927	17,425	66%	34%
76	2025	4	01/04/2025	9,424	5,975	15,399	61%	39%
77	2025	5	01/05/2025	11,156	6,023	17,178	65%	35%
78	2025	6	01/06/2025	13,344	6,070	19,414	69%	31%
79	2025	7	01/07/2025	7,457	6,118	13,574	55%	45%
80	2025	8	01/08/2025	9,084	6,165	15,249	60%	40%
81	2025	9	01/09/2025	12,430	6,213	18,643	67%	33%
82	2025	10	01/10/2025	10,357	6,260	16,617	62%	38%
83	2025	11	01/11/2025	12,088	6,308	18,396	66%	34%
84	2025	12	01/12/2025	14,277	6,355	20,632	69%	31%
85	2026	1	01/01/2026	8,389	6,403	14,792	57%	43%
86	2026	2	01/02/2026	10,017	6,450	16,467	61%	39%
87	2026	3	01/03/2026	13,363	6,498	19,861	67%	33%
88	2026	4	01/04/2026	11,290	6,545	17,836	63%	37%
89	2026	5	01/05/2026	13,021	6,593	19,614	66%	34%
90	2026	6	01/06/2026	15,210	6,640	21,850	70%	30%
91	2026	7	01/07/2026	9,322	6,688	16,010	58%	42%
92	2026	8	01/08/2026	10,950	6,735	17,685	62%	38%
93	2026	9	01/09/2026	14,296	6,783	21,079	68%	32%
94	2026	10	01/10/2026	12,223	6,831	19,054	64%	36%
95	2026	11	01/11/2026	13,954	6,878	20,832	67%	33%
96	2026	12	01/12/2026	16,143	6,926	23,068	70%	30%
97	2027	1	01/01/2027	10,255	6,973	17,228	60%	40%
98	2027	2	01/02/2027	11,883	7,021	18,903	63%	37%
99	2027	3	01/03/2027	15,229	7,068	22,297	68%	32%
100	2027	4	01/04/2027	13,156	7,116	20,272	65%	35%
101	2027	5	01/05/2027	14,887	7,163	22,050	68%	32%
102	2027	6	01/06/2027	17,076	7,211	24,286	70%	30%
103	2027	7	01/07/2027	11,188	7,258	18,446	61%	39%
104	2027	8	01/08/2027	12,816	7,306	20,122	64%	36%
105	2027	9	01/09/2027	16,162	7,353	23,515	69%	31%
106	2027	10	01/10/2027	14,089	7,401	21,490	66%	34%
107	2027	11	01/11/2027	15,820	7,448	23,268	68%	32%
108	2027	12	01/12/2027	18,009	7,496	25,505	71%	29%
109	2028	1	01/01/2028	12,121	7,544	19,665	62%	38%
110	2028	2	01/02/2028	13,749	7,591	21,340	64%	36%
111	2028	3	01/03/2028	17,095	7,639	24,733	69%	31%
112	2028	4	01/04/2028	15,022	7,686	22,708	66%	34%
113	2028	5	01/05/2028	16,753	7,734	24,487	68%	32%
114	2028	6	01/06/2028	18,941	7,781	26,723	71%	29%
115	2028	7	01/07/2028	13,054	7,829	20,883	63%	37%
116	2028	8	01/08/2028	14,681	7,876	22,558	65%	35%
117	2028	9	01/09/2028	18,027	7,924	25,951	69%	31%
118	2028	10	01/10/2028	15,955	7,971	23,926	67%	33%
119	2028	11	01/11/2028	17,686	8,019	25,705	69%	31%
120	2028	12	01/12/2028	19,874	8,066	27,941	71%	29%
121	2029	1	01/01/2029	13,987	8,114	22,101	63%	37%
122	2029	2	01/02/2029	15,614	8,161	23,776	66%	34%
123	2029	3	01/03/2029	18,960	8,209	27,169	70%	30%
124	2029	4	01/04/2029	16,888	8,257	25,144	67%	33%
125	2029	5	01/05/2029	18,619	8,304	26,923	69%	31%
126	2029	6	01/06/2029	20,807	8,352	29,159	71%	29%
127	2029	7	01/07/2029	14,920	8,399	23,319	64%	36%
128	2029	8	01/08/2029	16,547	8,447	24,994	66%	34%
129	2029	9	01/09/2029	19,893	8,494	28,387	70%	30%
130	2029	10	01/10/2029	17,820	8,542	26,362	68%	32%
131	2029	11	01/11/2029	19,552	8,589	28,141	69%	31%
132	2029	12	01/12/2029	21,740	8,637	30,377	72%	28%
133	2030	1	01/01/2030	15,853	8,684	24,537	65%	35%
134	2030	2	01/02/2030	17,480	8,732	26,212	67%	33%
135	2030	3	01/03/2030	20,826	8,779	29,606	70%	30%
136	2030	4	01/04/2030	18,753	8,827	27,580	68%	32%
137	2030	5	01/05/2030	20,485	8,874	29,359	70%	30%
138	2030	6	01/06/2030	22,673	8,922	31,595	72%	28%
139	2030	7	01/07/2030	16,786	8,969	25,755	65%	35%
140	2030	8	01/08/2030	18,413	9,017	27,430	67%	33%
141	2030	9	01/09/2030	21,759	9,065	30,824	71%	29%
142	2030	10	01/10/2030	19,686	9,112	28,798	68%	32%
143	2030	11	01/11/2030	21,417	9,160	30,577	70%	30%
144	2030	12	01/12/2030	23,606	9,207	32,813	72%	28%