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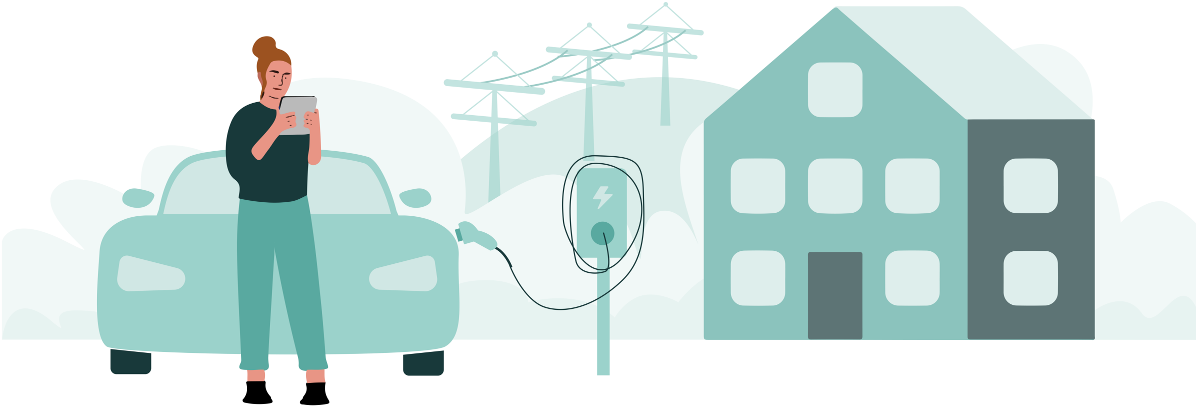

Investigating Vehicle-to-grid from a User-centric Perspective

Master’s thesis in Industrial Design Engineering

ALICE EVERTSSON & ALEXANDRA NYLANDER

DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE
DIVISION DESIGN & HUMAN FACTORS

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Department of Industrial and Materials Science

Division Design and Human Factors

Chalmers University of Technology

SE-412 96 Göteborg

Sweden

Telephone + 46 (0)31-772 1000

Cover:

Illustration of an EV user connecting their vehicle to the grid, made by Alice Evertsson and Alexandra Nylander

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Abstract

The rising energy demand from an increasingly electrified society reliant on renewable energy sources poses a significant challenge to the electricity grid, causing imbalances and peak demands. A supplement to grid expansion is the use of energy storage technologies such as batteries to stabilise the grid. Today, passenger vehicles are parked 96 percent of the time, and with the growing number of electric vehicles and the trend towards larger batteries, they present an excellent opportunity for energy storage. These potential forms the core of vehicle-to-grid. Previous research focuses on technical aspects and stakeholder collaboration but lacks the perspective of electric vehicle users. Hence, this thesis aims to explore electric vehicle users' willingness to adopt bidirectional charging as a mean to redistribute energy consumption and avoid peaks in energy demand.

The project entailed four distinct phases: *initial research, user research, design sprint 1* and *design sprint 2*, involving literature studies, user studies, concept development and concept evaluation. The project approach combined the divergent and convergent phases of the double diamond framework with a co-creation approach, involving a consistent user group throughout the entire project in order to provide deeper insights into the user perspective of vehicle-to-grid by allowing for the progressive development of ideas and feedback.

The project yielded in three key results: an identification of five potential vehicle-to-grid user archetypes, four key design principles for user adoption of vehicle-to-grid, and a design proposal of a vehicle-to-grid solution fulfilling the needs and requirements of the identified user archetypes.

It could be seen that the intrinsic motivation of the user archetypes towards V2G differed based on their drivers and blockers, affecting how they perceived the use of a V2G solution. The four key design principles, *simplicity*, *transparency*, *customisation,* and *system integration*, was developed as a framework to enable the design of a V2G solution catering to all of the identified user archetypes.

Furthermore, the thesis demonstrates the feasibility of designing a solution for diverse user groups, paving the way for widespread adoption of V2G technology. Additionally, understanding the user-centric perspective is crucial for future dissemination and adoption, an aspect this thesis contributes to significantly due to limited existing research in this area within the V2G domain.

Keywords: Vehicle-to-grid, bidirectional charging, vehicle-to-home, user adoption, user-centric product development, energy storage, future energy solution

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Lastly, our gratitude goes to the experts and users who dedicated their time and efforts to participate in surveys, interviews, and workshops. Their invaluable insights have greatly contributed to our deeper understanding of the user perspective of vehicle-to-grid.

Alice Evertsson & Alexandra Nylander

Gothenburg, June 2024

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1. Introduction

1.1. Background

The equilibrium between electricity production and consumption is crucial for the functioning of the power system. However, the ongoing electrification of society poses a significant challenge to the electricity grid due to its continuously increasing demand for energy. Today, temporary imbalances in the system can occur due to fluctuations in energy production or surges in energy consumption, leading to what are known as peak demands. Further, due to the electrification's continuous increase in energy demand, in combination with a growing reliance on renewable energy sources, characterised by their unpredictable production, the risk of imbalances increases (Svenska kraftnät, 2024a).

Furthermore, inadequate infrastructure and capacity limitations within the grid exacerbates these challenges. When large amounts of energy are consumed at once, the electricity grid is not adequately sized to handle the transmission from producers to consumers. This leads to capacity shortage, despite sufficient energy production, leading to that there is not enough energy where it is needed (Svenska kraftnät, n.d.; Vattenfall, n.d.-b).

If the equilibrium between production and consumption cannot be maintained, the consequences could be severe, potentially leading to power shortages or widespread outages with significant societal implications.

Traditionally, addressing capacity shortages and grid imbalances has involved expanding the electricity grid and energy production capacity. However, this approach is not only costly but also cannot keep pace with the rapid electrification of society. Hence, it is necessary to find other approaches. One approach is leveraging energy storage technologies such as batteries to stabilise the grid. Energy storage systems can bridge short-term power outages and store excess energy generated by renewable sources for later use. The ability to regulate energy flow has become increasingly vital as the gap between production and consumption widens (Svenska kraftnät, 2024a).

As part of the electrification, the number of electric vehicles (EV) in Sweden is continuously increasing, with a more than four-fold increase in numbers between 2020 and 2024 (Power Circle, n.d.). Given that passenger vehicles are parked 96 percent of the time and that the batteries are becoming larger and larger to meet the demand of longer ranges, they present an excellent opportunity for energy storage (Gullberg, 2015). These potential forms the core of *vehicle-to-grid* (V2G), which enables bidirectional energy flow between the EV and the grid. Through V2G, EVs can supply energy to the grid during peak demand periods and recharge during off-peak hours, contributing to grid stability and resilience (Power Circle, 2024).

V2G has been the subject of extensive research and development in recent years. Currently, there are numerous pilot projects taking place, two of them being Public EV Power Pilots (PEPP) and PAVE taking place in Gothenburg. These projects engage various stakeholders, including those from the electricity grid sector, charging infrastructure providers, automotive manufacturers, and academia. While these projects primarily focus on technical aspects and collaboration among stakeholders, there remains a notable gap in understanding the user perspective.

Understanding the user perspective is crucial for enabling the adoption and sustainable integration of V2G technology. Users play a vital role in the V2G system by providing battery capacity, making them key stakeholders. Their engagement and participation are essential for the system's success, as user behaviour directly impacts the reliability and efficiency of V2G operations. Additionally, insights into user needs and concerns help in designing tailored solutions that enhance satisfaction and adoption rates.

Economic viability is also dependent on users' willingness to participate and their perceived value of the service. By understanding user motivations and barriers, policymakers can create effective incentives and policies that encourage participation. Addressing user concerns about security, privacy, and control builds trust and acceptance, which are critical for the widespread adoption of V2G technology. Overall, incorporating the user perspective ensures the development of a robust, user-friendly, and economically viable V2G system.

1.2. Aim

The aim of this thesis is to investigate electric vehicle users' willingness to adopt bidirectional charging as a mean to redistribute energy consumption and avoid peaks in energy demand.

1.3. Goal

The goal is to deliver insight into how a potential solution could be designed in order to facilitate the implementation of bidirectional charging during the early stages of technology adoption. Furthermore, the thesis should provide insights that aids the development of a feasible solution that carefully consider the interplay between users, technology, and societal factors.

1.4. Research Questions

- What are the key factors necessary to ensure user adoption among electrical vehicle users for energy sharing through bidirectional charging?

- What are the current user-centric requirements for creating a solution that enable bidirectional charging and how can these requirements be anticipated to evolve in the future?

- How can a solution be designed to enable electric vehicle users to adopt bidirectional charging to help flatten the peaks in energy demand?

1.5. Delimitations

The scope of this project includes, as previously mentioned in earlier paragraphs, a user-centric investigation of how bidirectional charging can be used to redistribute energy and mitigate peaks in energy demand. For this project, the following delimitations were made:

Privately used electric vehicles

The study will be limited to focus on privately owned or leased vehicles, or any scenario where users perceive ownership and responsibility of the vehicle. This excludes vehicles shared in fleets or similar arrangements, as well as company vehicles.

This limitation is set to contrast previous and ongoing projects focusing on fleets and is further based on recommendations from experts consulted in the project. Furthermore, this limitation is based on the fact that evaluation criteria may differ between privately owned or leased vehicles and non-privately owned or leased vehicles. One such aspect is the concern about battery degradation and other potential wear and tear on the vehicle due to the use of bidirectional charging, which may be of greater importance when users perceive ownership and responsibility over their vehicle compared to when they do not.

Home charging

Home charging encompasses both private and public charging that occurs at residential locations, such as home driveways or residential parking areas. This limitation is set based on the timing of peak energy demand and what is deemed reasonable in relation to it. Given the delimitation to privately owned or leased vehicles, which tend to be at home during peak demand times, home charging becomes of significant interest.

Vehicle-to-grid and vehicle-to-home

Bidirectional charging involves various applications with similar capabilities to alleviate strain on the electrical grid (EV Connect, 2023). In this project, the focus will be on vehicle-to-grid (V2G) and vehicle-to-home (V2H) applications.

2. The Power System, Bidirectional Charging and User Behaviour Related to Electric Vehicle Usage

This chapter presents the theoretical foundation essential for this thesis. It covers a range of topics related to the Swedish electricity grid, including its structure and functions, and the broader context of electrification. Additionally, it addresses the significant challenges faced by the electricity system, such as energy shortages and peak demand issues. The chapter delves into the mechanisms supporting the power system, exploring the concepts of bidirectional charging, which encompasses both V2G and V2H potentials and their implementation. Furthermore, it examines the role of batteries and EV charging infrastructure, alongside user behaviours associated with EV usage, including charge point trauma and range anxiety.

2.1. The Swedish Electricity Grid

The Swedish electrical grid consists of three different sub grids, which all operate at different levels (Svenska kraftnät, 2022b). The tree levels of electricity grids are: *The transmission grid*, *the regional grid*, and *the local grid*. The regional grid and the local grid are often referred to as *the distribution grid*. An illustration of the Swedish electricity grid can be seen in figure 1.

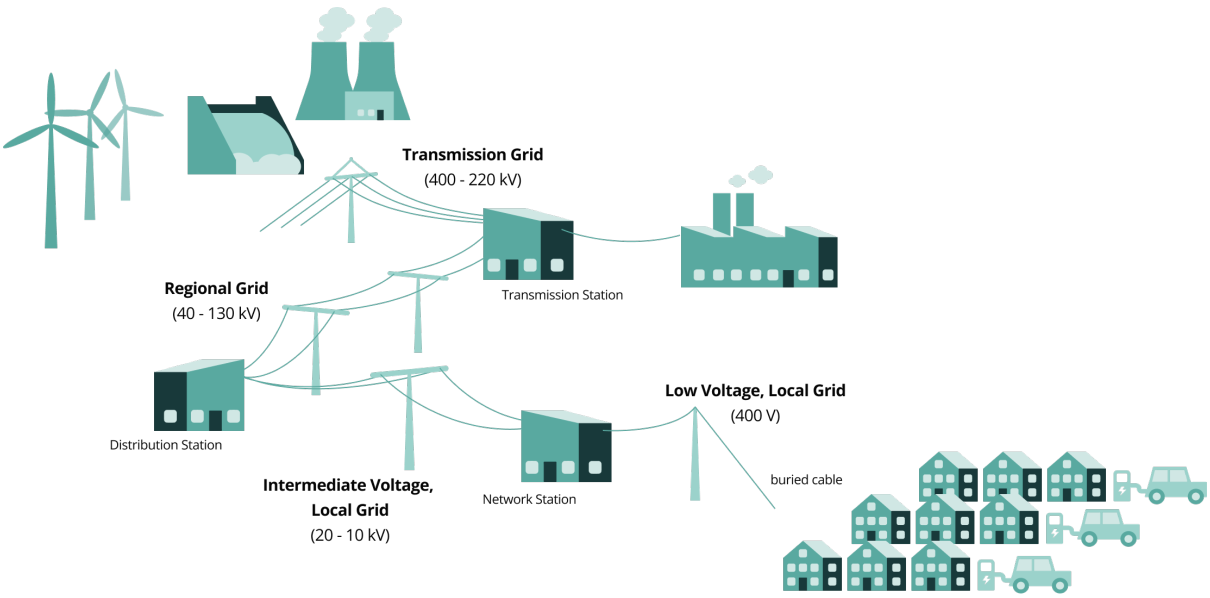

Figure 1. Illustration over the Swedish electricity grid.

Transmission Grid

The purpose of the Swedish transmission grid, previously called *National Network for Electricity,* is to serve as the backbone of the electricity network, facilitating the efficient transport of substantial electrical loads to distribution networks throughout the nation (Svenska kraftnät, 2022b).

Direct connections to the transmission grid are established for significant electricity producers and large-scale consumers. This infrastructure facilitates, for instance, the transmission of electricity generated in northern Sweden to the southern regions. Wind farms for example are connected to the electricity grid through underground cables or overhead lines at various voltage levels (Vattenfall, n.d.-a). *Svenska kraftnät* is responsible for and manages all connections to the transmission grid. Companies interested in connecting themselves must apply for this (Svenska kraftnät, 2023c).

Sweden has one of the oldest transmission grids in Europe and large proportion of the grid is reaching the end of its technical life time and therefore are in great need of replacement (Svenska kraftnät, 2023a). Besides the need of upgrading the grid due to end of technical lifetime the transmission grid needs to be needs to be expanded in order to meet the growing need of electricity, mainly caused by the commonly spread electrification in today's society. Expanding the transmission grid is also necessary in order of allowing a more efficient European electricity market.

The transmission grid consists of approximately 17,500 km of power lines, roughly 175 transformer and switching stations as well as foreign connections with both alternating and direct current (Svenska kraftnät, 2023b). The transmission grid is connected with international grids in Europe and allows for international commerce of electricity (Svenska kraftnät, 2023a). The grid primarily comprises high-voltage alternating current (AC) wires, with approximately three-quarters operating at 400 kV and the remaining quarter at 220 kV (Svenska kraftnät, 2024h). Today, when new wire lines are constructed, they are usually constructed with 400 kV AC technology, which is recognised as the most efficient method for electricity transmission and has become an established international standard.

In contrast, direct current (DC) is utilised only in exceptional circumstances and under specific conditions (Svenska kraftnät, 2024h). The preference for high-voltage AC is driven by its dual advantages of efficiency and environmental friendliness. High-voltage lines allow for the transportation of larger quantities of electricity while minimising transmission losses, making them a more sustainable option. Lower voltage alternatives would require a greater number of lines to achieve equivalent capacity. For instance, replacing a single 400 kV line may necessitate the installation of four to eight 220 kV lines. Consequently, Sweden, along with most other European countries, adopts the 400 kV voltage standard for its transmission network to optimise efficiency and minimise environmental impact.

An issue with a power line or within a transformer station in the transmission network could potentially lead to extensive power outages across Sweden (Svenska kraftnät, 2024f). Hence, it is imperative for the transmission grid to be resilient and dependable. This guarantees the efficient delivery of electricity to its designated destinations and enables prompt resolution of any disruptions. Additionally, maintaining equilibrium between production and consumption is paramount, a topic which will be elaborated on in subsequent sections.

Svenska kraftnät fulfils multiple roles, serving as Sweden's *Transmission System Operator* (TSO) and regulatory authority alongside its responsibilities for grid maintenance and connections (Svenska kraftnät, 2023c). Ensuring the sustainability, safety, and cost-effectiveness of the national electricity transmission system is paramount. All entities connecting to the power system must adhere to regulations and ensure the reliable operation of their facilities. As TSO, Svenska kraftnät effectively coordinates the power system to maintain operational integrity, allocating market capacity, and swiftly restoring normal operations following any disruptions.

Distribution Grid: Regional Grid & Local Grid

The distribution network is utilised for the further distribution of electricity to and from the transmission grid (Svenska kraftnät, 2022b). The distribution network is divided into two parts: the regional grid and the local grids.

The regional grid connects to the transmission grid and facilitate the onward transportation of electricity to local networks (Svenska kraftnät, 2022b). The local grid handles the final stage of transportation of the electricity to the end consumers, such as households or businesses (Svenska kraftnät, 2022b).

The local grids consist of geographically delimited networks operating at voltages of 40 kilovolts or below, which are then reduced to 230 volts for household consumers (Svenska kraftnät, 2022b). Diverse electricity grid companies own these local networks, along with regional ones, and they take on system responsibility as *Distribution System Operators* (DSOs) (Svenska kraftnät, 2024e). Their duties include ensuring the sustainability, safety, and cost-effectiveness of their respective distribution systems. Smaller electricity producers may connect directly to the regional or local grid, with very small producers often linked directly to the local grid, including those selling surplus electricity for personal use (Svenska kraftnät, 2022b). Large local or regional grid companies typically oversee these connections, managing a distinct grid connection process involving permitting and design procedures. These networks generally operate at a voltage of 130 kilovolts (kV).

2.2. Electrification and Growing Demand for Electricity

To mitigate the climate impact, societal transition to fossil-free energy sources is imperative (Energimyndigheten, 2023). Large-scale electrification presents an opportunity to achieve this goal. Electrification fosters innovation, sustainability, and competitiveness among Swedish enterprises, reducing reliance on fossil fuel imports from geopolitically unstable regions. Long-term projections for Sweden's energy landscape indicate a substantial increase in electricity demand by 2050, potentially doubling from current levels. For example, in Gothenburg, the projected surge in power demand is estimated to be 600 MW (Tidningen energi, n.d.). This increase is equivalent to the current energy consumption of Sweden's third-largest city, Malmö.

Transitioning to a more electrified society poses challenges. Addressing these requires an expanded workforce in the energy sector, encompassing engineers, electricians, installers, researchers, investors, and governmental stakeholders (Energimyndigheten, 2023). According to an interim report from Energimyndigheten (2024) the Swedish electricity production is increasing at a faster rate than electricity consumption, and therefore, Sweden will experience growing electricity exports until 2026. The increasing production capacity provides a solid foundation for the larger industrial projects' forthcoming. Further the energy consumption is estimated to reduce until 2026 according to the same report from Energimyndigheten (2024).

One contributing factor to the rising electricity consumption until the end of the forecast period is the increasing demand for electricity in both the industrial and transportation sectors (Energimyndigheten, 2024). Meanwhile, in the transportation sector, electricity usage is projected to increase from 1.4 TWh in 2021 to 4.4 TWh in 2026. However, this increase is lower than previously forecasted due to various factors, such as the lack of incentives for low-emission vehicles.

Swedish electricity production is being significantly expanded until 2026 (Energimyndigheten, 2024). An example of this expansion is wind power, which nearly doubles its production from 27 TWh in 2021 to 52 TWh in 2026. The forecast indicates that the net electricity export will reach 46 TWh by 2026.

Sweden's historical reliance on hydropower, nuclear power, and more recently wind power has provided a stable electricity supply, fostering a sense of predictability, particularly due to hydropower (Energimyndigheten, 2024). Countries lacking hydropower for grid balancing have encountered greater challenges in adaptation. Denmark, for example, has made significant strides in this area compared to Sweden. Nevertheless, recent price fluctuations have sparked increased interest in this field among the public.

2.3. Energy and Capacity Shortage

An *energy deficit* occurs when the total domestic electricity production and imports fail to meet the yearly demand (Vattenfall, n.d.-b). Sweden typically exports more electricity than it imports throughout the year, resulting in an electricity deficit when production does not align geographically or temporally with demand (Svenska kraftnät, 2022a). This shortage happens when the demand for electricity exceeds the available supply at a particular moment (Vattenfall, n.d.-b).

Capacity shortage refers to the difficulty in efficiently transmitting electrical power to customers within certain geographical areas, even when the overall system has enough supply. This challenge is especially notable in densely populated regions such as large cities and significant consumers like data centres or other energy-intensive industries (Svenska kraftnät, n.d.). The issue of capacity shortage occurs when the electrical grid is not adequately sized to handle the transmission of electricity from producers to consumers, despite enough electricity being generated. In such cases, the limited capacity of the grid impedes efficient transmission (Vattenfall, n.d.-b).

2.4. Understanding Peak Demand and Fluctuating Energy Prices

The balance between electricity consumption and production is influenced by various factors, including weather and season, which in turn affects electricity prices (Naturskyddsföreningen, n.d.). When demand for electricity is high, prices rise due to an imbalance in production (Telge Energi, n.d.). These periods of high demand and consequently high prices are referred to as *peak demand periods*. According to data from Nord Pool, the largest energy market in the Nordics, these peaks manifest twice daily: once during the morning hours between 07:00-10:00, and again in the afternoon between 16:00-

21:00, approximately (Nord Pool, n.d.). It is imperative to acknowledge the potential variability in the pattern of peak demand periods on a day-to-day basis.

In figure 2, it is illustrated how energy prices can fluctuate throughout the day. Price levels peak during periods of grid congestions, e.g., when there is an imbalance in the energy system and insufficient capacity. The location of capacity shortages can vary, but they often occur in areas with lower local production and higher consumption. For instance, bidding area 4, depicted with the highest peaks in the figure, represents the southern parts of Sweden, which has less energy production compared to areas 1 and 2, located in the northern parts of the country.

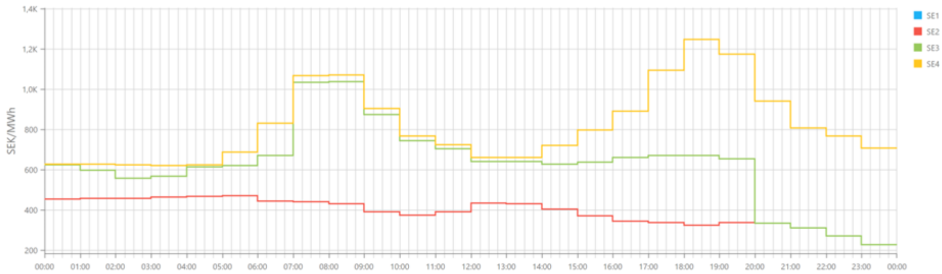

Figure 2. An arbitrary example of how electricity prices fluctuate throughout the day. The Graph clearly indicate how the peak demand reflects on the electricity price. (Nord Pool, n.d.)

2.5. Support off the Power System

The energy system is rapidly transitioning to include more renewable electricity production. This shift poses significant challenges in maintaining the balance of the power system, thereby necessitating an increased demand of flexible resources to help mitigate these imbalances. Ensuring sufficient energy reserves that can help balance the power system is crucial to maintain operational reliability in an efficient manner. These reserves consist, for instance, of production units, units that can adapt their electricity consumption or energy storage (Svenska kraftnät, 2024a). In this chapter, various ways of how the power system can be supported will be presented.

Frequency Balancing and Ancillary Services

For the power system to work as intended, there must always be a balance between the electricity produced and consumed. Monitoring frequency is one way to measure this equilibrium. In the Nordic synchronous area, a frequency of 50 Hz indicates an optimal balance. *Up steering* is used when the frequency drops below 50 Hz, indicating higher consumption than production. Conversely, *down steering* is used when the frequency exceeds 50 Hz, which is a result of either power production being increased, or power usage being decreased (Svenska kraftnät, 2024c). To uphold this equilibrium, Svenska kraftnät procures various reserves and ancillary services from *balance responsible parties* (BRP) (Svenska kraftnät, 2024d). Figure 3 shows an illustration of the frequency balancing of the power system.

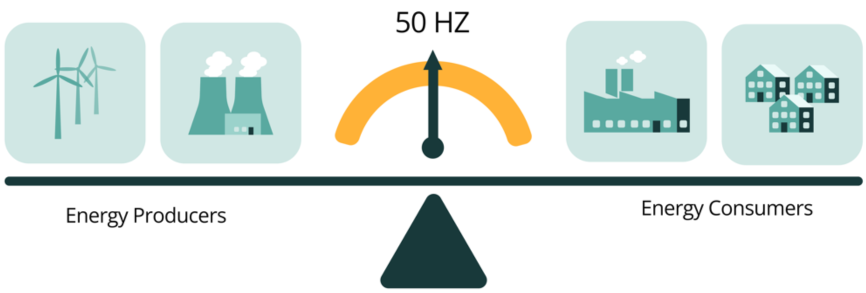

Figure 3. An illustration of the frequency balancing of the power system.

One such ancillary service used for frequency balancing is *Frequency Containment Reserve* (FCR). The task of FCR is to stabilise the frequency for any deviation and is hence crucial in maintaining the balance in the power system (Svenska kraftnät, 2024a). FCR is divided into three different types, more specifically, *Frequency Containment Reserve – Normal* (FCR-N), *upwards Frequency Containment Reserve – Disturbance* (FCR-D up) and *downwards Frequency Containment Reserve – Disturbance* (FCR-D down).

FCR-N is essential for stabilising the frequency during small deviations by up- or down steering and is automatically activated during deviations within the range of 49.90-50.10 Hz (Svenska kraftnät, 2024a, 2024d). Minimum bids for FCR-N are 0.1 MW, with trades for up- and down steering conducted the day before operation (Svenska kraftnät, 2023d).

FCR-D is automatically activated during disruptions in the power system (Svenska kraftnät, 2024d). It consists of two different reserves, one used for up steering, and one used for down steering. FCR-D up is activated when the frequency falls below 49.90 Hz and FCR-D down is activated when the frequency exceeds 50.10 Hz (Svenska kraftnät, 2024a). Minimum bids for FCR-D up and FCR-D down are both 0.1 MW, with trades executed one day before operation (Svenska kraftnät, 2023e, 2023f).

Participation and bidding in various ancillary service markets are restricted to BRPs, making direct engagement with Svenska kraftnät unattainable for private individuals. It is however noteworthy that the BRPs are not always the direct owners of the resources bid into ancillary service markets. Instead, they frequently establish agreements with resource owners, subcontractors, and/or aggregators, who, in turn, own or control the resources. Consequently, private individuals aiming to provide ancillary services typically function as subcontractors to BRPs, a process often facilitated through an aggregator (Svenska kraftnät, 2024c).

Flexibility Market

Adequate grid capacity is not only a concern for the transmission grid but also for the distribution grid. To address local grid capacity issues, local flexibility markets have emerged were regional and local grid operators in need of power or capacity purchase flexibility from actors with flexible energy assets, known as *flexibility service providers* (FSPs). Similar to the ancillary service market, the local flexibility markets aim at balancing the supply and demand of electricity to manage grid congestion within a specific bidding area (Power Circle, 2022; Svenska kraftnät, 2024g).

Flexible energy assets are resources that can vary their energy or power intake or output by delivering flexibility and thus involve flexible energy production, energy storage, and demand flexibility. Offering a flexible energy asset can thus mean that energy consumers adjust their energy consumption based on energy supply. Similarly, energy suppliers adjust their energy production to meet energy demand during a specific period. Hence, energy storage is a convenient way to provide flexible energy assets as it involves storing energy when there is an abundant supply, to then offer energy when the supply is low (Ellevio, 2024).

The local flexibility markets across Sweden operate under largely the same rules. For all markets, there is a minimum bid size of 0.1 MW and a minimum delivery time of 60 minutes, meaning that the flexibility provider commits to delivering a certain amount of energy during one hour. However, the delivery can be made in a shorter time than 60 minutes, as long as the amount of delivered energy remains the same. To ensure that the requested flexibility can indeed be delivered, a validation against a baseline is done. This baseline is a forecast of what the power consumption would have looked like under normal conditions if no flexibility had been provided (Power Circle, 2022).

Energy Arbitrage

Energy arbitrage leverages fluctuations in energy prices resulting from variations in energy supply and demand, meaning that the differences in energy price is exploited by purchasing energy during periods of low energy prices and storing it for later sale during periods of high prices (Aneke & Wang, 2016). Due to the energy prices being determined one day ahead, it is possible to anticipate which periods will have low or high prices (CheckWatt, n.d.).

In order to engage in energy arbitrage, it is necessary to be able to store energy. This is typically accomplished through the use of a *battery energy storage system* (BESS). The BESS could then be charged when prices are low and discharged when prices are high, alternatively, if a solar power system (PV system) is installed, it can be charged with solar energy and discharged during peak price periods (Aneke & Wang, 2016).

Moreover, energy arbitrage offers not only financial benefits but also contributes to grid stability by balancing energy consumption and production as it consumes energy when the supply exceeds demand and then supplying energy when the supply is low (CheckWatt, n.d.).

2.6. The Concept of Vehicle-to-grid

V2G is a technology that enables EVs to be integrated as active participants in the electrical grid system. Through V2G systems, EVs cannot only receive electricity for charging from the grid but also deliver surplus electricity back when needed (Bibak & Tekiner-Moğulkoç, 2021; Power Circle, 2024; Vattenfall, n.d.-c). The concept of V2G is particularly valuable for managing periods of high demand on the electrical grid, which otherwise could lead to inefficiencies and risks of surplus or shortage of electricity. By converting the batteries of EVs into flexible energy assets, V2G technology can contribute to balancing and stabilising the electrical grid (Bibak & Tekiner-Moğulkoç, 2021). Implementing V2G requires both hardware and software to enable two-way energy transfer between vehicle batteries and the grid (Power Circle, 2024). In the future, the involvement of many stakeholders will be necessary for V2G to function effectively. Figure 4 presents an overview of a hypothetical V2G system, highlighting some of the potential key actors.

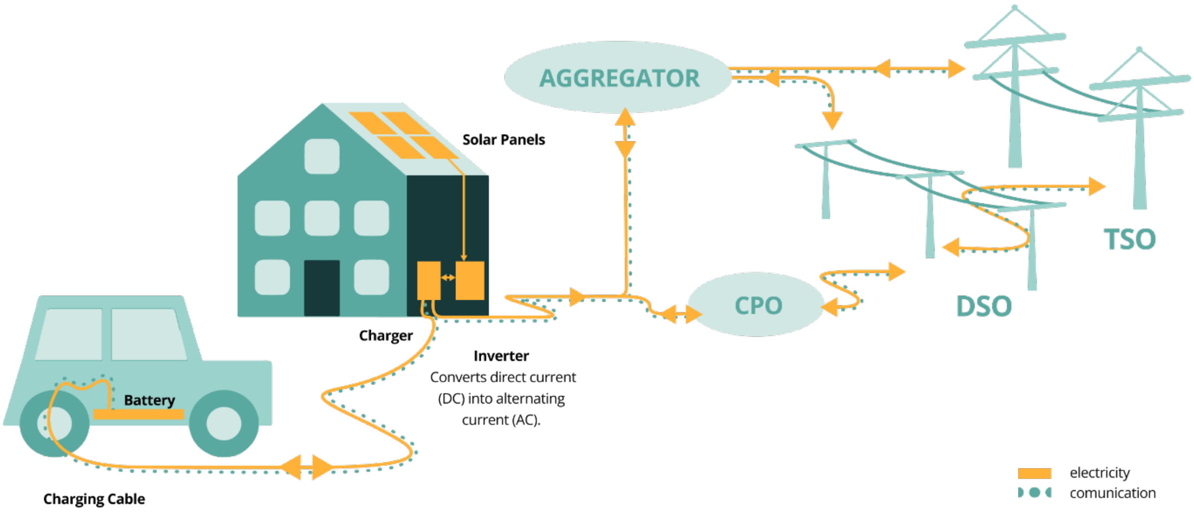

Figure 4. Overview of a potential V2G system that enables the EV to support the power grid.

By utilising V2G technology, EVs can become a crucial component of future smart grid systems, where they serve not only as transportation but also as active participants in the energy transition (Bibak & Tekiner-Moğulkoç, 2021; Power Circle, 2024; SVT Nyheter, 2024). Furthermore, leveraging existing vehicle batteries through V2G can eliminate the need for additional external batteries, thereby optimising resource utilisation and reducing costs associated with energy storage.

Although V2G does not generate new energy into the system, it represents a prospective element in addressing future energy challenges. The expansion of our electricity grid to accommodate growing demands is not a sustainable solution; hence, there is a need to explore more efficient energy utilisation methods. The capability to redistribute energy is what renders V2G and other application areas of bidirectional charging technologies noteworthy from an energy perspective.

2.7. The Concept of Vehicle-to-home

V2H is a technology that utilises electric vehicles as energy storage units for households (Power Circle, 2024). Through V2H systems, EVs can serve as a cost-effective alternative to external home batteries for storing surplus energy. While traditional home batteries typically have a storage capacity of about 10 kWh, EVs have significantly larger battery capacities, usually between 60 and 80 kWh. By integrating the EV into the home's energy system, V2H technology can utilise this larger battery capacity to optimise the consumption of selfgenerated energy from solar panel installations or to store electricity from the grid during periods of low prices or surplus (Zafar & Slama, 2022). The technology of V2H is viewed as a promising and potentially significant area of research, owing to its capability to address a range of issues pertaining to intelligent household electricity consumption and consumer energy demands. In this way, the EVs replace external home batteries and contributes to increased self-sufficiency and reduced dependence on external energy sources.

2.8. Potential of Bidirectional Charging

According to Power Circle, the aggregated battery capacity within EV batteries in Sweden reached 11,500 MWh in 2023 (Power Circle, n.d.). While the simultaneous discharge of the entire 11,500 MWh is theoretically unfeasible for grid relief purposes, it signifies considerable potential, this quantity of energy is substantial, assuming that 20 percent of it would be available for use, it would correspond to the annual consumption of 120 average households, as per Vattenfall's estimation of around 20,000 kWh annually for the electricity consumption of a residence heated by electricity (Vattenfall, 2024).

Another example to showcase the potential of the relatively large battery capacity available today is within the city of Gothenburg. Presently, the city has around 30,000 EVs, with an estimated surge to nearly 100,000 EVs by 2030 (Tidningen energi, n.d.). If these vehicles maintain an average capacity of 60 kWh, it implies an approximate energy reserve of 6 GWh within the city. In this scenario, utilising just 20 percent of this capacity would yield over 1 GWh to support the city's electrical grid. Notably, 1 GWh is significant and holds considerable importance during periods of high demand.

The V2G technology presents a significant potential for enhancing the flexibility of the electrical system by utilising EV batteries for energy storage and resale to the grid. Considering that passenger vehicles are parked 96 percent of the time and a future vision entails up to 90 percent of all batteries being integrated into vehicles, these mobile energy storage units could theoretically support Sweden's electricity needs for several hours (Skellefteå Kraft, n.d.-b). The Swedish Energy Agency anticipates an increasing integration of V2G, with complete adoption projected by 2050.

Figure 5 illustrates the theoretical capacity of V2G to mitigate peak demand fluctuations by serving as a battery storage source.

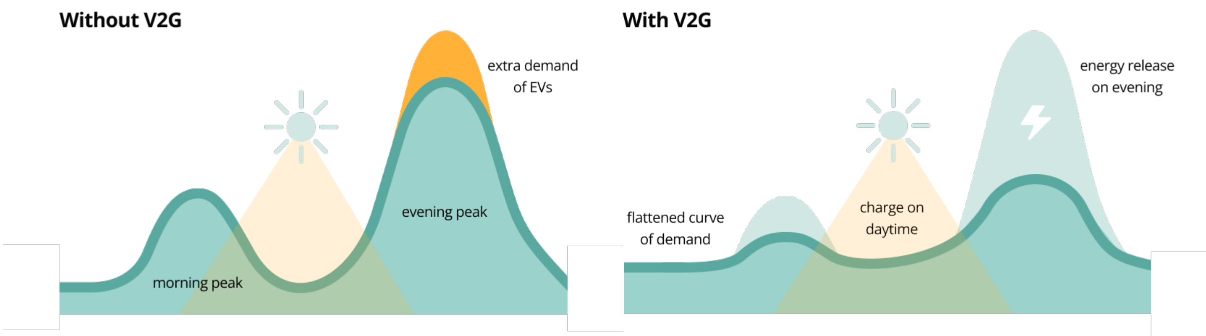

Figure 5. Illustrating how V2G has the potential to support the electricity grid and flatten out peak demand.

2.9. The Electric Vehicle and the Battery

A central component in bidirectional charging is the EV itself. Currently, there are various types of EVs including *Battery Electric Vehicles* (BEVs), *Plug-in Hybrid Electric Vehicles* (PHEVs), and *Hybrid Electric Vehicles* (HEVs).

While all EVs have batteries, only BEVs and PHEVs are plug-in EVs, meaning they can be charged by connecting to a charging infrastructure. In the context of V2G, BEVs are of particular interest due to their larger battery capacities, although PHEVs also offer some potential for V2G applications.

Therefore, when referring to EVs in this report, BEVs are specifically meant.

Battery Composition

Most of today's BEVs and PHEVs use lithium-ion batteries due to their ability to output high energy and power per unit of battery mass. This characteristic enables these batteries to be lighter and smaller compared to other rechargeable batteries (Alternative Fuels Data Center, n.d.; Lowe et al., 2010). Additionally, lithium-ion batteries also have a relatively long life cycle compared to other batteries (Lowe et al., 2010).

While there might be slight variations in the batteries from different manufacturers, they generally are constructed in a similar way. An EV battery consists of hundreds or sometimes thousands of small battery cells. These are connected in either series or parallel configurations within battery modules, which are then integrated into battery packs to achieve the required voltage and current outputs (EV Expert, n.d.-a).

The battery packs include a *Battery Management System* (BMS) which is a system that monitors and controls the batteries in an EV. The Battery Management System is a critical component of EVs, as it ensures that the battery is used and charged in a safe and efficient manner, helping to optimise battery performance, life and reliability (Hägglund, 2023; Lowe et al., 2010).

Battery Degradation

The battery is a critical component of an EV, and as it is one of the most expensive components in the vehicle it is required to have a long lifespan in order to achieve the economic viability of an EV (Timilsina et al., 2023). Regardless of the Battery Management System, the battery will degrade over time. *Battery degradation* refers to the battery's decreased ability to store energy over time and typically there are two types of aging: *calendar aging* and *cyclic aging*. The two types of ageing interact and co-exist (Skellefteå Kraft, n.d.-a). Hence, battery degradation is not linear and can be affected by several factors such as the chemical composition of the battery and ambient temperature (Skellefteå Kraft, n.d.-a).

Calendar aging comprises all aging processes that lead to a degradation of a battery cell independent of charge-discharge cycling, i.e., when the battery is at rest condition. It has been seen that calendar aging degradation is accelerated by a high state of charge (SOC) and high temperatures (Keil et al., 2016). Hence, a battery that often is fully charged will age faster (Skellefteå Kraft, n.d.-a).

Cyclic aging occurs due to the charge and discharge cycles of the battery. Factors such as the number of cycles, charging rate and the amount of energy used per cycle affect how quickly the battery ages (Skellefteå Kraft, n.d.-a).

Battery degradation will cause *capacity fade*, which is the loss of charge capacity over the lifecycle of the battery as well as *power fade,* being a decrease in voltage at a given discharge (Samadani et al., 2016).

When discussing V2G, one of the main concerns is accelerated battery degradation. The reduction in energy capacity that the battery degradation results in represents an additional cost that needs to be deducted from the profit generated by grid services (Thingvad et al., 2021). There are studies indicating that V2G might increase the cyclical aging, but it is still not uncertain whether V2G affects the battery degradation more than other types of charging. For example, traditional charging without smart technologies might have a greater impact on the calendar ageing than V2G has on cyclic ageing (Power Circle, 2024).

2.10. The Charging Process

Understanding the charging process of an EV is crucial when considering the implications of bidirectional charging. Hence, this chapter will cover the fundamental aspects of EV charging, the advancements in smart EV charging, as well as the distinctions between unidirectional and bidirectional charging. By examining these concepts, a comprehensive understanding of how bidirectional charging works and how it differs from traditional unidirectional charging can be gained.

The Basic Concepts of EV Charging

The charging process of an electric vehicle relies on three main components: the charging station, the charging cable, and the on-board charger. The charging speed will always be determined by the weakest link within this interconnected system (EV Expert, n.d.-b).

Charging stations are typically categorised as either AC or DC charging stations, each with distinct characteristics. Regardless of the type, the charging station initially receives AC power from the electricity grid. However, since the EV's battery requires DC power, this AC power must be converted into DC before utilisation.

In the case of AC charging stations, the conversion from AC to DC is facilitated by a rectifier, known as an *on-board charger* (OBC), located within the vehicle itself (E.ON, 2023). The on-board charger receives AC power and converts it into DC, subsequently transferring it to the vehicle's battery (see figure 6). Therefore, the charging speed is dependent upon the on-board charger's efficiency in receiving the alternating current from the source as well as the number of phases of the alternating current it is able to utilise.

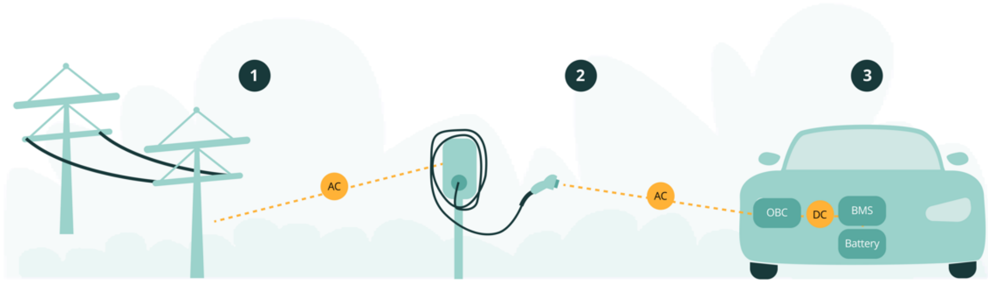

Figure 6. An illustration of AC charging of an EV.

AC charging stations are predominantly used for residential charging or public charging (E.ON, 2023). That is mainly due to their cost-effectiveness compared to DC chargers. However, the charging power with AC stations is relatively low, with the most powerful ones capable of delivering up to 22 kW, depending on the EV's battery capacity and the charger's power. Some vehicles, constrained by their on-board charger, can only accept up to 11 kW, resulting in longer charging times (Laddboxbolaget, 2022). Charging with 11 kW respectively 22 kW enables a full charge in approximately eight hours respectively four hours (Elbilsmagasinet, 2021). Hence, AC charging is suitable for when the vehicle is parked for a longer period of time, such as at home overnight or at the parking lot during work hours.

DC chargers on the other hand feature a powerful built-in rectifier that directly converts AC power, allowing for charging of the EV's battery directly, without passing the on-board charger (Svensk Fordonsladdning, 2020) (see figure 7). Hence, DC charging results in faster charging times and is therefore often referred to as *fast charging*. The faster charging time is a result both of that the battery is powered directly, but also due to DC charging using higher output power between 50 kW and 300 kW. The most common fast chargers in Sweden are 50 kW or 150 kW and enables a full charge in approximately two hours respectively one hour. However, it is not all vehicles that are able to utilise the full charging power. Vehicles produced in 2021 usually have 150 kW as maximum charging speed, whereas older vehicles usually have a maximum charging speed of less than 100 kW (Elbilsmagasinet, 2021). DC charging stations are therefore mostly positioned at motorway services and other key travel points to be accessible for when driving a longer journey (Shell Recharge, 2023).

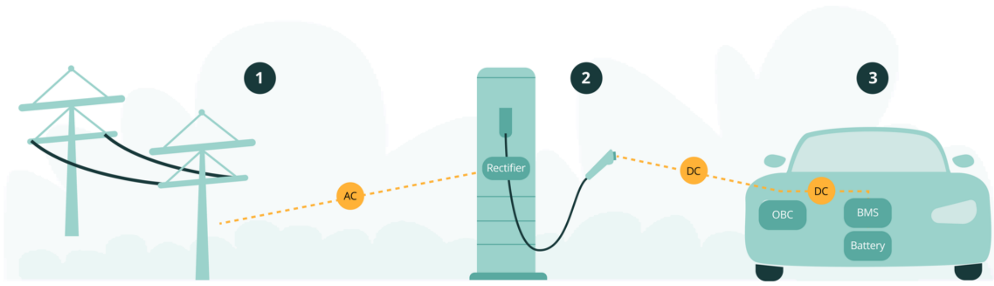

Figure 7. An illustration of DC charging of an EV.

Smart EV Charging (V1G)

One challenge that EVs present to the electricity grid is their potential to create large power peaks when charging. For instance, an 11kW charger consumes as much electricity as almost four ovens or eleven washing machines operating simultaneously (Göteborg Energi, n.d.). Hence, simultaneous charging of multiple EVs can strain the electricity grid, as it will not be able to deliver the high amount of energy that is required. When using so called *traditional charging*, the charging will begin at full power as soon as the vehicle is plugged in (Göteborg Energi, n.d.). Considering that many EV owners plug in their car when returning home from work, the charging of EVs exacerbates the traditional power consumption curve as this time of day typically coincides with the grid's highest load (Power Circle, 2021).

Smart charging, also called V1G, offers a solution to these challenges by leveraging connectivity to enable charging that is dynamically adjusted based on various parameters. This adaptability allows for charging at reduced power levels or during off-peak hours, optimising energy consumption (Power Circle, 2021). By postponing charging to periods when the grid experiences lower demand, the EV acts as a flexible energy asset, helping balance energy consumption, as illustrated in figure 8. A key prerequisite for smart charging is the ability to shift vehicle charging times. AC charging, which typically occurs when vehicles are parked for extended periods, presents a significant opportunity for smart charging utilisation, given that passenger cars are parked on average 90 percent of the time (Power Circle, 2021). Furthermore, while DC charging does not offer the same flexibility in time shifting, integrating charging stations with battery storage can mitigate this limitation. This setup allows batteries to be charged during periods of low grid demand and discharged rapidly when vehicles plug in during peak periods, providing charging services without adverse effects on the grid (Power Circle, 2021).

V2G shares similarities with smart charging in terms of its capacity to regulate both charging power and charging hours. Hence, it is noteworthy that V2G is not only encompassing balancing the grid by contributing with energy when the supply is low, but also consuming energy when the supply is high.

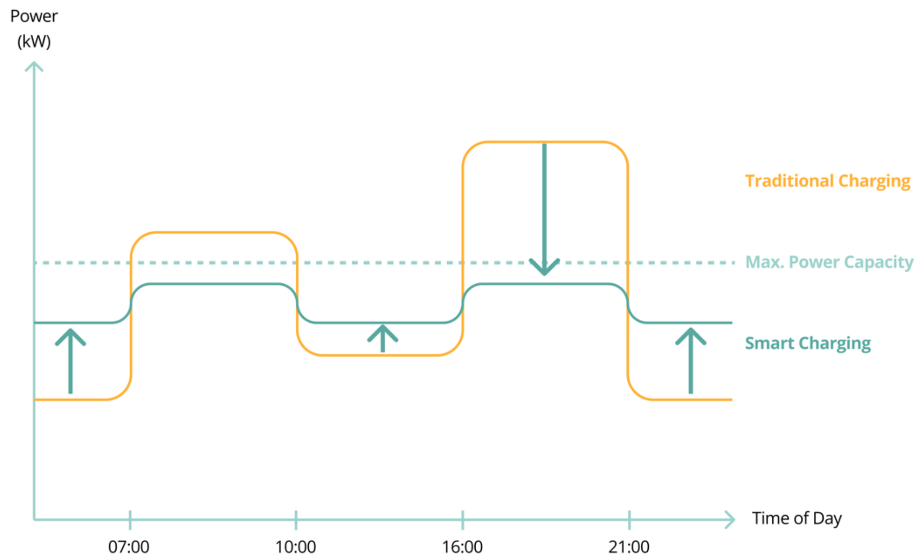

Figure 8. An illustration of how smart charging can help even out peak demands.

Unidirectional Charging and Bidirectional Charging

Unidirectional charging, which can be considered the conventional method of charging, entails power flowing in one direction. AC power from the grid is converted to DC power either in the vehicle or in the charging station depending on whether it is AC or DC charging, and then stored in the battery (go-e, 2023).

In contrast, *bidirectional charging,* which underpins V2G technology, enables power to flow in two directions: from the grid to the vehicle's battery, and from the battery back to the grid. However, for power to be fed back to the grid, it must undergo conversion from DC to AC which is a capability that is not yet widely available in today's chargers (go-e, 2023).

A critical technical consideration regarding bidirectional charging is determining whether the conversion should occur in the vehicle's on-board charger, i.e., AC charging, or via an inverter located in the charging station, i.e., DC charging (Power Circle, 2024). The location of the power electronics and control mechanisms significantly influences which component is responsible for communication and adherence to grid electricity feeding regulations. Additionally, it determines whether the increased technology costs should be allocated to the vehicle or the charging infrastructure. Currently, various actors are actively developing solutions for both configurations (Power Circle, 2024).

2.11. Standards

Standardisation serves as a crucial mechanism for advancing technology development in the interdisciplinary field of V2G, involving multiple stakeholders. Standardisation ensures alignment and progress by facilitating collaboration and providing a framework for innovation.

This chapter offers an overview of the standards related to charging infrastructure and the evolution of V2G technology, illustrating their integral connection to the development and implementation of V2G technology.

Standards for Charging

To ensure a streamlined and standardised charging process for EVs, several charging standards have been developed over time. Presently, diverse standards are employed for EV charging across the industry. Different car and charging brands adopt varying standards, some even developing proprietary ones (Tibber, n.d.). The global establishment of these standards also differs, with some being more widely recognised and utilised than others. Each standard operates uniquely, affecting aspects such as charging speed, efficiency, and compatibility with AC or DC charging. Some of the most spread ones are presented below.

Type 1 (SAE J1772) is a charging standard primarily used in North America and Japan (Nordic Institute, 2023). It utilises single-phase AC charging and is compatible with most EVs on the market. Type 1 charging cables feature a plug that connects to the vehicle and another end that connects to the charging station, allowing EV owners to charge their vehicles at public charging stations or with a home charging box.

Type 2 (IEC 62196-2) is the charging standard in Europe (Nordic Institute, 2023). It supports both single-phase and three-phase AC charging and is compatible with most EVs and charging stations. Type 2 charging cables also feature a plug that connects to the vehicle, but they also have a built-in communication function that allows the charging station to communicate with the vehicle. This enables the charging station to monitor the charging process and adjust the charging according to the vehicle's needs.

CCS (Combined Charging System) is a standard that combines AC and DC charging (Nordic Institute, 2023). The CCS connector is compatible with the Type 2 connector and is primarily used in Europe and North America.

CHAdeMO is a Japanese standard primarily used by Nissan and Mitsubishi (Nordic Institute, 2023). It utilises DC charging and is compatible with certain electric vehicles and charging stations. CHAdeMO currently stands as the only charging protocol globally with bidirectional charging (V2G) functionality enabled (CHAdeMO, n.d.).

Standards and Integration of V2G

Ensuring the seamless integration of V2G technology necessitates additional standards beyond those governing charging. While existing standards are in place and under development, further standards are needed to address emerging challenges and complexities. These standards are vital for facilitating interoperability and ensuring smooth operation between EVs and the grid (Noel et al., 2019b).

Enhanced standards for bidirectional power flow control may be required to optimise energy exchange between EVs and the grid, considering factors such as grid stability and user preferences. As V2G systems become more integrated into grid infrastructure, cybersecurity becomes a critical concern. Developing new standards focusing on cybersecurity protocols and best practices for V2G communication and data exchange is imperative to safeguard the integrity and security of V2G operations.

Standards aimed at facilitating the integration of V2G systems into grid operations and enabling EVs to effectively provide grid services, such as frequency regulation and demand response, are essential(Noel et al., 2019b). These standards would outline communication protocols, data formats, and interoperability requirements. Efforts should be directed towards enhancing interoperability between different V2G systems to ensure plug-and-play compatibility, allowing EVs from various manufacturers to seamlessly interact with diverse charging infrastructure and grid equipment. Additionally, developing standards addressing data management, privacy, and data sharing practices in V2G systems is necessary to establish guidelines for handling sensitive information while safeguarding user privacy.

ISO15118 stands out as a key standard governing hardware and communication between vehicles and chargers, facilitating V2G operations. While the latest version of this standard is still evolving, it is expected to provide comprehensive V2G functionality. Vehicles and chargers must implement ISO15118 with the same version to enable bidirectional charging and communication.

Looking forward, collaboration among stakeholders, including standards organisations, industry players, regulators, and researchers, is pivotal in shaping the future standards landscape for V2G. Considering grid codes is essential for V2G operation across different grid areas and national borders. ISO15118 mandates that communication between chargers and the control system supports V2G. Effective communication with the power grid is crucial for maximising the utility of V2G.

To implement V2G effectively, it is necessary to develop robust communication protocols, compatible hardware, and efficient control systems. This includes ensuring interoperability between different manufacturers' equipment, upgrading grid infrastructure, and establishing regulatory frameworks that support V2G integration. Additionally, creating sustainable business models will incentivise participation from all stakeholders, ensuring the economic viability and widespread adoption of V2G technology.

2.12. V2G Actors and Business Models

V2G is a complex system involving multiple stakeholders. Due to its intricate nature, effective collaboration among these stakeholders is essential for the development, implementation, and operation of the entire concept. While EV owners are the primary stakeholders, the hypothetical actors needed are presented below and in figure 9.

- *EV owners* constitute a crucial actor group within V2G systems (Noel et al., 2019a). They provide vehicles equipped with V2G capabilities, allowing them to interact with the grid by supplying excess energy or drawing power as required. EV owners may opt to engage in V2G programs to contribute to grid stability or receive compensation for their energy contributions.

- *Utility companies* serve as central actors in V2G systems, tasked with managing electricity distribution and supply (Noel et al., 2019a). They incentivise EV owners to participate in V2G programs to stabilise the grid, manage peak demand, and effectively integrate renewable energy sources.

- *Charging infrastructure providers* deploy and maintain the necessary infrastructure for V2G operation, ensuring that EVs can connect bidirectionally to the grid, facilitating energy flow to and from the vehicle (Noel et al., 2019a).

- *Grid operators* oversee the operation and upkeep of the electric grid, coordinating electricity flow between EVs and the grid to ensure stability, reliability, and compliance with regulatory standards (Noel et al., 2019a).

- *Regulatory bodies and government agencies* establish policies, regulations, and standards governing V2G implementation, providing incentives and frameworks to promote adoption and ensure safe integration into the energy system (Noel et al., 2019a).

- *Technology developers and suppliers*, including vehicle manufacturers, software developers, and hardware suppliers, contribute to V2G advancement by developing technology solutions to enhance efficiency, performance, and interoperability (Noel et al., 2019a).

- *Research institutions and academia* contribute valuable insights and expertise to V2G development through research, development, and innovation, addressing technical challenges and optimising V2G performance (Noel et al., 2019a).

- *Aggregators* act as intermediaries between individual electric vehicle EV owners and the energy grid (Noel et al., 2019a). By pooling the energy resources from multiple EV batteries, aggregators can efficiently manage and optimise the distribution and storage of electricity.

Figure 9. Potential actors and stakeholders involved in V2G.

Depending on the proposed business models, the included stakeholders may assume slightly different roles. Sovacool et al. (2020) identifies twelve stakeholder types across industrial firms, households, and electricity suppliers, impacting activity systems in terms of content, structure, and governance. These stakeholders encompass original equipment manufacturers, dealers, households, and community fleets, offering a variety of business models from vehicle sales to mobility as a service.

While the specifics of initial business models and actors remain unclear, collaboration across sectors is evidently crucial. Overall, the potential for V2G business segments is expansive and extends beyond vehicles alone. Regardless of whether the business model revolves around vehicle fleets, public charging, or home charging, the role of the vehicle user remains pivotal (Sovacool et al., 2020). Additionally, both actors and business models may be influenced by the services vehicles provide to the grid. Depending on the functions and services offered, different actors may become involved.

The necessity for aggregators depends on whether the business model is centralised or decentralised (Sovacool et al., 2020). Moreover, aggregators are expected to play a critical role in optimising the collective energy storage capacity of EV fleets to efficiently deliver valuable grid services (Giordano et al., 2023). They communicate with grid operators to understand grid requirements and market conditions, adjusting charging and discharging schedules accordingly. By aggregating energy resources from multiple EVs, aggregators offer grid operators a more flexible and responsive resource for balancing supply and demand, enhancing stability, and integrating renewable energy sources. Additionally, aggregators enable EV owners to monetise their vehicle's battery capacity by participating in grid services programs, creating opportunities for revenue generation and cost savings.

2.13. User Behaviour

Considering the focus of this thesis, it is essential to investigate theories related to user perspectives. Examining user behaviours that may impact future interactions with V2G technology is of paramount importance. This chapter addresses demand flexibility, a critical factor for V2G, as well as the phenomena of range anxiety and charge point trauma. These issues currently affect EV users and are anticipated to be significant for future V2G users as well.

Demand Flexibility

Demand flexibility refers to the ability of consumers to adjust their electricity consumption patterns in response to changes in price signals, grid conditions, or other external factors (Hennlock et al., n.d.). It enables consumers to actively participate in managing electricity demand, thereby contributing to grid stability, efficiency, and sustainability. Demand flexibility allows consumers to shift their electricity usage to times when energy is abundant and cheaper or reduce consumption during peak demand periods when energy is scarce and more expensive (Energimarknadsinspektionen, 2020). This flexibility helps optimise the utilisation of resources, reduces the need for costly infrastructure upgrades, and supports the integration of renewable energy sources into the grid. Overall, demand flexibility plays a crucial role in ensuring a reliable, resilient, and cost-effective electricity supply system.

Customer contribution to demand flexibility involves their ability and willingness to control their electricity usage (Energimarknadsinspektionen, 2020). This control can entail adjusting the consumption of electricity, either increasing or decreasing it, to help balance the overall load on the grid. As renewable energy production and societal electrification continue to grow, flexible demand becomes crucial for maintaining grid stability. Increased flexibility can alleviate strain on the grid during peak demand periods, leading to more efficient grid utilisation and reducing the need for infrastructure expansion and the risk of power shortages (Hennlock et al., n.d.). Moreover, flexible electricity usage can mitigate the need for investing in new power generation infrastructure and reduce the activation of high-emission production resources during scarcity situations. Overall, enhanced demand flexibility fosters a more economically efficient electricity system and enhances the likelihood of achieving climate and energy policy objectives.

Range Anxiety and Charge Point Trauma

EV and BEV drivers may experience two distinct psychological phenomena: *range anxiety* and *Charge Point Trauma* (CPT) (Chamberlain & Al-Majeed, 2021). Range anxiety occurs along the route while CPT at the charging station.

Range anxiety refers to the fear or stress associated with the limited driving range of EVs and the uncertainty of finding charging stations when needed (Nadine Rauh, Thomas Franke, Josef F. Krems, 2015). It primarily revolves around concerns regarding the ability to reach destinations without running out of battery power and the availability of charging infrastructure along the route. In contrast, CPT extends beyond range anxiety to encompass broader anxieties related to the range of the EV, availability, location, payment processes, and operability of public rapid charge points for EVs (Chamberlain & Al-Majeed, 2021).

While range anxiety focuses primarily on concerns about an EV's driving range and the need for charging stations, CPT encompasses a wider range of anxieties, including the availability and accessibility of charging infrastructure, consistency in payment processes, and reliability in charging station operations (Chamberlain & Al-Majeed, 2021). EV users often reduce range stress by maintaining ample safety margins, with their comfortable range typically accounting for about 80 percent of the available range. Increasing users' comfort range through experience can alleviate range anxiety, as prolonged EV usage has been shown to enhance range competence over time. However, mastering the management of range anxiety may require extensive driving experience. CPT can affect both new and experienced EV drivers, as it arises from challenges related to the usability and reliability of charging infrastructure rather than solely from concerns about driving range. While both phenomena can affect EV drivers' psychological well-being and driving behaviour, CPT represents a more comprehensive and nuanced understanding of the challenges faced by EV users in accessing and utilising public charging infrastructure. Both range anxiety and CPT are important considerations for EV adoption and need to be addressed to encourage more people to switch to electric vehicles.

Precise range estimation and energy consumption strategies, along with the expansion and development of infrastructure, are some ways to mitigate range anxiety (Shrestha et al., 2022). Real-world factors affecting an EV's range, such as traffic, gradients, ambient temperature, and driving speed, are being addressed to provide more accurate range estimations. Additionally, optimising energy consumption, ensuring the even distribution of charging stations, and introducing range extenders can alleviate range anxiety for users.

CPT involves improving EV charging infrastructure, standardising payment processes, enhancing user experience, increasing transparency, providing education and support, and fostering collaboration among stakeholders (Chamberlain & Al-Majeed, 2021). By addressing these factors, users' psychological, physiological, and behavioural distress associated with EV charging can be alleviated, promoting greater adoption of electric vehicles and a more supportive charging environment.

3. Method

The project approach has drawn inspiration from the double diamond but has been slightly adapted to fit the nature of the project. The double diamond is a framework for the design process where the two diamonds represent a process of exploring a problem more widely and deeply, i.e., divergent thinking, and then taking a focused action, i.e., convergent thinking. It contains the four phases *discover*, *define, develop* and *deliver* (The Design Council, n.d.).

The discover phase is aimed at understanding the challenges and problems that needs to be solved, whereas the define phase is aimed at defining the challenges in a different way based on the insights from the discover phase (The Design Council, n.d.).

The develop phase aims at exploring different answers to the clearly defined problem. Subsequently, the deliver phase aims at testing the different solutions in order to reject those that do not work and improve the ones that do (The Design Council, n.d.).

This project has consisted of four clear phases: *initial research, user research, design sprint 1* and *design sprint 2*. The initial research and the user research have been characterised by the discover and define phases of the double diamond, whereas both design sprint 1 and design sprint 2 have been characterised by the develop and deliver phases of the double diamond. Thus, the initial research phase and the user research phase have constituted the first diamond, whereas design sprint 1 and design sprint 2 have constituted the second diamond in the double diamond approach.

Furthermore, the project has been permeated by co-creation through user involvement during the entire project, from the initial research phase to design sprint 2. During the initial research phase, the user involvement was in form of expert interviews, whereas in the user research phase the user involvement was with vehicle users. From the survey, a group of EV users was selected for consistent involvement throughout the rest of the project. Co-creation is a collaborative design approach that engages the users as co-designers based on the principle that they are the experts of their own experiences and needs and can thus contribute with valuable perspectives in the design process and thus deepen the insights. The decision to involve the same user group from the user research phase trough to design sprint 2 was made to enable the users to build upon their previous thoughts and understandings. This continuity aimed to provide deeper insights into the user perspective of V2G by allowing for the progressive development of ideas and feedback.

The project approach as a whole has been illustrated in figure 10.

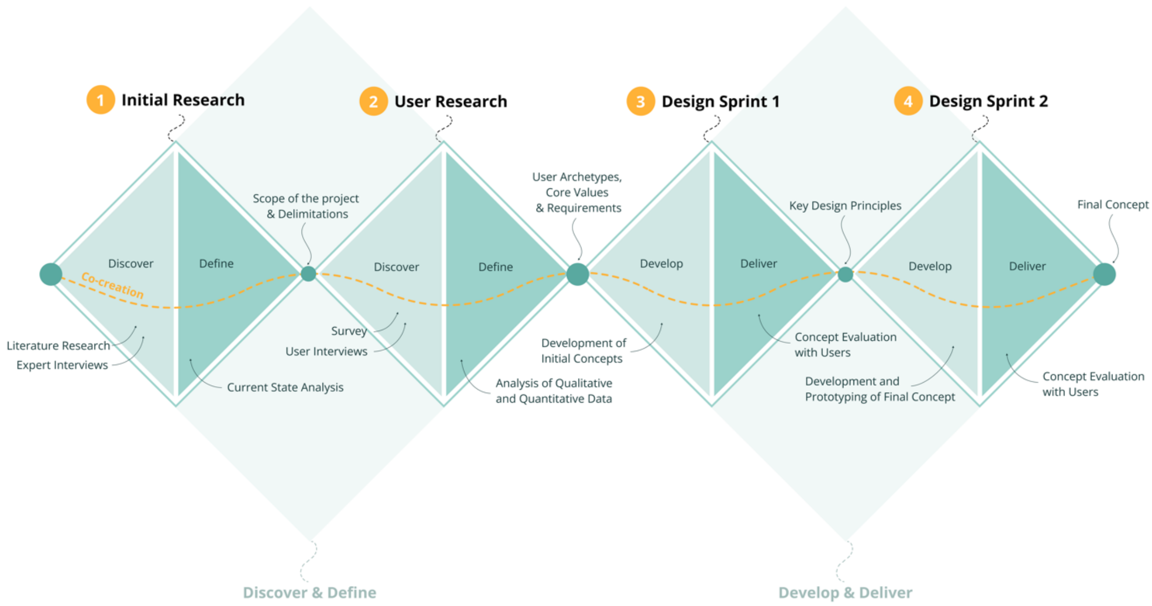

Figure 10. An illustration of the modified double diamond approach applied to the project.

3.1 Initial Research

The aim of the initial research phase was to gather a comprehensive understanding about V2G technology, encompassing its various application areas and future potential, while also exploring the user perspective related to EV usage and V2G.

Hence, the initial research consisted of a literature study to gain theoretical knowledge as well as expert interviews to gain insights from industry professionals and to validate and add to the findings from the literature study.

The initial research phase was essential for establishing the overall scope of the project and to steer the direction of subsequent user research. By synthesising insights from both the literature study and the expert interviews, the research objectives of the project could be defined.

3.1.1 Literature study

A literature study was conducted to gain insight into how V2G technology works, its potential to mitigate energy and capacity shortages, and previous advancements within the area. Additionally, the literature study aimed to identify critical aspects related to user adoption and behaviour design.

Literature was initially gathered through a combination of searches in Google, within the database Google Scholar and through recommendations from the interviewed experts. Additional sources were then identified through the initially collected literature. The sources used are therefore a combination of academic papers, reports from relevant organisations as well as information from relevant stakeholders' websites.

The literature was then evaluated based on its relevance to the topic and its credibility. The relevant literature was then examined and organised by different subtopics regarding the electricity grid and power system, the electric vehicle and bidirectional charging as well as user behaviour and user adoption.

Due to the exploratory nature of this project, the research was rather open, however some of the keywords used was the following:

- “Vehicle-to-grid”
- “V2G”
- “Vehicle-to-home”
- “V2H”
- “Bidirectional charging”
- “V2G stakeholders”
- “V2G potential”
- “V2G integration”
- “Electricity grid”
- “Power system”
- “Electrification”
- “Capacity shortage”
- “Peak demand”
- “Frequency balancing”
- “Support of the power system”
- “Battery degradation”
- “EV charging”
- “Charging Standards”
- “Standards Bidirectional Charging”
- “Demand Flexibility”
- “Charge Point Trauma”
- “Range Anxiety”
- “User Adoption”

3.1.2 Expert Interviews

To gain comprehensive insights into various aspects of V2G, a total of eight expert interviews were conducted. These interviews provided invaluable perspectives from professionals working within different fields and disciplines related to V2G.

The interviewed experts were carefully selected based on their expertise and experience in areas such as electrification of transport, integration into the energy system, on-going V2G pilot projects in Gothenburg and battery technologies, among others. Details of the interviewed experts and their roles can be found in table 1.

Table 1. The interviewed experts.

Role	Company	Expertise
Advisor Renewable Energy Distribution	Knightec	Technical aspects, including batteries and energy storage
Senior Researcher	RISE	Involvement in the project *Dansmästaren* - User perspective regarding demand flexibility and charging
Area Manager Innovation	Lindholmen Science Park	Involvement in the project *PEPP* – Overall perspective over project
Expert E-mobility	Power Circle	Integration of V2G
Flexibility market responsible	Göteborg Energi	DSO perspective, interaction and systematic level V2G
Researcher at Electric Power Engineering	Chalmers	Involvement in various V2G projects regarding technical aspects, including battery degradation and bidirectional charging
Senior Researcher	RISE	Involvement in *PEPP* - User perspective of V2G
Post. Doc Building Technology	Chalmers	Involvement in *PAVE* – User perspective of V2G

The interviews were conducted in an unstructured manner with minimal predetermined questions. Any predetermined questions were tailored to each expert, allowing for a free-flowing discussion. This approach enabled experts to share insights based on their specific knowledge, facilitating a deeper exploration of relevant topics.

3.2 User Research

The primary aim of the user research phase was to acquire both quantitative and qualitative insights into the anticipated users of V2G technology. This involved comprehending their overall attitudes towards the technology, along with their underlying concerns and motivational factors. Furthermore, the goals of this phase included identifying potential user groups and elucidating the defining characteristics of each user segment.

3.2.1 Survey

The purpose of the survey was to identify potential user groups among vehicle owners, establish a fundamental understanding of general attitudes towards V2G technology, ascertain the level of interest both EV and non-EV owners have in the technology, and gain insights into the driving and charging habits of today's EV owners to facilitate a deeper understanding of how the technology should be adapted to fit into users' daily lives.

As the first step in the user research, the purpose of the survey was to:

- Identify potential user groups among vehicle owners.
- Establish a fundamental understanding of general attitudes towards V2G technology.
- Ascertain the level of interest in V2G technology among both EV and non-EV owners.
- Gain insights into the driving and charging habits of today's EV owners.

Furthermore, the aim of the survey was to gather both quantitative data on current driving and charging behaviours and qualitative data regarding attitudes towards V2G technology.

The survey targeted a broad range of vehicle owners, irrespective of car model or ownership of an EV. Individuals who rent, utilise company cars, lease, or otherwise utilise vehicles without direct ownership were intentionally excluded from participation in the survey. This decision was made to ensure that perspectives were gathered exclusively from those who bear the financial responsibility for accessing the vehicle. The approach was deemed necessary given the likelihood of financial investments being involved, and to mitigate the risk of divergent perspectives arising from personal financial investment. Emphasising ownership was considered important, as it cannot be discounted that including EV users who lease their cars may introduce differing attitudes towards investments and compensation.

The survey was intended to be completed individually and was conducted using Google's digital tool, Google Form. A targeted sampling method was applied to ensure that the survey was directed towards individuals who currently own a minimum of one vehicle within their household or by themselves. Respondents that did not own their own vehicles were rolled out of the survey.

To reach vehicle owners, the survey was published in various Facebook forums. Some targeted both EV owners and non-EV owners, while others catered specifically to each group. These forums were deliberately chosen not to be specific to any particular car brand, allowing for a broader representation of participants. Some of the EV forums were *Elbil och Laddhybrid i Sverige* with over 15,000 members and *Elbilsladdning i Sverige* with nearly

15,000 members. Additionally, there were several smaller forums catering to various types of vehicles, like *Bilentusiaster* with nearly 5,000 members.

To ensure the representativeness of the responses, introductory questions about gender, age, life situation, position of home, etc., were included. This measure aimed to ensure that the results reflected a diversified group of respondents so that the results could eventually be generalised and applied to a larger population, i.e., be generally applicable to all vehicle owners.

To meet the purpose and goal of the survey, it was necessary to state the questions in a way allowing it to collect both quantitative and qualitative responses. Therefore, the survey was constructed to be a hybrid form combining elements from both preparatory and descriptive surveys. The closed-ended questions aimed to obtain quantitative data, similar to the approach in an exploratory study, while the open-ended free-text questions aimed to generate qualitative data (Bryman, 2016), similar to the method in a descriptive study.

As the survey aimed to cover both current behavioural patterns and attitudes towards V2G, which encompassed several comprehensive subject areas, there was a risk that such a survey would require significant time to complete. Since longer surveys are often associated with an increased risk of dropout from respondents, it was crucial to have designed the survey with well-structured questions and an intuitive design (Bryman, 2016). After the introductory questions about the respondent's background and personal information, the survey was organised into sections focusing on different aspects, such as charging habits, driving behaviour, presence of solar panels, or engagement in flexible services, as well as attitudes towards V2G. An adaptive survey method and design were used to avoid asking irrelevant questions to users, such as those who did not currently have solar panels installed, aiming to further reduce the risk of dropout.

Before the survey was published in various forums, a pilot test was conducted. The pilot testing of the survey aimed to evaluate the clarity of the survey to ensure that respondents understood the questions asked as intended. Test participants were asked to answer the survey questions and then provide feedback on any ambiguities or suggestions for improvement. Based on this feedback, adjustments and improvements were made to the questions to ensure that the survey was as clear and relevant as possible when it was subsequently distributed to the broader participant group.

By applying these methodological strategies, the survey aimed at generating comprehensive and representative data that could contribute to a fundamental understanding of EV owners' attitudes and behaviours related to V2G technology. The full survey can be found in appendix A.

3.2.2 Analysis of Survey

The quantitative survey data underwent thorough examination and interpretation using the Excel software. Through systematic grouping and classification of responses across various inquiry domains, correlations were identified. Notably, comparative analysis was conducted, comparing respondents' evaluations of V2G technology interest with demographic indicators such as residential circumstances or vehicular ownership within their households. Excel's functionality enabled not only the organisation of data but also the exploration of interrelationships spanning multiple variables. Furthermore, regression analysis was employed to determine and elucidate the interdependencies among different factors.

The qualitative data from the survey's open-ended questions was analysed utilising a KJ analysis, which is a method for externalising, comprehending, and structure extensive volumes of unstructured, diverse, and seemingly unrelated qualitative data (Hartson & Pyla, 2012). The KJ method comprises four fundamental steps; label making, label grouping, chart making and explanation (Kunifuji, 2016). During label making, key facts or issues related to the data are recorded on separate pieces of paper or sticky notes. In the label grouping step individual notes are rearranged and dispersed on a table, and then reviewed multiple times to group them based on their similarities. In the chart making step the grouped notes are organised into clusters or categories, forming an affinity diagram. Finally in the last step, explanation, the affinity diagram is analysed and explained to derive insights and conclusions from the grouped data. In this project, this approach allowed for the identification of recurring patterns, emerging concepts, and nuanced insights present within the qualitative responses.

By analysing both the qualitative and quantitative data using various methodologies, trends and correlations were identified. This encompassed discerning perceived advantages and disadvantages of V2G, as well as mapping interest levels in V2G.

3.2.3 User Interviews

After completing the survey, a series of user interviews were conducted with the aim to delve deeper and acquire more qualitative insights into the lives of EV users, their vehicle usage patterns, charging patterns and their perspectives and attituded on V2G technology. A total of nine interviews were conducted, each lasting approximately 1-1.5 hours each. The interviews were conducted via digital video conferencing due to the geographic dispersion of participants across different parts of Sweden. Recordings of the interviews were made to facilitate retrospective analysis. All interviews were held in Swedish to minimise the likelihood of misinterpretations and misunderstandings, as all participants were native Swedish speakers.

Towards the conclusion of the survey, participants were invited to express their interest in participating in further studies, and those who volunteered were considered for the interviews. The selection process aimed to choose interview participants who represented a diverse spectrum of EV users, despite the challenges posed by the broad and heterogeneous nature of this demographic. The selection of participants from the group of volunteers was carefully conducted. The primary focus was to choose individuals who expressed diverse levels of interest in V2G technology.

For the user interviews a total of nine participants was selected. The participants and their profiles are presented in table 2.

Table 2. Presentation of the participants in the user interviews.

Interviewee ID	Living Situation (residence type and area)	Expressed level of interest in V2G Technology
Interviewee 1	Villa, rural	2
Interviewee 2	Apartment, city	3
Interviewee 3	Apartment, city	4
Interviewee 4	Villa, rural	4
Interviewee 5	Farm, suburban	5
Interviewee 6	Villa, rural	5
Interviewee 7	Apartment, city	6
Interviewee 8	Villa, rural	6
Interviewee 9	Villa, rural	6

An effort was made to incorporate a diverse cohort of participants residing in different residential environments, including rural, urban, and suburban settings, to ensure the breadth of the investigation. This diversity extended to encompassing users with varying vehicle usage patterns, who owned different car brands, and had differences in the number of vehicles and persons per household.

Before conducting the actual interviews, participants were provided with a sensitising material. Sensitising is a method in qualitative research used to deepen understanding of a phenomenon or preparing a person example prior an interview (Sleeswijk-Visser et al., 2005). This process involves triggering, encouraging, and motivating participants to think, reflect, wonder, and explore aspects of their personal context at their own pace and in their own environment. A sensitising material, comprising brief introductory information about V2G to ensure a basic level of knowledge among participants, along with a reflective task encouraging them to consider their car usage beforehand. The sensitising material is presented in appendix B.

The purpose of sensitising was to prepare participants for the upcoming interviews, ensuring they were equipped with the necessary background knowledge and mental framework to engage meaningfully with the discussion topics. Additionally, it aimed to eliminate potential barriers such as knowledge gaps or difficulties in understanding the forthcoming interview questions (Sleeswijk-Visser et al., 2005).

Following a brief presentation and introduction, the initial phase of the interview commenced. The method of re-enactment was employed to enable participants to interactively narrate their daily car usage experiences. This method was chosen for its suitability in mapping out the mundane aspects of everyday life and understanding participants' perceptions and emotions within these routine moments (Pink et al., 2017).

To facilitate the re-enactment process, a digital world created in Figma was utilised to visually depict the participant's daily movements. Participants were asked to describe an average day in their life and could navigate through the simulated city environment. Further, the participants were prompted to reflect on aspects such as time, location, state of charge, and purpose of each journey they placed themselves in. The aim of the re-enactment was to provide a comprehensive understanding of participants' daily routines involving their car usage and traveling. The digital mock-up utilised in the re-enactment is presented in appendix C.

The remaining part of the interview followed a semi-structured approach and utilised various scenarios to assist the user in engaging with the topics presented. These scenarios aimed to explore how the user would act, feel, and reason in different situations concerning charging, re-planning trips, contributing to V2G, compensation related to V2G, and thoughts on V2G and its interconnections. Most questions were open-ended, while some were more leading. Some of the scenarios presented to the user were deliberately extreme, such as being connected to V2G and unable to interrupt access to their car for over an hour, designed to provoke various emotions. The interview guide including the interview questions is presented in appendix D.

The goal of the second part of the interviews was to access qualitative insights that could later be translated into requirements and pain points. Furthermore, the aim was to understand the causality between different behaviours and reasoning in users' daily lives.

3.2.4 Analysis of user interviews

Following the transcription of each user interview recording, the KJ analysis methodology was utilised to organise quotes and extract key insights. This facilitated the identification of common themes and recurring patterns across the interviews. Consequently, a set of user archetypes was established based on this data, alongside the identification of drivers, blockers, and requirements for each archetype.

3.3 Design Sprint 1

The aim of the first design sprint was to develop multiple concepts for a comprehensive V2G solution and subsequently evaluate them with users to gain insights into which features that are necessary for user adoption.

The findings from the initial research and the user research were incorporated into the design sprint in order to develop concepts that addressed the previously identified requirements.

The design sprint encompassed a divergent phase dedicated to ideation and concept development, followed by a convergent phase focused on evaluating the concepts to determine their viability.

3.3.1 Ideation and concept development

Brainwriting and Braindrawing

During the ideation session, a combination of brainwriting and braindrawing was utilised. Both methods involve the participants, in this case the project team, writing down or drawing their ideas on a predetermined theme, such as an identified problem, on a piece of paper within a set time. When the time is over, the paper is passed on to the next participant who can then build on the idea. In both brainwriting and braindrawing, the rule is that one should not criticise one's own or someone else's ideas. Ideas that are out of the box are good and by combining ideas and developing them further, they can become better. Both brainwriting and braindrawing should also aim for quantity rather than quality (Wikberg Nilsson et al., 2015).

The session was conducted digitally on post-it notes in FigJam and began with deciding on themes to ideate upon. In this case, twelve themes were chosen, and they were chosen based on the requirements identified from the initial research and the user research. The chosen themes were the following:

- How can the solution provide confirmation acknowledging the user's contribution to stabilising the grid and benefiting society?
- How can the solution be designed to encourage the user to stay connected when having the option to cancel a session?
- How can the solution provide information about SoC before, during and after a V2G session?
- How can the solution guarantee a specified SoC during and after a V2G session?
- How can the solution through design increase the interest/incentive to change habits related to vehicle usage?
- How can the solution make it easier for the user to make decisions regarding their V2G contribution?
- How can the solution provide the user with an understanding of how V2G can benefit the power system?
- How can the solution communicate what investments that are required for V2G, but also what the user gets back from contributing?
- How can the solution clearly communicate the current energy supply and demand?

- How can the solution enhance the user's feeling of contribution, communicate how much they contribute and clearly state how the user can increase their contribution?

- How can the solution enhance the user's feeling of being part of new, innovative technology?

- How can the solution provide the user with the opportunity to be informed about, manage, and plan their SoC levels?

Once the themes were determined, a timer was set on five minutes and each participant then ideated on one specific theme until the time was out. This was repeated until all participants had ideated on each idea. Lastly, the participants collectively reviewed, refined, and categorised all the ideas.

At this stage, it became evident that the proposed ideas were on a more detailed level than what the project required at that moment. Therefore, a quick second session was conducted with themes related to the overall design of a V2G solution. This resulted in the following three themes:

- Planning of a V2G session

- SOC management

- Cancelling of an ongoing V2G session

The ideas from the first session were considered and revisited during design sprint 2.

Morphological Matrix

To develop concepts based on the ideas generated during the ideation session, all ideas were compiled into a morphological matrix. This method entails listing the various functions that the solutions should fulfil in one column, with potential solutions for each function listed in the rows. By combining a solution for one function with a solution for another function, different concepts can be created (Wikberg Nilsson et al., 2015).

The different themes from the ideation session served as the functions, while the generated ideas served as solutions to each function. Through this, a range of diverse concepts for an overall design of a V2G solution was systematically developed.

Visualisation of concepts through user journeys

To visualise the developed concepts, a user journey was created for each concept. A user journey is a scenario-based sequence of steps depicting how a user interacts with a company, product, or service to achieve a specific goal. The journey involves understanding the user experience across various touchpoints, which are points of interaction throughout the journey (Kaplan, 2023; Salazar, 2016).

For each concept, the touchpoints were identified, and user journeys were then visualised using both text and illustrations. The text provided detailed information about each touchpoint, whereas the illustrations helped enhance the user's understanding and perception of them.

3.3.2 Concept evaluation

To evaluate the developed concepts, a workshop was conducted together with users. All users had participated in the earlier user interviews in the project and this approach was chosen for two purposes. Firstly, the previous interviews served as sensitising for the workshop, ensuring that all users were aware of their EV usage and had reflected on V2G integration in their everyday life. Secondly, it avoided the time-consuming process of recruiting new users.

To effectively organise the workshop, all previously interviewed users were asked to fill in a form to provide their availability. This allowed for booking time slots that accommodated everyone's schedules. Ideally, each session would include 3-4 participants to contrast various user opinions and better understand different user types within a broader context. Based on the users' availability, one workshop session was organised with 4 participants.

The composition of participants aimed to represent all of the identified user types to an as large extent as possible in order to provide a comprehensive and representative evaluation of the concepts. The users that participated in the workshop are presented in table 3.

Table 3. Presentation of the participants in the workshop.

Interviewee ID
Interviewee 1
Interviewee 4
Interviewee 7
Interviewee 9

The workshop lasted one hour and encompassed a focus group and a co-creation session. The focus group aimed at evaluating the concepts both individually and as a group, and the co-creation session aimed at developing a concept collaboratively as a way to refine the evaluated concepts. The interview guide including the interview questions is presented in appendix E. Work templates from both the individual evaluation and the co-creation session can be found in appendix F and appendix G.

Focus group

The focus group was divided into an individual reflection and a group reflection. During the individual reflection, the participants accessed dedicated workspaces in the digital tool Mural (see appendix F). Within these workspaces, the users were presented the different concepts and asked to evaluate these against two Likert scales. The first scale assessed the statement "This concept would make me feel free in my car usage" rated on a scale on to five, where one indicated "does not agree at all" and five indicated "completely agrees". The second scale assessed the statement "It feels uncomplicated to fit this concept into my everyday life" on the same scale. Additionally, the participants were asked to identify one advantage and one disadvantage for each concept. The participants were also provided with a toolbox containing various emoji stickers which they could use to express emotions associated with specific touchpoints in the user journey for each concept. After evaluating all concepts individually, they were asked to do an overall reflection to conclude their thoughts and to compare the concepts against each other.

Following the individual reflection, the workshop proceeded with a group reflection. This reflection was based on the two questions "Which of the concepts do you think would work best and why?" and "Is there any element of either concept that would be a decisive factor for you not to actually use the service? ". However, this discussion was open-ended, allowing the participants to explore and discuss various aspects of V2G and potential solutions freely.

Co-creation

Co-creation is a method for allowing different stakeholders from various backgrounds collaborate in the design process of a product or service. Due to the participants different roles and backgrounds, they can provide diverse insights, providing the designers with a more holistic view of what a product or service should include (The Interaction Design Foundation, n.d.). Co-creation is usually facilitated through workshops, and the same goes for this project.

During the co-creation session, one of the project team members acted as a facilitator, while the other served as a designer, working together with the users.

The session was divided into two parts, the first one being a brainstorming session where the users and the designer ideated around essential components of a functional V2G solution. In Mural, the participants shared a workspace where they were provided with post-it notes to write their ideas on (see appendix G). In the second part, the group collectively designed the ultimate V2G solution, based on the ideas from the brainstorming. The group was asked to consider what needs to happen before, during, and after a V2G session in order to make the solution as comprehensive as possible. To help the group, they were provided with a toolbox of mediating tools in terms of icons, stickers, emojis to create a user journey of the ultimate concept.

Analysis of the workshop result

The workshop discussions were transcribed onto post-it notes, which were then analysed using a KJ analysis method. The post-its were organised into four main categories being critical insights, drivers, blockers, and ideas from users. Each category was then summarised into key takeaways, which were carefully considered during the subsequent design sprint 2.

3.4 Design Sprint 2

The aim of the second design sprint was to select and refine a concept for the further development of the user journey, utilising insights gleaned from previous stages, focus groups, and co-creation sessions. This process aimed to identify the most suitable concept for advancement while considering the mobile application's role as a mediating tool.

The goal was to deliver both an iterated user journey and a mobile application prototype that embodies this refined concept and functions as an effective mediating tool for future testing. This prototype would simulate the envisioned user journey, allowing users to interact with it and provide valuable feedback. Ultimately, the objective was to ensure that the chosen concept aligns seamlessly with user requirements and expectations, enhancing the overall user experience.

3.4.1 Ideation and concept development

User journey

In this design sprint, the development of the user journey was further refined, building upon the findings of the analysis and feedback obtained during the first design sprint. Insights from the co-creation session were also incorporated into this process.

The refinement began with an evaluation of five distinct user journeys, compared against feedback and results gathered from both the focus group and the co-creation session. This evaluation allowed for the identification of crucial elements and those less desired by users, which informed the composition of the final user journey. Through a series of iterative sessions, a comprehensive user journey was crafted, integrating significant aspects from the initial five iterations into a cohesive whole.

Prototyping

Concurrently with the ongoing development of the user journey, a prototype for a mobile phone application was developed. The primary objective of this prototype was to serve as a mediating tool for future testing, aiming to provide users with a more comprehensive simulation of the envisioned concept's functionality in real-world scenarios. Additionally, the aim was to advance closer to addressing research question 3: “How can a solution be designed to enable electric vehicle users to adopt bidirectional charging to help flatten the peaks in energy demand?”

The process commenced with initial ideation and rapid sketching to outline a rough wireframe, ensuring alignment with the evolving user journey. Insights from the previous brainstorming sessions in design sprint 1 were integrated, along with feedback obtained from the focus group and co-creation sessions. Subsequently, the wireframe underwent further development to evolve into a fully functional app prototype. Figma served as the primary platform for both wireframing and prototyping endeavours.

3.4.2 Concept evaluation

Combined User interview & User test

The final user interviews and combined user tests were conducted individually with users. The objective of these tests was to enable users to interact with the mediating tool (the app prototype) both freely and within different scenarios. The overarching goal was to gain qualitative insights into the user experience of the app and to gather overall thoughts on the concept.

Each interview commenced with a brief introduction to the application, followed by a setup scenario and several different scenarios based on the user's previous configurations during setup. Users were given the freedom to navigate and interact with the mediating tool while verbalising their thoughts. Following each scenario, a set of reflective questions was posed, allowing for further feedback from the user. Most scenarios aimed to prompt users on how they would respond in various situations, such as planning a long-distance drive or being away from their vehicle for several days. Furthermore, a general discussion was held regarding the prototype and its interaction. The full interview guide can be found in appendix H.

In total five interviews were conducted. Each interview session lasted approximately one hour and followed a semi-structured approach, presenting most participants with the same scenarios. However, some participants encountered fewer or more scenarios based on their individual settings.

All interviews and tests were conducted digitally with users who had participated in previous user tests. Sessions were recorded, and users shared their screens to facilitate comprehensive evaluation of their interactions and movements.

The selection of users for the test was conducted by inviting previously involved individuals to participate. All users available during the testing period were interviewed, meaning there was no specific selection process for these interviews. The purpose of utilising the same users was to conduct follow-up assessments regarding their perceptions of the evaluation and development process, and to delve deeper into addressing their requirements, motivations, and obstacles. The users participating in the final testing are presented in table 4.

Table 4. Presentation of the participants in the final testing.

Interviewee ID
Interviewee 1
Interviewee 4
Interviewee 7
Interviewee 8
Interviewee 9

By involving the same users that participated in the previous interviews and/or focus groups, there was no need to reintroduce anyone to the new technology, thereby minimising potential disruptions. Furthermore, the users were initially chosen to align with previously identified user archetypes, ensuring a diverse representation among participants.

Analysis of Results

The interviews/user tests were analysed by transcribing each interview, followed by the utilisation of an affinity diagram (KJ analysis) to organise and categorise similar feedback. This method enabled the identification of area-specific insights and feedback, which can be leveraged for the further refinement of the concept. Additionally, these insights are instrumental in drawing conclusions about user requirements for enhancing user adoption.

4. Result

4.1. Vehicle User Behaviour and Vehicle-to-grid Availability

Understanding users' vehicle usage is crucial for effectively integrating V2G technology into the energy infrastructure. By delving into the patterns of vehicle usage, it is possible to understand when vehicles could be available to support grid.

Key aspects in understanding vehicle usage patterns include examining the types of trips taken by vehicle users to discern patterns of routine and analysing temporal aspects of vehicle usage, including when the vehicle is used, parked, or charged, in relation to peak demand.

As a future V2G user may not necessarily be an EV user today but could currently be a non-EV user, it is essential to examine patterns and habits for both groups. This helps to understand if the type of vehicle one drives influences the user's usage pattern and whether this might affect overall usage patterns as non-EV users transitions to EV users.

4.1.1 Understanding Users' Travel Behaviour

In the survey, participants were asked to estimate the distance they travelled for various types of trips during a typical week. They provided this information for five pre-defined types of trips, assumed to represent the most common categories. The types of trips included:

- Commutes to and from work
- Providing rides to other household members for work, school, or preschool
- Trips to and from leisure activities, either for the user themselves or providing rides to other household members
- Planned errands
- Short, unplanned trips

Based on this, it could be calculated what proportion of the total distance travelled by the user in a week each type of trip represents. Based on which types of trips the users travelled the longest distances for in a week, six different user groups could be identified. These groups were as follows:

1. *Makes a significant portion of their trips to and from work*
   This user group does between 61-100 percent of their total traveling distance to and from work. As work hours are normally routine, it can be assumed that this group's travel patterns are also likely to be routine and predictable.

2. *Makes a significant portion of their trips providing rides to other household members for work, school, or preschool*
   This user group does between 61-100 percent of their total traveling distance on providing rides to other household members for work, school, or preschool. Similar to trips to and from work, these trips are often part of a regular routine and are likely planned in advance.

3. *Makes a significant portion of their trips to and from leisure activities, either for the user themselves or providing rides to other household members*

This user group does between 61-100 percent of their total traveling distance to and from leisure activities, either for the user themselves or providing rides to other household members. Leisure activities can vary in terms of routine and planning, making it challenging to determine the consistency of travel patterns within this group.

4. *Makes a significant portion of their trips doing planned errands*
   This user group does between 61-100 percent of their total traveling doing planned errands. While these trips by definition always are planned, they may not adhere to a strict routine and can hence vary in frequency and timing.

5. *Makes a significant portion of their trips doing short, unplanned trips*
   This user group does between 61-100 percent of their total traveling distance doing short, unplanned trips. These trips are by definition not planned in advance and are often spontaneous, contributing to less predictable travel patterns.

6. *Makes mixed types of trips*
   This user group does 60 percent or less of their total traveling distance in a week on one type of trip, indicating that this user group uses their vehicle for two or more types of trips more frequently than the other user groups. The diversity of trip types suggests a less uniform travel pattern compared to other user groups.

As seen in figure 11, it was most common to mainly do mixed types of trips, followed by making a significant portion of the trips to and from work. The least common groups were those that primarily provided rides to other household members for work, school, or preschool or those who drove short, planned trips.

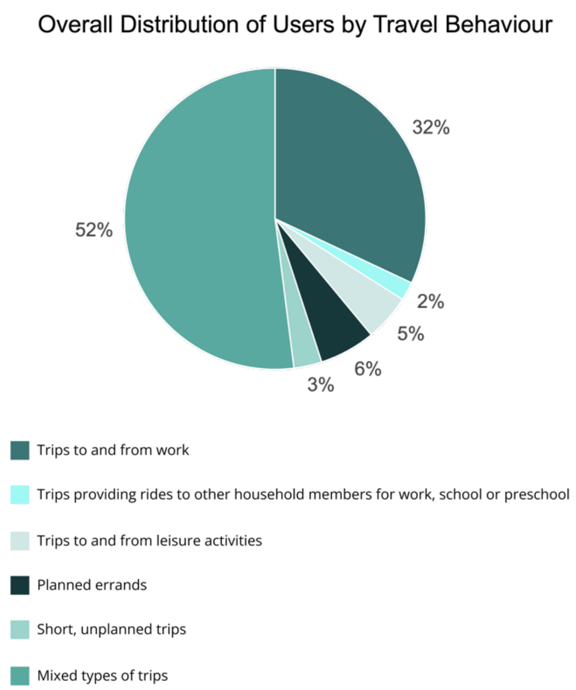

Figure 11. A diagram illustrating the overall distribution of users by travel behaviour.

To ascertain whether driving habits are influenced by driving an EV or a non-EV, the distribution of trip types for each group respectively was analysed. The findings revealed that EVs are more frequently used for trips to and from work compared to non-EVs (see figure 12). Conversely, non-EVs are more frequently used for planned errands than EVs. However, it is important to note that the sample size of non-EV respondents was significantly smaller than that of EV respondents. Hence, it is not possible to exclude that these differences could be due to factors other than the type of vehicle. Nevertheless, the analysis overall indicates that there are no substantial differences in driving patterns based on vehicle type. Therefore, driving behaviours appear to be more user-dependent and are not significantly influenced by which type of vehicle the user drives.

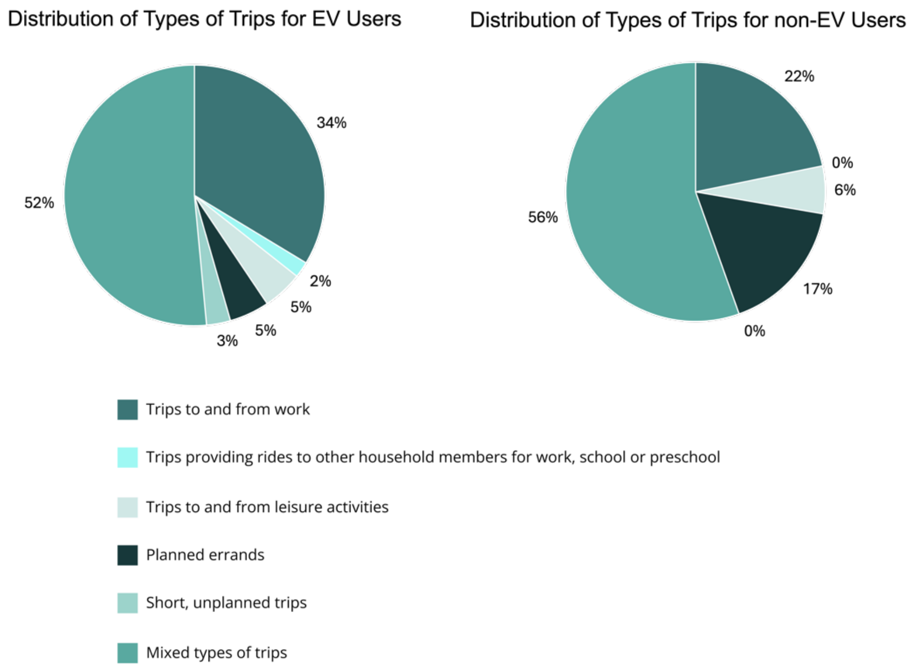

Figure 12. A diagram illustrating the distribution of types of trips depending on type of vehicle.

4.1.2. Understanding Users' Charging Behaviour

To understand the EVs availability to support the grid, it is essential to understand the vehicles' whereabouts throughout the day, as well as during which time periods the vehicle is in use and when it is parked. By investigating when and where EVs charge, it is possible to deduce when the vehicle is parked for extended periods as well as its location during these times.

In the survey, the respondents were asked about their charging behaviours. They were asked whether they had a charging station at home, the frequency of charging at various locations during a week, as well as during which hours of the day their vehicle usually is plugged in. The specified charging locations in the survey were:

- At home
- At the workplace

- At a fast charging station
- At other parking locations, such as the grocery store, shopping centre or the gym

Due to the various ways, it is possible to charge an EV, it was initially investigated whether EV users typically have charging stations at home or not, and how that influences their primary charging location. From the survey, it became evident that the majority of EV users, 85 percent of the respondents, have a charging station at home (see figure 13).

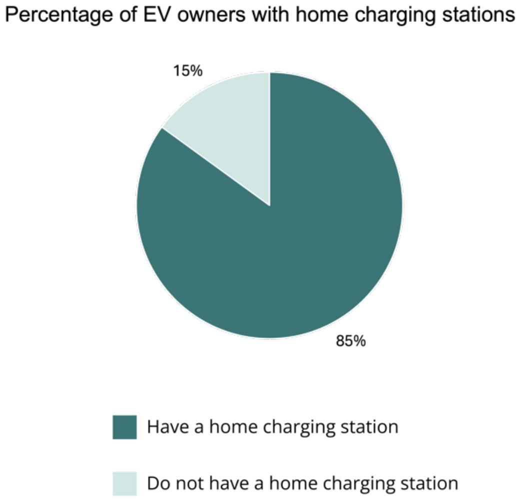

Figure 13. Diagram illustrating the percentage of users with a charging station at home.

Among the users with a charging station at home, nearly 60 percent conducted all of their charging at home, while just over 20 percent did the majority of their charging at home or at various locations, respectively (see figure 14). Conducting the majority of charging at home means that between 51-99 percent of charges occurs at home, while charging at various locations indicates that fewer than 50 percent of charges occurs at a single location and that charging thus occurs at two or more locations. Comparatively, users without a charging station at home were more likely to conduct the majority of their charging at other locations than at home. Over 20 percent stated that they conducted all of their charging at home (by plugging in the car to a regular power outlet instead of a charging station), while slightly over 30 percent indicated that they conducted the majority of their charging at their workplace or at various location, respectively. Over ten percent of the users without a charging station at home stated that they conducted the majority of their charging at other parking locations, such as the grocery store or their gym (see figure 14). Thus, it can be assumed that having a charging station at home results in it being predominately used for charging, reducing the likelihood of using chargers at other locations on a weekly basis.

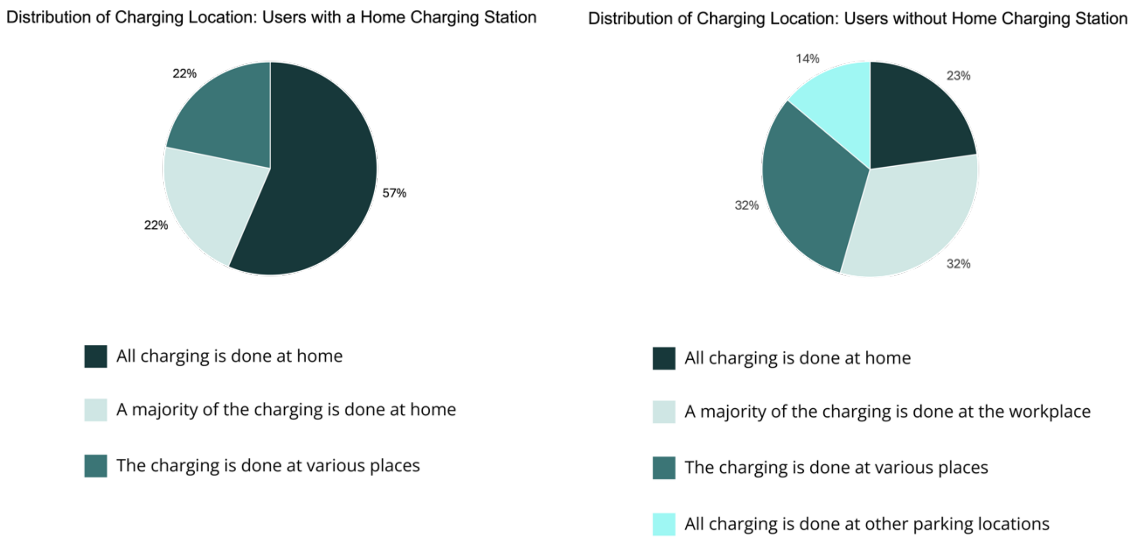

Figure 14. Diagram illustrating the distribution of charging locations based on the presence of a charging station at home.

Further investigation focused on when respondents indicated that their vehicles where plugged-in, aiming at determining when the vehicles are parked for an extended period of time and presumably not in use. The day was divided into four segments based on when peak demands usually occur, giving the four intervals *06:00-10.00 (peak demand), 10:00-16:00 (no peak demand), 16.00-21.00 (peak demand),* and *21:00-07.00 (no peak demand).* Based on the hours the respondents had specified that their vehicles were plugged in, they were divided into being plugged-in or not during each time interval. How many hours of each interval the vehicle was plugged in was not considered. From this, it became evident that the presence of a charging station at home and primary charging location largely influenced when the vehicles are plugged in. As shown in figure 15, the user groups without a charging station at home that conducts the majority of their charging at the workplace or at various locations were predominately plugged-in during the peak demand in the morning, and thereafter during the day between 10:00 and 16.00. Similarly, the group without a charging station at home that conducts all of their charging at other parking locations were predominately plugged-in during these time intervals. This suggests that these user groups could potentially contribute to balancing the grid through V2G by discharging during the peak demand in the morning, and by charging during the day. Conversely, the groups with a charging station at home that conducts all of their charging at home, the majority of their charging at home, or charging at various locations, along with those without a charging station at home that conducts all of their charging at home, were primarily plugged-in during the peak demand in the evening, and thereafter during the night (see figure 15). This indicates that these user groups could potentially contribute to balancing the grid through V2G by discharging during the peak demand in the evening and by charging during the night.

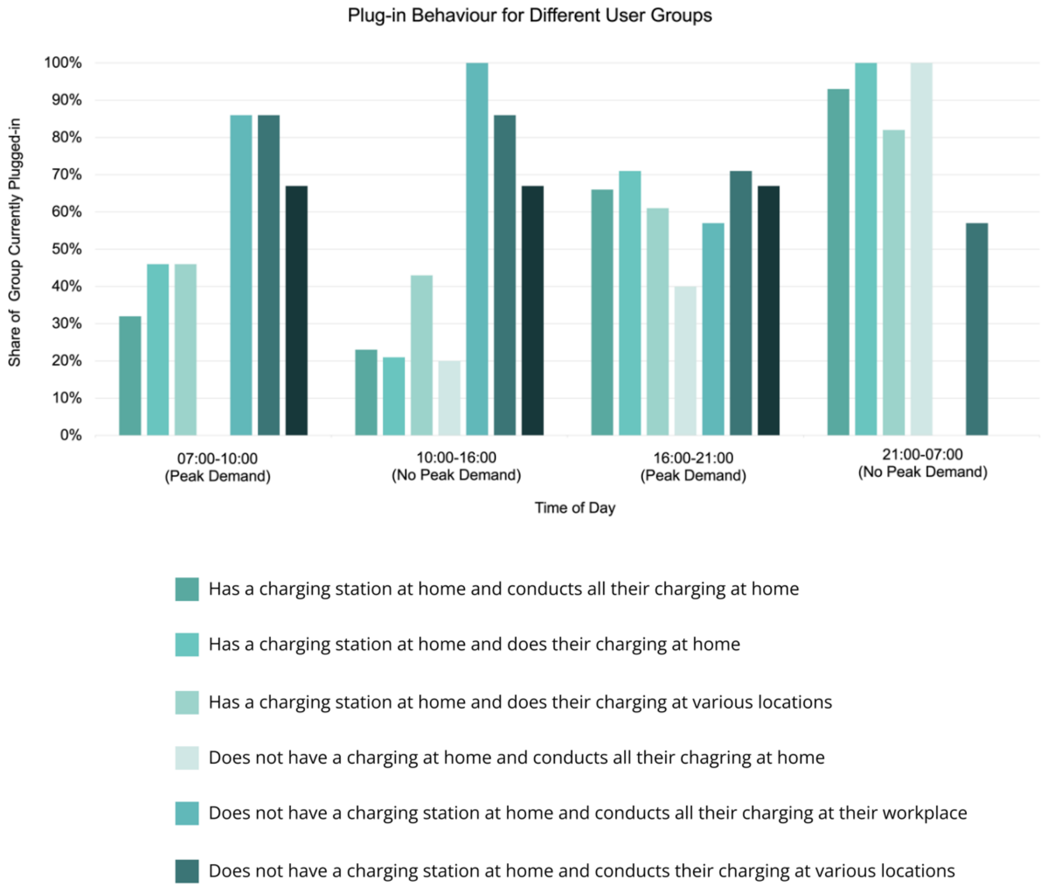

Figure 15. Diagram illustrating charging patterns in relation to peak demands based on users' possession of a charging station at home and their charging locations.

However, these charging habits are presumably strongly connected to the charging infrastructure available to the user. During the user interviews, several users with a charging station at home expressed willingness to charge at other locations, such as at their workplace, if only the charging infrastructure were available. Similarly, it cannot be known if the users without a charging station at home does not have one because the charging infrastructure

> ***"If there were better charging facilities, I would charge at work"***

> ***"As long as it is in places where I am already spending time, I see no problem with it if the infrastructure is provided. Then it is fine."***

> ***"If there were charging stations where I buy groceries or so, then absolutely. But there are not any today"***

allows them not to have one, or if there are other reasons behind. Some user quotes regarding charging at other places than home can be seen in figure 16.

Figure 16. Quotes from users with a charging station at home regarding charging at other places than home.

Nevertheless, no correlations were found between users' travel patterns and vehicle charging times, although it is conceivable that travel patterns influence charging decisions. Trips to and from work were the most common type of trip regardless of charging patterns.

In summary, based on survey data, seven user groups were identified regarding charging behaviours, potentially affecting when vehicles are available for V2G:

- *Potentially available to balance the grid by discharging during the peak demand in the evening and by charging during the off-peak hours during night:*
    - Has a charging station at home and conducts all of their charging at home
    - Has a charging station at home and conducts the majority of their charging at home
    - Has a charging station at home and does their charging at various locations
    - Does not have a charging station at home and conducts all their charging at home

- *Potentially available to balance the grid by discharging during the peak demand in the morning and by charging during the off-peak hours during the day:*
    - Does not have a charging station at home and conducts the majority of their charging at their workplace
    - Does not have a charging station at home and conducts their charging at various locations
    - Does not have a charging station at home and conducts all of their charging at other parking locations such as the grocery store or the gym.

4.2. User Perception of Vehicle-to-grid

4.2.1. Expressed interest in V2G

In the survey, the participants were asked to rate their overall interest in V2G technology on a scale from 1 to 6. Subsequently, during analysis, ratings falling within the range of 1 to 2 were classified as indicating low interest, those between 3 and 4 were considered moderate interest, and those falling within the range of 5 to 6 were interpreted as reflecting high interest.

The survey data indicates a minimal distinction in interest between EV drivers and non-EV drivers. The average interest in V2G technology among non-EV drivers is 4, while among EV drivers it is 4.1, both falling within the moderate interest category. The median score is 4.5 for non-EV drivers and 4 for EV drivers. However, due to differing response rates, with 18 responses from non-EV drivers and 152 from EV drivers, there is a slight imbalance in the number of data points, which may affect the results. The result is presented in appendix I.

Furthermore, the data indicates that both EV drivers and non-EV drivers exhibit similar driving patterns, as previously presented in the preceding chapter. This insight, along with the findings from the previous chapter, allows for a comprehensive analysis of the data for both EV and non-EV drivers collectively for the following parts.

When examining the results regarding differences in interest based on the type of driving habits, the result from the survey data indicates that the interest is lower among the two groups that spend most of their driving on providing rides to other household members and planned errands, as indicated by average score 2.7 and 3.2, respectively, both falling within the category of moderate interest. However, it is important to note that the number of responses within these two groups are relatively small compared to other groups, rendering the data less reliable.

Conversely, the group that spend most of their driving on short, unplanned trips demonstrates the highest interest, with an average score of 5, categorising as high interest. Albeit this group is also relatively small in comparison.

The groups that do most of their driving commuting to and from work, to and from leisure activities, and those with an even distribution of driving all express similar moderately high interest levels in the higher range, with averages scores of 4.1, 4.4, and 4.1, respectively. The result is presented in appendix I.

Survey respondents were asked to provide information on both their living arrangements and location. Based on the survey data, residential location (city, suburb, rural area) appears to have no significant influence on interest in V2G. Interest levels remain moderately high across all residential groups. Analysis of the results indicates that expressed interest in V2G does not notably differ based on whether one resides in a city, average score 4.1, suburb, average score 4.2, or rural area, average score 4.3.

However, when examining interest according to residential type (villa, apartment, farm, or row or semi-detached house), the data suggests that interest in V2G remains consistent relatively regardless of living arrangement. Villas, average score 4.2, apartments, average score 4.1, and farms, average score 4.3, express moderate interest (with row houses at the lower end and the others at the higher end), while semi-detached houses, average score 3.2, show lower interest. It is important to note, however, that responses from row and semi-detached houses were limited. The result is presented in appendix I.

However, when grouping and comparing interests based on both residence type and residential area, notable differences emerge.

Upon aggregating residence type and residential area, analysing living situations, insights from the survey data reveal heightened interest among those residing in a villa within the city or suburb, as well as a farms in rural areas. Notably, villas located within urban settings express the highest interest levels, averaging 4.8, indicative of a strong interest. Similarly, villas situated in suburban areas and rural farms express moderate interest levels at the upper range, averaging 4.3 each. Importantly, none of these groups express low interest. Conversely, the lowest level of interest is observed among semi-detached houses in suburban areas, with an average score of 2.8. The result is presented in appendix I.

In the survey, EV drivers were asked questions regarding their charging habits, including whether they have a home charging station. In addition to inquiring about home charging stations, they were also asked where they charge. In response to this question, they were given several options to choose from: at home, at work, at fast charging stations, or at other parking locations.

Based on the survey data, the users without home charging station that do their majority of charging at home, users with home charging station that do the majority of charging at home, and users without home charging station and all charging is done at other parking locations express the highest levels of interest, scoring 5, 4.5, and 4.7, respectively (all three indicating a high interest).

However, both the users with a home charging station that only charge at home and users without a home charging station that do all charging at other parking locations are smaller in size compared to the group users with home charging station that do the majority of charging at home, and thus are not equally reliable. The lowest interest is observed in the group user without home charging station and charging is done in various places with an average of 2.1 (indicating low interest). The other groups all express moderate interest. The result is presented in appendix I.

4.2.2. Purpose of driving EV and perceived benefits of V2G

In the survey, EV drivers were questioned about the primary motivation behind their choice to drive an EV. Respondents were instructed to provide their responses in their own words. Of the respondents, 36 percent cited economic reasons as their major motivation, while 28 percent indicated environmental reasons as their primary driver. Additionally, 25 percent stated that their choice was influenced by both economic and environmental factors, whereas 12 percent cited other reasons. The distribution can be seen in figure 17.

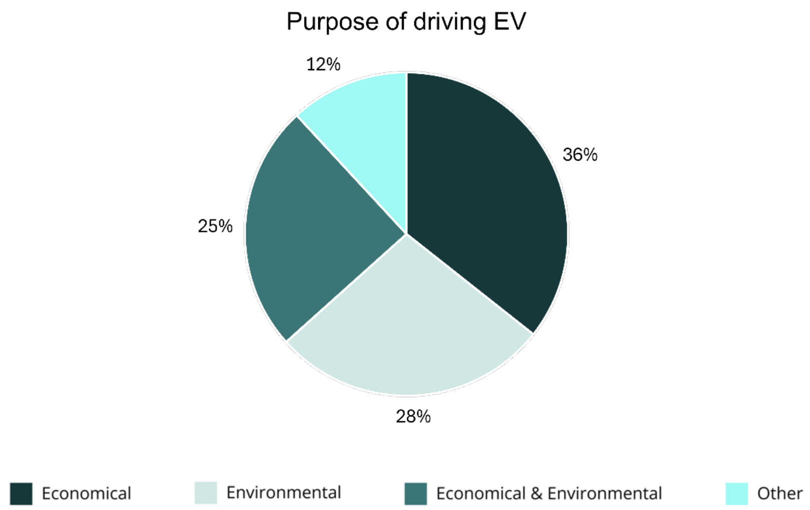

Figure 17. Distribution of primary reasons for driving an EV.

In the survey, participants were also asked to express their perceived benefits of utilising V2G technology. This question was designed to allow respondents to freely articulate their responses in their own words. Through analysis using a KJ method, the following themes of perceived benefits and disadvantages were identified:

- Reduced electricity costs.
- Opportunity to earn an extra income.
- Potential for enabling an energy reserve for users' own homes (V2H).
- Contributing to stabilising the electricity grid.
- Contributing to the welfare of the society.

Identified areas of drawbacks consist of:

- Concerns about reduced flexibility or interference with personal freedom.
- Fear of battery degradation.
- Uncertainties regarding the implementation and functionality of the technology in users' everyday lives.
- Apprehension about insufficient battery capacity in the vehicle when needed (SoC).
- Concerns about overall complications and high investment costs.
- Doubts about long-term economic viability.

Figure 18 provides an overview of the identified themes.

Figure 18. Identified areas of perceived benefits and drawbacks amongst the EV drivers.

Further categorising the open-ended responses regarding the advantages of V2G and juxtaposing them with the stated interest in V2G, the results indicate some differences.

For the groups citing economics or the environment as the primary reason for driving an EV, the greatest expected benefit of V2G is the economic factor. A notable 53 percent of those driving an EV for economic reasons cite economic benefits as the primary advantage, compared to 47 percent among those driving an EV for environmental reasons. However, 37 percent of the individuals in this group cited societal and environmental benefits as the most prominent advantages of V2G, compared to 25 percent in the economic benefits group. This suggests a potential connection between the primary motivations for driving EVs and the perceived benefits of V2G. It indicates that individuals motivated by environmental benefits are more likely to recognise and prioritise the environmental advantages of V2G, while those driven by economic reasons may focus more on the financial benefits.

For the group indicating both economic and environmental reasons for driving an EV, the results are more varied. 30 percent indicate that societal and environmental benefits are the primary advantage, while 25 percent cite economic benefits. Another 25 percent mention the ability to serve as an energy reserve or power their own household in emergencies as the major advantage, a significantly larger percentage than in the previous two groups cite the primary reason for driving an EV. Figure 19 illustrates the distribution of perceived primary benefits of V2G according to the primary motivation for driving an EV.

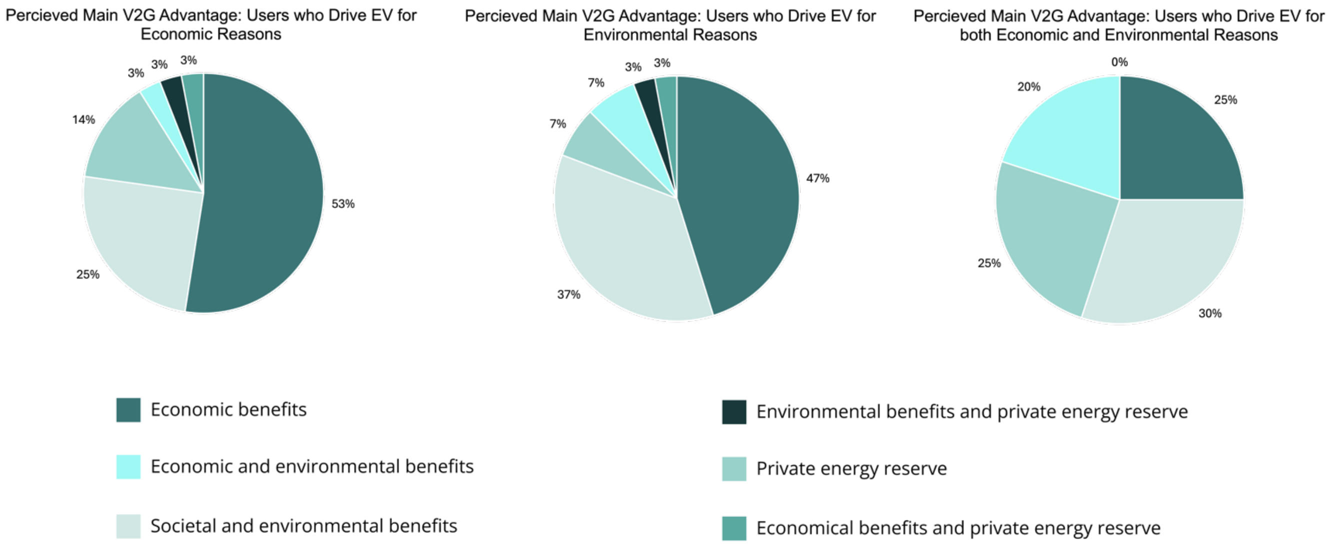

Figure 19. Distribution of perceived largest benefits of V2G based on major reason for driving EV.

This result is notably intriguing as the focus was on discerning the perceived benefits of V2G technology among EV drivers, informed by their existing knowledge or viewpoints. The analysis of the result purposefully opted not to investigate the perceived advantages among non-EV drivers to pre-empt any potential biases stemming from their need to adapt their habits to EV driving. This approach also aids in distinguishing between the inherent drawbacks of EVs and those perceived, such as concerns regarding vehicle charging.

4.2.3 View on compensation connected to V2G

In the survey, respondents were also prompted to indicate their stance on compensation for V2G. They were presented with the five following options to choose from:

- No, I'm not interested in V2G at all
- No, knowing it's good for the environment is enough for me
- No, the knowledge that I can use my car as a power bank for the household is sufficient
- Yes, at least to cover the cost of the investment
- Yes, I want to feel like I'm making money by sharing my electricity with others

The results were analysed in comparison to the respondents' primary reason for driving an EV. This comparison aimed to discern any correlations between the motivation for driving an EV and the desire for compensation. Across all three groups of EV drivers, the majority indicated a preference for some form of economic benefit, albeit with varying levels of compensation. Figure 20 illustrates the distribution of compensation preferences among these three groups.

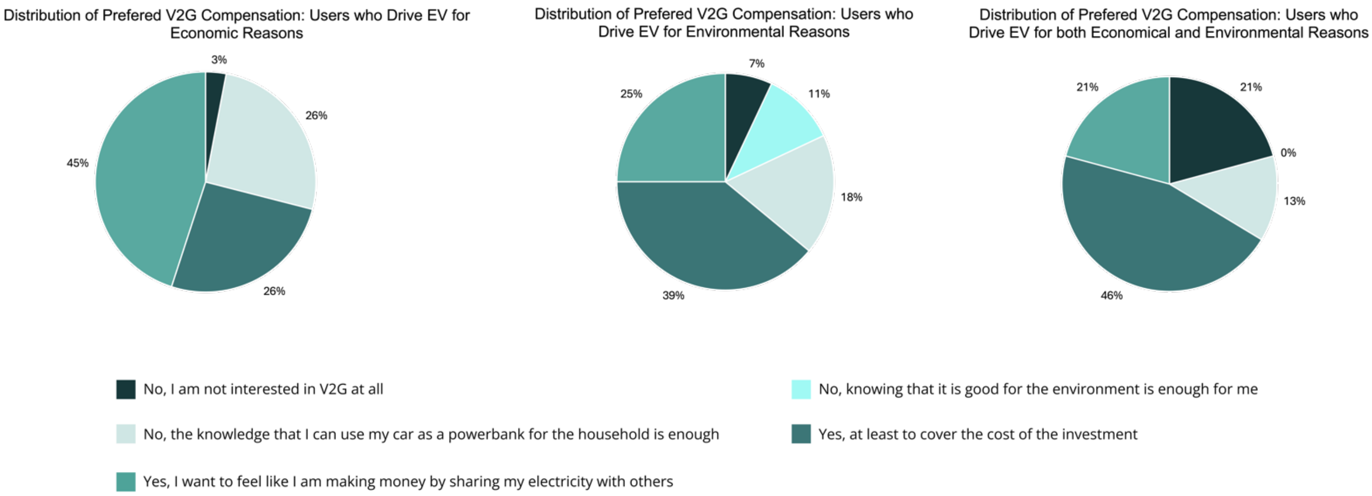

Figure 20. Distribution of compensation preferences based on major reason for driving EV.

4.3. Identified User Archetypes

Based on the analysis of survey data and insights gathered from user interviews, a user typology was developed to capture the various trends and opinions observed. This typology was not solely based on statistical correlations but also on qualitative insights. It comprised five distinct user archetypes, each with their own motivations, barriers, and requirements.

Reluctant Rose

The first identified user archetype is *Reluctant Rose* (see figure 21). Rose is characterised by scepticism and a tendency to anticipate and fear potential problems, even before they occur. She typically exhibits a reluctance to refrain from travel opportunities, preferring immediate access to her vehicle by interrupting V2G sessions. Additionally, Rose expresses a desire to establish and modify personal SoC thresholds for V2G usage due to a concern about insufficient SoC levels after a V2G session when she needs it.

Control and autonomy are paramount for Rose. She feels triumphant when she does not have to compromise her flexibility or habits by engaging in scheduled flexible services or using alternative charging locations and times. While Rose does want to contribute to V2G efforts, her motivation to change her daily habits is relatively low because she perceives numerous barriers. Therefore, compensation plays a crucial role and might even be necessary for her to overcome any doubts or obstacles. Furthermore, an automated system is preferable for Rose, as it minimises the time spent monitoring the V2G service, aligning with her preference for flexibility and convenience.

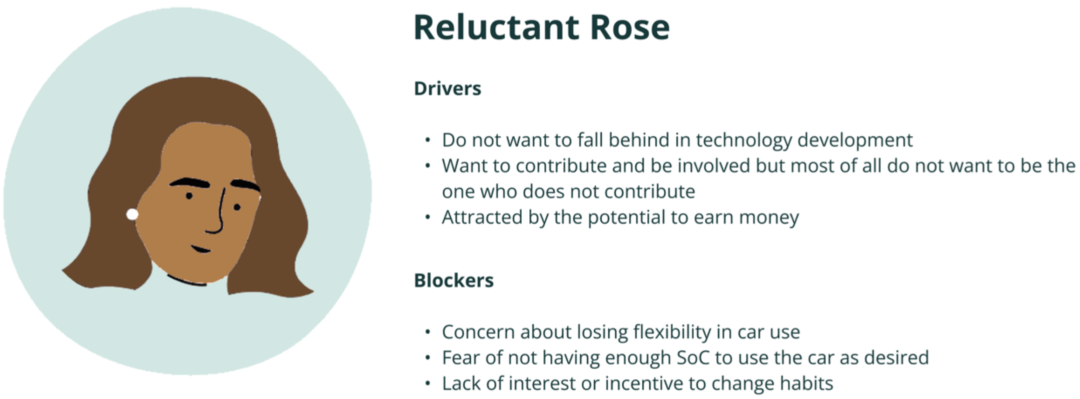

Figure 21. User archetype Reluctant Rose and summary over her main drivers and blockers.

Careful Carl

The second user archetype identified is *Careful Carl* (see figure 22). Carl tends to be somewhat insecure and struggles with decision-making. While he demonstrates a curiosity about V2G technology, he remains unconvinced and harbours several apprehensions. Carl alternate between recognising the potential benefits of the technology and feeling sceptical about his ability to contribute and the advantages he would gain from participation. Due to his cautious nature and numerous apprehensions, Carl is likely to be a laggard or late adopter of V2G technology. He prefers to wait for others to take the lead and successfully adopt V2G technology before feeling secure and convinced.

Carl exhibits a level of uncertainty concerning his possibility to organise and manage daily activities, which directly impacts his integration with V2G. Therefore, it is imperative for him to have the assurance that he can terminate an ongoing V2G session, if necessary, readily access his vehicle, and secure his SoC. Furthermore, Carl's uncertainty extends to concerns about the level of commitment V2G participation might entail from him, emphasising the importance of minimising the need to adjust settings repeatedly.

An essential aspect for Carl is ensuring that any compensation adequately reflects his investments. While he seeks compensation for sacrificing his flexibility in using his vehicle whenever and for contributing to V2G, he understands that earning money from it is not a strict requirement. The precise amount he seeks may vary depending on the circumstances. Despite his hesitations, Carl's requirement for compensation does not render him entirely resistant to altering his routines. He remains open to adjusting his habits, contingent upon several factors.

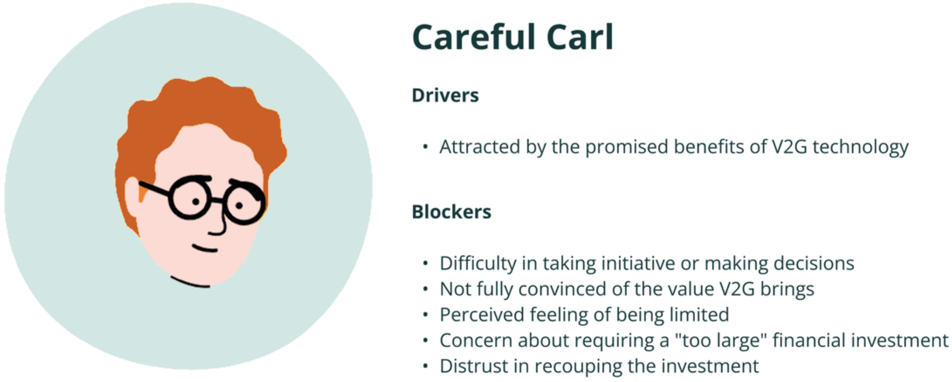

Figure 22. User archetype Careful Carl and summary over his main drivers and blockers.

Idealistic Isabella

The third user archetype identified is *Idealistic Isabella* (see figure 23). Isabella embodies a strong sense of civic courage and a commitment to altruism. Motivated primarily by a desire to contribute positively to society, she believes in her ability to make a difference and derives satisfaction from the knowledge that her actions serve a greater good. Consequently, Isabella does not demand significant compensation or her involvement in V2G, although she still expects to recover her investment and associated costs. Importantly, she insists that no intermediary or third party should profit from her contributions. Her willingness to contribute hinges on the premise that her efforts benefit society.

Isabella demonstrates a proactive approach to supporting V2G initiatives by adjusting her driving and charging schedules to optimise their impact. She is prepared to forego certain trips and sacrifice some flexibility in favour of furthering societal welfare. Despite her altruistic motives, she values the convenience of being able to interrupt V2G sessions, provided she can regain access to her vehicle within a reasonable timeframe, typically within 30 minutes.

With an unwavering belief in the transformative potential of technology, users like Isabella view V2G as a promising means of effecting positive change. Due to her high level of motivation, it would not be difficult to encourage Isabella to adopt the new V2G technology. However, she has a lingering concern that the advent of new technology may displace older systems without necessarily contributing to a more sustainable society overall. She is particularly worried about discarding functional technology without a solid foundation, which could lead to increased environmental damage due to unnecessary waste and resource consumption.

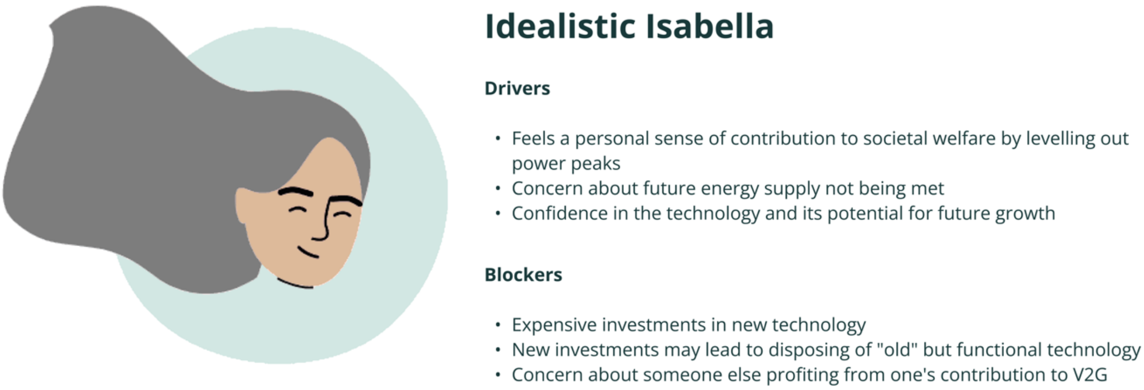

Figure 23. User archetype Idealistic Isabella and summary over her main drivers and blockers.

Tech-savvy Thomas

The fourth user archetype identified is *Tech-savvy Thomas* (see figure 24). Thomas is deeply intrigued by technology and innovative solutions, evident in his keen interest in monitoring and implementing smart solutions within his home environment. He willingly invests in home electricity to integrate smart digital products seamlessly.

One of Thomas's primary motivations for engaging with V2G is his curiosity about new technology. He is highly likely to be an early adopter of V2G as soon as it becomes available in the market. His curiosity and passion for technology are akin to that of a hobbyist, and he readily acquires the necessary gadgets and tools, even if there's uncertainty about its economic returns or investment coverage. Nevertheless, the prospect of maximising efficiency, minimising costs, and potentially earning from his contribution entices him.

While Thomas prefers automation, he also values the ability to customise settings according to his preferences. Users like to Tech-Savvy Thomas seek control and detailed insights into various parameters governing home connectivity.

Thomas remains pragmatic, owning a car primarily for the freedom it affords him. Functionality is crucial to him, thus, the ability to interrupt a V2G session is paramount. However, he is open to sacrificing flexibility for less critical errands. He appreciates the possibility to plan and interrupt sessions, as long as he can regain access to his vehicle within a reasonable timeframe, typically within 30 minutes.

Despite his belief in technology, Thomas harbours some scepticism or concern about the integration of future solutions with existing systems. His awareness of the complexity involved in creating a functional V2G system contributes to this scepticism. He values smart solutions and prioritises convenience in his daily life, seeking to simplify rather than complicate his routines.

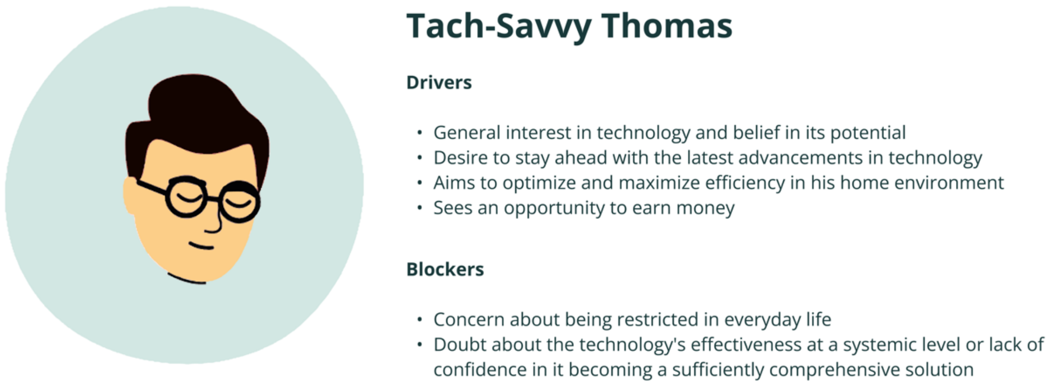

Figure 24. User archetype Tech-Savvy Thomas and summary over his main drivers and blockers.

Self-sufficient Sara

The fifth user archetype is *Self-sufficient Sara* (see figure 25). Sara is characterised by a keen interest in independently empowering her household. The ability to use her car as a power source for her home serves as a significant incentive for her. Generally, Sara does not have high demands for compensation as long as her car can support her household needs. However, in the context of V2G arrangements, she believes there should be compensation to account for factors such as battery degradation and electricity costs.

Although Sara does not have a specific interest in technology, she is not disinterested either. She does not have strong preferences regarding the level of interaction she desires with future solutions. Nonetheless, she is concerned that contributing energy to the grid might leave her car's battery with insufficient energy when she needs it.

Sara also harbours some scepticism about the broader impact of her contribution to V2G. She primarily sees the personal benefits of this new technology, which makes her cautious about its overall effectiveness for the society.

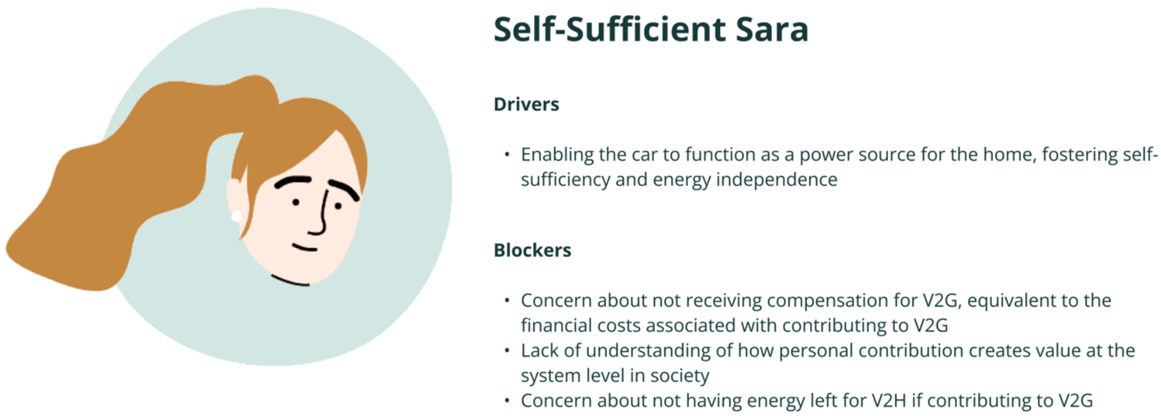

Figure 25. User archetype Self-Sufficient Sara and summary over her main drivers and blockers.

Furthermore, the level of intrinsic motivation to change habits varies among the different user archetypes. As seen in figure 26, Reluctant Rose exhibits low intrinsic motivation to change her habits and therefore she requires more extrinsic incentives to adopt the technology. Idealistic Isabella on the other hand demonstrates a high intrinsic motivation to change her habits in order to contribute to the greater good. The differences in level of intrinsic motivation are showcased in figure 26.

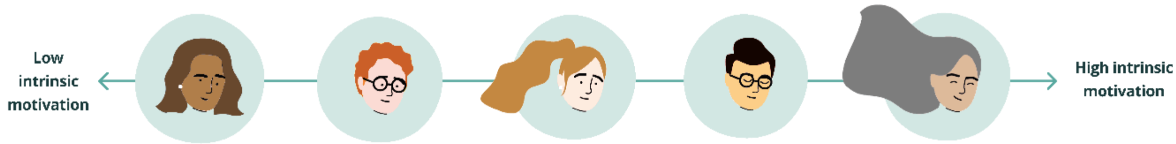

Figure 26. Showcasing the level of intrinsic motivation among the different user archetypes.

4.4 Requirements and Core Values

Recognising that individuals in real life may exhibit traits from multiple user archetypes is crucial. This complexity stems from the diverse range of motivations, values, and preferences that shape human behaviour. For instance, someone may have a strong interest in technology, like Tech-savvy Thomas, while also placing high value on societal contribution, similar to Idealistic Isabella. When designing strategies or interventions to promote technology adoption, it is essential to consider the nuanced interplay of motivations and values inherent in everyone. By acknowledging this complexity and embracing the diversity of user archetypes, a more holistic and effective approach can be developed to resonate with the varied needs and preferences of users.

Based on the identified user archetypes, along with their respective drivers and blockers, a list of requirements was compiled. Some requirements in the list cater to multiple user archetypes, while others are specific to just one archetype. The number of archetypes a requirement corresponds to does not affect its importance. Rather, it signifies its relevance across various user types. Since each archetype represents a combination of traits rather than an actual user, addressing all archetypes ensures comprehensive design coverage. By prioritising the needs of critical users, represented by these archetypes, a solution that inherently meets the requirements of all users can be created, including those with fewer specified needs. It is important to note that all requirements are weighed equally, as it cannot be definitively determined which are of greater significance. The full list of requirements and the corresponding user archetype can be found in appendix J.

Furthermore, based on the requirements, a set of core values was established. The core values align with the needs of all user archetypes and serve as a framework guiding the remaining stages of the design process. The core values identified were *freedom*, *efficiency*, *value creation*, *transparency*, *seamlessness,* and *user-friendliness* (see figure 27).

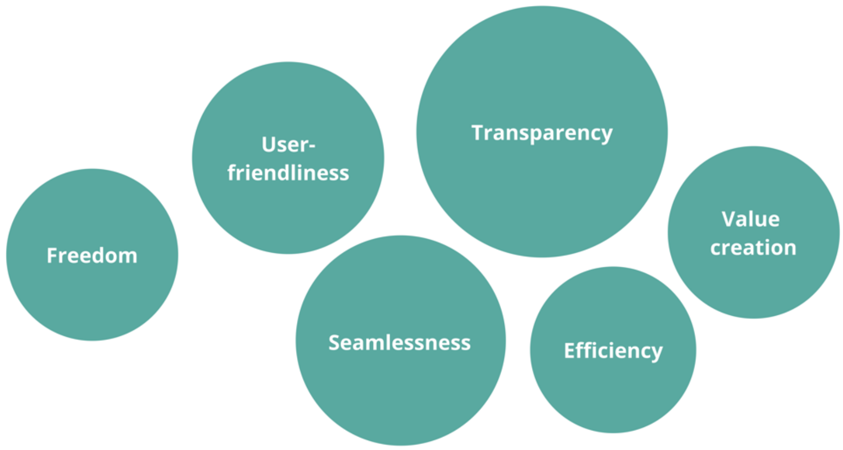

Figure 27. The six identified core values

Transparency

Transparency is crucial for ensuring that users clearly understand who the actor behind the service is. Users express varying levels of trust and preferences regarding the actor providing the service. For instance, many users have indicated that they would have greater trust in an electricity provider over a car manufacturer. Regardless of the actor, it is essential that users know who benefits from their participation and where the profits are directed. Users do not want to be misled. Uncertainty can diminish their incentive and motivation to contribute. The core value of transparency relates to requirements 2, 5, 8, 9, 10, 12, 13, 15, 17, 18, and 25.

Value Creation

Value creation refers to the importance of that the service must feel valuable for users to utilise in order to be willing to contribute. This value can be economic, or users can perceive that they are creating value through their actions, contributing to the overall system, and supporting it. The feeling of value creation is important and needs to be affirmed. The core value creation aligns with the requirements 1, 2, 3, 8, 10, 11, 14, 15, 16, 20 and 25.

Freedom

Freedom is critical, and even the perception of flexibility is extremely important. Users have expressed the need to be able to withdraw from the service, if necessary, even if they do not anticipate needing to do so. Many users own a car primarily for the sense of freedom it provides and are unwilling to compromise on this. Naturally, the degree of freedom and flexibility is linked to potential rewards and the extent of value creation, but flexibility and freedom are fundamental prerequisites for users to find participation attractive. The core value freedom aligns with the requirements 4, 5, 6, 9, 17 and 26.

Efficiency

Efficiency requires that the service be resource-efficient and efficient in general. Users must feel that the service is efficient in all aspects, from electricity usage to time efficiency. The core value efficiency aligns with the requirements 1, 5, 6, 9, 12, 17, 21, 22, 23, 24 and 26.

User-friendliness

User-friendliness is essential and a future service must be easy to understand and use. This is related to freedom as the service needs to be convenient and not time-consuming or complicated. The core value user-friendliness aligns with the requirements 1, 2, 5, 9, 12, 13, 17, 22, 23 and 25.

Seamlessness

Seamlessness in the service design ensures that it functions well in daily life and integrates with other services and apps. Seamless integration is related to efficiency and user-friendliness, ensuring that the service is easy to use and fits naturally into users' routines. The core value seamlessness aligns with the requirements 21, 22 and 23.

It is important to emphasise that these core values should not be viewed as rigidly formulated requirements. Instead, they were intended to function as guiding principles that would permeate the further concept development.

The identified requirements and core values formed a fundamental basis upon which subsequent concept development was built. They served as the guiding principles and essential criteria that informed the creation and refinement of new concepts throughout the development process.

4.5 Five Initial Concepts

Based on the identified requirements and core values, five different concepts were created to explore potential future solutions. Each concept is presented through a distinct user journey, aiming to investigate users' preferences regarding functionality. Concept 1 features a robustly automated system, while Concept 2 focuses on user pre-planning. Conversely, Concept 3 involves manual control over the connection to V2G, and Concept 4 presents a semi-automated system with limited energy utilisation permissions. Concept 5 distinguishes itself by placing emphasis on enhanced user engagement.

The five concepts are designed with inspiration from the strategy of Design for Sustainable Behaviour.

Strategies for Designing for Sustainable Behaviour

The adoption of V2G is likely to entail behavioural changes among vehicle users regarding their vehicle usage patterns. When designing for sustainable behaviour, there are several strategies to consider to effectively engage users and achieve desirable behaviours. Lidman & Renström propose a model categorising these strategies (Lidman & Renström, 2011). The model comprises five different strategy categories called Enlighten, Spur, Steer, Force and Match. The first four categories require the user to change their behaviour in some way, whereas the fifth category, Match, requires little to no adaptation from the user.

Enlighten
The strategies within the category Enlighten aim to foster sustainable behaviour by providing users with information or by facilitating reflection. This may involve informing about environmental issues, to cultivate positive attitudes towards the desired behaviour among the users or highlighting the behaviours of others to establish a positive subjective norm (Lidman & Renström, 2011).

Spur
In the category Spur, the design strategies focus on encourage users to adopt desired behaviours through various means. These strategies focus on emphasising the behaviour itself and other positive consequences, rather than solely environmental benefits. This can be done by designing products and services to motivate users intrinsically or extrinsically, where the latter can be done through rewards and social incentives amongst other (Lidman & Renström, 2011).

Steer
Strategies within the Steer category aims at guiding users towards desired behaviours by making them the more evident choice. This can involve constraining undesired behaviours by making it physically or cognitively challenging, while facilitating the desired behaviours by making them easy to perform (Lidman & Renström, 2011).

Force
The strategies within the category Force aim to compel the desired behaviour upon the user through limited functionality or by restraining undesired behaviour. However, the success of these strategies hinges on users accepting the limitations imposed on the undesired behaviours (Lidman & Renström, 2011).

Match
In contrast to the previous categorise, Match strategies focus on adapting products and services to user’s existing behaviours or intentions. This could entail minimising the environmental impact of the user’s initial behaviour or by facilitating sustainable behaviours that the users already desire, thus aligning with users’ preferences and capabilities (Lidman & Renström, 2011).

Similarly, Zachrisson et al. discuss the distribution of control between users and products along a spectrum (Zachrisson et al., 2012). At one end of this spectrum, the user is left in complete control, whereas on the other end, the user has no control at all. Leaving the control to the user lets the user decide if and how their behaviour should be changed, whereas when leaving the control to the product, the product forces the user to behave in a certain way or causes the behaviour automatically Between these extremes, various strategies can enable, encourage, guide, seduce, or steer users towards desired behaviours. The effectiveness of these strategies partly depends on users' intentions and motivation. Generally, the more the intentions of the user are in line with the intended behaviour, the more control the user may have and vice versa (Zachrisson et al., 2012).

Hence, it can be summarised that the choice of design strategy depends on factors such as user motivation and intention. While strategies like Enlighten may suffice for highly motivated users, those lacking motivation may require more control from products, such as in Steer or Force categories. Match offers an alternative approach that seamlessly integrates behaviour change into users' daily routines, minimising the need for conscious reflection.

For clarity and coherence, the relationships between these five concepts are graphically represented in figure 28. The x-axis delineates the spectrum between automation and manual control, while the y-axis illustrates the balance between user control and system autonomy.

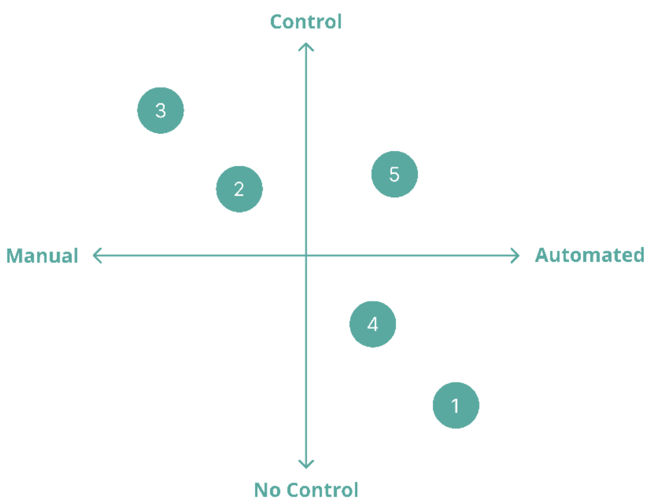

Figure 28. Schematic presentation over the relation between the five concepts in terms of level of automatisation and user control.

Concept 1, illustrated in figure 29, can shortly be described as a fully automated system with minimal user interaction requirements. In practice, users agree to grant the vehicle/service access to their personal data such as driving patterns, charging schedules, or personal calendars, enabling the system to identify patterns and habits. Consequently, the system autonomously detects times when the user does not need their vehicle and determines it appropriate to connect for offering support services or contributing to the grid. Moreover, the system discerns when it needs to recharge the battery, concluding V2G sessions in a timely manner before the user is anticipated to require the vehicle to ensure sufficient charging. In this concept, users are expected to utilise their EV in a manner consistent with their current practices, excluding V2G functionality. The significant alteration lies in the requirement for the charging cable to be plugged in whenever the vehicle is parked at home, or optionally, solely when they intend to activate V2G. Users receive compensation for allowing their vehicle to participate in supporting the electrical grid.

The concept is designed to utilise the design for sustainable behaviour principle *Match*, which focuses on adapting products and services to existing user behaviour and reducing the environmental and social consequences of that behaviour. This approach is suitable for users with lower motivation, such as the reluctant or resistant types, like *Reluctant Rose*. It ensures that users do not need to change their existing usage patterns and can continue using their cars as usual. Furthermore, due to its automated nature, this concept caters to all identified user archetypes, making it universally applicable.

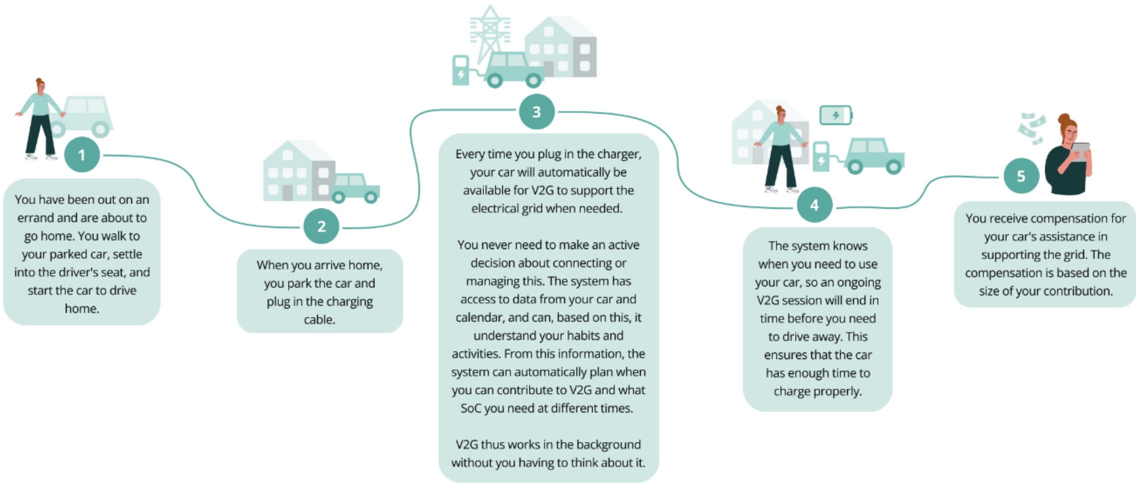

Figure 29. The user journey of concept 1.

Concept 2, illustrated in figure 30, is based on users pre-planning, requiring users to specify at least 24 hours in advance, the days and duration for which their vehicle is available to support the electrical grid. This planning is facilitated through an accompanying mobile application, allowing users to set desired SoC levels and post-V2G session charging preferences. As users plan in advance, they receive compensation corresponding to their planned contribution to supporting the grid.

On the days when users return home and plug in their charging cable, with a scheduled V2G session, the session initiates without further user interaction. The vehicle connects and concludes the session according to the pre-planned settings established by the user. Following the session's completion, the vehicle continues charging to reach the desired SoC level and may continue charging if desired and there is surplus electricity available at that time.

If the users realises that the scheduled session no longer suits their needs, they can access the application to cancel it. In such cases, users may need to return a portion of the compensation already received. If a session needs to be cancelled prematurely, the SoC may be lower than the one specified for post-V2G sessions, but it will never fall below the minimum SoC set by the user.

Concept 2 draws inspiration from the design principle *Spur* from the of Design for Sustainable Behaviour framework and incorporates the theory of loss aversion bias. By offering upfront compensation, this concept seeks to incentivise greater user contribution while discouraging disengagement to avoid the risk of losing the received compensation. This approach is particularly effective for user archetypes characterised by high motivation and a strong commitment to making a positive impact, such as *Idealistic Isabella* or *Tech-savvy Thomas*. However, depending on the size of the compensation offered, it may also motivate other user archetypes to participate.

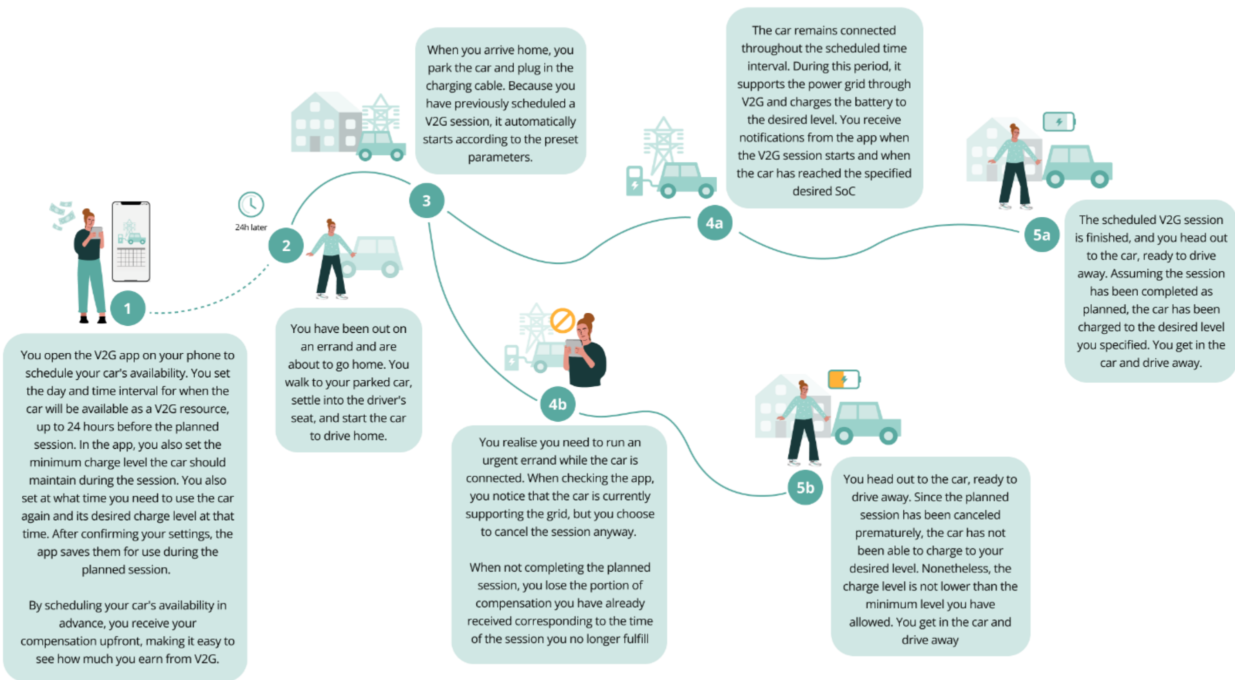

Figure 30. The user journey of concept 2.

In Concept 3, illustrated in figure 31, the user manually controls the connection to V2G through the accompanying mobile application. Users initiate the vehicle connection spontaneously when they deem it an appropriate time according to their schedule. The vehicle remains connected until the user manually ends the session via the mobile application. Users receive compensation corresponding to their contribution towards keeping the vehicle connected and supporting the electrical grid.

Concept 3 draws its main inspiration from the design for sustainable behaviour principle *Spur*, where users receive more compensation based on their level of contribution. The manual disconnection required to end a V2G session is also influenced by the *Steer* principle, encouraging users to remain more connected. This concept is designed to accommodate multiple user archetypes but is particularly well-suited for individuals like *Careful Carl*, as it aims to provide a strong sense of freedom without overcommitment.

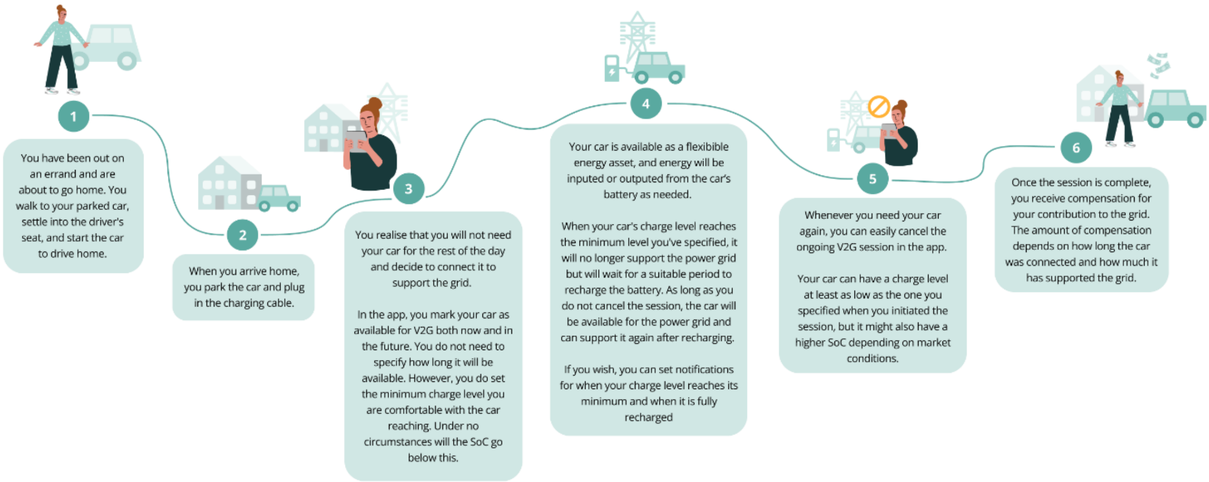

Figure 31. The user journey of concept 3.

Concept 4, illustrated in figure 32, incorporates a pre-set-up process where, before utilising the service, users must make some initial configurations and accept the terms and conditions. This is because this concept revolves around the ability to draw a small amount of energy from the vehicles battery to support the electrical grid whenever the vehicle is connected to a charger. The user can specify the amount of energy that can be drawn in the background. For instance, the user can set a range from their maximum charge limit of 80 percent down to a minimum of 60 percent SoC from which energy can be freely drawn for grid support if needed.

If users are planning a longer trip with the vehicle, they need to access the mobile application to deactivate the background V2G function, allowing the vehicle to charge fully without any energy being drawn to the grid. The user receives compensation based on their contribution over a specified period, such as a month.

Concept 4 draws inspiration from the design for sustainable behaviours principles *Match* and *Steer*, as it aims to automatically encourage user contribution to V2G without significantly disrupting their existing habits. While not entirely automatic, its simplicity could potentially appeal to most user archetypes.

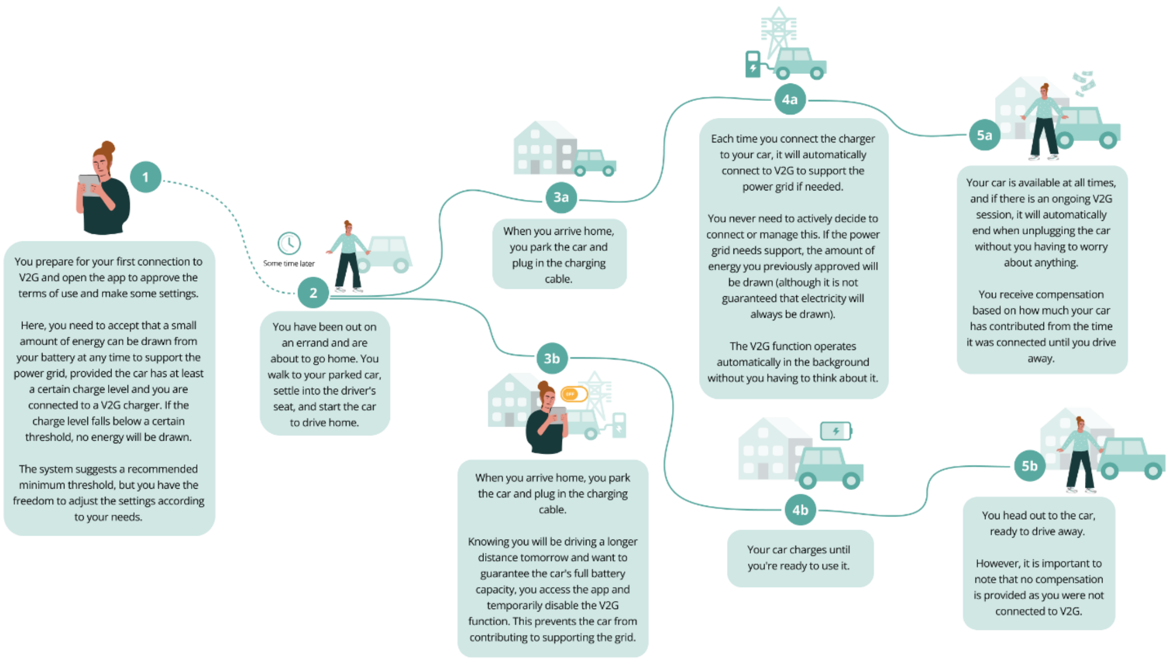

Figure 32. The user journey of concept 4.

Concept 5, illustrated in figure 33, is centred on greater user involvement. For instance, the user receives notifications when it is prognosed that the energy demand will be low and the energy prices favourable and the user is at a parking location with charging opportunities. The notifications may also alert the user about anticipated peaks in energy demand later in the day, prompting them to charge their vehicle now to provide support services during peak times, rather than needing to charge during the peak themselves. When the user's vehicle is connected to a charger, they receive a notification when V2G support is required. The user then responds to the notification to approve or decline the vehicle's connection. The user has the option to refrain from connecting their vehicle if it does not suit them. The vehicle automatically manages charging after any discharge to the grid. The SoC will never fall below the minimum level set by the user. When the user no longer wishes for their vehicle to be connected, they need to end the connection to the grid. If the user does not need their vehicle for several days and chooses to keep it connected, the vehicle can contribute to the grid during that time. The user receives compensation based on their contributions.

Concept 5 draws inspiration from the design for sustainable behaviours principle of *Enlighten*, aiming to motivate individuals through enhanced knowledge and informative notifications regarding the consequences of their actions. While the primary objective of this concept is to strengthen motivation, it is not tailored primarily for users with lower interest who may prefer minimal interference. Nonetheless, its informative approach possesses the capability to arouse the interest and engagement of users through its method of communication.

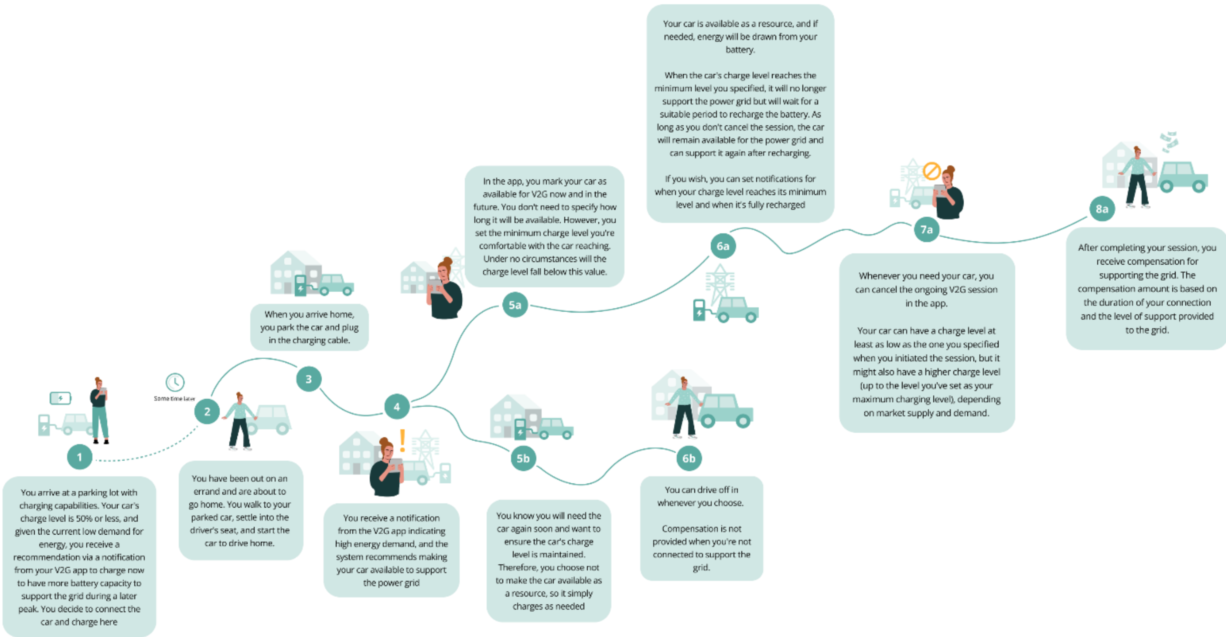

Figure 33. The user journey of concept 5.

For a detailed overview of the five initial concepts' user journeys, see appendix K.

4.6 Focus Group – Individual Reflection, Discussion & Co-creation

The focus group provided a variety of insights into user perceptions of the various concepts. While individual feedback varied, there was significant consensus among participants on many aspects. Through discussion and co-creation, additional elements that users would like to see incorporated into the presented concepts were identified. Participants individually evaluated the five concepts, each illustrated through distinct user journeys. Overall, the participants rated the concepts similarly in terms of how they constrained their level of freedom and their ease of integration into daily life.

Upon evaluating the different concepts, participants highlighted distinct pros and cons for each concept.

Concept 1 was perceived favourably for not requiring any personal administration due to its completely automatic nature, thereby granting users a sense of freedom. However, it was seen as unrealistic by many users as it was perceived as too futuristic. This resulted in low trust levels.

Concept 2 received mixed feedback. Some users appreciated the moderate level of interaction it offered, which allowed them to control their experience to a certain extent. Conversely, other users found the requirement to manually input their availability into a mobile application to be cumbersome and inconvenient.

Concept 3 was praised for enabling users to make the car available and manage its availability themselves. Despite this advantage, there were concerns about the risk of forgetting to mark the car as available, and the overall process was viewed as requiring too much manual handling.

Concept 4 was regarded positively for its efficiency, as users only needed to indicate when the car was unavailable, a less frequent task compared to marking it as available. However, this convenience could be compromised if users forget to mark the car as unavailable when it actually is.

Concept 5 stood out for its helpful feature of suggesting optimal charging opportunities and prompting users to connect when needed, which could be easily accepted via the app. Nevertheless, some users felt that the system required too much interaction, which detracted from its overall convenience.

The transition from individual reflections to collective discussion revealed a convergence of thoughts among the participants, though opinions differed on certain functionalities. Despite these differences, there was consensus that concept 5 was the most suitable for integration into their daily lives, making it the favoured solution. However, participants debated the level of interaction required by concept 5. While they appreciated the notifications and the ability to accept a V2G connection, some felt that the interaction demands were excessive.

This discussion served as a prelude to the following co-creation session. The transition to the ideation phase was smooth, facilitated by the participants' fruitful dialogue about the desired features of the concept. The participants collaborated to find solutions that would satisfy everyone, though some compromises were necessary. However, the co-creation session did not result in a concrete visualised user journey as intended. Instead, extensive deliberation focused on the features and functionalities and how they would cater to users' needs and might be incorporated into a concept.

During the co-creation session, the users proposed numerous features and functionalities they deemed necessary for a future solution, many of which were echoed in the five different concepts presented. Overall, the users expressed that they want a solution offering customised settings, where they can control the amount of information they receive and choose whether to connect their vehicle to the network. They also sought the ability to enable or disable features offering various incentives based on their location, such as favourable charging opportunities nearby. Users also desired flexibility in choosing compensation models and visibility into their earnings and contributions, with the option to customise the amount of information they received. Furthermore, the users expressed a strong need to be able to interrupt an ongoing V2G session at any time, even if it would result in lost compensation. Some quotes from users regarding these issues of finding the perfect balance and the importance of offered flexible solutions are presented in figure 34.

> “ ***But then again, it's about the amount of information, how much you want to know versus simplicity. It's not easy.*** ”

> “ ***I would like to see different compensation depending on how complicated it is or how much effort you put in.*** ”

Figure 34. Quotes from users regarding finding the right balance of information and the relationship between effort and outcome.

Given that many vehicles are shared among multiple users within a household, there is a wish for access to the same information, tools, and settings from multiple user accounts. Additionally, considerations were raised regarding addressing potential battery degradation issues, with suggestions including different cost models, warranties, or leasing options for the vehicle. Figure 35 presents a quote from a user expressing doubts about having V2G in a shared car.

> “ ***We are always talking about a 1:1 relationship; I own my car, and I'm the only one who drives it. This becomes really complicated if multiple people are using the car and have different ideas about what it needs to be used for. Who earns the money then?*** ”

Figure 35. Quote from a user regarding sharing a car and uncertainties about how to solve the compensation and management for V2G.

During the discussions, participants emphasised the importance of freedom on multiple levels. Beyond the necessity of being able to cancel a V2G session, it is essential to design a future solution that minimises disruption to users' daily routines and avoids excessive time or engagement requirements. Achieving this balance entails ensuring that users do not need constant interaction with the solution but are comfortable with occasional engagement in less common situations. To address varying user preferences, participants expressed a strong need for customised settings. For example, they desired control over minimum SoC charging levels and notification settings, ideally customisable during initial setup and periodically adjusted. Figure 36 presents a quote from a user regarding the importance of having limits that control the minimum SoC.

> “ ***You need to have a limit for the lowest charge level, like a threshold of 30-40% that you can set. So yes, there will be a setting for that in some way.*** ”

Figure 36. Quote from user expressing the desire to set a minimum SoC level and the urge to do this themselves.

Furthermore, participants discussed and agreed that with the right settings, the solution could be adjusted to provide individuals with perceived freedom and the appropriate level of interaction. Transparency was also highlighted as a priority for the future solution, with a clear and understandable business model crucial for user trust. Users must feel secure, knowing there are no hidden actors benefiting from their services and be able to track energy transfers to and from their battery back to the grid.

While monetary compensation was discussed, participants agreed that it alone is not the sole driver behind users' contributions to V2G, though it does play a significant role. While some users may not compromise their flexibility for smaller sums, larger amounts, over a few hundred SEK, may lead users to reconsider their flexibility, such as foregoing an errand or adjusting their charging schedule. However, they emphasised that it was still critical to have the option to interrupt an ongoing V2G and risk losing their compensation, even with higher compensation. This allows the user to decide whether the compensation is sufficient for them to forgo using their car in that specific situation.

Figure 37 presents quotes from users discussing the relationship between compensation and flexibility.

> “ ***If I decide that I need to go to ICA, then I guess I can walk walk or take the bike, but I will not do it for 13 öre.*** ”

> “ ***If I need to walk a few hundred meters but earn 300 SEK, then I would think "great, then I can have a better lunch."*** ”

Figure 37. Quotes from users providing insights into their thoughts on compensation in relation to flexibility and effort.

Furthermore, participants expressed a desire for a solution that enables seamless integration between various systems, such as vehicle or charging control. This aligns with their preference for a simple and effortless solution that seamlessly fits into their daily lives without requiring extensive integration or effort. The need for constant interaction and concerns about a future solution requiring more interaction than users currently experience in managing their charging were identified as significant barriers to adopting a future V2G solution.

4.7 Evolution of Core Values into Key Design Principles

Based on the insights from the focus group and the previously stated core values, four key design principles were compiled, formulating a framework for developing a V2G solution. These principles aim at encapsulating the essence of each user archetype, while facilitating the process of catering to a broad range of users.

The four key design principles are *simplicity, customisation, system integration* and *transparency* and is presented in more detail below.

Simplicity

The solution should enable the user to interact with V2G effortlessly, minimising the need for manual intervention if desired. Despite initial concerns about app proliferation, users overwhelmingly agreed that V2G interaction should occur within a single app for accessibility and ease of use.

Customisation

Acknowledging the diverse needs and preferences of users, the solution should emphasis customisation. Users should have the flexibility to tailor the solution to their specific driving habits and lifestyle requirements, thereby ensuring seamless integration into their daily routines. This aspect is a crucial aspect for widespread adoption of the technology.

System integration

To achieve simplicity and address concerns about app proliferation, the solution should focus on seamless integration with other systems and stakeholders.

Transparency

The solution should provide the users with clear and comprehensive information regarding their contributions to the grid, and the benefits they derive from participating. Additionally, transparency within the solution itself is paramount, ensuring users understand its operation and the stakeholders involved in the V2G ecosystem.

4.8 The Final Concept

Based on the key design principles, a final design proposal for a potential V2G solution was developed.

To visualise the concept, a user journey was created to showcase the flow of the concept and to visualise the users' journey when engaging with the solution. To make the touchpoints in the user journey more tangible, an app prototype was developed to provide a more in-depth visualisation of how a user could interact with such a V2G solution.

4.8.1 Description of Final Concept

The concept is based on users having a vehicle and a home charger supporting V2G technology. To interact with the V2G solution, users have an app that combines common functionalities of a car app with V2G functionalities. This means that users can manage charging, V2G, climate control, and vehicle locking/unlocking, and more, all within the same app.

Overall, the concept is structured around four major blocks. These are as follows:

1. *Set-up*
   Entails initial configuration and setup of the V2G system, ensuring compatibility and user preferences.

2. *Everyday Mode*
   Enables effortless daily interaction with the V2G system, focusing on convenience and minimal user intervention.

3. *Long Distance Mode*
   Allows for adjustments for extended travel, ensuring that V2G functionalities do not

interfere with long-distance driving needs.

4. *Grid Optimisation Mode*
   Provides enhanced grid support during peak demand times, optimising energy usage, and providing benefits to both the user and the grid.

Figure 38 illustrates these blocks and how they are interconnected.

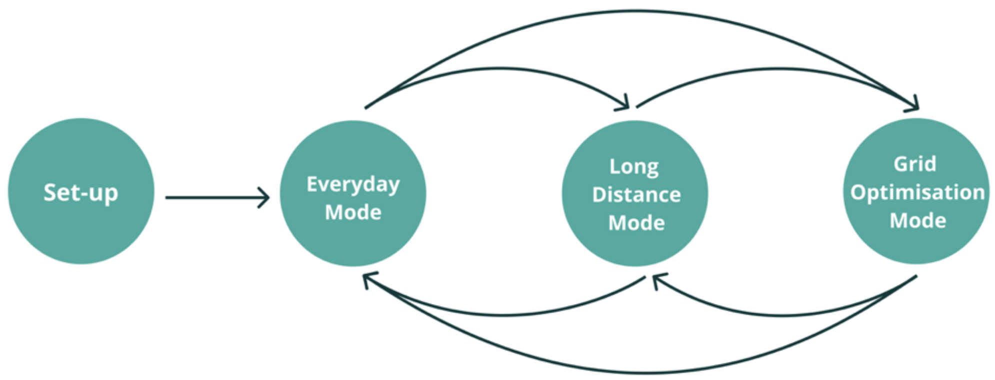

Figure 38. Illustration of the blocks of the final concept and their interconnections.

For a detailed overview of the final concept, including user journeys and app wireframes, see appendix L and appendix M, respectively.

Set-up

When using the V2G solution for the first time, the user must first set up the service (see figure 39). When doing the set-up, the user is first introduced to V2G trough a brief description of the technology and its functionality, as well as its role in supporting the power system. In the set-up, the user also has the opportunity to customise their preferences, determining the level of interaction they wish to have with the app on a day-to-day basis. They also get to set parameters such as charge limits, minimum SoC for V2G sessions, and preferred way of compensation. All these settings can easily be adjusted later within the app to accommodate changes in preferences.

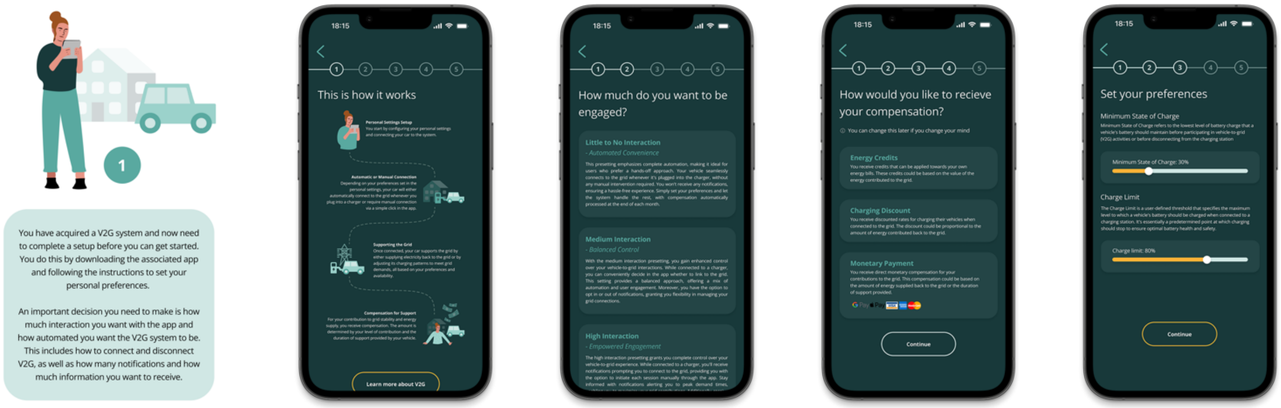

Figure 39. The user journey and app interface of the set-up.

Everyday Mode

The purpose of the everyday mode is to accommodate the users' everyday vehicle usage. In the set-up, the user set their preferences regarding how much they wish to interact with the app on a day-to-day basis, which charge limit they wish to have as well as setting a minimum SoC they would need to feel safe contributing to V2G. These pre-settings are applied when the everyday mode is activated and can be changed at any time within the app if the user's preferences change.

Within the everyday mode, the user also has the opportunity to set custom charge settings for specific days and times of the week. These settings ensure the users have a preferred SoC at specific times, to ensure that they can use their vehicle as intended.

Depending on the desired level of interaction with the service, it slightly differs what the everyday mode entail. In the set-up, the user got to choose between three different interaction levels:

Little to no interaction

The pre-setting *little to no interaction* (see figure 40) emphasises complete automation, making it ideal for users who prefer a hands-off approach. The vehicle will seamlessly connect to the grid whenever it's plugged into the charger, without any manual intervention required, and support the grid, when necessary, within the SoC interval specified by the user. The user will not receive any notifications, ensuring a hassle-free experience. Simply, the user set their preferences and then the system handle the rest, with compensation automatically processed at the end of each month.

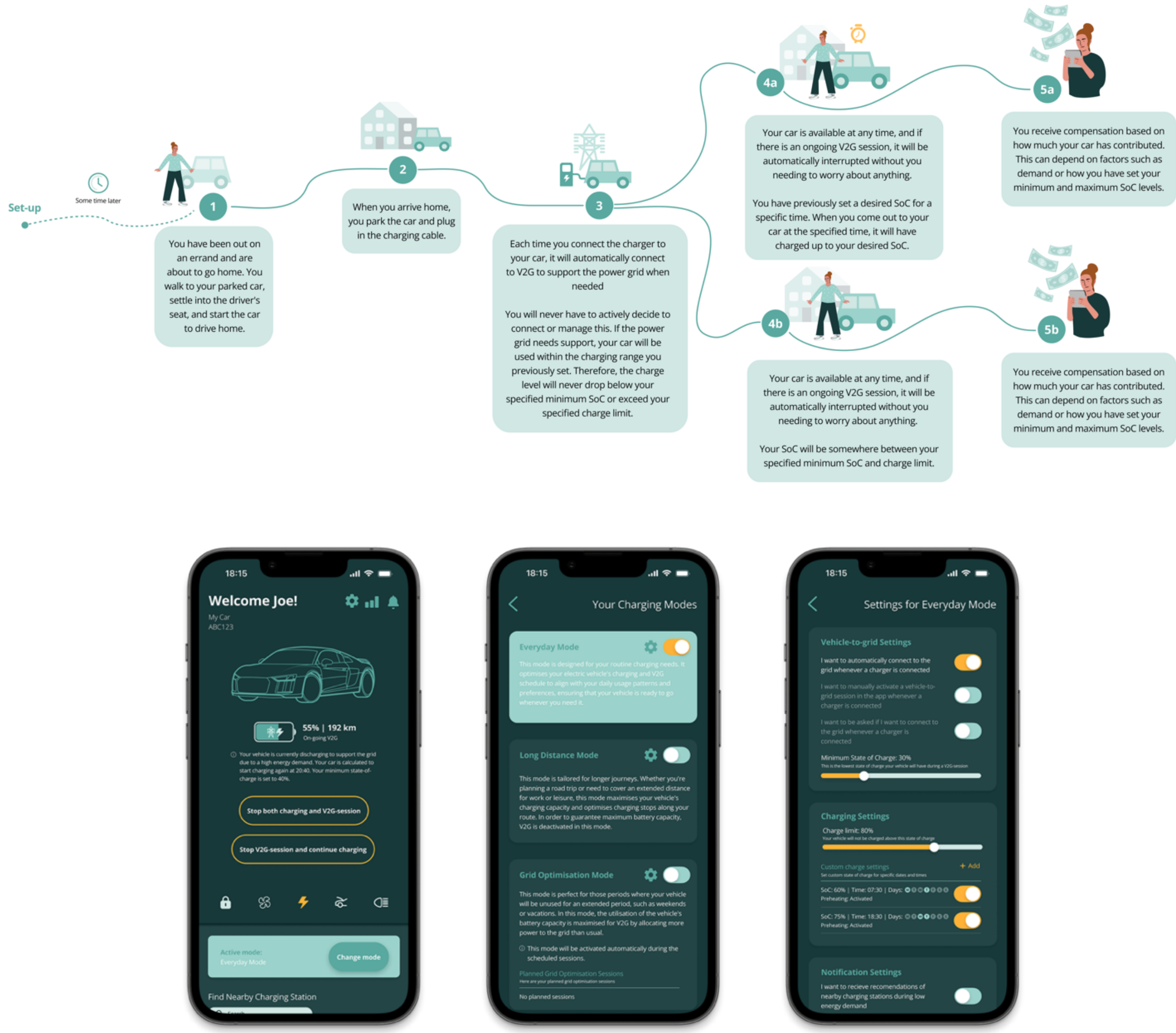

Figure 40. The user journey and app interface of the little to no interaction pre-setting.

Medium interaction

With the pre-setting *medium interaction* (see figure 41), the user gains enhanced control over their V2G interactions. While connected to a charger, the user can conveniently decide in the app whether to connect to the grid. This setting hence provides a balanced approach, offering a mix of automation and user engagement.

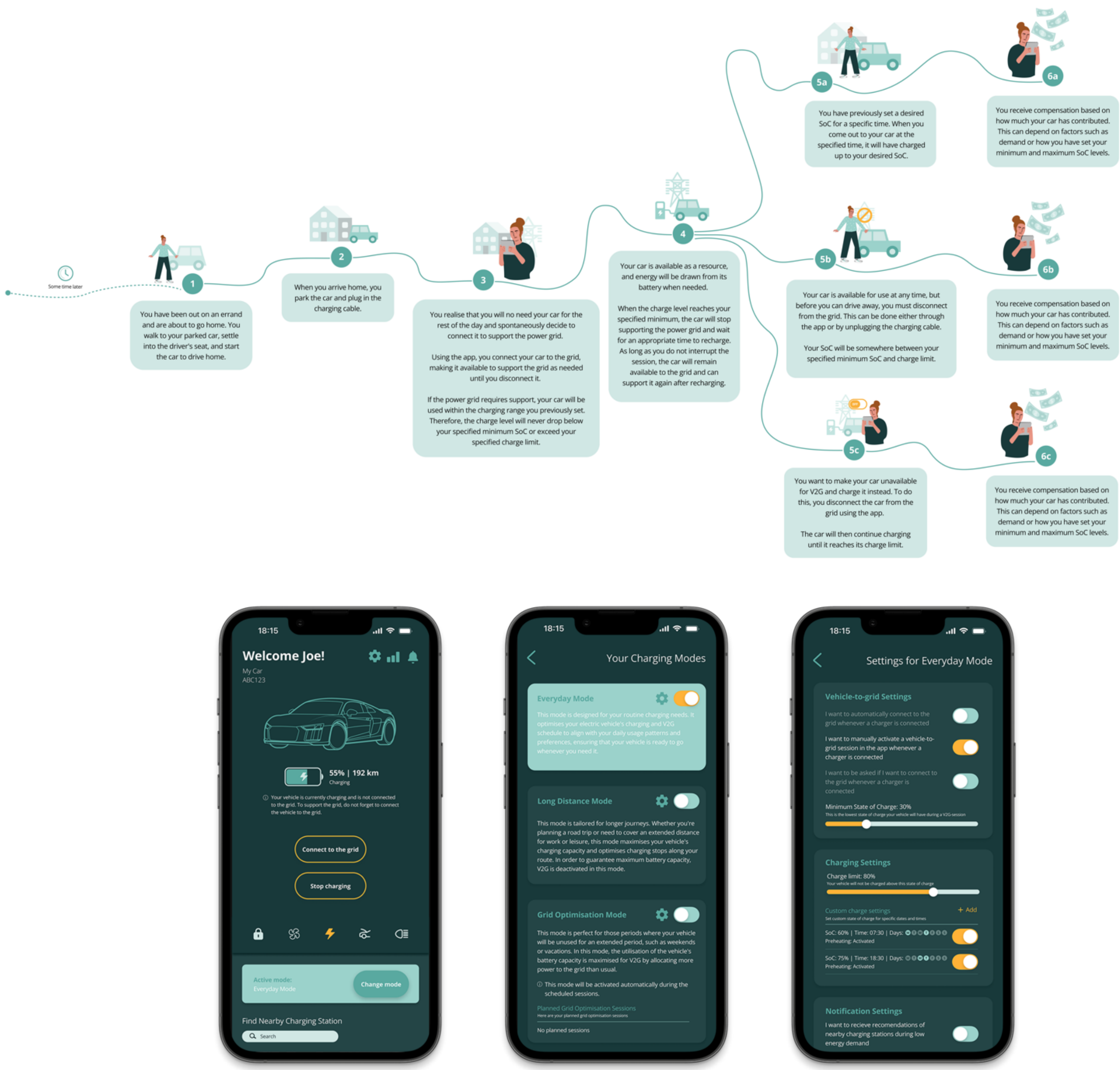

Figure 41. The user journey and app interface of the medium interaction pre-setting.

High interaction

The pre-setting *high interaction* (see figure 42) gives the user complete control over their V2G experience. When connected to a charger, the user receives notifications prompting them to connect to the grid, providing the user with the option to initiate each session manually through the app. The user stays informed with notifications alerting them to peak demand times, enabling them to maximise their grid contributions. Additionally, the user receives notifications about nearby chargers when energy demand is low to promote charging at of-peak hours, as well as weekly reports over their contribution. This to allow the user to optimise their charging strategy and make the most of available resources.

Figure 42. The user journey and app interface of the high interaction pre-setting.

Long Distance Mode

The purpose of the long distance mode (see figure 43) is to accommodate users when they want to do longer trips than usually, without requiring them to change their day-to-day settings. When the user is going on a longer trip than usual, the long distance mode can then be activated.

Currently, many EV users change their charging limit before going on a longer trip and similarly, the long distance mode is made for maximising the vehicle’s charging capacity and to optimise the charging stops along the user’s route. Hence, when the user activates this mode, V2G is deactivated, and the vehicle will only charge. The charge limit will automatically be set to 100 percent to allow maximum charge capacity. When the user gets back from their trip, the user will activate the everyday mode again.

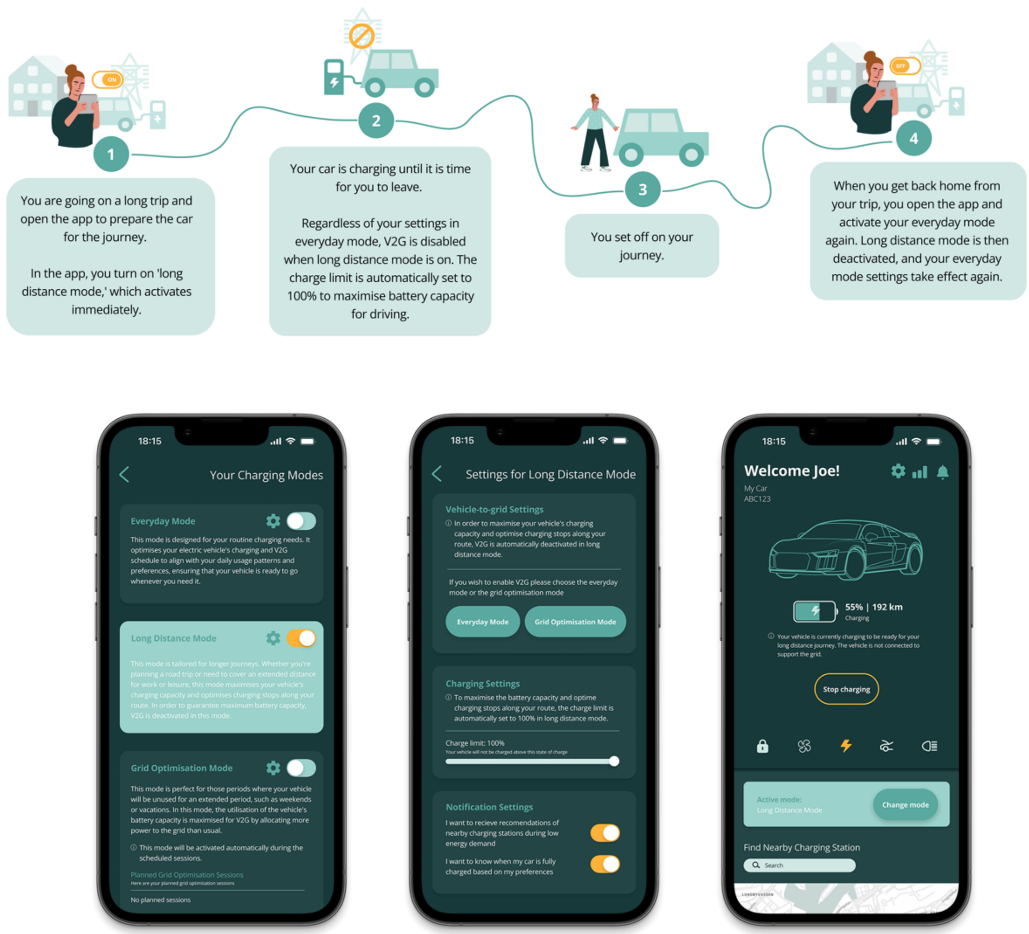

Figure 43. The user journey and app interface of the long distance mode.

Grid Optimisation Mode

The purpose of the grid optimisation mode (see figure 44) is to make it easy for users to maximise their vehicle's V2G availability during periods when the vehicle is not in use, such as during weekends or vacations. In this mode, the utilisation of the vehicle's battery capacity is fully utilised to support the grid by allocating more power to the grid than usual.

To activate this mode, the user needs to plan a grid optimisation session in the calendar and select a start and stop time for the session. In this mode, the minimum SoC the user normally has in their everyday mode is overridden and the battery can be charged and discharged however to best support the grid. When planning a grid optimisation session, the user also gets to set a charge limit that only applies to this session, and this also acts as the guaranteed SoC at the ends of the session.

Figure 44. The user journey and app interface of the grid optimisation mode.

Statistics Page

In the app, the user can access a statistics page providing them with an overview of their vehicle usage (see figure 45). In this page, the user can find information about their V2G contributions and earnings, their driving history, energy usage and charging history among other things.

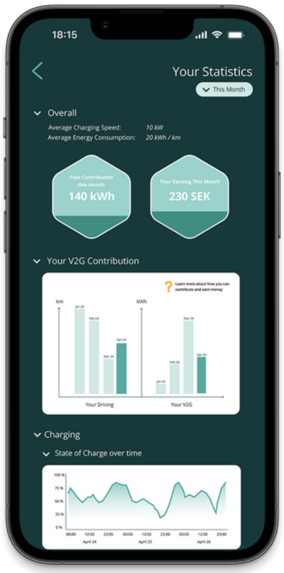

Figure 45. The app interface of the statistics page.

4.8.2 The Users' Perception of the Final Concept

The final concept was evaluated with users to understand their perception of it and determine whether it met their needs and requirements. Overall, it became evident that all of the users were pleased with the final concept and saw that a V2G solution like this could work in their daily lives. Given that all user archetypes were represented by the participants in the evaluation, there is nothing to indicate that any user archetype's needs and requirements are not addressed by the solution. This demonstrates that it is possible to cater to a broad range of users with a single V2G solution, given that the key design principles are followed.

More detailed results from this evaluation are presented according to the key design principles to clearly illustrate how users perceived the final concept based on these principles.

Simplicity

One of the major factors identified affecting the users' willingness to adopt V2G was their perception of the V2G solution's simplicity.

A key feature positively impacting this perception in the final concept was the ability to switch between different usage modes. An insight from previous parts of the study was that many vehicle users have travel habits that does not vary significantly from day to day, allowing the everyday mode to cover the users' daily need. By setting their preferences only once, users could rely on the everyday mode to manage their charging and V2G, allowing them to not think about charging and V2G in their everyday. This was well appreciated by all of the user archetypes during the final tests. Moreover, the ability to easily adjust settings when their daily routine changed, such as requiring a different minimum SoC, was highly valued.

The option to activate long distance mode for special occasions or grid optimisation mode for additional support without altering everyday settings was also seen as very convenient. Users found this feature streamlined, allowing them to avoid making multiple adjustments. Some quotes regarding how the users perceived using the different usage modes can be seen in figure 46.

“This was easy”

“It must be easy to handle the modes, and it is easy in this solution”

Figure 46. Quotes from users regarding having and using different usage modes.

However, some of the users expressed that it would have been even easier if the long distance mode could be planned similarly to the grid optimisation sessions, with an automatic switch back to everyday mode once the session ended.

Another aspect significantly influencing the perceived simplicity of the solution was the user interface. All users agreed that an aesthetically pleasing and easy-to-use interface enhanced the overall feeling of simplicity for the V2G solution. The final testing revealed that all of the users appreciated the design of the app prototype, both aesthetically and functionally. They also emphasised the importance of clearly indicating which mode was active and whether the car was connected to the grid in a solution like this.

Regarding the set-up process, the users had mixed opinions. While some appreciated the initial V2G introduction, others found it unnecessary and preferred to skip it. Some users wanted more detailed descriptions of the different interaction levels, possibly supplemented with videos, while others felt there was too much text. This highlights the challenge of balancing sufficient information with conciseness, emphasising the importance of proper UX writing in these types of contexts.

Customisation

Despite the set-up being perceived as text-heavy by some of the users, the idea of a set-up was well received as an easy way to customise the V2G solution to individual needs. The perception of customisation also enhanced the simplicity of the solution.

The functionality of having different interaction levels to choose from was universally praised by the users as it allowed them to choose pre-settings that matched their needs and easily allowed them to adjust these settings if required. Two participants chose little to no interaction, while three chose high interaction. However, two of the latter group mentioned they chose this interaction level for learning purposes and expressed that they expected themselves to switch to lower interaction levels once they became familiar with the service. Furthermore, all users agreed that having suggested levels for the charge limit and minimum SoC was beneficial, with the suggested settings being well-received. Regarding the choice of compensation method, the users appreciated having options, even though most preferred energy credits, which allowed them to offset their electricity bills instead of receiving direct payments.

System integration

A majority of the users expressed that that having V2G functions integrated with other car-related functions in a single app would be convenient and reduce the need to use multiple apps. Figure 47 presents quotes from users highlighting their preference for having V2G and other car-related functions combined in one app.

> “*It would be nice to only have to use one app instead of three*”

> “*The fewer apps you need to open to achieve what you need to do, the better*”

> “*I like this app better than my current car app*”

Figure 47. Quotes from users regarding overall app usage.

However, some users expressed concerns that car companies might resist such integration if they did not develop it themselves, or that some loyal customers might be reluctant to switch from their preferred car app.

Transparency

The statistics page provided the users with a sense of transparency regarding their contributions and earnings, making it clear how they could contribute or earn more. Most users felt these statistics would increase their motivation to contribute more to V2G, although they noted this might be more interesting initially.

Furthermore, the V2G introduction in the set-up was perceived as a good way to get an overview of the service and how it works in more detail, thus proving a sense of transparency.

5. Discussion

5.1. Main Results and V2G in General

5.1.1. Main Results in Relation to Previous Research

The topic of V2G has been intensely researched during the past years. While the majority of the research has focused on the technological aspects of V2G, there has also been significant attention on implementation strategies, stakeholder involvement, and the dynamics within the V2G ecosystem. However, the development of V2G technology has predominantly been driven by technological advancements rather than user-centric perspectives. This thesis aims to fill that gap by providing a new user-focused perspective that has not been extensively explored.

While other projects have mainly focused on public charging, vehicles in carpools, and demand flexibility in relation to vehicle usage, this thesis has focused on privately owned or privately leased vehicles charged at home, again providing a new perspective. Where V2G will first be implemented remains to be seen, as previous research varies regarding where the best opportunities lie. On one hand, solutions that utilise carpooling suggest simpler implementation by facilitating aggregation, whereas private home charging is less complex than public charging and could thereby ease implementation from a user perspective.

According to Mehdizadeh et al. (2023) previous research has found the following factors to be more or less important for user adoption of V2G:

- Financial compensation (e.g. discount on charging/parking tariff)
- The anxiety of being left with a car not sufficiently charged for trip length requirements
- Beliefs regarding battery degradation
- The ease of use of the user interface on the charging station
- Keeping control over charging or discharging
- V2G charging point location
- Communication processes for promoting V2G
- Societal contribution to sustainable energy
- User-friendliness of the whole system

While Mehdizadeh et al. (2023) state that financial compensation and minimum agreed SoC are the major factors, the results of our study partly agree but are not limited to those factors. Our study has found that the core values for a V2G solution important for user adoption are simplicity, customisation, system integration, and transparency.

The results of our thesis show that an important aspect for user adoption of V2G is simplicity, meaning that the solution should be easy to interact with and that the need for manual intervention should be minimal if desired. Similar results were found in the project Dansmästaren, conducted to investigate flexible public charging. In Dansmästaren the importance of a user interface that is easy to use and a charging principle that is easy to understand was identified, in order to enable flexible charging where users charge when the grid capacity is good (Bartusch et al., 2023). This also aligns with the aspects of "ease of use of the user interface on the charging station" and "user-friendliness of the whole system" mentioned as critical for V2G adoption by Mehdizadeh et al. (2023).

Our study also showed that customisation is crucial in order to cater to the broad user group that potential V2G users represent. Hence, it was found that users should have the flexibility to tailor the V2G solution to their specific travel behaviour and lifestyle requirements, thereby ensuring seamless integration into their daily routine. From Dansmästaren it could be stated that because it takes longer to charge an EV and it has to be done more frequently than refuelling a fossil-fuelled vehicle, they are not comparable and hence it is just a necessary evil. Therefore, charging of an EV needs to be integrated into the user's daily life differently than refuelling (Bartusch et al., 2023). The same reasoning could be seen in our study, but applied to V2G, supporting the finding that V2G should work seamlessly with the user's daily life and car usage to enable widespread adoption of the technology.

Another important aspect identified regarding the importance of V2G integrating seamless into the user's daily life was the possibility to interrupt an ongoing V2G session. In order for the users to trust to adopt V2G this would be a necessary option, even though many of the users expressed that they probably would use it seldomly. This also aligns with the results from Dansmästaren, where they saw that one way to counteract the uncertainty that energy flexibility brings could be and "opt-out" function (Bartusch et al., 2023)

On the same topic, ensuring sufficient charge when needed was highlighted as a major aspect for adoption by Mehdizadeh et al. (2023), something that also became apparent in our study. However, Mehdizadeh et al.'s study (2023), showed that on average, people indicated they would allow V2G use if an electric car's battery contained at least 71 percent power at any given time which differed from the results of our study where users expressed much lower SoCs to feel comfortable. However, this highlights the importance of customisation of a V2G solution to cover a broad range of users. Furthermore, in both our study and Mehdizadeh et al.'s study (2023), it could be seen that lower concerns regarding minimum guaranteed charge increase trust in using the technology, which can be achieved by allowing the user to override the minimum SoC whenever needed. However, in Mehdizadeh et al.'s study (2023) it was assumed that the vehicles' batteries would be available for V2G up to 100 percent SoC, which was something that the users in our study were very clear that they would not agree to.

The aspects regarding system integration and transparency found in this thesis do not seem to be as researched previously. The importance of seamless integration with other systems identified is closely linked to simplicity, as this is a prerequisite for the solution to be perceived as smooth to use by the user. However, no other research supporting this has been found, even though the topic of app proliferation among EV users is often discussed. Furthermore, the importance of transparency in a V2G solution was identified, both regarding clear and comprehensive information about the users' contributions to the grid and the benefits they derive from participating, but also regarding the operation behind V2G and the stakeholders involved in the V2G ecosystem. The former aligns with findings from a study on Norwegian users that states that promoting the environmental advantages of V2G can motivate non-EV users to transition and embrace V2G (Mehdizadeh et al., 2024). In our study, the same effect was seen among EV users. However, transparency regarding the operations and actors is not a widespread finding and hence interesting to investigate further, as this study found that the actor behind a V2G solution could influence adoption.

One important aspect highlighted in other studies is the financial compensation from V2G. According to Mehdizadeh et al. (2023), this is even one of the major aspects influencing V2G adoption. Whereas a study in Germany found that financial compensation was not an important incentive for using V2G, a study in the Netherlands showed that financial compensation was a significant factor for adopting V2G for both EV users and non-EV users (Mehdizadeh et al., 2023). In Norway, it was shown that financial drivers are indirectly associated with a higher intention to use V2G (Mehdizadeh et al., 2024). In our thesis, the results showed that financial compensation of some sort is crucial for user adoption, even though some users expressed that they might not necessarily require compensation to make their vehicle available for V2G. Nonetheless, the users generally agreed that any costs incurred should be covered, and for some user archetypes, compensation was a determining factor in how much they would be willing to compromise their vehicle usage and charging behaviour. This aligns with the results that Mehdizadeh et al. (2024) presents about concerns about battery degradation or worries about the battery capacity of EVs reduce the probability of V2G adoption but that users can be encouraged to adopt V2G by providing financial compensation.

Interestingly, similar to our study, Dansmästaren found that many associate EV ownership with environmental and cost benefits. In our study, these emerged as the main reasons for choosing to drive an EV. Likewise, these were the two advantages seen regarding participating in V2G. It was observed that those who saw the environmental benefits of driving an EV perceived the advantages of V2G to be more environmental compared to those who had an EV for economic reasons. We also found that this group did not need to earn money from V2G to the same extent; it was enough to cover investment costs and, to some extent, that it was good for the environment. This somewhat aligns with Mehdizadeh et al. (2023), who identified that people who strongly perceived the usefulness of the V2G service were less likely to request high monetary compensation.

Previous studies have not distinguished different types of potential V2G users given these identified drivers and blockers, which is something that our study does trough the identified user archetypes and key design principles. This provides new insights on how a V2G solution should be designed with EV users in focus.

5.1.2. Overall Evaluation of Vehicle-to-grid from a User-centric Perspective

When examining the potential of V2G technology, it is anticipated that the number of EVs will significantly increase in the coming years in line with the electrification of society. Given this, the energy storage capacity provided by EVs is expected to increase substantially. While it is certain that the number of EVs will rise, it is also worth considering the total number of personal vehicles that will be in use. In recent years, it has been observed that personal vehicles remain parked and unused for a large portion of the time, leading to the exploration of alternatives such as car sharing and *Mobility as a Service* (MaaS). As car sharing aims to increase the utilisation rate of each vehicle, an increase in this alternative means of accessing vehicles would both reduce the total number of available EVs and decrease the time each vehicle would be available to support the grid. Since V2G depends on a sufficient number of vehicles being available for energy storage and requires vehicles to be parked and unused for extended periods, this raises the question of whether car sharing can be effectively combined with V2G. While car sharing could consolidate an energy reserve in one place, facilitating aggregation, it contradicts the fundamental principles of V2G.

One critical aspect identified for user adoption of V2G is their perceived flexibility regarding the ability to use a vehicle whenever they want. Not owning a vehicle, but accessing one through car sharing, can be thought to result in similar concerns. Hence, it can be asked whether access to cars through car sharing, rather than private ownership, increases or decreases the willingness to adopt V2G. On one hand, the barrier to accessing a car through car sharing and the resulting reduced flexibility might be so significant that V2G adoption becomes unlikely. On the other hand, it could facilitate V2G adoption since users may already be accustomed to rethinking their flexibility and vehicle usage.

Moreover, if car ownership is shifted away from the users, it could potentially reduce concerns about battery degradation and the depreciation of the vehicle's value due to V2G. This consideration applies not only to car sharing but to MaaS in general.

Looking at future energy needs, Svenska kraftnät has made a forecast up to year 2050 (Svenska kraftnät, 2024b). This forecast indicates that the development of renewable energy sources will continue, increasing both variability and uncertainty in energy production. This, in turn, increases the need for flexible energy usage and energy reserves, which positively impacts the relevance of V2G in the long term. Since V2G would likely entail a significant investment cost for users, the long-term need for V2G to support the grid is an important aspect from a user perspective. Many users have expressed a willingness to contribute, as long as their investment costs and other costs related to their contribution are covered. The potential for a sustained need for V2G suggests that these costs could be covered, as the demand would ensure compensation is available. Addressing the concern of covered investment costs is another area where MaaS could be beneficial, as users would not have to bear the high investment costs and would face less risk.

5.2 Method and Implementation

The chosen research methodology for this thesis, known as the double diamond approach, proved to be highly effective. Its systematic and structured nature aligned seamlessly with the objectives of the study. The distinct phases of discovery, definition, development, and delivery within the double diamond approach facilitated a comprehensive and coherent exploration of the research aim.

Due to the aim of this thesis, investigating users' willingness to adopt bidirectional charging, user involvement plays a crucial role. From the inception of the thesis, users were involved in every phase of the project, underscoring the importance of selecting appropriate individuals for engagement. However, the broad scope of users, limited to those with access to a privately owned vehicle, posed challenges in achieving representative sampling.

For the initial survey, a deliberate effort was made to post the survey in various Facebook forums and groups catering to vehicle owners and enthusiasts, ensuring broad outreach.

Forums and groups specific to certain car brands were avoided to maintain inclusivity. Despite these efforts, there is a risk that individuals lacking interest in bidirectional charging were not adequately represented in the data.

Recruiting participants from Facebook forums provided a practical way to reach a diverse audience despite potential biases. While forum users may differ from the general population, this approach enabled efficient recruitment, gathering insights from a wide range of perspectives. By targeting specific criteria, such as vehicle ownership or interest in sustainable technologies, relevance to the research topic was ensured. Despite limitations, such as self-selection bias, careful analysis and interpretation of data can enhance the validity of findings.

In selecting participants for the initial round of user interviews, priority was given to individuals expressing different levels of interest in bidirectional charging. Factors such as location, type of residence, and daily driving habits were also considered to maximize diversity. However, it is worth noting that participants with the highest interest levels were more likely to remain engaged, potentially biasing the sample towards more enthusiastic users. This underscores the importance of ensuring representation across all interest levels.

Moving forward, it is recommended to include larger sample sizes to better capture diverse perspectives and potentially identify clearer trends in the data. Additionally, future research should explore alternative engagement strategies to reach underrepresented user groups, such as community outreach programs or partnerships with local organisations.

Approximately 200 responses were received, with a significant majority being from EV users. While the smaller number of responses from non-EV users did not yield substantial insights, it was chosen to focus the thesis specifically on current EV owners.

The user interviews yielded valuable qualitative data and insights, proving to be an effective method for gaining nuanced understanding. The interview structure was effectively designed, with the re-enactment session particularly enlightening, providing a nuanced comprehension of users' everyday experiences, routines, and driving behaviours.

Using co-creation as a foundational approach throughout the project significantly enhanced user engagement and involvement. This strategic choice to involve the same set of users consistently, rather than recruiting new participants for each phase, yielded numerous advantages.

Firstly, the continuous involvement of the same users provided them with multiple opportunities to express their opinions. This iterative engagement facilitated a deeper understanding of each individual's perspectives and preferences. While incorporating new users at each stage could have introduced a broader range of viewpoints, it also carried the risk of producing less profound insights due to the lack of continuity in feedback.

Secondly, maintaining a consistent user base likely fostered a sense of trust and comfort among participants. This trust was crucial in encouraging users to share their thoughts more openly and honestly. The rapport built over time ensured that the feedback provided was candid and reflective of true user sentiments.

Furthermore, the ability to track and follow up on previous user comments was instrumental in verifying and building upon their earlier inputs. This ongoing dialogue not only confirmed the consistency of user feedback but also enabled us to refine our understanding and better align our project outcomes with user expectations. In conclusion, the decision to involve the same users throughout the project was essential in maximising the benefits of the co-creation method. This approach deepened our insights, enhanced the reliability of the feedback received, and ultimately contributed to the success of our project.

In the second design sprint, a mediating object was employed to facilitate a more tangible simulation of a potential solution, aiming to elicit more comprehensive feedback from users. This method was of paramount importance in the study, given the exploratory nature of the investigation. By providing users with a physical object for interaction, feedback was based on concrete experiences rather than abstract conjectures. Despite the focus being on developing a minimum viable product for testing, the criticality of visual and functional elements in shaping user perceptions and usability was recognised.

The decision to utilise a mediating object necessitates a deeper examination. Beyond its role as a prototype, this tool (the mobile application) acted as a conduit between conceptual ideas and practical user engagement. By facilitating user interaction with a physical prototype, significant insights into user preferences were acquired, affirming that concerns previously identified as potential blockers had been appropriately addressed in the solution. This approach facilitated more nuanced discussions during the final evaluation and added qualitative insights. The incorporation of a mediating design tool proved instrumental in bridging the divide between conceptualisation and user insights, significantly enhancing the efficacy of the design process.

5.3 Reflections and Suggestions for Future Work

This chapter outlines the key areas of recommendations derived from this master thesis. The recommendations focus on three critical aspects: user requirements, technical requirements, and business model considerations. Addressing these areas comprehensively provides a robust framework for the effective development, implementation, and adoption of V2G solutions. Figure 48 illustrates these areas of recommendations, highlighting the interconnected nature of user needs, technical feasibility, and business strategy in creating a viable V2G ecosystem.

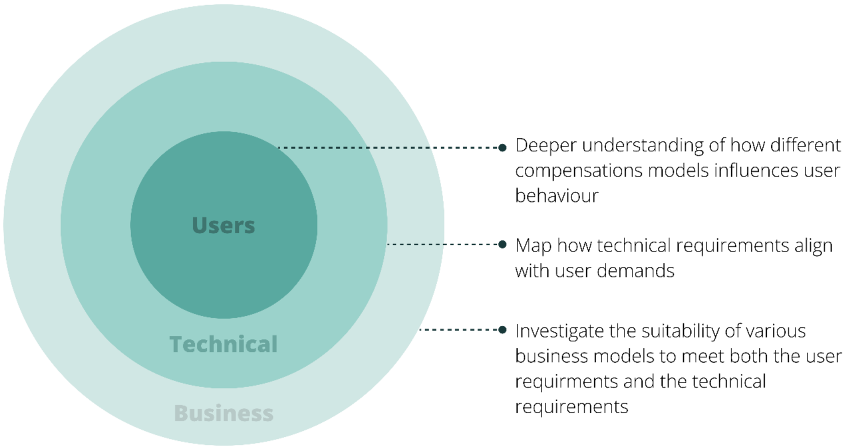

Figure 48. Illustration of areas of recommendations for further investigation

User Requirements

Further exploration of user requirements is crucial to ensure the effective development and implementation of future V2G technology. Understanding the distinct boundaries and detailed needs of users across different segments is essential for establishing clear and precise expectations for the technology and its future development. By delving deeper into user requirements, it is possible to identify more nuanced preferences and priorities of various user groups, enabling tailored solutions to better meet their needs.

One important aspect to investigate is the interplay between compensation and the willingness to be flexible or change habits and compromise on one's perceived freedom. This study indicates that the amount of compensation and the method of receiving it significantly influence users' willingness to change their habits to accommodate vehicle-to-grid technology. Therefore, it is necessary to further investigate this aspect to gain a deeper understanding of how various compensation models affect user behaviour. This insight will be vital in designing strategies that encourage user participation and enhance the overall success of V2G implementation.

Technical Requirements

This project identified several user requirements for a V2G solution, which can be used to set the technical development criteria. It is essential to investigate how these requirements align with existing technical constraints. If there are conflicting requirements due to technical limitations, it is important to explore how users perceive these constraints to find common ground.

Understanding both the user perspective and technical requirements is crucial for designing strategies that effectively address user needs. For instance, if interrupting a V2G session is a strong user demand, its technical feasibility must be determined. Ensuring that technical capabilities align with user requirements is vital for the success of the solution. Meeting both technical and user requirements is fundamental to developing a viable and user-friendly V2G solution.

Further investigation into these technical issues and their alignment with user requirements will provide valuable insights, enabling the development of a solution that is both technically feasible and user-centric. This balanced approach is essential for fostering user acceptance and achieving the widespread adoption of V2G technology. A comprehensive understanding of user requirements facilitates effective communication with stakeholders and actors responsible for V2G service development. Clear and well-defined user requirements serve as a roadmap for technology developers, guiding them in creating solutions that address specific user needs and preferences. By identifying and understanding these needs, developers can ensure that the technology meets user expectations and delivers maximum value, thereby contributing to the successful adoption and utilisation of V2G services for the benefit of both users and stakeholders.

Business Model

It is essential to examine how a business model for a V2G solution can accommodate both user and technical requirements to create a feasible and viable solution. During user interviews, focus group sessions, and result evaluations, participants frequently discussed how compensation and its magnitude could influence their behaviour. Since the technology is still in development and has not yet been established in the market, some aspects remain unexplored. Consequently, it was not possible to incorporate detailed technical specifications regarding potential types of flexibility services or energy support that V2G users might provide in the future, along with corresponding compensation mechanisms, into the solutions. Examples of pricing or business models were not integrated into the material presented to participants in the study.

To enhance the depth of the user research, it would have been advantageous to offer users various compensation models, sizes, and alternative forms of compensation, allowing them to articulate their preferences. Given the potential influence of compensation considerations on users' perceptions and willingness to compromise, further exploration of this aspect is strongly recommended to enrich the understanding of users' expectations regarding the technology.

Additionally, a comprehensive overview should be pursued, as it has become evident throughout the project that users seek a seamless solution and prefer integration with existing services they already use. Further investigations are necessary to determine how different business models may impact user engagement and whether they adequately address user requirements. Understanding the interplay between user preferences, technical feasibility, and compensation mechanisms is crucial for developing a business model that supports the successful adoption and utilisation of V2G technology. By addressing these aspects, developers can create a solution that is not only technically viable but also attractive and valuable to users, thereby fostering greater user acceptance and engagement.

6. Conclusion

The ongoing electrification of society and the transition to renewable energy sources are imperative from a sustainability perspective. However, these transitions present significant challenges to the power system, which requires reinforcement to accommodate this shift. While expanding the electricity grid is one solution, it is costly and cannot keep pace with the rapid energy transition. Hence, another approach is energy storage solutions. With the increasing number of EVs, V2G emerges as a valuable possibility for energy storage. However, for V2G to be effective, widespread adoption among EV users is crucial as the entire concept would falter otherwise. This thesis aimed at investigating what is necessary for EV users to adopt V2G as well as how a V2G solution could be designed to take the EV users into account.

The study found that V2G has the potential to be seamlessly integrated into vehicle users' daily routines based on their usage patterns, thereby enabling EVs to support the electricity grid by evening out peaks in energy demand. However, the success of V2G relies on expanding the charging infrastructure to ensure users can easily make their vehicles available when needed.

Furthermore, it became apparent that there is a high level of interest in V2G among both EV users and non-EV users. Many perceive both the economic benefits for themselves and the societal benefits of V2G as significant advantages, serving as motivational factors for their contribution. However, for users to adopt V2G technology, it must not interfere with their vehicle usage, and it must be easy to use and understand. Five potential V2G user archetypes were identified in the study, and although the identified user archetypes had varying considerations regarding how much interference and complexity they could tolerate without losing interest, these considerations were generally consistent across the different user archetypes. Based on this, it was identified that from an EV user's point of view, an ideal V2G solution should prioritise effortless user interaction, customisation to fit individual needs, seamless integration with existing systems, and transparent information accessibility.

Additionally, it became evident that compensation is a crucial aspect of user adoption. Even though some users expressed that they may not necessarily require compensation to make their vehicle available for V2G, it was generally agreed that any costs incurred should be covered. Thus, compensation would be necessary to address investment costs and potential depreciation of the vehicle due to battery degradation. For some user types, compensation was a determining factor in how much they would be willing to compromise their vehicle usage and charging habits. However, the amount and form of compensation in relation to these concerns requires further investigation.

Lastly, a concept was developed based on the insights and requirements identified. This concept serves as a proposal for how a V2G solution could be designed. Despite the diverse drivers, blockers, and requirements of the different user types, the positive user feedback this concept received demonstrates that it is possible to create a V2G solution that appeals to a broad user base. This indicates strong potential for widespread user adoption of V2G technology, which is essential for its full utilisation and the benefits it promises.

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Appendices

Appendix A – The Survey Questions

Undersökning av ditt bilanvändande

Vi är två studenter från Chalmers Tekniska Högskola som nu gör vårt examensarbete där vi undersöker vad det ställs för krav på dubbelriktad laddning från ett användarperspektiv. För att förstå detta är vi intresserade av att få en bättre inblick i bland annat körvanor samt vilka möjligheter och utmaningar man ser med dubbelriktad laddning.

Enkäten tar cirka 10 minuter att fylla i och riktar sig till dig som idag äger eller privatleasar din bil (både el/hybrid bil och bensin/diesel).

Genom att svara på denna enkät bidrar du med värdefulla insikter till vårt arbete.

Om du har några frågor eller övriga funderingar gällande enkäten eller projektet är du välkommen att kontakta oss på:

ealice@chalmers.se *eller* alenyl@chalmers.se

Tack så mycket på förhand!

Vänligen,
Alexandra Nylander & Alice Evertsson

Allmänt om dig och din bil (frågor till alla respondenter)

Hur gammal är du?

- 18-24 år
- 25-29 år
- 30-34 år
- 35-39 år
- 40-44 år
- 45-49 år
- 50-59 år
- 60-64 år
- 65-69 år
- 70-74 år
- 75-79 år
- 80-84 år
- 85+ år

Vilket kön har du? Med kön menar vi könsidentitet, alltså det kön du själv känner dig som.

- Kvinna
- Man
- Ickebinär
- Annat alternativ
- Osäker
- Vill ej svara

Hur ser din boendesituation ut?
(Välj den kombinationen som passar bäst in på dig)

	Villa	Radhus	Gård	Parhus	Lägenhet
City	○	○	○	○	○
Förort	○	○	○	○	○
Landsbygd	○	○	○	○	○

Hur många personer finns det i ditt hushåll?

	0	1	2	3	4	5	6
Antal vuxna (inklusive dig själv) i ditt hushåll	○	○	○	○	○	○	○
Antal barn i ditt hushåll	○	○	○	○	○	○	○

Äger eller privatleasar du/ni bil inom hushållet?

- ○ Nej
- ○ Ja, jag/någon i mitt hushåll äger bil
- ○ Ja, jag/någon i mitt hushåll privatleasar bil
- ○ Ja, jag/någon i mitt hushåll både äger och privat leasar bil

Hur många bilar har du/ni i hushållet?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 4+

Hur många av bilarna i hushållet är elbilar eller hybridbilar av något slag?

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 4+

Allmänt om dig och din bil (frågor till respondenter med el- eller hybridbil)

Vad har du för elbil/hybridbil? (märke, modell och modellår)
Om du/ni har flera bilar i hushållet behöver du enbart specificera de som är el/hybrid.

Svar: ___________________________

Varför har du valt just den el- eller hybridbilen du har?
Svar: ___________________________

Hur mycket erfarenhet har du av att köra elbil?

- o < 6 månader
- o 6-12 månader
- o 1-2 år
- o 2-3 år
- o 3-4 år
- o 4-5 år
- o 5+ år

Varför har du valt att köra el/hybridbil istället för en bensin/dieselbil?

Svar: ___________________________

Körvanor (frågor till respondenter med el- eller hybridbil)

Under en vecka lägger jag uppskattningsvis så här många km/mil på respektive typ av körning:

	0 km	1-2 km	3-6 km	7-10 km	1-5 mil	6-10 mil	11-20 mil	20-40 mil	40+ mil
Till och från jobbet	o	o	o	o	o	o	o	o	o
Skjuts av andra i hushållet till jobb/skola/förskola	o	o	o	o	o	o	o	o	o
Till och från fritidsaktiviteter (för mig eller skjuts av andra i hushållet)	o	o	o	o	o	o	o	o	o
Planerade ärenden	o	o	o	o	o	o	o	o	o
Korta oplanerade resor	o	o	o	o	o	o	o	o	o

I de situationer du idag använder din el/hybrid-bil, hade du kunnat använda alternativa transportmedel för att ta dig dit?

	Jag kör inte denna typ av resor	Nej, det går inte	Ja, det finns kollektivtrafik men det är knöligt	Ja, det finns bra kollektivtrafik	Ja, det skulle kunna gå att samåka	Ja, det går att promenera eller cykla
Till och från jobbet	○	○	○	○	○	○
Skjuts av andra i hushållet till jobb/skola/förskola	○	○	○	○	○	○
Till och från fritidsaktiviteter (för mig eller skjuts av andra i hushållet)	○	○	○	○	○	○
Planerade ärenden	○	○	○	○	○	○
Korta oplanerade resor	○	○	○	○	○	○

Laddvanor (frågor till respondenter med el- eller hybridbil)

Har du egen laddbox? Om ja, vilken typ av laddbox har du?

Svar: ___________________________

Hur många gånger under en vecka pluggar du uppskattningsvis in din bil för laddning på följande ställen?

	0	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	+10
Hemma	○	○	○	○	○	○	○	○	○	○	○
På min arbetsplats	○	○	○	○	○	○	○	○	○	○	○
Snabbladdning	○	○	○	○	○	○	○	○	○	○	○
Övriga parkeringar (ex. mataffären, köpcentrum)	○	○	○	○	○	○	○	○	○	○	○

När på dygnet är din bil inpluggad? (välj alla timmar då din bil är inpluggad)

- ☐ 00:00
- ☐ 01:00
- ☐ 02:00
- ☐ 03:00
- ☐ 04:00
- ☐ 05:00
- ☐ 06:00
- ☐ 07:00
- ☐ 08:00
- ☐ 09:00
- ☐ 10:00
- ☐ 11:00
- ☐ 12:00
- ☐ 13:00
- ☐ 14:00
- ☐ 15:00
- ☐ 16:00
- ☐ 17:00
- ☐ 18:00
- ☐ 19:00
- ☐ 20:00
- ☐ 21:00
- ☐ 22:00
- ☐ 23:00

Varför väljer du att ha din bil inpluggad vid dessa tidpunkter?
Svar: ___________________________

Upplever du att det krävs att du planerar din laddning? I så fall när och hur planerar du?
Svar: ___________________________

Hur mycket laddning behöver du ha när du åker iväg för att du ska känna dig bekväm/trygg? Varför? (om olika landnivåer vid olika typer av resor, vänligen specificera)
Svar: ___________________________

Upplevda för- och nackdelar med att köra elbil (frågor till respondenter med el- eller hybridbil)

Vad upplever du som den största fördelen med att ha en elbil?
Svar: ___________________________

Vad upplever du som det mest utmanande med att ha en elbil idag?

Svar: ___________________________

Vad upplever du som den största farhågan med att ha en elbil?

Svar: ___________________________

Allmänt om dig och din bil (frågor till respondenter med bensin- eller dieselbil)

Vad är anledningen till att du väljer att köra en bensin- eller dieseldriven bil?

Svar: ___________________________

Under en vecka lägger jag uppskattningsvis så här många km/mil på respektive typ av körning:

	0 km	1-2 km	3-6 km	7-10 km	1-5 mil	6-10 mil	11-20 mil	20-40 mil	40+ mil
Till och från jobbet	○	○	○	○	○	○	○	○	○
Skjuts av andra i hushållet till jobb/skola/förskola	○	○	○	○	○	○	○	○	○
Till och från fritidsaktiviteter (för mig eller skjuts av andra i hushållet)	○	○	○	○	○	○	○	○	○
Planerade ärenden	○	○	○	○	○	○	○	○	○
Korta oplanerade resor	○	○	○	○	○	○	○	○	○

I de situationer du idag använder din bil, hade du kunnat använda alternativa transportmedel för att ta dig dit?

	Jag kör inte denna typ av resor	Nej, det går inte	Ja, det finns kollektivtrafik men det är knöligt	Ja, det finns bra kollektivtrafik	Ja, det skulle kunna gå att samåka	Ja, det går att promenera eller cykla
Till och från jobbet	○	○	○	○	○	○
Skjuts av andra i hushållet till jobb/skola/förskola	○	○	○	○	○	○
Till och från fritidsaktiviteter (för mig eller skjuts av andra i hushållet)	○	○	○	○	○	○
Planerade ärenden	○	○	○	○	○	○
Korta oplanerade resor	○	○	○	○	○	○

Stöd- och flextjänster (frågor till alla respondenter)
Stödtjänster och flexibilitetstjänster för balansering av elnätet är olika metoder som används för att hantera och optimera elförsörjningen. Dessa tjänster innebär att elkunder, inklusive hushåll och företag, kan bidra till att reglera elförbrukningen eller produktionen baserat på behovet i elnätet. Till exempel kan företag erbjuda stödtjänster genom att använda energilagringssystem för att lagra överskottsel under perioder med låg belastning och sedan släppa ut denna lagrade energi under perioder med hög efterfrågan. På liknande sätt kan flexibilitetstjänster innebära att elkunder anpassar sin elförbrukning eller produktion vid specifika tidpunkter för att hjälpa till att balansera belastningen på elnätet och undvika överbelastning. Dessa tjänster är avgörande för att skapa ett mer stabilt och effektivt elnät samt för att främja användningen av förnybar energi.

Har du solceller installerade på/i anslutning till din bostad?

- Ja
- Nej

Säljer du stöd- eller flextjänster?

- Ja
- Nej

Stöd- och flextjänster (frågor till respondenter som säljer stöd- eller flextjänster)

Förklara kort på vilket sätt du säljer stöd- eller flextjänster
Svar: ___________________________

Vad upplever du är den största fördelen med att sälja stöd/flextjänster?

Svar: ___________________________

Vad upplever du är den största nackdelen med att sälja stöd/flextjänster?

Svar: ___________________________

Vehicle-to-Grid (frågor till alla respondenter)

Vehicle-to-grid (V2G) är en teknologi som möjliggör att elbilar och laddhybrider kan användas som mobila energilager. Istället för bara att ladda bilbatterierna kan de även tömmas på lagrad energi tillbaka till elnätet när det behövs. På det sättet kan fordonen bidra till att balansera elnätet och hantera effekttoppar, samtidigt som de kan användas som vanliga fordon för transporter. V2G-tekniken öppnar upp möjligheter för smartare och mer effektiv hantering av elenergi i samhället.

På en skala 1-6, hur mycket kunskap skulle du uppskatta att du har om vehicle-to-grid?

1	2	3	4	5	6
○	○	○	○	○	○

På en skala 1-6, hur intressant tycker du att vehicle-to-grid verkar?

1	2	3	4	5	6
○	○	○	○	○	○

Givet att du har tillgång till en bil och laddbox med vehicle-to-grid-teknik, hade du kunnat tänka dig att koppla upp dig för att jämna ut effekttopparna? Detta skulle innebära att du inte har fri tillgång till bilen under tiden den är uppkopplad

- Ja
- Nej
- Vet inte

Om ja på föregående fråga, när hade du kunnat tänka dig att koppla upp dig?

- o Bara när jag vet att jag inte ska någonstans
- o Närsomhelst så länge jag vet att det finns tillräckligt mycket laddning när jag ska någonstans
- o Annat:________

Hade du kunnat tänka dig att köpa en ny bil för att få tillgång till vehicle-to-grid (V2G)?

- o Ja
- o Nej
- o Vet inte

Skulle finansiell ersättning vara viktig för att du skulle koppla upp din bil till V2G?

- o Nej, jag är inte intresserad av V2G över huvud taget
- o Nej, att det är bra för vår miljö räcker för mig
- o Nej, vetskapen att jag kan använda min bil som powerbank till hushållet räcker
- o Ja, åtminstone för att täcka kostnaden för investeringen
- o Ja, jag vill kunna känna att jag tjänar pengar på att dela min el med andra

Vad ser du som den största fördelen med att ha tillgång till V2G?

Svar: __________________________

Vad ser du som den största utmaningen med att ha tillgång till V2G?

Svar: __________________________

Deltagande i djupintervju (för alla respondenter)

Vi söker personer som hade velat ställa upp på djupintervjuer kopplade till vehicle-to-grid. Är du intresserad så kommer du dirigeras vidare till en sida där du får lämna dina kontaktuppgifter. Intervjuer kommer i huvudsak att ske digitalt via Teams.

Skulle du kunna tänka dig att bli kontaktad för deltagande i en djupintervju?

- o Ja
- o Nej

Finns det något annat du hade velat dela med dig av som inte framkommit under enkäten?

Svar: __________________________

Appendix B – Sensitising Material for User Interviews

Nu är det snart dags för din djupintervju!

Vi är mycket nyfikna på att få ta del av dina djupare åsikter och syn på elbilar och Vehicle-to-grid (V2G). För att underlätta och effektivisera intervjun har vi tagit fram lite kort information om V2G och några frågeställningar vi vill att du funderar kring innan din intervju.

Innan din intervju skulle vi uppskatta om du funderade kring följande:

Under en vanlig dag i mitt liv...

- När använder jag min/vår elbil/hybridbil? I vilka situationer?
- Hur mycket *state of charge* har bilen när jag kör iväg vid olika typer av körningar?
- Känner jag mig någon gång stressad över att ha låg *state of charge*? Isåfall i vilka situationer?
- Hur mycket tänker jag på att planera min laddning och planera min körning?

Vad är Vehicle-to-grid?

I Sverige och många andra länder är elpriset känt för att fluktuera under dagen, vilket delvis beror på de skiftande kapacitetsbehoven. Effekttoppar uppstår när efterfrågan är som högst, vilket pressar elnätet och driver upp priserna för konsumenterna.

Vanligtvis upplever vi två tydliga effekttoppar under dagen: en under morgontimmarna mellan ungefär kl. 07-09 och en under eftermiddagen/kvällen mellan kl. 17-19. Dessa toppar kan variera i styrka och tidpunkt beroende på faktorer såsom efterfrågan och tillgång på elektricitet, men även väder och andra förhållanden. För att undvika dessa och möta det växande elbehovet behöver vi jämnt fördela belastningen på elnätet.

En aktuell lösning för att jämna ut belastningen på elnätet är att använda olika former av energilagring, däribland batterier. Genom att lagra överskottsenergi under perioder med låg efterfrågan och sedan frigöra den under perioder med hög efterfrågan kan vi minska trycket på elnätet och därmed minska risken för effekttoppar och de höga priser som följer med dem. Denna strategi främjar inte bara en mer stabil och kostnadseffektiv elförsörjning utan bidrar också till att minska behovet av storskaliga infrastrukturprojekt för att möta framtida elbehov.

I kontexten av kapacitetsbristen och det behov vi har av att jämnt fördela belastningen på elnätet, blir det uppenbart att användningen av hemmabatterier kan vara en del av lösningen. Dock är kostnaden för hemmabatterier ofta hög för privatpersoner, samt har en relativt låg kapacitet. Ett genomsnittligt hemmabatteri har en kapacitet på cirka 10 kWh. Jämför man detta med de genomsnittliga kapaciteten för en elbil, som vanligtvis ligger mellan 40–100 kWh, blir det tydligt att möjligheten hade varit stor om dessa batterier kunde användas.

För att integrera elbilar som en del av lösningen för kapacitetsproblemen blir det intressant att utveckla dubbelriktad laddning. Denna teknik möjliggör inte bara att elbilar kan ladda från elnätet när det är låg belastning, utan även att de kan matar tillbaka överskottsel när efterfrågan är hög. På så sätt kan elbilarnas batterier fungera som en buffert för att jämna ut belastningen på elnätet och minska trycket under effekttopparna.

1

V1G – Smart Laddning

Smart laddning är en teknik som möjliggör intelligent hantering av laddningen för elbilar. Genom smarta laddningsenheter och kommunikationsteknologi kan laddningen schemaläggas för att dra nytta av lägre elpriser eller högre tillgänglighet av förnybar energi. Dessutom kan smart laddning balansera belastningen på elnätet genom att undvika att flera elbilar laddas samtidigt under perioder av hög efterfrågan, vilket minskar risken för effekttoppar och överbelastning.

V2H – Vehicle-to-Home

Med V2H-teknik kan elbilar användas för att leverera lagrad ström direkt till hemmets elektriska system, vilket gör dem till en praktisk backup-strömkälla vid strömavbrott eller för att minska energikostnaderna genom att utnyttja billigare el under låg efterfrågan eller generera el från förnybara källor när det är möjligt. Detta ökar resiliensen för hemmets energiförsörjning och kan bidra till att minska beroendet av externa energikällor.

V2L – Vehicle-to-Load

Genom V2L-teknik kan elbilar användas för att driva externa enheter eller ladda andra enheter utanför bilen, vid tillfällen då det saknas annan strömförsörjning. Detta ökar elbilens användbarhet och flexibilitet, och med inkluderingen av V2X, som inkluderar olika typer av energiutbyte mellan elbilar och andra enheter eller system, blir elbilen en integrerad del av det övergripande energiekosystemet.

V2G – Vehicle-to-Grid

V2G-teknik möjliggör att elbilar kan anslutas till elnätet för att inte bara ladda under låg efterfrågan utan också för att lagra överskottsenergi som kan återinjiceras i nätet under perioder av hög efterfrågan. På så sätt kan elbilarnas batterier fungera som en buffert för att jämna ut belastningen på elnätet och minska trycket under effekttoppar, vilket leder till en mer effektiv användning av energi och ökad pålitlighet för elnätet.

Figuren illustrerar olika nivåer av smart och dubbelriktad laddning.

Direkt laddning vs. Smart laddning

En av de utmaningar som kan uppstå med laddbara fordon är att de skapar stora effekttoppar när de behöver laddas. En 11 kW laddare använder nämligen lika mycket el som nästan 4 ugnar eller 11 tvättmaskiner samtidigt. Som nämnt ovan varierar kapacitetsbehovet under dagen, och när flera elbilar laddar samtidigt klarar vårt elnät inte av att leverera den höga energimängd som krävs. Denna risk är störst vid direkt laddning, där laddningen sker med full effekt direkt när sladden kopplas in i bilen. Problematiken ligger här i att en majoritet av elbilarna pluggas in direkt efter elbilsföraren kommit hem från jobbet, vilket allt som oftast är när elnätet redan är som mest belastat.

Det har blivit allt vanligare med så kallad smart laddning (V1G), som tillskillnad från den direkta laddningen anpassas utifrån olika parametrars och exempelvis sker med reducerad effekt eller vid en senare tidpunkt. Det finns flera nivåer av smart laddning, vilket illustreras i figuren nedan som en trappa där laddningen i ökande grad tar hänsyn till elsystemets behov. Direkt laddning motsvarar nivå noll, och nivå fyra är smart laddning optimerad utifrån elsystemets förutsättningar.

Figuren illustrerar de olika nivåerna som finns inom smart laddning

Idag supportar många utav laddboxarna smart laddning mellan nivå 1-3 beroende på olika funktionaliteter. På den fjärde nivån laddas inte bara bilen smart, utan den bidrar även med tjänster till elsystemet. Vehicle-to-grid, där bilen kan skicka tillbaka el till fastigheten eller elnätet, ingår i denna nivå av smart laddning. För att laddbara fordon ska kunna bidra med tjänster till elsystemet krävs det både hårdvara och mjukvara som är kompatibelt för detta.

Idag finns det redan flera bilmodeller från olika bilmärken som har hela eller delar av den teknik som krävs för dubbelriktad laddning. Även om vehicle-to-grid inte finns etablerat idag så är det mycket sannolikt att vi kommer kunna se tekniken på marknaden inom några år då det just nu pågår flera stora industriella satsningar och forskningsprojekt med olika industriaktörer och universitet.

Frågor eller funderingar?

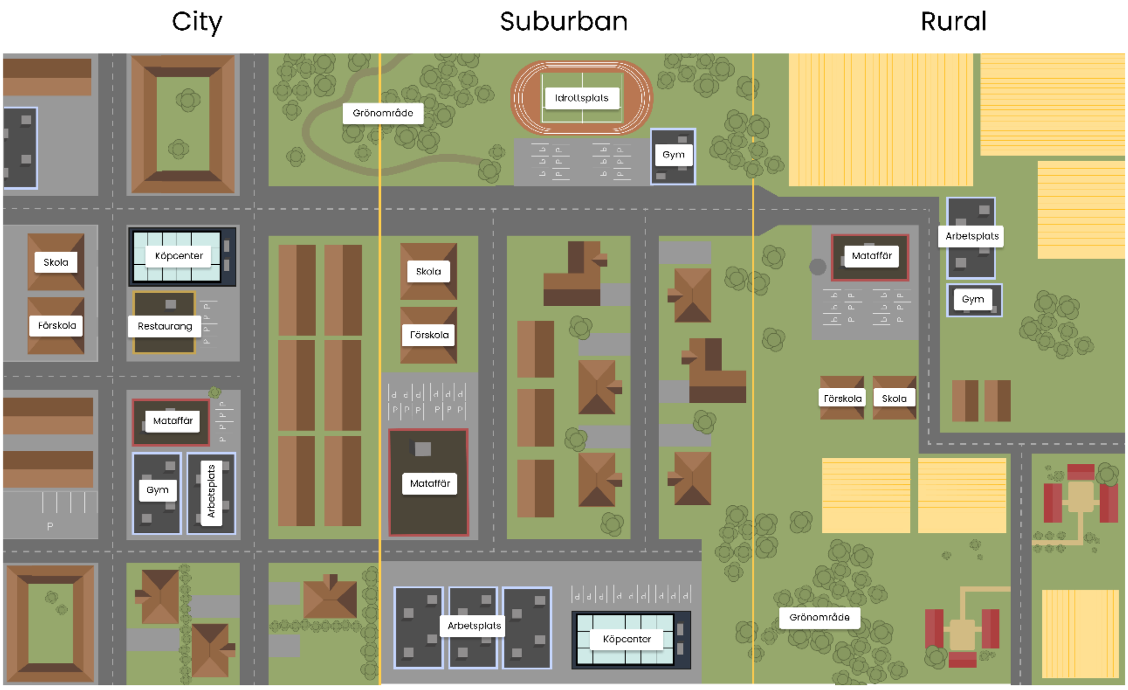
Har du några frågor eller funderingar kring detta material eller inför intervjun, tveka inte att höra av dig till någon utav oss. Det går bra att nå oss på följande:

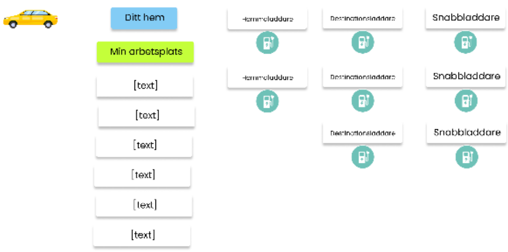
Alice Evertsson
alice.evertsson@knightec.se

Alexandra Nylander
alexandra.nylander@knightec.se

Tack för att du bidrar till vårt arbete!

Appendix C – Interview Guide Part 1, Current Habits, Re-enactment Material for User Interviews





Current Habits - Desktop Walkthrough

Innan intervjun bad vi dig att reflektera lite över din vardagliga bilanvändning och vi skulle nu vilja att du tar oss igenom en vanlig dag med fokus på ditt bilanvändande.

Vi kommer visa en modell av en stad och vi tänkte använda den som hjälpmedel för att demonstrera hur du och din bil rör er under en dag. Du beskriver vad du gör och så kommer vi flytta runt dig och din bil.

Exempel: jag ska åka och lämna mina barn på skolan runt 07.30. Bilen har 80% state of charge för jag har laddat under natten. Det är ca 2 km till deras skola. Därefter pendlar jag in till mitt arbete i stan...

Var skulle du säga att det känns representativt att placera ut ditt hem?
Nu vill vi att du tar oss igenom en genomsnittlig vardag?

Potentiella frågor i detta moment:

- ***Var kör du?***
- ***Vad är klockan då?***
- ***Hur långt är det dit (distansmässigt)? Alt. Hur lång tid tar det att köra?***
- ***Hur mycket state of charge har du när du kör iväg?***
- ***Hur mycket state of charge har du när du kommer fram?***
    - ***Hur känns det med olika state of charge?***
- ***Var och när laddar du? Varför laddar du då?***

Kontrollfrågor efter gått igenom en dag:

- ***Känner du att du fått med de aktiviteter och transporter du gör under en vanlig dag?***
- ***Har du stor variation i din vardag?***
- ***Har du ofta xxx state of charge när du åker hemifrån?***
- ***Har du oftast xxx när du kommer hem?***
- ***Är det någon gång i din vardag du upplever din bilanvändning krånglig? Isåfall var, när och varför?***

Solceller/Flextjänster

Du har svarat i enkäten att du levererar flextjänster... kan du beskriva lite kortfattat på vilket sätt och hur?

- ***Hur upplever du det?***
- ***Vad ser du för fördelar?***
- ***Nackdelar?***

Appendix D – Interview Guide part 2, User Interviews

Intro V2G (max 5 min)

Nu kommer vi gå över till att fokusera på vehicle-to-grid. Innan intervjun fick du lite infomaterial skickat till dig, baserat på den, och kanske om du läst mer om det tidigare, vad är din initiala uppfattning om den här tekniken? Är det något du tänkt på?

Härnäst kommer vi presentera ett antal scenarion där du kan tänka att vehicle-to-grid som koncept är helt på plats och du har tillgång till både en bil och laddare som supportar detta.

Försök också att ha i åtanke att dessa scenarion i vissa fall kan vara något extrema och inte nödvändigtvis så ett vehicle-to-grid koncept faktiskt skulle fungera, utan de är formulerade på ett sådant sätt för att fungera ur ett undersökande perspektiv.

Har du några direkta frågor eller funderingar som du vill lyfta innan vi kör igång?

Scenario 1 – Oplanerat ärende och bilen låst (max 10 min)

Scenario: Du har precis kommit hem från jobbet och parkerat din elbil. Du har inte planerat att använda din bil något mer idag och har därför kopplat upp den för att ladda och för att erbjuda bilen som en flexibilitetsresurs. Du ställer dig i köket och börjar laga middag när du plötsligt inser att du saknar ingredienser och skulle behöva ta dig till affären för att handla. Du kommer då på att bilen är låst som flexibilitetsresurs och öppnar appen för att kolla statusen.

1. I appen kan du se att din bil är uppkopplad som flexibilitetsresurs, men du kan inte se hur lång tid det är kvar på sessionen. ***Hur känner du och vad gör du i den här situationen?***

   Om negativa känslor:
   hade du här velat avbryta sessionen och gå miste om ersättningen du skulle fått för din erbjudna tjänst?

   Om man svarar att man tar en annan bil eller hjälp av en annan person:
   Hur hade du agerat om du bara har tillgång till en bil/ bara dig själv, hur hade du agerat då?

   Om man bara har en bil:
   Tror du att du hade känt annorlunda om du hade tillgång till en extra bil?

   I det här scenariot handlade det om att du inte kunde åka till mataffären direkt när du behövde det. ***Hur hade det känts i en annan situation? Hade det varit annorlunda? Varför?***

2. I ett annat scenario där du ställs inför samma situation, så kan du däremot se i appen att bilen utgör en flexibilitetsresurs i 2 timmar till. ***Hur känner du och vad gör du i den här situationen?***

   Om negativa känslor:

hade du här velat avbryta sessionen och gå miste om ersättningen du skulle fått för din erbjudna tjänst?

Om man svarar att man tar en annan bil eller hjälp av en annan person:
Hur hade du agerat om du bara har tillgång till en bil/ bara dig själv, hur hade du agerat då?

Om man bara har en bil:
Tror du att du hade känt annorlunda om du hade tillgång till en extra bil?

I det här scenariot handlade det om att du inte kunde åka till mataffären direkt när du behövde det. ***Hur hade det känts i en annan situation? Hade det varit annorlunda? Varför?***

3. I ytterligare ett annat scenario där du ställs inför samma situation, så kan du fortfarande se i appen hur länge till bilen utgör en flexibilitetsresurs. Den här gången är det 30 minuter till. ***Hur känner du och vad gör du i den här situationen?***

    Om negativa känslor:
    hade du här velat avbryta sessionen och gå miste om ersättningen du skulle fått för din erbjudna tjänst?

    Om man svarar att man tar en annan bil eller hjälp av en annan person:
    Hur hade du agerat om du bara har tillgång till en bil/ bara dig själv, hur hade du agerat då?

    Om man bara har en bil:
    Tror du att du hade känt annorlunda om du hade tillgång till en extra bil?

    I det här scenariot handlade det om att du inte kunde åka till mataffären direkt när du behövde det. ***Hur hade det känts i en annan situation? Hade det varit annorlunda? Varför?***

Om man har svarat att man avbryter på någon utav frågorna ovan:

Nu har vi pratat om vehicle-to-grid, men om vi skulle prata vehicle-to-home i stället, alltså att du använder bilens batteri som en reservenergikälla in i hemmet. Under kapacitetstopparna då elpriset är högt driver du ditt hem med el från din bil, och kan således undvika höga elpriser. ***Om samma situation som vi tidigare pratade om uppstod då din bil var uppkopplad och försörjde ditt hem med el, hade du förhållit dig annorlunda till situationen?***

Om hade förhållit sig annorlunda om det är V2H:
- ***Varför känns det annorlunda vid V2H än V2G?***
- ***Hade V2H överlag varit mer attraktivt än V2G?***

Scenario 2 – Flexibilitet och planering gällande bilanvändning

1. Du är intresserad av att erbjuda din elbil som flexibilitetsresurs och presenteras två olika alternativ från den du säljer tjänsten till:

   Det första alternativet innebär att du lovar att koppla upp din bil som flexibilitetsresurs mellan kl. 18-20 nu på **fredag**. Du behöver binda dig eller göra ändringar till tidsintervallet senast 24h innan.

   Det andra alternativet är att erbjuda bilen som flexibilitetsresurs "på studs", i detta fall strax innan 18 på **fredag**. Detta alternativ innebär att du inte behöver planera i förväg utan kan erbjuda bilen mer spontant när du ser att det passar dig.

   Givet att alternativ 1 är mer fördelaktigt för energibolagen kommer detta att ge en högre ersättning än alternativ 2. Båda alternativen ger dock ersättning.

   Vilket av alternativen hade du valt och varför?

   Följdfrågor:

   Om följdfråga angående hur stor skillnaden är alt. om personen väljer alt. 2:
   Fråga hur stor kompensationen för god framförhållning bör vara för att personen skulle överväga det.

   Om väljer alternativ 1:
   Hur långt innan hade du känt dig bekväm med att lova bort bilen?
   Om ersättningen för de båda alternativen hade varit samma, hade man fortfarande valt att planera eller hade man valt alternativ 2 istället? *

2. ***Hur långa tidsintervall tror du att du skulle ha möjlighet att vara uppkopplad för att erbjuda flexibilitetstjänster?*** (tänk teoretisk och genomsnittligt utifrån ditt dagliga schema)

   Hur långa perioder skulle du vara bekväm med att vara uppkopplad om man var låst under denna tiden?

   I enkäten angav du **"Ja, åtminstone för att täcka kostnaden för investeringen"** gällande ersättning. ***Hur resonerar du kring det?***

   Om man angett att man inte behöver eller är intresserad av finansiell ersättning:
   Luska lite i om brist på finansiell ersättning påverkar deras faktiska flexibilitet, skulle de bidra mer eller mindre än de användare som vill ha finansiell ersättning. Man kan koppla tillbaka till frågan där bilen är låst och man förlorar sin ersättning om man avbryter. Hur hade man ställt sig till det om man inte fick någon ersättning från början.

Scenario 3 – Övriga frågor

1. I enkäten angav du att du behöver ha **"Laddar till 100% och det är en resa som kräver laddstopp. Vid resor under 20-25 mil så behövs ej laddning under resan".** för att känna dig bekväm när du kör iväg med din elbil.
   Vad i procent motsvarar detta en dag då du åker ska åka ett mindre ärende?
   Hur skulle det kännas om du inte hade fullt?

   Efter en avlutad V2G session, ***hur skulle du ställa dig till att ha en lägre state of charge än detta?*** Det är ju inte säkert att du kommer behöva bilen precis efteråt.

2. En utav farhågorna för V2G som finns bland användare är att man är orolig för att bilen inte kommer att ha tillräckligt med state of charge när man behöver bilen nästa gång. ***Givet detta, hur hade du känt kring att det finns en förutbestämd miniminivå för bilens state of charge efter en V2G session? Hade det minskat oron?***

   Hade denna gränsen kunnat vara fabriksinställd på ex. 30%, eller hade du själv behövt kunna ställa in den efter din körning för att det ska kännas tryggt?

3. ***Hur ställer du dig till att avstå från vissa resor för att ha mer energi kvar i batteriet och kunna bidra med mer när du väl är uppkopplad?*** *Ex avstå från att köra till mataffären och handla under eftermiddags toppen och istället låta bilen var uppkopplad de timmarna (du handlar någon annan tidpunkt)*

   Hade du mot högre ersättning tänkt annorlunda angående din planering och kunnat avstå visa resor, i så fall hur resonerar du?

4. ***Hur hade du ställt dig till att planera om dina körningar på ett sådant sätt att du laddar på andra ställen?*** Exempelvis genom att börja ladda på jobbet för att ha mer batterikapacitet när du påbörjar vehicle-to-grid sessionen när du kommer hem.

   Hade du mot högre ersättning tänkt annorlunda angående din planering och kunnat avstå visa resor, i så fall hur resonerar du?

5. ***Givet allt vi har pratat om idag, skulle du kunna se tekniken i din vardag?***
   Om ja, på viket sett/hur ser du att v2g skulle finnas eller fungera i din vardag?
   Om nej, varför? Hur ser du på tekniken?
   Överlag: Lämna utrymme här för om de har allmänna åsikter om tekniken eller dylikt

6. ***Givet att tekniken finns på marknaden, hur hade du velat styra och hålla koll på din laddning och flextjänster? Exempel. Om en applikation, vem är aktören bakom?***

Avslutning

Det var alla frågor från vår sida, är det någonting du upplever att vi har missat eller något annat som du vill ta upp?

Får vi lov att höra av oss till dig för senare steg i vår studie?

Tack och hej!

Appendix E – Interview Guide for Workshop with Users

Del 1. Introduktion

Hej och välkomna!

Roligt att ni ville ställa upp på den här workshopen. Det hjälper vårt arbete jättemycket så vi är väldigt tacksamma för att ni tar er tid.

Workshopen kommer bestå av tre delar. Först en individuell reflektion, följt av en gruppreflektion och därefter lägga lite tid på att tillsammans skapa och vidareutveckla koncept.

Vi kommer förklara efter hand vad exakt ni förväntas göra, men har ni några frågor så får ni givetvis avbryta och fråga.

Vi kommer arbeta i ett verktyg som heter Mural.
I teams chatten hittar ni nu en länk, som ni ska gå in på och få tillgång till vår gemensamma arbetsyta.

https://app.mural.co/t/aliceevertsson6531/m/aliceevertsson6531/1712565283994/b7858eae97a7a76e1d5849e3069e9cb65e304baf?sender=ua4f67397fd1b9db5ea323362

Har alla kommit in på länken?
Ni navigerar enkelt genom att "klicka och dra" med musen...

Del 2. Individuell reflektion

Vi börjar direkt med den första delen som är en individuell reflektion. Navigera till den arbetsyta som har ert namn. Ni ska bara arbeta i er egen yta.

Ni får gärna börja med att läsa igenom att läsa instruktionerna men i stora drag kommer ni i den här delen presenteras fem olika potentiella V2G-koncept. Ni läser igenom ett koncept och svarar därefter på en liten reflektion som ligger under varje koncept.

När ni har tagit er igenom alla fem koncept kommer ni till en sektion där ni ombes att samla era tankar för den efterkommande gruppdiskussionen. Fundera här på om ni har något koncept ni föredrar och varför, men fundera även på hur koncepten skiljer sig åt och hur de förhåller sig till varandra.

Ni har 20 minuter på er och vi rekommenderar att ni lägger ca 3 minuter per koncept och sedan 5 minuter på slutreflektionen. Vi kommer att säga till var 5:e minut för att hjälpa er att hålla koll. Vi vet att det är ganska mycket att läsa igenom och reflektera kring, men kom ihåg att ni inte behöver ge det mest utförliga och genomtänkta svaret utan vi är intresserade av era initiala tankar och känslor.

Så om ni är redo så börjar era 20 min nu.

Del 3. Gruppdiskussion

Nu när ni har fått reflektera över de fem koncepterna individuellt ska vi diskutera dem i grupp och om ni vill kan ni använda era anteckningar från den individuella reflektionen som stöd.

Innan vi går vidare skulle vi vilja fråga om det är okej att vi spelar in under resten av workshopen. Detta för att enklare kunna gå tillbaka och höra era resonemang i efterhand så vi kan vara mer närvarande här under workshopen

- ***Vilket av koncepten upplever du skulle fungera bäst? Varför? (rikta frågan till en specifik person)***
- ***Finns det något element i något av konceptet som skulle vara avgörande för att du faktiskt inte skulle använda tjänsten?***

Del 4. Co-creation

Nu går vi över till den mer kreativa delen av workshopen.

Tillsammans utgör ni 4 och Alexandra nu ett designteam med uppgiften att utveckla det vi tycker är det mest optimala V2G konceptet.

Först kommer vi börja med en snabb idégenerering. Ni ska tillsammans skriva ner de saker som ni finner är de viktigaste att ha med i en V2G lösning på de gula post-it lapparna. Vi kommer ta 5 minuter till att göra detta.

sätt timer på 5 min Genomför steg A

Bra... Nu ska vi utifrån detta sätta ihop ett helt koncept. Ni har en uppsättning dekaler och ikoner att tillgå för att enkelt kunna visualisera era idéer.

Det är viktigt att vi samarbetar och det går hur bra som helst att testa olika idéer, göra om och testa olika alternativ.

Till detta kommer ni att ha 15 minuter till ert förfogande innan vi sammanfattar och avslutar.

sätt timer på 15 min

Okej där var tiden slut.
sätt timer på 5 min

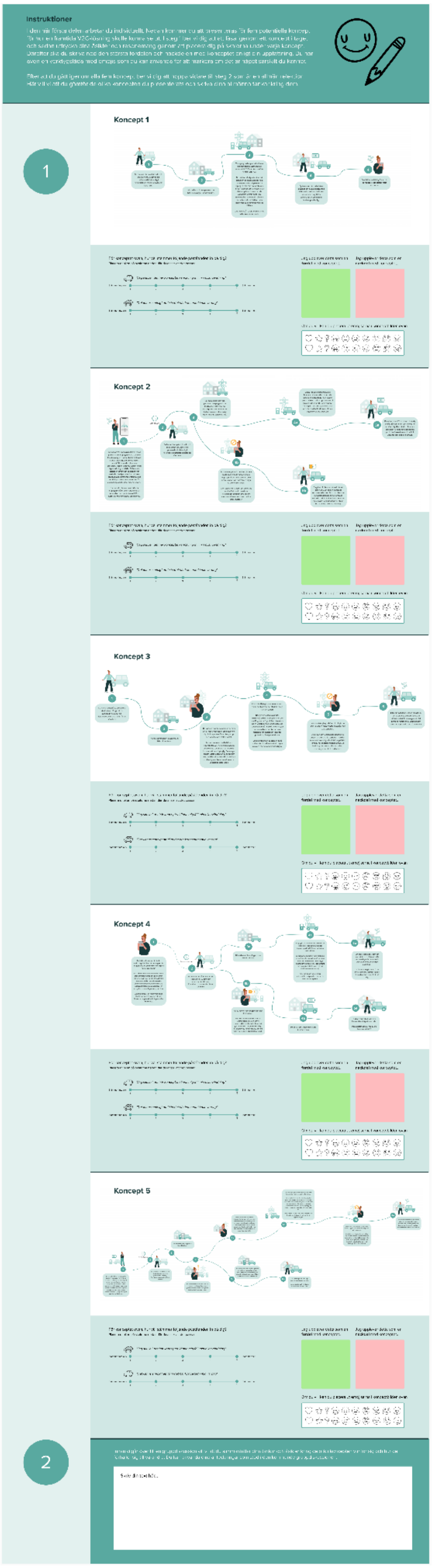
- ***Vad skulle ni säga är det som gör ert koncept till det ultimata konceptet?***
- ***Hur skiljer det sig från koncepten ni presenterades för i början av workshopen?***

Del 5. Avslut

Tack för en väl genomförd workshop. Vi kommer nu under eftermiddagen skicka ut en inbjudan till nästa utvärderingstillfälle där ni kan boka en intervjutid som passar er. Ni kommer att få en biobiljett även för det tillfället om ni ställer upp där.

Är det något ni skulle vilja ta upp? Några reflektioner som dykt upp?

Appendix F – The Workspace from the Focus Group



Appendix G – The Workspace from the Co-creation Session

Appendix H – Interview Guide for Final User Testing

Introduktion

Hej och välkommen till dagens intervju och stort tack för att du återigen ställer upp.

Sedan sist vi sågs har vi arbetat vidare med vårt projekt och början nu närma oss slutet. Baserat på resultat och feedback både från enkät, djupintervjuer samt en fokusgrupp har vi nu tagit fram ett potentiellt framtida koncept som vi vill ha din hjälp att utvärdera.

Det kommer gå till som så att vi kommer presentera några olika scenarios för dig och du kommer få interagera med en app-prototyp. Vi kommer både be dig göra specifika saker samt själv få välja hur du interagerar. Vi kommer ställa några frågor allt efter hand och i slutet kommer det finnas tid till om du har andra åsikter och tankar.

Vi tänker att vi börjar med en kort introduktion till appen. Vi kommer nu att visa kortfattat hur den fungerar och vilka funktioner den har. Tanken med detta är att du inför de kommande scenarierna ska vara väl förtrogen med appen.

* Skärmdelar och ger introduktion till appen

Del 1 – Set Up

* Innan vi fortsätter vill vi fråga om vi får spela in under resten av intervjun

Nu börjar vi med scenarios och du kommer få interagera själv med appen.

* skickar länk till figma till användaren

Du har precis skaffat utrustning för att kunna stödja elnätet genom V2G och har laddat ner den tillhörande appen/ add on till din nuvarande bil-app.

Innan du startar upp och börjar använda allt behöver du göra en liten set-up för att få de inställningar som passar dig bäst.

Öppna länken och när du fått upp fönstret skulle vi vilja be dig dela din skärm.

Okej nu är det fritt fram att börja läsa och klicka sig igenom denna kortfattade set-up'en... Du får mer än gärna genom hela intervjuns gång försöka tänka högt och ta oss igenom din tankeprocess när du interagerar med appen.

* noterar vilket mode användaren väljer för att sedan skicka den figma prototyp som motsvarar det mode'et

Little to no interaction

Nu går ni över till nästa del och lite fler scenarios och du har fått en ny länk skickad till dig. Öppna den och dela därefter din skärm...

Del 2 - Everyday Mode

Tänk dig att du har varit ute på ett ärende och sätter dig i bilen för att köra hem. När du kommer hem sätter du in laddsladden. Eftersom du valde att du vill ha "little to no interaction" i set-up'en kommer bilen så fort det finns ett behov att koppla upp sig till gridet.

Du har fullt upp med dina sysslor och aktiviteter och behöver inte interagera med appen för att styra någonting. När du kommer på att du behöver åka iväg med bilen går du bara ut till den som vanligt och kör iväg. Du kommer i slutet av varje månad erhålla ersättning för det du bidragit med.

- ***Tror du att du någon gång skulle känna ett behov att använda appen av någon anledning? (ex kolla laddnivå eller v2g). Varför?***
- ***Skulle du vilja redigera dina personliga inställningar för hur konceptet fungerar? Varför? Hur då?***
- ***Upplever du att det är någonting som saknas?***

Del 3 - Long Distance Driving Mode

I nästa scenario har du planerat att du att resa bort över helgen. Du kommer köra en längre sträcka och behöver därför ha tillräckligt med batteri....

- ***Vad gör du? (Ändrar du mode? Ställer du in högre laddnivå? Eller timer?)***
- ***Aktiverar användaren modet? Varför? Varför inte?***

Du har nu kommit hem igen och återgår till din vardag...

- ***Vad gör du nu?***

Long Distance Driving modet är aktiverat tills dess att man avaktiverar det/aktiverar ett annat mode.

- ***Kommer användaren ihåg att avaktivera modet? Är detta ett smidigt sätt?***

Del 4 - Grid Optimisation Mode

I det här caset ska du och din familj iväg på semester. Ni åker iväg den 4:e maj och kommer vara borta till den 11 maj, dvs en vecka. Bilen är hemma hela tiden och kommer inte användas av någon.

- ***Hur resonerar du i det här fallen?***
- ***Planerar användaren in en session på Grid Optimisation Mode? Om ja, vad driver dem? Hur resonerar dem? Om nej, varför inte?***
- ***Vad tycker du om funktionen "Grid Optimisation Mode"? Vad tycker du om att det planera och tidssätts i ett intervall? Poäng med grid optimasation spontant?***

Medium Interaction

Nu går ni över till nästa del och lite fler scenarios och du har fått en ny länk skickad till dig. Öppna den och dela därefter din skärm...

Del 2 - Everyday Mode

Du har nu varit ute på ett ärende och sätter dig i bilen för att åka hem. När du kommer hem parkerar du din bil och pluggar in laddsladden. Du vet med dig att du inte kommer använda bilen något mer idag så du öppnar appen för att koppla upp den till nätet...

- ***Hur känns det att starta V2G såhär, dvs att själv behövs koppla upp sig? Hade du velat ändra inställningarna?***

Din bil är uppkopplad och stöttar nätet vid behov.

Nästa morgon behöver du bilen och du måste avsluta uppkopplingen.

- ***Skulle du föredra att bara dra ur laddsladden till bilen eller kan du tänka dig att avsluta uppkopplingen i appen på samma sätt som du startade den?***

Del 3 - Long Distance Driving Mode

I nästa scenario har du planerat att du att resa bort över helgen. Du kommer köra en längre sträcka och behöver därför ha tillräckligt med batteri....

- ***Vad gör du? (Ändrar du mode? Ställer du in högre laddnivå? Eller timer?)***
- ***Aktiverar användaren modet? Varför? Varför inte?***

Du har nu kommit hem igen och återgår till din vardag...

- ***Vad gör du nu?***

Long Distance Driving modet är aktiverat tills dess att man avaktiverar det/aktiverar ett annat mode.

- ***Kommer användaren ihåg att avaktivera modet? Är detta ett smidigt sätt?***

Del 4 - Grid Optimisation Mode

I det här caset ska du och din familj iväg på semester. Ni åker iväg den 4:e maj ock kommer vara borta till den 11 maj, dvs en vecka. Bilen är hemma hela tiden ock kommer inte användas av någon.

- ***Hur resonerar du i det här fallen?***
- ***Planerar användaren in en session på Grid Optimisation Mode? Om ja, vad driver dem? Hur resonerar dem? Om nej, varför inte?***
- ***Vad tycker du om funktionen "Grid Optimisation Mode"? Vad tycker du om att planera och tidssätts i ett intervall? Poäng med grid optimasation spontant?***

High Interaction

Nu går ni över till nästa del och lite fler scenarios...

Everyday Mode

Du står parkerad på en parkering med laddmöjligheter och eftersom du har valt att ha på notiser för du en notis om att det finns laddare i närheten samt att det är ett bra läge att ladda då elen är billig.

- ***Vad gör du? Hur resonerar du?***

Det är ett annat tillfälle och du har varit ute på ett ärende och sätter dig i bilen för att åka hem. När du kommer hem parkerar du din bil och pluggar in laddsladden.

Några timmar senare under eftermiddagen får du en notis i din mobil. Notiser informerar dig om att det förväntas komma en effekttopp och undrar om du vill koppla upp din bil för att supporta elnätet. Du vet att du inte kommer använda bilen något mer idag så du klickar på notisen och din bil app öppnas.

- ***Vad gör du?***

Din bil är uppkopplad och stöttar nätet vid behov.

Nästa morgon behöver du bilen och du måste avsluta uppkopplingen.

- ***Skulle du föredra att bara dra ur laddsladden till bilen eller kan du tänka dig att avsluta uppkopplingen i appen på samma sätt som du startade den?***

I slutet av varje vecka får du en notis med en vecko-summering över ditt bilanvändande och "V2G-ande"... du klickar på den och får upp detaljerna...

- ***Hur upplevde du detta?***
- ***Tror du att veckosummerignar skulle motivera dig eller vara intressanta att se?***

Del 3 - Long Distance Driving Mode

I nästa scenario har du planerat att du att resa bort över helgen. Du kommer köra en längre sträcka och behöver därför ha tillräckligt med batteri....

- ***Vad gör du? (Ändrar du mode? Ställer du in högre laddnivå? Eller timer?)***
- ***Aktiverar användaren modet? Varför? Varför inte?***

Du har nu kommit hem igen och återgår till din vardag...

- ***Vad gör du nu?***

Long Distance Driving modet är aktiverat tills dess att man avaktiverar det/aktiverar ett annat mode.

- ***Kommer användaren ihåg att avaktivera modet? Är detta ett smidigt sätt?***

Del 4 - Grid Optimisation Mode

I det här caset ska du och din familj iväg på semester. Ni åker iväg den 4:e maj och kommer vara borta till den 11 maj, dvs en vecka. Bilen är hemma hela tiden och kommer inte användas av någon.

- ***Hur resonerar du i det här fallen?***
- ***Planerar användaren in en session på Grid Optimisation Mode? Om ja, vad driver dem? Hur resonerar dem? Om nej, varför inte?***
- ***Vad tycker du om funktionen "Grid Optimisation Mode"? Vad tycker du om att planera och tidssätts i ett intervall? Poäng med grid optimasation spontant?***

Del 5 – Generella frågor

- ***Hur upplevde du de olika "modesen"? Tror du att du hade använt dem?***
- ***Är det någonting du saknar i det här lösningsförslaget?***
  - ***Inställningar? Funktioner?***
  - ***Eller känner du att du kan skräddarsy konceptet så att det passar i din vardag?***
- ***Vad tycker du på en generell nivå om att ha V2G funktionerna integrerade i samma app som bil funktionerna?***
  - ***Smidighet?***
- ***Hur intressant tror du att du skulle tycka det skulle vara att följa och hålla koll på din statistik?***

    - ***Skulle du gå in och titta på din statistik?***
    - ***Skulle detta motivera dig till att vilja bidra mer?***
    - ***Någon form av statistik du saknar?***
    - ***Finner du det mer intressant med statistik som rör dit bilanvändande, laddning eller V2G?***
- ***Hur resonerade du gällande ersättningen? Varför valde du den typ av ersättning som du gjorde?***
- ***Något annat du vill tillägga?***

Appendix I - Interest in V2G

Interest EV drivers VS non-EV drivers

	Numbers of responses	*Intrest Average*	*Interest Median*
Non-EVs	18	4	4,5
EVs	152	4,1	4

Interest based on traveling behaviour (both EVs & non-EVs)

	Numbers of responses	*Intrest Average*	*Interest Median*
Trips to and from work	54	4.1	4
Trips providing rides to other household members for work, school or preschool	3	2.7	3
Trips to and from leisure activities	8	4.4	4.5
Planned errands	10	3.2	3
Short, unplanned trips	5	5	5
Mixed types of trips	87	4.1	5

Interest based on living area

	Numbers of responses	*Intrest Average*	*Interest Median*
City	46	3.8	4
Förort	65	4.2	5
Landsbygd	60	4.1	4

Interest based on type of residence

	Numbers of responses	*Intrest Average*	*Interest Median*
Villa	107	4.2	5
Apartament	38	4.1	4
Farm	11	4.3	5
Townhouses	13	3.2	3
Semi-detached houses	2	2.5	2.5

Interest based on living situation (living area & residence type)

	Numbers of responses	Intrest Average	Interest Median
gård landsbygd	9	4.3	5
lägenhet landsbygd	1	6	6
radhus landsbyggd	1	4	4
villa landsbyggd	47	4	4
gård förort	1	5	5
lägenhet förort	12	3.9	4
radhus förort	8	2.8	3
villa förort	44	4.3	5
lägenhet city	22	4	4.5
parhus city	2	2.5	2.5
radhus city	4	3.8	3.5
villa city	15	4.8	5

Interest based on charging habits

	Numbers of responses	Intrest Average	Interest Median
Has a charging station at home and does all their charging at home.	73	4	4
Has a charging station at home and does the majority of their charging at home.	28	4.5	5
Has a charging station at home but charges at different locations.	28	4.4	5
Does not have a charging station at home but charges only at home.	5	5	5
Does not have a charging station at home and does the majority of their charging at the workplace.	7	4.4	5
Does not have a charging station at home and charges at different locations.	7	2.1	2
Does not have a charging station at home and does all their charging at other parking areas (supermarkets, gyms, etc.).	3	4.7	5

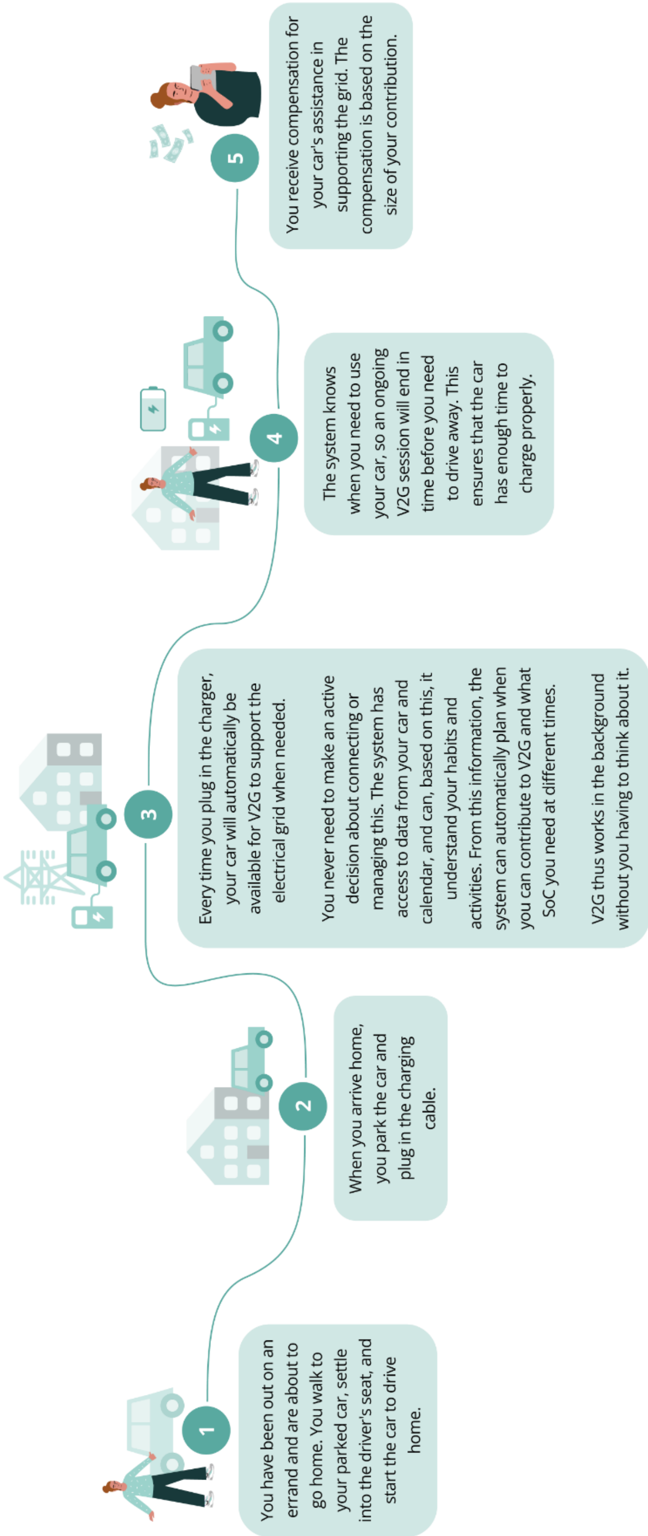
Appendix J – List of User Requirements

	Requirement	Corresponding User(s)
1	Facilitate user adoption of the technology and connection to V2G.	Reluctant Rose
2	Provide confirmation acknowledging the user's contribution to stabilising the grid and benefiting society.	Reluctant Rose
3	Enable users to earn money through V2G.	Reluctant Rose
4	Offer the ability to terminate a V2G session.	Reluctant Rose, Careful Carl, Idealistic Isabella, Tech-Savvy Thomas
5	Provide information on State of Charge (SoC) before, during, and after a V2G session.	Reluctant Rose
6	Ensure a specified charging level during and after a V2G session.	Reluctant Rose, Careful Carl, Idealistic Isabella, Tech-Savvy Thomas
7	Provide motivation for why an individual user should join.	Reluctant Rose
8	Enable understanding of why the user is important for the system.	Careful Carl
9	Facilitate decision-making regarding V2G usage for the user.	Careful Carl
10	Enable understanding of why V2G is important for the energy system.	Careful Carl
11	Offer compensation that offsets the investment.	Careful Carl, Idealistic Isabella, Tech-Savvy Thomas
12	Clearly communicate the costs, requirements, and offered compensation.	Careful Carl, Idealistic Isabella
13	Communicate service setup, payment models, and future forecasts.	Careful Carl, Idealistic Isabella, Tech-Savvy Thomas
14	Reinforce the user's feeling of contribution.	Idealistic Isabella
15	Communicate how the user contributes.	Idealistic Isabella
16	Clearly indicate how users can contribute more.	Idealistic Isabella
17	Clearly communicate the status of energy supply and demand.	Idealistic Isabella
18	Specify which stakeholders are involved, who profits from the services, and by how much.	Idealistic Isabella
19	Further requirements for a "fair" cost model where the user/service provider is the major financial beneficiary, not an intermediary.	Idealistic Isabella
20	Enhance the feeling of being part of new innovative technology.	Tech-Savvy Thomas
21	Facilitate integration of other electronics/services/features in the user's home.	Tech-Savvy Thomas
22	Consider system integration, with the potential to connect to other solutions and services in the future.	Tech-Savvy Thomas
23	Enable integration with home or other products.	Self-sufficient Sara
24	Provide a cost model that offsets the expenses of V2G.	Self-sufficient Sara
25	Clearly communicate how the user contributes to grid stabilisation and society.	Self-sufficient Sara
26	Enable users to be informed, control, and plan State of Charge (SoC).	Self-sufficient Sara

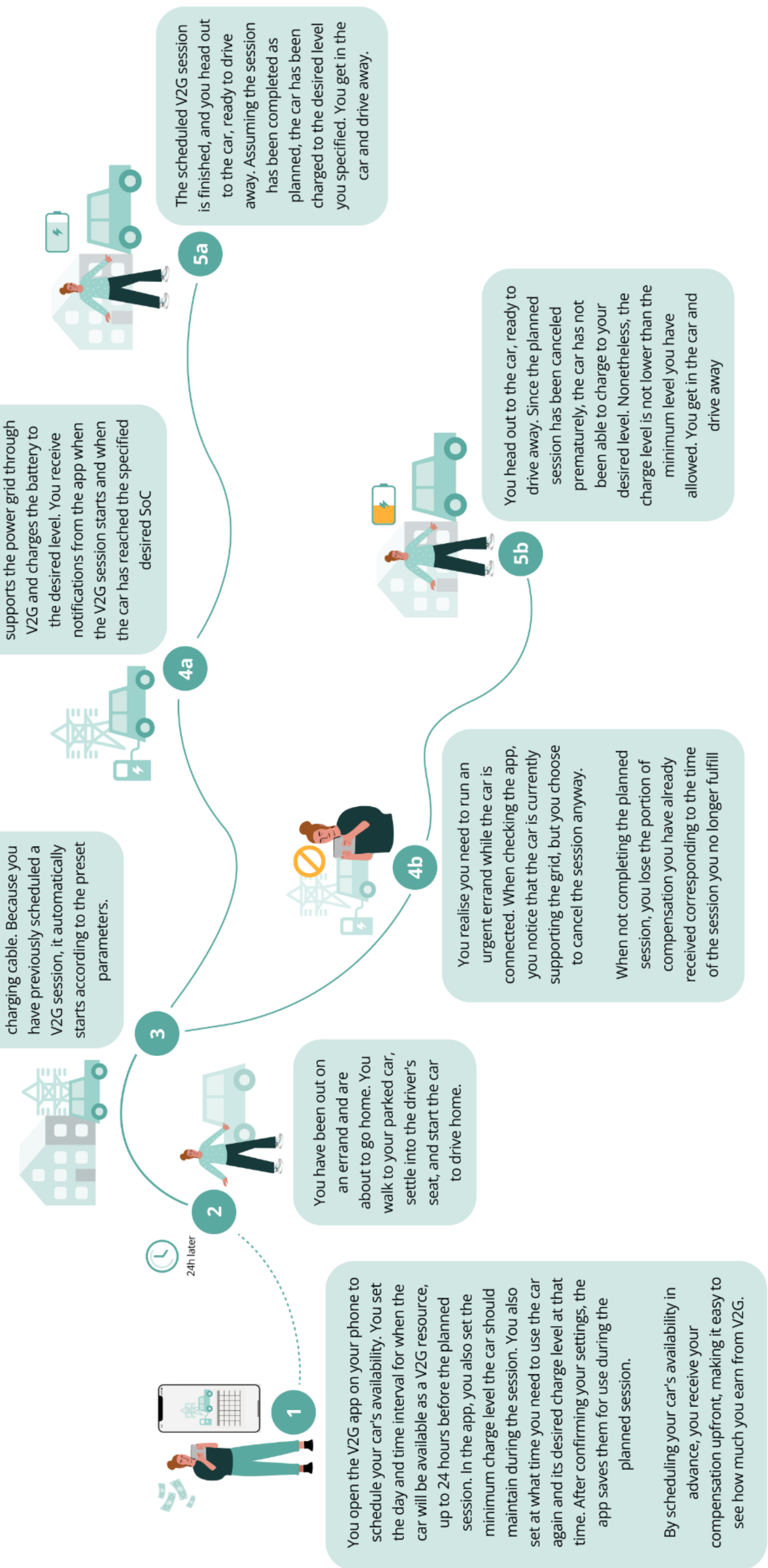
Reluctant Rose · Careful Carl · Idealistic Isabella · Tech-Savvy Thomas · Self-sufficient Sara

Appendix K – The User Journeys of the Five Initial Concepts

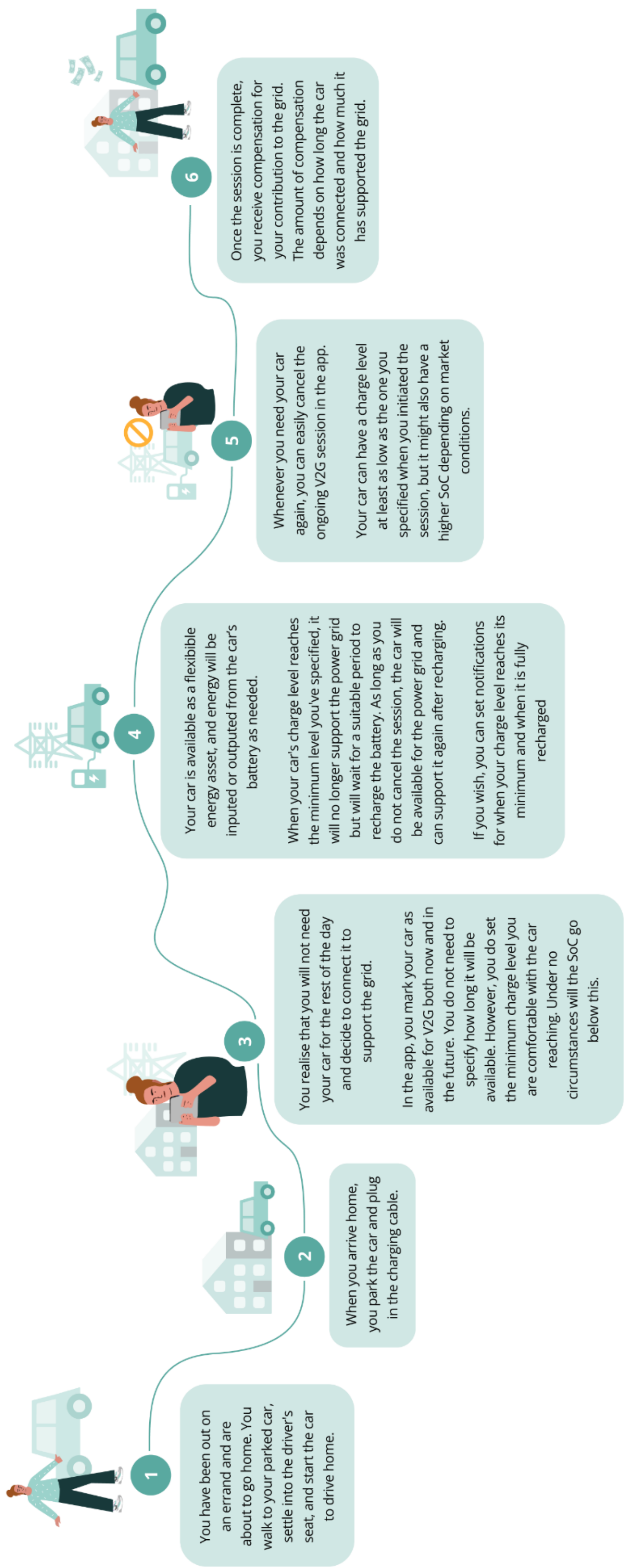
Concept 1



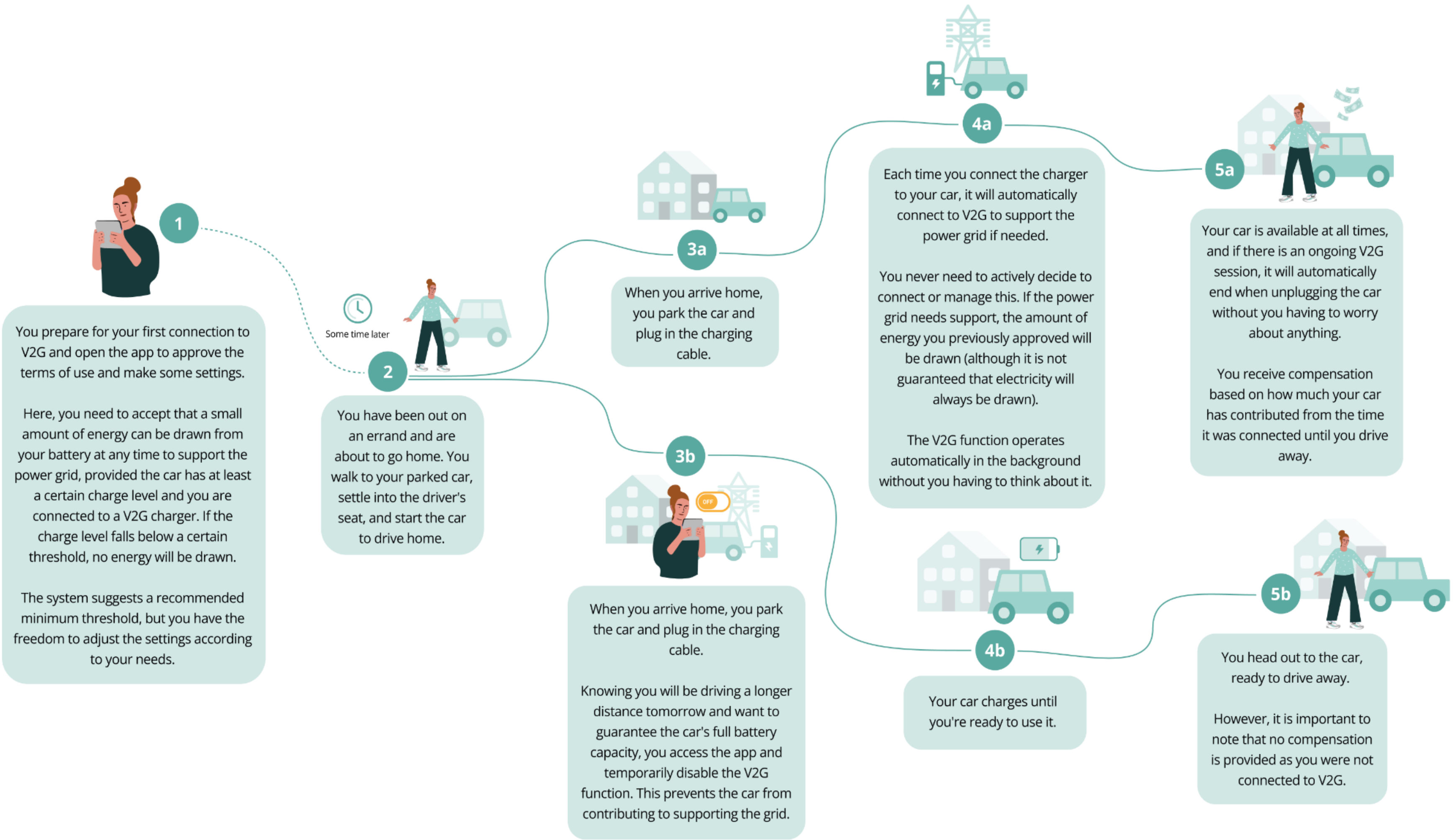
Concept 2


1
You open the V2G app on your phone to schedule your car's availability. You set the day and time interval for when the car will be available as a V2G resource, up to 24 hours before the planned session. In the app, you also set the minimum charge level the car should maintain during the session. You also set at what time you need to use the car again and its desired charge level at that time. After confirming your settings, the app saves them for use during the planned session.
By scheduling your car's availability in advance, you receive your compensation upfront, making it easy to see how much you earn from V2G.
24h later
2
You have been out on an errand and are about to go home. You walk to your parked car, settle into the driver's seat, and start the car to drive home.
3
When you arrive home, you park the car and plug in the charging cable. Because you have previously scheduled a V2G session, it automatically starts according to the preset parameters.
4a
The car remains connected throughout the scheduled time interval. During this period, it supports the power grid through V2G and charges the battery to the desired level. You receive notifications from the app when the V2G session starts and when the car has reached the specified desired SoC
5a
The scheduled V2G session is finished, and you head out to the car, ready to drive away. Assuming the session has been completed as planned, the car has been charged to the desired level you specified. You get in the car and drive away.
4b
You realise you need to run an urgent errand while the car is connected. When checking the app, you notice that the car is currently supporting the grid, but you choose to cancel the session anyway.
When not completing the planned session, you lose the portion of compensation you have already received corresponding to the time of the session you no longer fulfill
5b
You head out to the car, ready to drive away. Since the planned session has been canceled prematurely, the car has not been able to charge to your desired level. Nonetheless, the charge level is not lower than the minimum level you have allowed. You get in the car and drive away

Concept 3

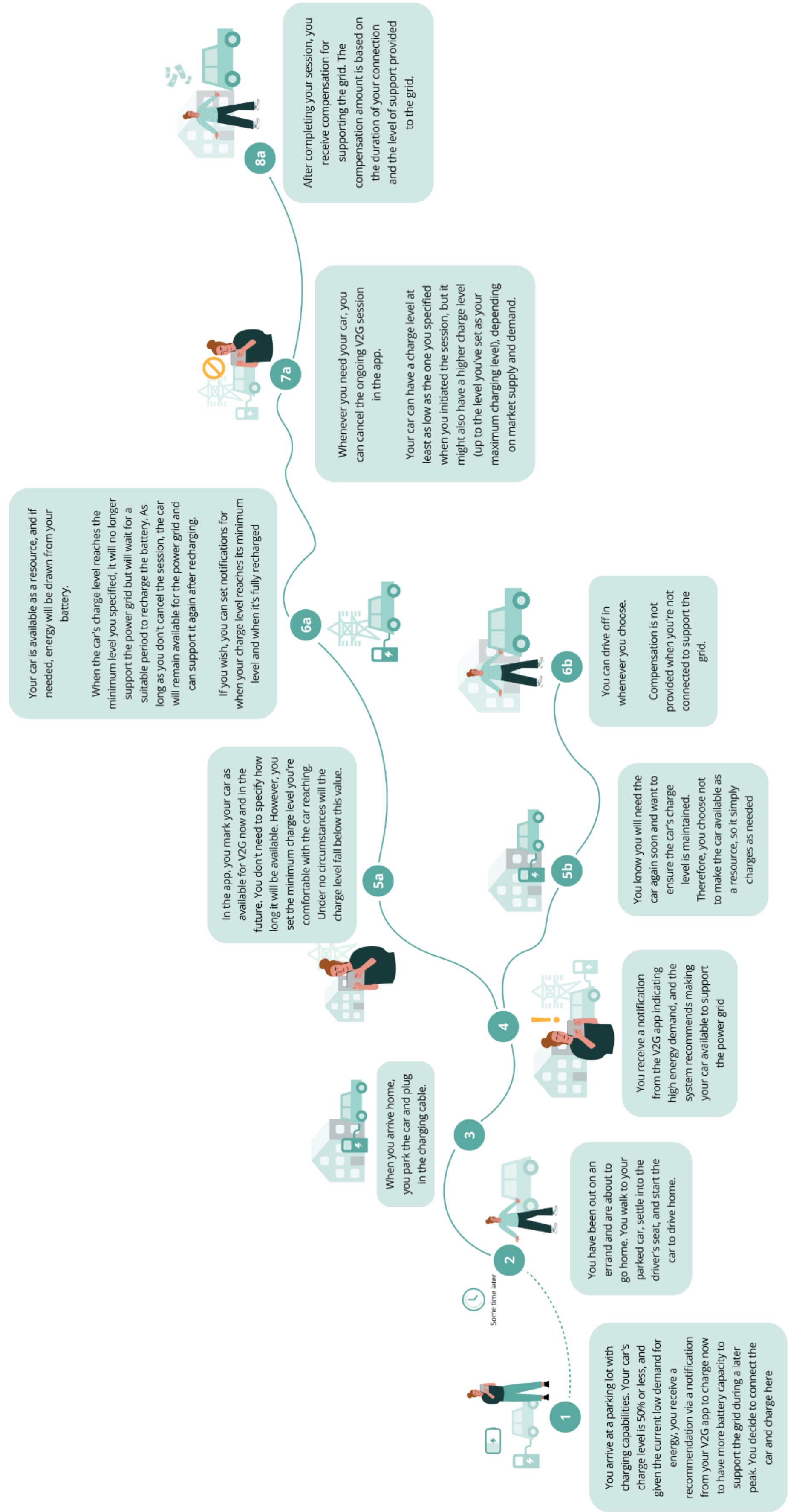

1
You have been out on an errand and are about to go home. You walk to your parked car, settle into the driver's seat, and start the car to drive home.
2
When you arrive home, you park the car and plug in the charging cable.
3
You realise that you will not need your car for the rest of the day and decide to connect it to support the grid.
In the app, you mark your car as available for V2G both now and in the future. You do not need to specify how long it will be available. However, you do set the minimum charge level you are comfortable with the car reaching. Under no circumstances will the SoC go below this.
4
Your car is available as a flexibile energy asset, and energy will be inputed or outputed from the car's battery as needed.
When your car's charge level reaches the minimum level you've specified, it will no longer support the power grid but will wait for a suitable period to recharge the battery. As long as you do not cancel the session, the car will be available for the power grid and can support it again after recharging.
If you wish, you can set notifications for when your charge level reaches its minimum and when it is fully recharged
5
Whenever you need your car again, you can easily cancel the ongoing V2G session in the app.
Your car can have a charge level at least as low as the one you specified when you initiated the session, but it might also have a higher SoC depending on market conditions.
6
Once the session is complete, you receive compensation for your contribution to the grid. The amount of compensation depends on how long the car was connected and how much it has supported the grid.

Concept 4



1
You prepare for your first connection to V2G and open the app to approve the terms of use and make some settings.
Here, you need to accept that a small amount of energy can be drawn from your battery at any time to support the power grid, provided the car has at least a certain charge level and you are connected to a V2G charger. If the charge level falls below a certain threshold, no energy will be drawn.
The system suggests a recommended minimum threshold, but you have the freedom to adjust the settings according to your needs.
Some time later
2
You have been out on an errand and are about to go home. You walk to your parked car, settle into the driver's seat, and start the car to drive home.
3a
When you arrive home, you park the car and plug in the charging cable.
3b
OFF
When you arrive home, you park the car and plug in the charging cable.
Knowing you will be driving a longer distance tomorrow and want to guarantee the car's full battery capacity, you access the app and temporarily disable the V2G function. This prevents the car from contributing to supporting the grid.
4a
Each time you connect the charger to your car, it will automatically connect to V2G to support the power grid if needed.
You never need to actively decide to connect or manage this. If the power grid needs support, the amount of energy you previously approved will be drawn (although it is not guaranteed that electricity will always be drawn).
The V2G function operates automatically in the background without you having to think about it.
4b
Your car charges until you're ready to use it.
5a
Your car is available at all times, and if there is an ongoing V2G session, it will automatically end when unplugging the car without you having to worry about anything.
You receive compensation based on how much your car has contributed from the time it was connected until you drive away.
5b
You head out to the car, ready to drive away.
However, it is important to note that no compensation is provided as you were not connected to V2G.

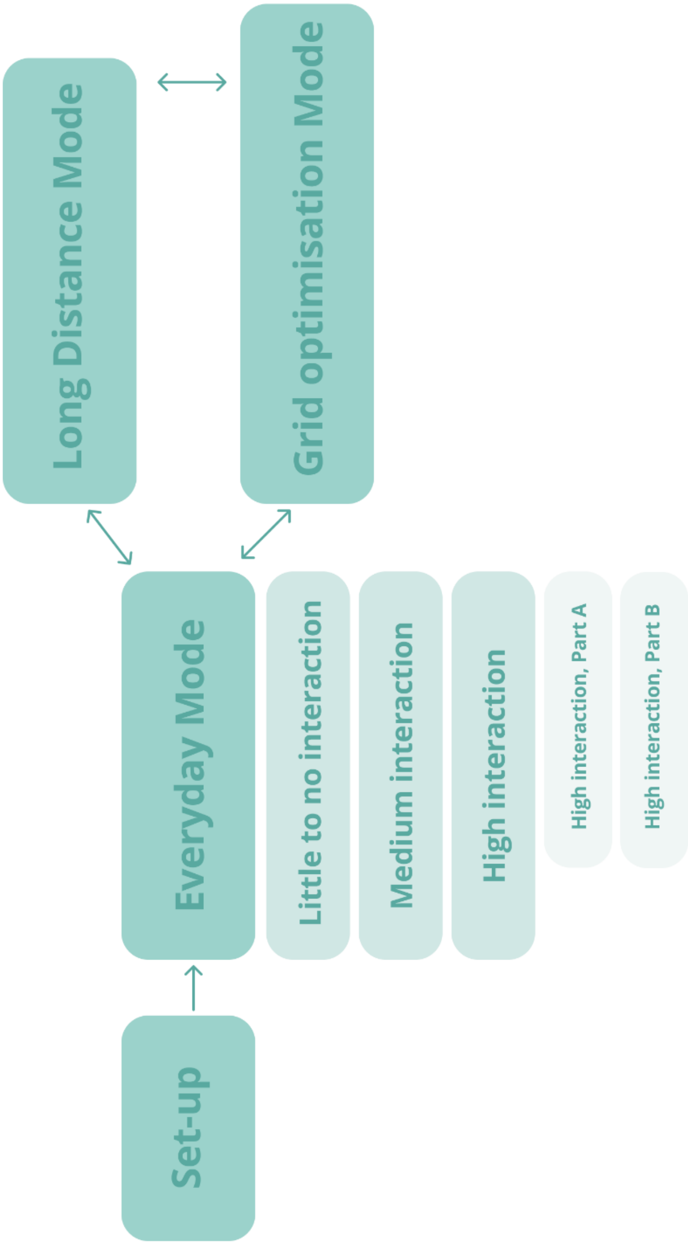
Concept 5



1
You arrive at a parking lot with charging capabilities. Your car's charge level is 50% or less, and given the current low demand for energy, you receive a recommendation via a notification from your V2G app to charge now to have more battery capacity to support the grid during a later peak. You decide to connect the car and charge here
Some time later
2
You have been out on an errand and are about to go home. You walk to your parked car, settle into the driver's seat, and start the car to drive home.
3
When you arrive home, you park the car and plug in the charging cable.
4
You receive a notification from the V2G app indicating high energy demand, and the system recommends making your car available to support the power grid
5a
In the app, you mark your car as available for V2G now and in the future. You don't need to specify how long it will be available. However, you set the minimum charge level you're comfortable with the car reaching. Under no circumstances will the charge level fall below this value.
5b
You know you will need the car again soon and want to ensure the car's charge level is maintained. Therefore, you choose not to make the car available as a resource, so it simply charges as needed
6a
Your car is available as a resource, and if needed, energy will be drawn from your battery.
When the car's charge level reaches the minimum level you specified, it will no longer support the power grid but will wait for a suitable period to recharge the battery. As long as you don't cancel the session, the car will remain available for the power grid and can support it again after recharging.
If you wish, you can set notifications for when your charge level reaches its minimum level and when it's fully recharged
6b
You can drive off in whenever you choose.
Compensation is not provided when you're not connected to support the grid.
7a
Whenever you need your car, you can cancel the ongoing V2G session in the app.
Your car can have a charge level at least as low as the one you specified when you initiated the session, but it might also have a higher charge level (up to the level you've set as your maximum charging level), depending on market supply and demand.
8a
After completing your session, you receive compensation for supporting the grid. The compensation amount is based on the duration of your connection and the level of support provided to the grid.

Appendix L – The User Journey of the Final Concept

Overview of Final Concept Journey

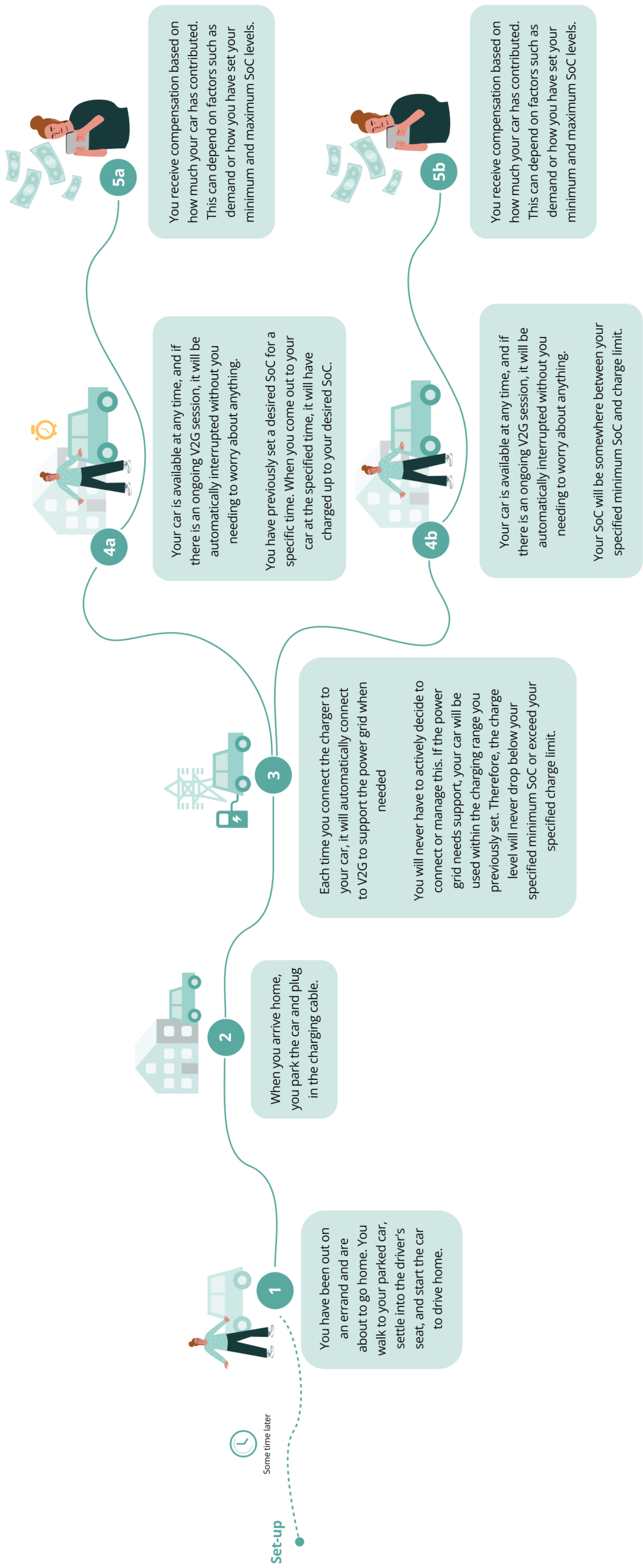


The Set-up

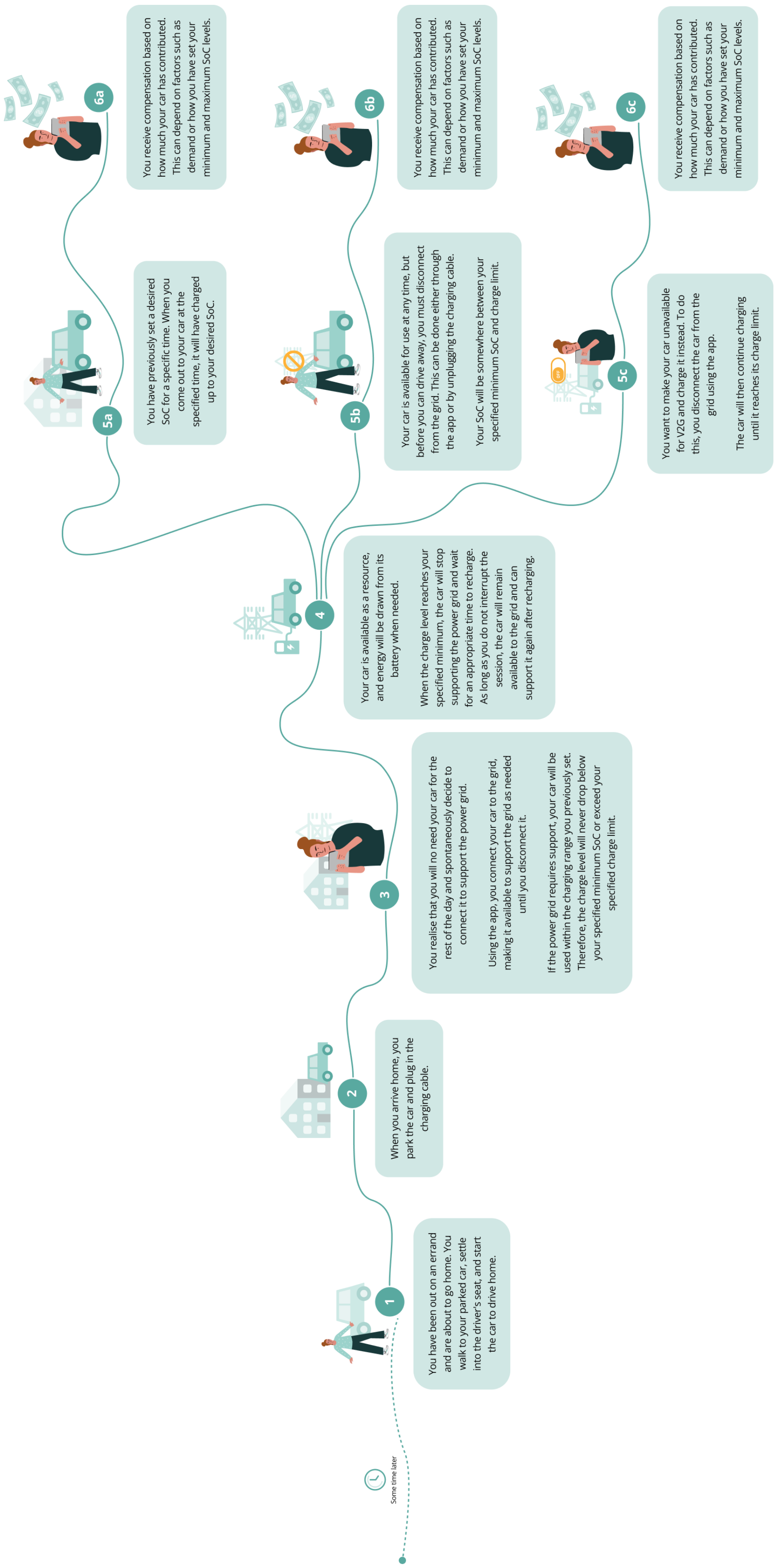
You have acquired a V2G system and now need to complete a setup before you can get started. You do this by downloading the associated app and following the instructions to set your personal preferences.

An important decision you need to make is how much interaction you want with the app and how automated you want the V2G system to be. This includes how to connect and disconnect V2G, as well as how many notifications and how much information you want to receive.

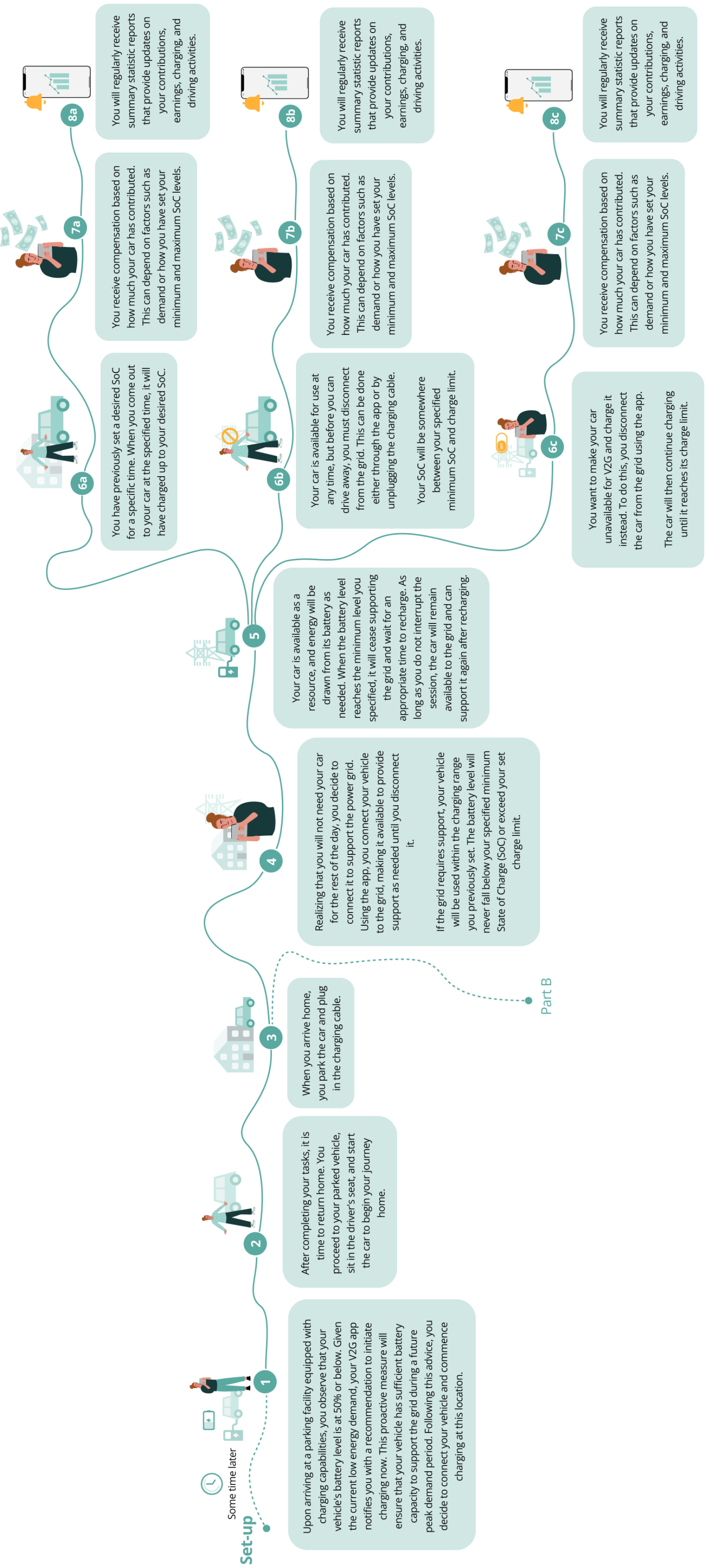
Everyday Mode – Little to No Interaction



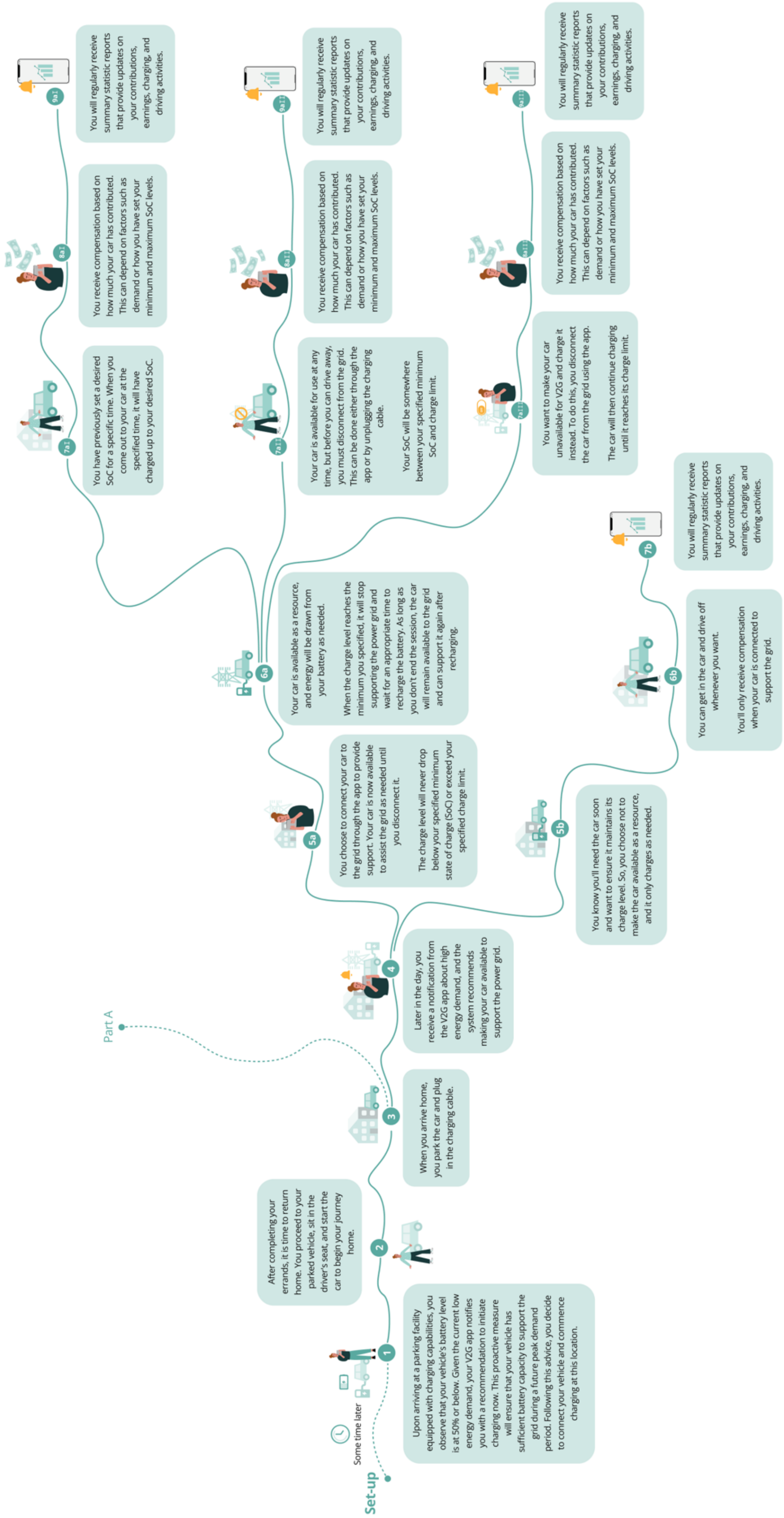
Everyday Mode – Medium Interaction



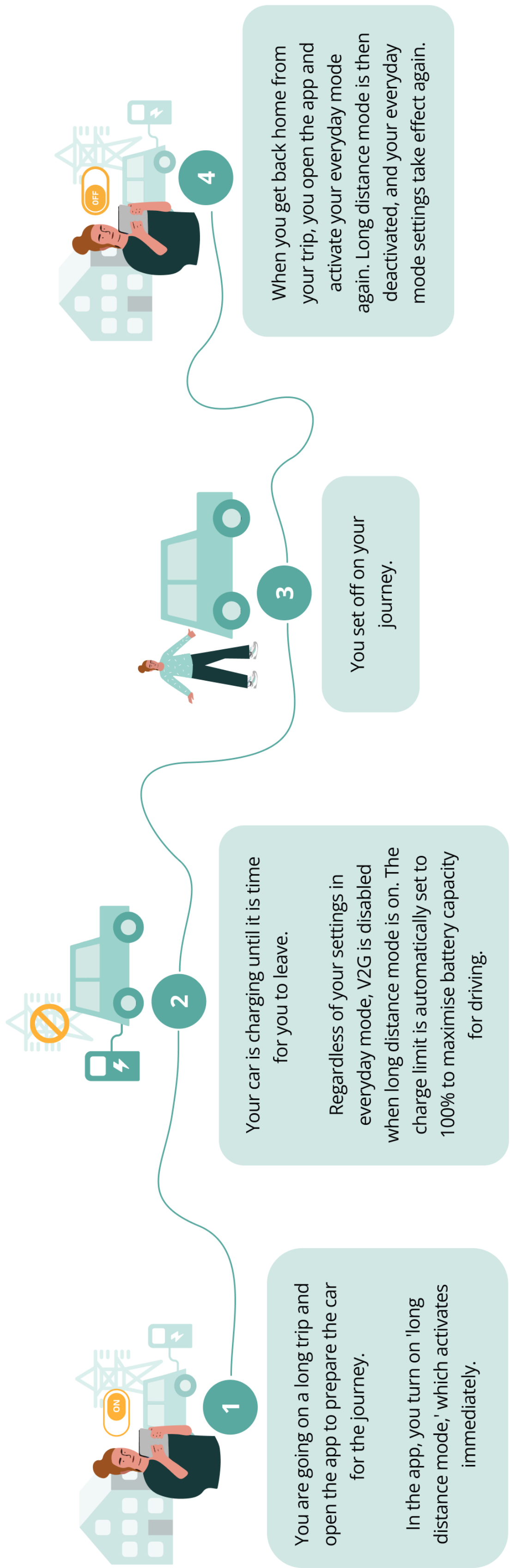
Everyday Mode – High Interaction (A)



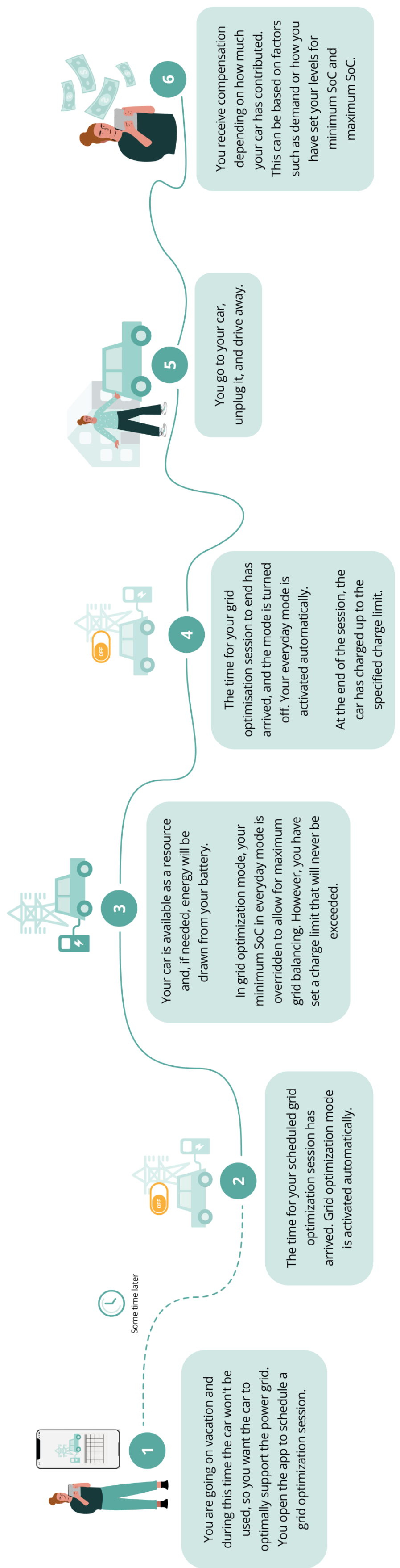
Everyday Mode – High Interaction (B)



Long Distance Mode

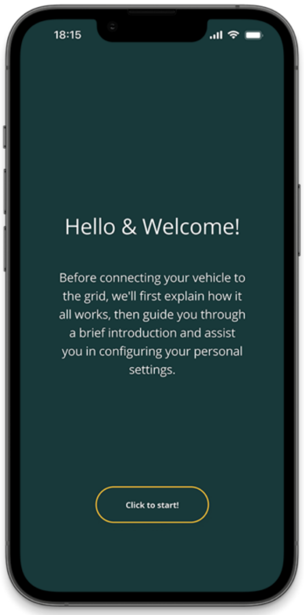


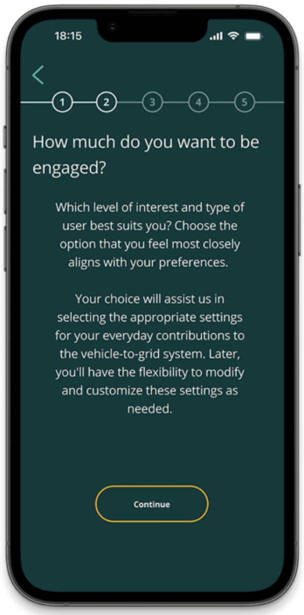
Grid Optimisation Mode

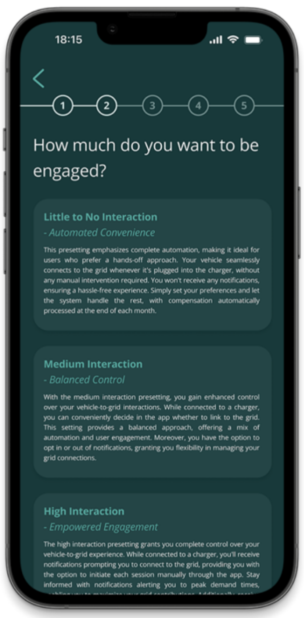


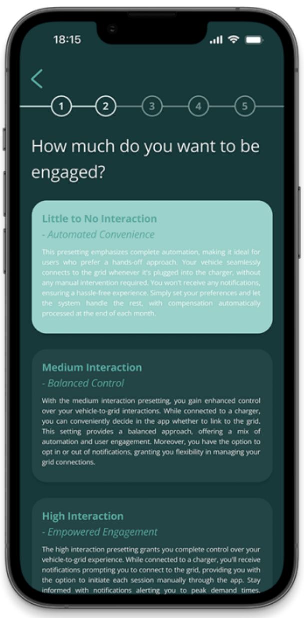
Appendix M – The App Wireframes of the Final Concept

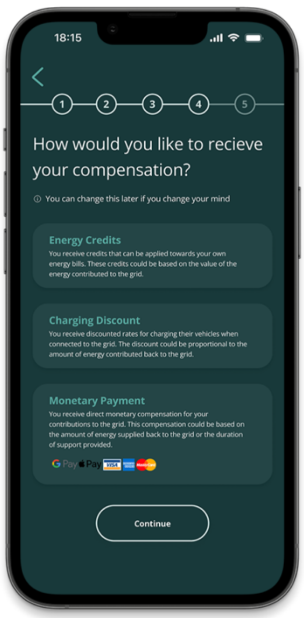
The Set-up

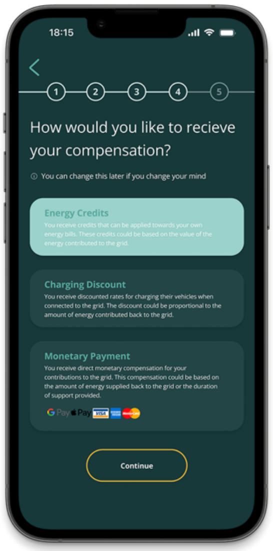


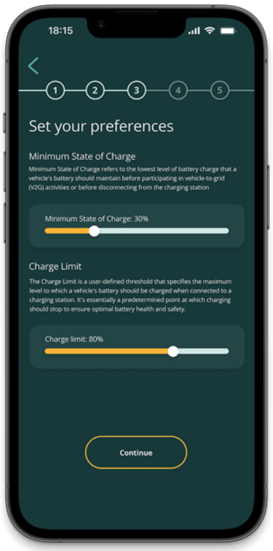


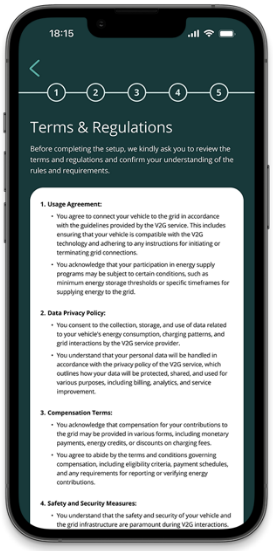


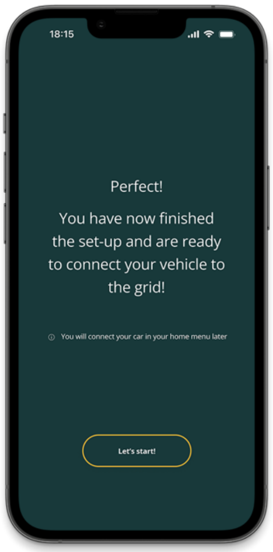





18:15
1
2
3
4
5
How would you like to recieve your compensation?
You can change this later if you change your mind
Energy Credits
You receive credits that can be applied towards your own energy bills. These credits could be based on the value of the energy contributed to the grid.
Charging Discount
You receive discounted rates for charging their vehicles when connected to the grid. The discount could be proportional to the amount of energy contributed back to the grid.
Monetary Payment
You receive direct monetary compensation for your contributions to the grid. This compensation could be based on the amount of energy supplied back to the grid or the duration of support provided.
G Pay
Pay
VISA
Continue

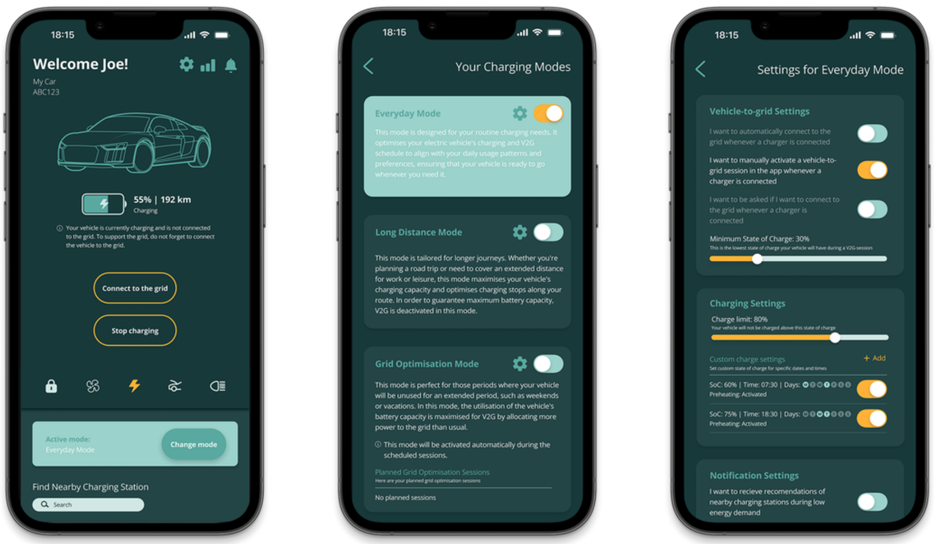

18:15
1
2
3
4
5
Set your preferences
Minimum State of Charge
Minimum State of Charge refers to the lowest level of battery charge that a vehicle's battery should maintain before participating in vehicle-to-grid (V2G) activities or before disconnecting from the charging station
Minimum State of Charge: 30%
Charge Limit
The Charge Limit is a user-defined threshold that specifies the maximum level to which a vehicle's battery should be charged when connected to a charging station. It's essentially a predetermined point at which charging should stop to ensure optimal battery health and safety.
Charge limit: 80%
Continue


18:15
1
2
3
4
5
Terms & Regulations
Before completing the setup, we kindly ask you to review the terms and regulations and confirm your understanding of the rules and requirements.
1. Usage Agreement:
• You agree to connect your vehicle to the grid in accordance with the guidelines provided by the V2G service. This includes ensuring that your vehicle is compatible with the V2G technology and adhering to any instructions for initiating or terminating grid connections.
• You acknowledge that your participation in energy supply programs may be subject to certain conditions, such as minimum energy storage thresholds or specific timeframes for supplying energy to the grid.
2. Data Privacy Policy:
• You consent to the collection, storage, and use of data related to your vehicle's energy consumption, charging patterns, and grid interactions by the V2G service provider.
• You understand that your personal data will be handled in accordance with the privacy policy of the V2G service, which outlines how your data will be protected, shared, and used for various purposes, including billing, analytics, and service improvement.
3. Compensation Terms:
• You acknowledge that compensation for your contributions to the grid may be provided in various forms, including monetary payments, energy credits, or discounts on charging fees.
• You agree to abide by the terms and conditions governing compensation, including eligibility criteria, payment schedules, and any requirements for reporting or verifying energy contributions.
4. Safety and Security Measures:
• You understand that the safety and security of your vehicle and the grid infrastructure are paramount during V2G interactions.


18:15
Perfect!
You have now finished the set-up and are ready to connect your vehicle to the grid!
You will connect your car in your home menu later
Let's start!

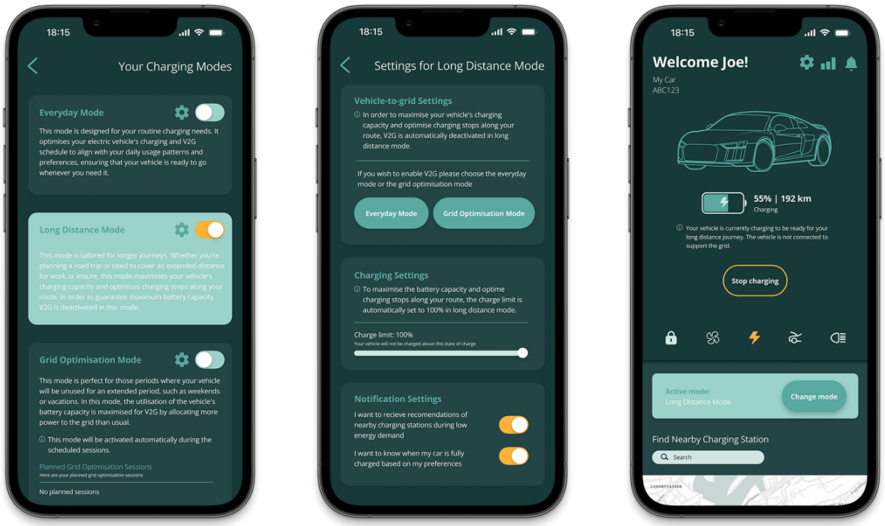
Everyday Mode - Little to no interaction

Everyday Mode - Medium Interaction

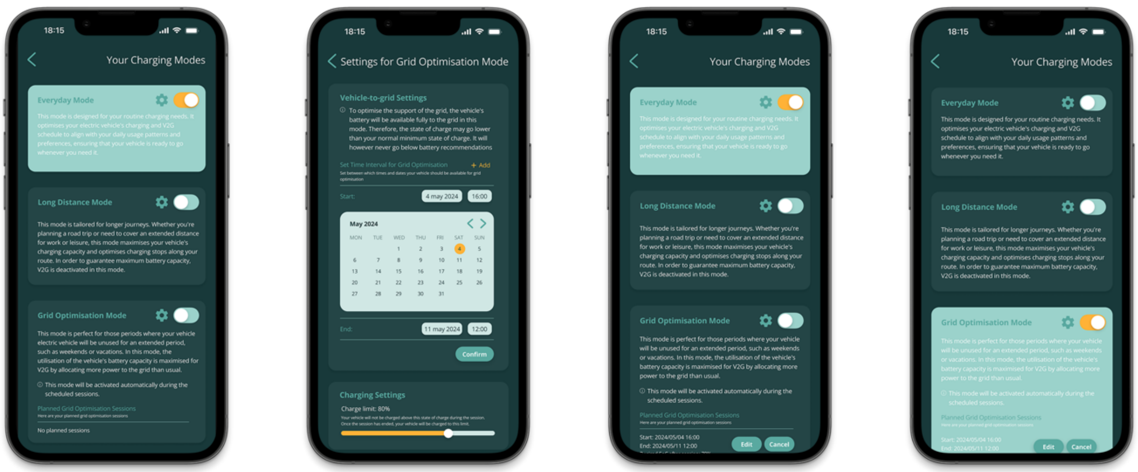


Everyday Mode - High Interaction

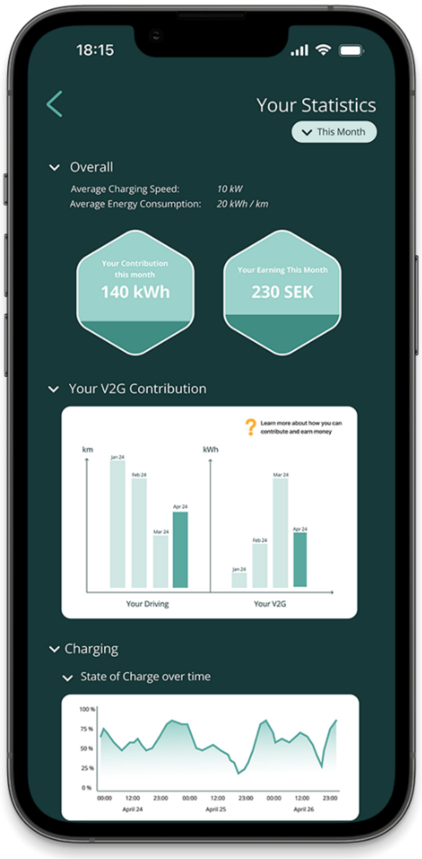
Long Distance Mode



Grid Optimisation Mode



Statistics Page



DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
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