Investigation of Charging Solutions for Users of Plug-in Hybrid Electric Vehicles

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Abstract

Electrification of vehicles is a global concern in the pursuit of cleaner transportation (Ståhl et al, 2013). Hybridization of electric vehicles has become an important trend, as they can uphold the conventional vehicle range, which has been the main barrier to adoption of pure electric propelled vehicles (Bergman, 2013). Vattenfall is involved in several projects related to charging of these vehicles. The purpose of this study is to understand the Plug-in Hybrid Electric Vehicle (PHEV) users’ electric charging, driving habits and needs. The aim is to develop a solution and charging offer corresponding to their preferences and future needs. This implies to indicate strategic directives for Vattenfall and their involvement in the development of an infrastructure for charging of Electric Vehicles (EVs).

In order to frame the scope of the project, primary data was collected from sources, such as electric vehicle enthusiasts and professionals within electric mobility. This resulted in identification of three essential aspects of consideration within electric mobility: the Market, Infrastructure and the Vehicles (Ståhl et al, 2013). In order to understand the users’ habits and needs an interview study was conducted. The empirical study was delimited to private owned PHEVs in Sweden. Both quantitative and qualitative data was collected through telephone interviews with users of PHEVs. The interviews treated questions regarding the users’ car choice and purchase criteria, driving and charging habits, and thoughts about future charging solutions.

The results of the empirical investigation and the technical specifications were analyzed in order to draw conclusions about the potential market, the needs and preferences and conditions for future potential solution in the shape out of a charge offering. The outcome of the analysis was transferred into requirements on product characteristics for a future charging solution and a recommendation to Vattenfall as an energy supplier. Vattenfall should take the step towards a differentiated product, in order to and become competitive. Whereby, they justify value for their customers by providing them with installation services, favorable energy contracts, electric billing specifications, communications and intelligence integrated into the charging solution.
Sammanfattning

Elektrifiering av fordon är en global angelägenhet i jakten på renare transporter (Ståhl et al., 2013). Hybridisering av eldrivna fordon har blivit en viktig trend, eftersom de kan upprätthålla samma räckvidd som en konventionell bil med förbränningsmotor, vilket tidigare har varit det huvudsakliga hindret för acceptansen av eldrivna fordon (Bergman, 2013). Vattenfall engagerar sig i flera projekt med anknytning till laddning av eldrivna fordon, där denna studie är en del av det engagemanget. Syftet med denna studie är att förstå användarna av laddhybridfordon, deras kör- och laddningsvanor, samt behov beträffande laddning med el. Målet är att utveckla ett erbjudande som motsvarar deras önskemål och kan värdeöka och underlätta laddningen i vardagen. Detta innebär att indikera strategiska direktiv för Vattenfall och deras medverkan i utvecklingen av en infrastruktur för laddning av elbilar.


Acknowledgments

This study is written as a Master’s Thesis within Integrated Product Development and Industrial Production at The Royal Institute of Technology. The assignment was initiated by Vattenfall Business Development in order to contribute to the understanding of a new user group within electric mobility, which had not yet been investigated.

We want to show our gratitude to Vattenfall and Nazif Gulsen, our fellow advisor at the company for giving us the opportunity of conducting this assignment. Moreover, thank you to all employees at Vattenfall who contributed to our investigation and helped us realize the project with their competence.

We also want to thank all of the respondents and professionals within E-mobility, who supported us and contributed with their valuable experiences in the study. Last but not least, thank you Europeiska motorer, Bilia Solna and Project Elbil2020, who provided us insight in the plug-in hybrid technology.

Jenny Janhager Stier, our supervisor at the Royal Institute of Technology, thank you for all the appreciated support and for useful knowledge.

Ellen Angelin and Dzenita Damjanovic

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1. Introduction

This chapter aims to introduce the reader to the field of E-mobility and the different stakeholders within the industry. The reader is further introduced to the stakeholders’ part within the field and finally the purpose of the study and the description of the assignment.

The last decade the awareness of the fossil fuel dependence has been a huge matter in debate world-wide. On several national levels the search for alternative fuels has been major, whereby powertrains have become a global concern in the pursuit of cleaner transportation (Ståhl et al, 2013). On European level directives regarding the vehicle fleet and emissions have lately been tensed. Different norms force the development and utilization of technologies in new and efficient ways. Successively, new markets arise and new game fields are being established for different actors within alternative fuel types (Sköldberg et al, 2013).

In line with the European initiatives, the Swedish Parliament has stated goals and visions regarding a fossil independent vehicle fleet by 2030 (Sköldberg et al, 2013). Consequently, Vattenfall together with other stakeholders, have taken initiative and created a roadmap of how to achieve this objective, “Roadmap 2030” (Ståhl et al, 2013). The purpose of this initiative is to mobilize actors within the Swedish automobile industry, in order to support the electric vehicle market. The goal from present until 2015 is to establish a foundation for the market and strive to eliminate barriers to adaptation of electric vehicles, in order to further build the market from 2016. This requires further interaction among different stakeholders putting focus on the electrification of vehicles, as an industry of Electro mobility, E-mobility.

The actions that need to take place within E-mobility can be described as interplay between the market, vehicles and infrastructure (Ståhl et al, 2013). The market involves the users of the electric vehicles and the charging infrastructure. As illustrated in figure 1 below, the Electric Vehicle Triangle is a model developed to demonstrate the necessary aspects of consideration, in order for the E-mobility to prosper (Konnberg & Larsson, 2012; Bergman, 2013).

![Electric Vehicle Triangle](image)

**Figure 1.** The EV triangle model shows the relationship between; Market (Users), Infrastructure (Charging Technology) and Vehicles (Cars) (Ståhl et al, 2013; Konnberg & Larsson, 2012)
Accordingly, collaborations between companies within different areas of expertise are being established, in order to found new innovations in the development of an infrastructure for Electric Vehicles (EVs). It is of great importance and interest to encourage this development for all parties involved, in order to empower the use of EVs and further reduce our ecological footprint (Sköldberg et al, 2013). However, as for all other industries, the key to run the conversion to EVs is profitability and revenue for the actors involved (Ståhl et al, 2013).

The E-mobility industry had few barriers of adoption in the introduction of pure electric vehicles, also called Battery Electric Vehicles – BEV. Drivers experienced a feeling called "Range Anxiety" which is the feeling drivers experience when they perceive fear of running out of electricity (Khan & Kockelman, 2012). Consequently, drivers worry about being stranded on the side of a road with a discharged battery (Khan & Kockelman, 2012). For longer trips this requires detailed planning of the trip, in order to be able to complete a full route and possibly prevent the anxiety. Subsequently, this can discourage the drivers and affect their driving experience negatively. A pattern of hesitation has been identified among the potential buyers of EVs, and research shows that drivers and users most likely experience "Range Anxiety" (Lennart, 2013; Admir, 2013; Bergman 2013). It is believed that there is a correlation between the range anxiety and the drivers lack of knowledge regarding their charging options on the road (Lennart 2013; Bergman, 2013).

1.1. The Plug- in Hybrid Electric Vehicles - PHEV

For the technology to be viable, new alternatives need to be developed for the users without affecting the driving experience negatively, even better enhance it (Ståhl et al, 2013). Hybridization of vehicles is considered to be an important trend in the conversion towards BEVs and zero emission, as they can uphold the conventional vehicle range. A variation of this technology is the Plug-in Hybrid Electric Vehicle, PHEV. This vehicle has a powertrain whose is a combination of an internal combustion engine (ICE) and a plug-in chargeable battery, which can be recharged by plugging it to the electric grid. Since the PHEVs have the possibility of utilizing the existing electric grid for charging, supposedly this should not require major changes in the infrastructure of the electrical grid (Jarod et al, 2012). Besides, this technology aims to be integrated in the users charging and driving habits, without requiring additional effort from the driver (Bergman, 2013). As of the year 2012, several PHEV car models were released on the Swedish automotive market and new models are upcoming the next few years (Goldmann, 2012). Even with the potential of PHEVs there are still barriers to overcome, in order to succeed with market penetration of EVs.

1.1.1. Vehicles – Cars

The extended knowledgebase required from the car manufacturers and the novelty of the technology result in high development costs, which is consequently reflected in the final purchase price of the vehicles (Ståhl et al, 2013). The major issue for the car manufacturer is the battery capacity, in relation to weight and purchase price. Uncertainty of the battery technology and regulations regarding incentives for environmentally friendly vehicles means that the car manufacturers cannot assess nor guarantee a resale value of the car.

1.1.2. Infrastructure - Charging Technology

Regarding infrastructure and charging technology, one discussed issue is how to decrease the charging times for BEVs. The charging time is reliant on several factors; the maximum power that the charging spot can supply, charging equipment, the vehicle's charging capacity and battery size. Faster charging speed, termed “fast charging”, is highly
discussed topic for BEVs. The definition of fast charging is vague, but generally a possible limitation for the term is that the user should be able to wait by the vehicle until the charging is finished, about 10 minutes (Jalvemo et al, 2010). This requires more power than a domestic socket outlet can provide and more speed, as it normally takes 6-9 hours using the domestic socket outlet (Herbert, 2009; Jalvemo, et al, 2010). However, the current PHEV models do not possess the ability of fast charging, which limits them to use the power provided from the domestic socket outlets.

Generally, different types of charging call for different types of charging equipment. Requests are made to drive standardization of charging equipment, in order to support the establishment of charging infrastructure (Ståhl et al, 2013). Standardization of charging equipment is a constantly ongoing process, involving numerous stakeholders. International Electrotechnical Comission, IEC, is the main body for standardization of conditions for charging of EVs. The standards are usually set on European level and implemented in regulations on national levels (CENELEC, 2011; EU, 2006). As the BEVs are totally reliant on electric charging, standardization of such conditions is important in order to create a functional infrastructure for charging. On the other hand, the PHEVs are not dependent on the charging infrastructure for their charging, since they can utilize their ICE for propulsion (IEC, 2011).

1.1.3. Market – Users

The current advantage of the plug-in electric vehicles, such as BEV and PHEV, is the ability of utilizing the existing electric grid for charging. However, long charging times calls requests for faster charging options, but standardization issues makes it difficult to establish fast charging opportunities in public places. The narrow public charging infrastructure and the fact of PHEVs models are limited for fast charging, makes most users depended on private parking or charging places.

Thus far, the focus of the development of EVs has been at the car manufacture, hence research and development of the technical specification of the vehicle. Alongside, the perspective of the users and user-driven development, such as activities within charging infrastructure and adoption, have been falling behind (Bergman, 2013). Currently, the pricing of a PHEV is approximately 80 000 SEK more expensive, than the corresponding model without the plug-in opportunity (Holmqvist, 2013). Since the uncertainty and insecurity of a technology exist, an barrier of adoption appears. This barrier to adoption of EVs is one of many experienced from potential drivers, together with technical uncertainty, economic and financial aspects (Egbue & Long, 2012; Bandhold et al, 2009). Limited charging possibilities together with technical and economic uncertainty calls attention for investigation of the users preferences and behaviors, in order to overcome these barriers to adoption “(Ståhl et al, 2013).

In order for the E-mobility industry to gain foothold, it is important for the different actors to collaborate and increase the competence within the technology. Vattenfall work within E-mobility involves several projects related to charging of these vehicles, in which studies of BEV users have been conducted (Nazif, 2013). As the PHEV users are arising as a new segment within EV, it requires effort and investigation in R&D projects, since they have different prerequisites for driving and charging on electricity compared with BEVs. Overall, it is of great importance to encourage and take advantage of the trendsetting PHEVs, hence they have the potential to take course in the adoption of BEVs and the E-mobility market. Consequently, motivation and development of charging technology is considered a central aspect, due to fundamental condition in their driving on electricity (Ståhl et al, 2013). As mentioned above, Vattenfall have initiated several project around E-mobility. Their interest and vision is further to gain insight in the world of PHEV drivers.
and their needs and preferences, in order to develop a future charging solutions and services. The initiation of this study is one of their projects along the way.

1.2. Purpose and Definitions

The purpose of this study is to understand the Plug-in Hybrid Electric Vehicle users’ electric charging, driving habits and needs. The aim is to develop a solution for a charging offer corresponding to their preferences. This implies to indicate strategic directives for Vattenfall and their involvement in the development of an infrastructure for charging of EVs.

1.3. Description of Assignment

This study is an investigation of charging solutions for Plug-in Hybrid Electric Vehicle users, whereby the following research questions have been directly addressed:

- What motivates the private PHEV drivers in their car purchase?
- What are the PHEV users their charging and driving habits?
- What are their needs and preferences regarding electric charging?

In excess of the above mentioned question, the study aims to address following questions:

- Is there a market for charging related offers for PHEV drivers?
- How can the PHEV drivers’ preferences be addressed in a conceptual charging offer focused for home appliance?
- What strategic approach can Vattenfall take to extend their involvement towards the segment of Plug-in Hybrid Electrical Vehicles, in order to bring forward a product offer within charging solution that addresses these users?

1.4. Delimitations

- The study will mainly focus on the perspective of current PHEV users.
- The empirical investigation will focus on PHEV users of car models launched after 2011 i.e. Volvo V60 Plug-in Hybrid, Toyota Prius Plug-in Hybrid, Chevrolet VOLT and Opel Ampera.
- The study is geographically limited to Sweden, further Vattenfall’s involvement within the Swedish market for E-mobility.
- The study will only address connections of EVs for conductive charging with alternating currents, presented by IEC (2010). Therefore, it will only regard safety aspects/modes for equipment and charging under such conditions, which are presented by IEC (2010).
- The study will not include type 3 connectors and will only concern charging cases where the cable is not permanently attached to the vehicle.
- The study does not specify an approach regarding time estimation and/or financial estimations covering the study.
2. Methodology

This chapter aims to explain the methodology used when approaching the research questions. Additionally, a chapter of analytical tools are explained, which are used in the analysis of the technological research against the empirical investigation.

The working process was divided into different stages, after the factors impacting the industry of E-mobility. Initially a brief pre-study was made, followed by a division of the information concerning the technical specification of the charging equipment and car models. Further, an empirical investigation was performed, in order to collect empirical data about the PHEV users on the market. The approach is briefly illustrated in figure 2.

**Figure 2.** A model of different activities performed, in order to reach recommendations for Vattenfall.

### 2.1 Pre-study

At the beginning of the study a pre-study was performed to understand and clarify the current state of the EVs, with focus on PHEV. Nevertheless, the pre-study was made in order to define the problematic area and the scope of the research. Latest resources and information was captured by gathering data from both primarily and secondary sources (Sørensen et al, 1996). The primarily data collection was referred to direct sources, in this case EV-enthusiasts, PHEV users and professionals within E-mobility. The gathering of secondary data included investigation of statistical information, reports and studies within the field of E-mobility.

In order to understand different stakeholders within E-mobility, experts and project leaders for ongoing national projects were consulted. In addition, two unstructured telephone interviews were conducted with two EV enthusiasts. Furthermore, questionnaires and different forms were placed on social media, blogs and others sites. This was made in order to address current user and future potential drivers for the
empirical investigation. As it is a new and innovative field of studies, it is important to both observe and understand the technical barriers, as well as the social barriers for adoption of the vehicles (Bergman, 2013). In order to fully understand the PHEV drivers, driving tests were performed during the pre-study. The tests were performed, to gain a clear context of the users concerns regarding the car and charging. They also contributed to an overall picture of the E-mobility and the potential user-experience. Moreover, secondary data was reviewed with focus on aspects and stakeholders affecting the market acceptance of EVs, PHEVs and related charging technology.

The pre-study resulted in an identification of three important aspects regarding the development of charging technology, cars and users. These three aspects were the foundation of the literature review and the further investigation of the PHEV market, all affecting the future of the E-mobility. Finding the balance between the three aspects is essential, in order to successfully commercialize EVs (Konnberg & Larsson 2012).

2.2. Technical Specification of Charging Technology and Cars

To be able to fully understand the users of PHEV, research was made on the technology and products available on the E-mobility market. Additional, secondary data collection was performed within charging technology, car models and a market research. By gathering information within the research field, enabled preparation of the empirical investigation by theoretically understanding the users charging situation. The result was used in further analysis of the markets potential and growth. The outcome of the literature review was the theoretical chapters presented in “Technical Specification of Charging Technology” and “Introduction of Car Models and Market Research”.

2.3. Empirical Investigation of Users

The empirical investigation consisted of both quantitative and qualitative data collection. The investigation was conducted in order to understand the PHEV users’ needs and preferences regarding charging of a PHEV, whereby the outcome was later used in further analysis. The interview and knowledge applied in the investigation was gained during literature review and complemented by the literature results. Empirical interview questions were generated around three areas defined by Vattenfall, regarding the users:

- Car choice and Purchase criteria
- Charging and Driving habits
- Charging solution and Pricing

At the time of interviews there were 142 drivers of private registered PHEVs in Sweden, whereby 96 of registered drivers were approached by telephone to contribute in interviews. The response ratio of the contacted drivers was 36 respondents, who participated in the empirical investigation in consensus with Vattenfall, the respondents were further divided into three groups, according to the users’ car models:

- Group: “V60” - Volvo V60 Plug-in Hybrid
- Group: “Toyota” - Toyota Prius Plug-in Hybrid
- Group: “Others” - Opel Ampera and Chevrolet VOLT

The interviews were conducted with the 36 respondents using two interview guides referred to as, “long interviews” and “short interviews”, presented in Appendix A and Appendix B. Firstly, all 36 respondents were interviewed in a short interview. Later on, 13 respondents were additionally interviewed with an extension of questions, referred to as
long interview. The extension was further used for the qualitative data collection in the compilation of the empirical result. The distribution of respondents and interviews conducted is illustrated in figure 3 below. The group “Others” is considered to be a too small sample, in order to represent and reflect the whole segment of Opel Ampera and Chevrolet VOLT drivers. The qualitative data collection was therefore disregarded, as the quantitative data was further used in the report.

<table>
<thead>
<tr>
<th>Data collection:</th>
<th>Group 1 – Volvo V60</th>
<th>Group 2 – Toyota Prius Plug-in</th>
<th>Group 3 – Others</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantitative data collection</td>
<td>12 Respondents</td>
<td>20 Respondents</td>
<td>4 Respondents</td>
<td>10 – 15 min</td>
</tr>
<tr>
<td>Qualitative data collection</td>
<td>6 respondents</td>
<td>6 Respondents</td>
<td>(1 Respondent)</td>
<td>+ 30 – 45 min</td>
</tr>
</tbody>
</table>

**Figure 3. Illustrating the distribution of total 36 respondents.**

### 2.3.1. Quantitative Data Collection

The quantitative data collection consisted of short telephone interviews with 36 respondents, followed by the distribution previously shown in figure 3. The interviews were conducted using a structured approach with predefined questions and given answering alternatives. This approach was chosen in order to be able to compile and compare empirical data and findings statistically. The interviews were performed during a time period of 10-15 minutes with 21 questions, whereby the short interview guide is presented in Appendix A.

### 2.3.2. Qualitative Data Collection

The qualitative data collection was performed with 13 respondents out of the 36 respondents. The 13 respondents participating in the long interview were approached as an extension of the short telephone interview and the quantitative data collection, see figure 3. The qualitative data collection was performed using a semi-structured approach with open-ended question, allowing respondents to reflect up on their answers and opinions (Barriball & While, 1994). This approach was used due to retain a holistic picture over the drivers’ current charging situation. The respondents contributing to the qualitative data collection were asked 17 additional questions, over a time period of additional 30-45 minutes. In summary, the interview guide for the long interview was based on a total of 38 questions and approximately duration of totally 45-60 minutes. The long interview guide is presented in Appendix B.

The qualitative respondent group consisted of six respondents from the group “V60”, six respondents from the group “Toyota” and one Chevrolet VOLT respondent from the group “Others”. The extended questions followed the same structure in the categories; *Car Choice and Purchasing Criteria, Driving and charging habits* and *Charging Solution and Price*. During the long interview and qualitative data collection, notes were taken and thereafter compiled into a summary for every respondent. This summary was the foundation of the empirical findings and results.
2.4. Analysis

The analysis evaluated and compared the empirical findings towards the limitation of the technological aspects of possible charging scenarios and modes, but also towards the actual and available cars on the market. First was the general perception of E-mobility and the current state of EVs comprehended and analyzed, followed by the respondent’s opinions and views. The result from the empirical investigation was later analyzed according to the three earlier mentioned areas; Car choice and purchase criteria, charging and driving habits and Charging solution and pricing.

The purpose of the analysis was to understand the future PHEV users’ needs and requests, in order to determine the market potential regarding charging equipment for home usage. This was done by comparing the outcome of the empirical investigation with the results from the technology specification. Analysis was concluded, in order to highlight areas for improvement and respond to them in an offering that meets the needs of stakeholders. The contribution of the analysis gave the foundation of the drawn conclusions for requirements of a product offer and a strategic guidance.

2.4.1. The Analytical Tools

The primary and secondary data was analyzed partly by using aspects that Porter (2008) highlights to be important when analyzing an industry and the curve of adopted market share (Schilling, 2010). The adoption of technology is analyzed out of the user’s perspective, followed by an evaluation of the rivalry on the market to enter according to Porter’s forces.

In order to analyze the current market state and to make projections about the potential of the market, the curve of market share was used. In accordance with Everett M. Roger, with his the theory of diffusion of innovation, proposed a categorization of the people in different stages of adoption plotted in a bell-shaped curve, see figure 4 below. The process of accepting a new technology for a market appears in different stages, as users adopt it (Schilling, 2010).

![Figure 4. The bell-shaped curve of Everett M. Roger shows the different stages of adoption, complemented with the gained market share in percentage. The S-shaped curve illustrating the performance of technology towards effort given (Korhonen et al, 2012).](image)

In table 1 below the different stages was defined, together with the actual percentage of the market share in the left column. By using the adoption curve it was possible to map a rather diffuse industry, to a measurable stage. The different categories were further evaluated towards the users’ characteristics, in order to fairly schedule the progress of E-Mobility through the PHEVs users and their adoption.
Table 1. The five different characters of adoption are defined, together with the chasm, complementing figure 4 above (Schilling, 2010).

<table>
<thead>
<tr>
<th>Stage</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovators 2,5%</td>
<td>As the individuals are usually technology enthusiast with the resources to try out new technologies.</td>
</tr>
<tr>
<td>Early adopters 13,5%</td>
<td>Missionaries for the technology, as they are well integrated in the social sphere. The majority refers to this group in their decision-making of accepting a new technology.</td>
</tr>
<tr>
<td>The chasm</td>
<td>The critical for the technology. Early majority is looking for reference and confirmation of the technology being stable, thus it needs make progress in order to receive the credibility and loyalty from the coming early majority</td>
</tr>
<tr>
<td>Early Majority 34%</td>
<td>As the chasm is passed the third category can further increase the technology’s market share towards a point of reaching the critical mass and majority. The early majority is a part of the social sphere and has great interaction with the early adopters in the evaluation of new technology.</td>
</tr>
<tr>
<td>Late majority 34%</td>
<td>As the early majority, this third category also represent one third of the social sphere and market. The late majority are more conservative in their purchasing behavior and doubtful towards new technologies. The social sphere may pressure them in adopting the technology. Their financial state can limit them in taking risks regarding innovation and technologies, and need confirmation that the uncertainty in the technology has been resolved.</td>
</tr>
<tr>
<td>Laggards 16%</td>
<td>The fifth and last category are the laggards, they are often very skeptical to the technology and adopting it. Their purchasing behavior is based on past experience and reviews, more than an influence of the social sphere.</td>
</tr>
</tbody>
</table>

Further, the market for charging solution was analyzed, according to the highlighted aspects by Porter (2008), to gain knowledge about the external competitive environment and its potential attractiveness.

2.5. Development of Product Offer

The development of the product offer was founded on the analysis made from the previous chapter. Subsequently, after the analysis of market and identification of user preferences, a target market was chosen. Further, a product and a service were chosen for development, founding the creation of a product offer for home charging. Major requirements were developed for each of them according to the preferences of target customers identified.

The marketing mix model, Kotler’s four P’s of marketing, gave inspiration and structure for the development of a product offer and future recommendations (Azzadina, 2012). The framework was applied, in order to consider the relevant variables which impact the customers’ assessment of the product offer. In figure 5 the four variables stated by Kotler (1999) are shown: product, price, placement and promotion. These were addressed using the approach suggested by Kotler (1999); to define product characteristics, the customers’ willingness to pay, where users should buy the product and how they should be informed about it.
<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
<th>Placement</th>
<th>Promotion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionality,</td>
<td>List price,</td>
<td>Locations,</td>
<td>Advertising,</td>
</tr>
<tr>
<td>Quality,</td>
<td>Discounts,</td>
<td>Logistics,</td>
<td>Public relations,</td>
</tr>
<tr>
<td>Appearance,</td>
<td>Financing,</td>
<td>Channel members,</td>
<td>Message,</td>
</tr>
<tr>
<td>Packaging,</td>
<td>Leasing options,</td>
<td>Channel motivation,</td>
<td>Direct Sales,</td>
</tr>
<tr>
<td>Brand,</td>
<td>Allowances.</td>
<td>Market coverage,</td>
<td>Sales,</td>
</tr>
<tr>
<td>Service,</td>
<td></td>
<td>Service Levels,</td>
<td>Media,</td>
</tr>
<tr>
<td>Support</td>
<td></td>
<td>Internet,</td>
<td>Budget,</td>
</tr>
</tbody>
</table>

**Figure 5.** Kotler (1999) definitions of the 4P's of marketing mix.
3. Technical Specification of Charging Equipment

This chapter presents the technical specification concerning the charging equipment. There are several security modes and cases applying on the equipment. Depending on the vehicle inlet, different types of connectors can supply the vehicle with electricity. Furthermore, current charging solutions on the E-mobility market are presented. The aim of this chapter is to create understanding of the prerequisites affecting the charging equipment and the solutions available on the market.

There are two ways of recharging an EV and its battery from the electric grid, by means of conductive or inductive charging (Herbert et al, 2009). Conductive charging defines a metal connection between a vehicle and an electric supply. As for plug-in electric vehicles, this defines a cable connection between a socket, the vehicle’s inlet and the electric supply’s outlet (IEC, 2010).

Conductive charging of a BEV can either be done by using a charging station as Electric Vehicle Supply Equipment, EVSE, or a standard household/domestic socket outlet, (IEC,2010). The components and terms used for charging of EVs are illustrated in figure 6 below. These are the terms that will be used to describe charging equipment further on in the report.

Conductive charging equipment provides means for charging with alternating currents (AC) or direct currents (DC) (CENELEC, 2011). AC-charging is the most common way of household charging since it enables utilization of the existing electrical grid. Due to delimitations and scope, neither inductive charging nor DC charging will not be covered in this study, only specific aspects regarding DC-charging will be mentioned.

![Cable assembly = Detachable flexible cable with plug & connector](image)

**Figure 6.** The figure illustrates the definition of all components included in charging equipment for BEVs (IEC, 2010). Picture by Angelin (2011) inspired by IEC (2010).

Charging speed is defined as the time it takes to charge a vehicle’s battery (CENELEC, 2011). Common terms used to describe charging speed for cars are: slow, normal, accelerated, fast charging. However, the terminology is rather vague and those terms are not firmly defined yet. For instance, both AC and DC currents can provide currents for
slow charging, as well as for fast charging. The factors affecting the charging time and speeds are; the maximum power ($kW$) that the charging spot can supply, combined with the vehicle’s charging capacity and the installed battery size ($kWh$). The power at the charging place is determined by the nominal current and voltage supplied and limited by an over-current protection. As well as the vehicle’s charging capacity is limited by its internal protection device. Consequently worth notifying; not all vehicles possess “fast charging” capabilities, i.e. this applies to the vehicle covered in this report as well.

3.1. Charging Cases

There are three main ways of establishing a connection between the car and the electric supply equipment, using conductive charging. This represents the charging cases; Case A, Case B and Case C, defined by the International Electrotechnical Commission (IEC), 2010 and illustrated in figure 7-9. This study only concerns the charging Cases B and C.

Figure 7. Case A: **Cable is permanently attached** to the vehicle with a socket outlet mating plug (IEC, 2010). Picture by Angelin (2011) inspired by IEC (2010).

Figure 8. Case B: **Detachable cable assembly** that involves charging cable, socket outlet mating plug and vehicle inlet mating connector (IEC, 2010). Picture by Angelin (2011) inspired by IEC (2010).
3.2. Charging Modes

In order to assure safety during electric charging, IEC (2010) has defined safety modes for charging equipment using alternating currents. These conditions are described in the safety modes 1-3 illustrated in figure 10-12, which defines suitable solutions for national variations of safe charging. The technical aspects concerning all three charging modes are shown in in the comparison chart in table 2 below.

**Table 2. Technical aspects of the three different safety modes, table by Milton (2011).**

<table>
<thead>
<tr>
<th>Charging modes</th>
<th>Type</th>
<th>Phase</th>
<th>Current (max A)</th>
<th>Voltage (max V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode 1</td>
<td>AC</td>
<td>Single</td>
<td>16</td>
<td>250*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Three</td>
<td>16</td>
<td>480*</td>
</tr>
<tr>
<td>Mode 2</td>
<td>AC</td>
<td>Single</td>
<td>32</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Three</td>
<td>32</td>
<td>480</td>
</tr>
<tr>
<td>Mode 3</td>
<td>AC</td>
<td>Three</td>
<td>32</td>
<td>480</td>
</tr>
</tbody>
</table>

*Sweden, Household: 230 V single-phase and 400 A three-phases.

3.2.1. Mode 1

*Differential protection upstream:* During mode 1 charging a domestic socket outlet is used and requires no further installation, other than a residual current device (RCD) (IEC, 2010), see figure 10. Application in Sweden covers up to 16 A and 230 V single-phase connection on the supply side, or a maximum of 400 V using three phases (Herbert, 2009).
3.2.2. Mode 2

*Differential protection*: Special safety control unit positioned on the charging cable (IEC, 2010). This equipment is applicable during charging from a domestic socket outlet with RCD, but also when higher demand on safety is required. The safety equipment provides the same communication and verification as defined in mode 3, but only between the vehicle and control unit (Herbert, 2009). Figure 11 presents an illustration of mode 2 charging.

![Mode 2 Illustration](image)

**Figure 11.** Illustration of charging conditions for safety mode 2 (IEC, 2010). Picture by Angelin (2011) inspired by IEC (2010).

3.2.3. Mode 3

*Differential protection and communication*: Installation of a dedicated EVSE by the socket outlet, which provides communication regarding the connection between the vehicle and electric supply (IEC, 2010), in figure 12. Continuously, it verifies that the plug and connector are correctly connected, on the supply and vehicle side, and that the residual current device is complete. When the connector is uncoupled from the vehicle inlet, the electric supply gets interrupted, subsequently the release of the connector is enabled.
3.3. Charging Types - Connectors and Standards

The charging modes described places demands on other features of equipment, such as the connectors used in the for connection to the vehicle inlet, charging Case B and Case C, as well as on the connector used as plug for connection to the socket outlet, in the charging Case B. Terminology of charging connectors and plugs are shown in figure 6 above.

As mentioned in the introduction, requests are made to drive standardization of charging equipment, in order to support the establishment of a charging infrastructure for EVs (Ståhl et al, 2013). Whereby, standardization of the technical specification of connectors and their applications is a central topic within the organizations working with standardization (CENELEC, 2011).

3.3.1. Domestic Socket Outlet and Plug - Schuko

Household/Domestic charging – implies utilizing a single-phase domestic socket outlet with RCD providing maximum currents up to 16 A (CENELEC, 2011) A standard Swedish domestic socket outlet usually provides 10 A and a load of 230 V using single-phase connection, shown in figure 13 (Jalvemo et al, 2010). The socket outlet mating plug, normally referred to as Schuko, is a standardized earthed single-phased plug rated at 16 A. This type of charging enables utilization of the current electrical infrastructure in the households.
3.3.2. Charging Connectors - Type 1 and Type 2

**Mode 2 Charging equipment** - All PHEV cars in Sweden are delivered with a detachable charging cable assembly, similar to the one seen in figure 14, corresponding to safety mode 2 (Volvo,2013;Toyota 2,2013;Opel 2,2013). The cable assembly consists of a cable with mode 2 safety equipment and a Schuko plug for connection to the domestic socket outlet (IEC, 2010). Further the connector for connection to the vehicle inlet differs depending on the car model. There are two types of connectors for THE PHEV car models in Sweden, referred to as type 1 (Milton, 2011) and type 2 connectors. Type 3 connectors are excluded from the scope, since the PHEV models can only be charged with either type 1 or type 2 connectors.

**Figure 13.** To the left in the figure is the Schuko plug and to the right the mating domestic socket outlet, used for household charging (IEC, 2013).

**Figure 14.** Example of a mode 2 cable assembly, charging Case B. picture taken from Rarbach (2011)

SAE J1772 – Type 1 – This connector interface is today the most common on PHEV cars, it is currently found on Chevrolet VOLT (Chevrolet,2013), Opel Ampera (Opel 2,2013) and Toyota Prius Plug-in (Toyota 2,2013), see figure 15. The non-profit educational organization SAE – Society of Automotive Engineering has announced the J1772 to be the
standard connector for slow charging in North America. The connector is rated to maximum 250 V and maximum current of 32 A (Ponticel, 2012; Yazaki, 2013).

![SAE J1772 connector](image1)  

*Figure 15. SAE J1772 connector, Yazaki (2013), Scoop (2013).*

**Mennekes – Type 2** – The connector shown in figure 16, is connector a German invention and trade name for a type 2 connector. This connector is currently seen on the vehicle side of the Volvo V60 Plug-in Hybrid. The Mennekes connector (Rarbach, 2011) works for both single 10 A-16 A/230 V connection, but also three phase 63 A/400 V.

![Mennekes type 2 connector interface](image2)

*Figure 16. The mennekes type 2 connector interface: “Live x3, Neutral and Earth, plus two data communication pins. Two of the live pins would be redundant for single phase supplies.” (Milton, 2011).*

Depending on the car model and the vehicle inlet, the connector and the given type-label can vary. In spoken language connectors are mentioned by the OEM’s brand name, whereby figure 15 and figure 16 shows the largest supplier. However, the technical aspects for type 1 and type 2 connectors, and their applicable voltage ad current, are shown in table 3.
Table 3. Shows the technical aspects of the current definitions of type 1 and type 2 connectors, table by Milton (2011).

<table>
<thead>
<tr>
<th>Connector types</th>
<th>Phase</th>
<th>Current (max)</th>
<th>Voltage (max)</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Single</td>
<td>32</td>
<td>250*</td>
<td>1,2</td>
</tr>
<tr>
<td>Type 2</td>
<td>Single</td>
<td>70</td>
<td>480*</td>
<td>1,2</td>
</tr>
<tr>
<td></td>
<td>Three</td>
<td>83</td>
<td>480*</td>
<td>1,2,3</td>
</tr>
</tbody>
</table>

*The table presents the maximum field of application for the connectors.

3.4. Current Charging Products

As this study focuses on charging for private use and private investment, this part of the chapter will be concentrated on charging equipment and offers on the Swedish market and products available for home charging. Vattenfall’s current offer, the Wallbox, stands as reference point for the benchmark of the market. Further, international charging solutions and similar products will also be addressed, even if not available for the Swedish market.

3.4.1. Vattenfall’s Charging Station and Offer

The Wallbox is a charging station dedicated for private and corporate use. This product is a result of a partnership between Vattenfall and Volvo, V2 Plugin Hybrid Vehicle Partnership (Vattenfall & Volvo Cars, 2013), in which Vattenfall contributed within the development of the new Volvo V60 Plug-in Hybrid.

Together with the release of the Volvo V60 Plug-in Hybrid, the first three hundred buyers of the vehicle were approached by Vattenfall. The owners were approached with an offer involving the charging station Wallbox (KEBA, 2013), and installation of it, which can be found in Appendix C. Vattenfall executes sales and installation activities, whereby the charging station is supplied by their subcontractor KEBA (KEBA, 2013), The Wallbox is available in several variations and three of them can be viewed in figure 17. Other technical data from the supplier and options for the customer are presented in Appendix D.
The Wallbox's Attributes:

- Installation: Indoor/Outdoor,
- Mounting: Wall/Ground
- Mode3
- Cable: Attached or detached cable assembly
- Socket outlet variations: Type 2
- Compatible PHEVS: Volvo V60 Plug-in Hybrid
- Price: 12000 SEK, basic package with installation Appendix C.

In Vattenfall’s charging offer: To be able to install a Wallbox on the private property the user’s household needs to have a main fuse of 20 A, in order to take part of basic installation package. The main fuse enables the Wallbox to provide maximum current and voltage presented as household charging, see Appendix C. In application with the type 1 and type 2 connector presented earlier, the Wallbox is able to provide the vehicle with performance such as: the maximum power and charging speed from household charging. The Wallbox with connector configurations and application with the maximum power provided from Swedish households, illustrated in table 4 below.
Table 4. Showing technical aspects for the Wallbox, when installed with a basic package presented in Appendix C.

<table>
<thead>
<tr>
<th>Wallbox</th>
<th>Phase</th>
<th>Current (max)</th>
<th>Voltage (max)</th>
<th>Power (max)</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Single</td>
<td>16A</td>
<td>230V</td>
<td>3.7kW</td>
<td>1,2</td>
</tr>
<tr>
<td>Type 2</td>
<td>Single</td>
<td>16A</td>
<td>230V</td>
<td>3.7kW</td>
<td>1,2</td>
</tr>
<tr>
<td></td>
<td>Three</td>
<td>16A</td>
<td>400V</td>
<td>11kW</td>
<td>1,2,3</td>
</tr>
</tbody>
</table>

3.4.2. Direct Competition

In excess of the Wallbox, EV drivers in Sweden are offered several other options within charging solutions for home appliance. These products are therefore referred to as direct competition on the E-mobility market for charging solutions.

*HomeBox* is a charging device supplied by Nissan in cooperation with POD Point, see figure 18, which is promoted together with the BEV Nissan Leaf (Nissan, 2013). POD point provides several charging solutions, whereby figure 18 shows the one belonging to their “solo charge point family” (POD Point, 2013). The charging solution provides the users with the option to schedule their charging, view data such as charging duration and Start/Stop time. The customer has the additional option of choosing an energy meter, in which billing and usage reports are organized in an online account for the user. In addition it is equipped with lights, illustrating the status of the charging, but also a locking function, in order to lock it at specific times of the day. Installation can be made with help of an authorized NIC EIC-electrician and is made to be installed indoors or outdoors.

The *HomeBox’s* Attributes:

- ✓ *Installation:* Indoor/Outdoor
- ✓ *Mode 3*,
- ✓ *Type 1, type 2 not yet released*
- ✓ *Cable: Attached*
- ✓ *Cable length: 5 m*
- ✓ *Compatible PHEVS:* Toyota Prius Plug-in, Chevrolet Volt, Opel Ampera
**Figure 18.** The figure shows a picture of the available product from POD Point “HomeBox” (Nissan, 2013).

*Park & Charge charger* is a charger for permanent charging spots, see figure 19. It has an enclosure cap, which makes it withstand differing weather conditions (Park & Charge, 2012). Furthermore it is suitable for both indoor and outdoor mounting, however installation needs to be performed by an authorized electrician. Park & Charge holds a customer support service and can also perform the installation.

The Park & Charge charger’s Attributes:

- ✔ Installation: Indoor/Outdoor
- ✔ Mode 3
- ✔ Cable: Attached
- ✔ Type 1, Type 2
- ✔ compatible PHEVS: Volvo V60 Plug-in Hybrid

**Figure 19.** Park & Charge home charging station (Park & Charge, 2012).
Leviton is a provider of several charging stations, in partnership with Toyota and compatible with all their vehicles (Leviton, 2013). As shown in figure 20, Leviton’s Evr-Green 160 Home Charging Station, are available for order, but not officially introduced on the Swedish market. The charging station has an attribute of light indicators, illustrating the charging status. Further, it provides a bracket to manage and organize the cable when not in use and a locking system which prevents unauthorized use. It is stated that they have an industry exclusive Warranty, covering 10 years, with Leviton certified installation.

The Leviton Charging station’s Attributes:

✓ Installation: Indoor/Outdoor
✓ Cable: Attached
✓ Cable length: 5.48m
✓ Type 1 (SAE J1772)
✓ Compatible PHEVS: Toyota Prius Plug-in
✓ Price: 700 USD

Figure 20. Leviton’s Evr-Green 160 Home Charging Station (Leviton, 2013).

UM-EVSE is a charging cable assembly provided by Charge-Amps (Charge Amps, 2013), see figure 21. The cable assembly is suitable for mode 1 household charging. The user can set the current strength (6 A -16 A) appropriate for the circumstances. It has a built in flashlight, in order for the user to easily find the vehicle inlet during darker conditions. Furthermore, it has a cap protecting the connector against accumulate dirt, when not in use. In addition, it has a security code system which can be activated by the user. Consequently, when the code is activated the power supply is disabled and it becomes unusable for unauthorized users.

The UM-EVSE’s Attributes:

✓ No installation
✓ Mode1
✓ Cable: Detached cable assembly
✓ Cable length: 5.48m
✓ Type 1 (SAE J1772)
✓ Compatible PHEVS: Toyota Prius Plug-in, Chevrolet Volt, Opel Ampera
✓ Price: 4700 SEK
3.4.3. Indirect Competition – Engine Warmer Outlets/Stations

Except from the direct competition there are other products of charging equipment available on the Swedish market, described as indirect competition for charging solutions. In engine warmers or engine warmer outlets exist on the majority of private properties, public and corporate parking places (Olov, 2013). As seen in figure 22, the engine warmers utilize the existing electric grid with a voltage of 230 V and normally requires a Schuko Plug for usage. On the right hand side in figure 22, an engine warmer outlet developed by ABB is shown (Voltimum, 2005). This product has a feature that recognizes the outdoor temperature and determines if the engine needs to be plugged in and the duration of the connection time.

The Engine Warmer’s Attributes:

✓ Installation of outlet
✓ Cable: No cable included
✓ Mode1- Schuko plug
✓ Compatible with mode 2 equipment.
✓ Compatible PHEVs: Volvo V60 Pug-in hybrid, Toyota Prius Plug-in, Chevrolet Volt, Opel Ampera

Figure 21. Charge-Amps UM- EVSE detached cable assembly (Charge Amps, 2013).

Figure 22. To the left in the figure is a picture of engine warmers at a parking in Luleå, Sweden, (Olov, 2013). To the right in the figure is an engine warmer by ABB (Voltimum, 2005).
3.4.4. International Competition

Under this section, charging solutions on the international market are presented. These products are not available on the Swedish market, hence contain interesting features and attributes. It serves as a good benchmark of potential competitors in the future.

*GM Voltec* is a development brought from Bosch Group, who has developed a line of charging solutions for EVs (Bosh, 2013). The GM Voltec presented in figure 23 is a designed charging station by Bosch and is available as an optional complement to the Chevrolet Volt. It has multiple color LED lights illustrating the status of the charging. There is a flashlight built into the vehicle connector to enable easy coupling of the connector.

*The GM Voltec’s Attributes:*

- **Installation:** Indoor/Outdoor
- **Mounting:** Wall/Pedestal
- **Cable:** Attached
- **Cable length:** 7 m
- **Type 1**
- **Compatible PHEVS:** Toyota Prius Plug-in, Chevrolet Volt, Opel Ampera

![GM Voltec Charging Station](image-23)

**Figure 23. Bosch Group GM Voltec charging station (Bosh, 2013).**

*The WattStation- Wall mount* is on of GE Industrial product developed for home charging (GE 1, 2013). GE has developed a line of several charging station, with options of connecting to a network port as well as non-connected alternatives. An example shown in figure 24 is the Wall Mount. This product has a two piece mounting bracket design, which is designed to enable installation and removal by a single person. The hard wire has three different entry options; top, bottom and rear, whereby the cable can be wound up around the station when not in use. Remarkably, GE’s charging stations can be connected to a cloud service, which is an integrated software platform called Wattstation connect (GE 2, 2013). This software provides the user with the option of controlling and monitoring their charging station. It gives them status update about charging and diagnoses, which allow the users to manage issues remotely. Currently, neither the product WallMount nor the service WattStation is available on the Swedish market.
The WattStation- Wall mount’s Attributes:

- Installation: Indoor/Outdoor
- Mounting: Wall/Pedestal
- Cable: Attached, Organized
- Type 1
- Compatible PHEVs: Toyota Prius Plug-in, Chevrolet Volt, Opel Ampera

Figure 24. The GE WattStation – Wall mount by GE industrial (GE 2, 2013).

Furthermore, GE has a product, soon to be launched within the WattStation line, also called The Wattstation (GE 3, 2013). This product is more directed towards public parking places, but has some interesting features, see figure 25. It has the possibility of retracting the cord into the charging station, which protects it when not in use. It is a modular station, which enables and simplifies upgrading of charging equipment. This product, as their entire product line, can be connected to the WattStation software.

The WattStation’s Attributes:

- Installation: Indoor/Outdoor
- Mounting: Pedestal
- Cable: Attached, Organized
- Modular
- Compatible PHEVS: Volvo V60, Toyota Prius Plug-in, Chevrolet Volt, Opel Ampera

Figure 25. The GE WattStation – Pedestal by GE industrial (GE 3, 2013).
4. Introduction of Car Models and Market Research

This chapter is an introduction of the technical specification concerning the available Plug-in Hybrid Electric Vehicles, PHEV. Further, a comparison chart is compiled with the available car models on the Swedish market. Lastly, an introduction of the current Swedish Vehicle fleet is given, with historic changes on the market.

There are several different types of electric vehicles and the categorization mostly depends on the assembly of their powertrain, in the vehicle. Moreover, Electric Vehicle – EV – covers the category of all vehicles, fully or partly driven by an electrical power source. Further, there are abbreviations for the EVs with different combination of driving modes, inspired by International Electrotechnical Commission (IEC, 2011) in table 5. In this study the terminology will be used according to the European generic guidelines, compiled in table 5.

Table 5. Electrical Vehicles - different configurations and powertrains (IEC, 2011; Volvo, 2013).

<table>
<thead>
<tr>
<th>EV - Electric vehicle</th>
<th>Totally or partly driven by an electric power source, a generic term that includes BEV, HEV, PHEV and EREV</th>
<th>Example:</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEV – Battery Electric Vehicle</td>
<td>• Totally driven by an electric power source. Battery provides the electric motor with stored electricity.</td>
<td>Volvo C30, Nissan Leaf, Ford Focus Electric, Tesla Model S</td>
</tr>
<tr>
<td></td>
<td>• Charge battery by plugging it to the electricity grid.</td>
<td></td>
</tr>
<tr>
<td>HEV – Hybrid Electric Vehicle</td>
<td>• Combination of an electric motor and an Internal Combustion Engine (ICE)</td>
<td>Example:</td>
</tr>
<tr>
<td></td>
<td>• The electric motor works as a complement parallel to the ICE</td>
<td>Toyota Prius,</td>
</tr>
<tr>
<td></td>
<td>• Battery is charged by the energy provided from regenerative braking.</td>
<td></td>
</tr>
<tr>
<td>PHEV – Plug-in Hybrid Electric vehicle</td>
<td>• Combination of an electric motor and an Internal Combustion Engine (ICE)</td>
<td>Example:</td>
</tr>
<tr>
<td></td>
<td>• The electric engine works parallel to the ICE</td>
<td>Volvo V60 Plug-in Hybrid, Toyota Prius Plug-in Hybrid</td>
</tr>
<tr>
<td></td>
<td>• Charge battery by plugging it to the electricity grid.</td>
<td></td>
</tr>
<tr>
<td>EREV – Extended Range Electric Vehicle</td>
<td>• The electric motor works as the main power source with an on-board ICE connected in series, in order to extend the range.</td>
<td>Example:</td>
</tr>
<tr>
<td></td>
<td>• Battery is charged by plugging it in to the electric grid. If discharged during drive the generated electricity is provided by the ICE.</td>
<td>Chevrolet VOLT, Opel Ampera</td>
</tr>
</tbody>
</table>
The car models covered by the study are Plug-in Hybrid Electric Vehicles (PHEV) and Range-Extended Vehicle (REV). The car models considered in this study are; Volvo V60 Plug-in Hybrid, Toyota Prius Plug-in Hybrid, Opel Ampera and Chevrolet VOLT. The Plug-in Hybrid Electric Vehicle – PHEV – is an extension of a Hybrid Electric Vehicle, HEV. All vehicles that are able to plug-in and utilize the electric grid, in order to charge the battery are referred to as Plug-in Electric Vehicle-PEV. Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV) can generically be called PEV.

A PHEV is powered by two sources of energy; an electric motor and an Internal Combustion Engine, ICE. The electric motor is supplied with electrical energy through a battery pack integrated in the vehicle, see figure 26 below. The battery pack can be charge externally by plugging it to the electric grid. Furthermore the stored energy from regenerative braking and deceleration of the ICE, internally recharges the battery. The ICE is supplied with fuel from a regular fuel tank, most commonly with petrol or diesel. The configuration of the powertrain - interaction between the electric motor and the ICE - can vary depending on the models. In figure 26 below, a parallel configuration of the powertrain is illustrated, together with a common description of the general PHEV. (Berman, 2010)

![Figure 26. A simple illustration of a parallel configuration of a powertrain. The vehicle is categorized as a PHEV, with an mode 2 charging situation (Bergman, 2010).](image)

The utilization and interaction of the two power sources can vary depending on the car model and configuration of the powertrain. Further, Fridén and Sahlin (2012) explains that there are three different configurations; parallel, series - parallel and series configuration:

- **Parallel configuration of the powertrain** - The electric motor and the ICE are coupled separately and can directly be used to power the vehicle. They can either be used separately or combined together, depending on the directions from the vehicles control system or a manual choice by the driver.

- **Series configuration of the powertrain** - The electric motor powers the vehicle solely with electric energy, whereby the ICE assists the battery. The ICE is
decoupled from the wheel axis and generates only electrical energy to charge the battery when discharged, in order to be able to supplying the electric motor with electricity (Freyermuth et al, 2008).

- **Series-Parallel/Power Split configuration** – A combination of the two configurations mentioned above. This configuration enables transmission featured in both parallel and series configuration. The technic enables the transmission of energy and power split, so the battery for instance can benefit from deceleration (Freyermuth et al, 2008).

### 4.1. Volvo V60 Plug-In Hybrid

The Volvo V60 Plug-in Hybrid was for the first time introduced at the *Genèva Motor Show in March 2011* (Vattenfall, Volvo Cars, 2013). The production of the car series started in autumn 2012, subsequently the first series of 1000 cars were made for the model year 2013, see figure 27 below (Kryssare, 2013; Volvo, 2013). 300 cars were dispensed and sold in Sweden, whereby potential buyers could sign up on a list of interest (Lilja, 2013). Further, the 300 exclusive selected drivers received a purchasing offer.

For the model year of 2014, the production is increased to a series of 5000 vehicles. Approximately, 30 % of the total volume of vehicles are dedicated to Sweden and the Scandinavian countries. Germany, Schweiz, Belgium, France, Netherlands and Great Britain will be allocated the remaining percentage, approximately between 5-15 % per country (Kryssare, 2013).

![Figure 27. Volvo V60 Plug-in Hybrid on the road (Volvo Cars, 2013).](image)

Volvo V60 Plug-in Hybrid is one of the most equipped cars in the category of PHEV. The first series of 300 Vehicle where only available in the highest and most luxuries category of accessories and interior (Lilja, 2013; Volvo, 2013). The car is further referred as three cars compiled into one car. The car is all-wheel drive, whereby the front wheel drive is empowered by a turbo diesel engine with 215 horse powers. Additionally, the rear wheels are equipped the electric motor on 70 horse power (Vattenfall, Volvo Cars, 2013).
The car is drivable and equipped with three different driving modes, see figure 28 (Volvo, 2013):

- **“Pure”** – The car is driven by the electric motor and with a full charged battery the driving range is 50km on pure electricity and 0 % of emission.
- **“Hybrid”** – This is the preset mode when the car is started. Hybrid-mode is where the cooperation between the combustion engine and electric motor is optimized, in order to reach optimal fuel consumption. The total driving range is 1200 km.
- **“Power”** – This mode generates the power and high performance of the car, further also enables the utilization of the 285 horse power. The power mode combines the best out of the electric motor (70 horse power) and the diesel engine (215 horse power) for maximal capacity. The acceleration from 0-100 km is made in 6,9 sec and the maximum speed is 230 km/h. (Vattenfall & Volvo Cars, 2013)

![Figure 28](image)

**Figure 28. The three electable driving modes: Pure, Hybrid and power (Volvo Cars, 2013).**

The electric motor is supplied with electricity from a lithium-ion battery on 11,3 kWh and 400 V (Vattenfall, Volvo Cars, 2013). The Volvo V60 Plug-in Hybrid charges with a type 2 charging connector. The vehicle inlet is placed on the front left-side, with an interface compatible with Mennekes connector, see figure 29 below.

The charging speed, from a discharged battery to a fully charged battery, is approximately:

- 16 A – 3-4 h
- 10 A – 4-5 h
- 6 A – 6-8 h

(Vattenfall & Volvo Cars, 2013; Volvo, 2013).

![Figure 29](image)

**Figure 29. Volvo V60 Plug-in Hybrid connected to a charging box. Vehicle inlet is placed on the left-side front (Vattenfall & Volvo Cars, 2013).**
4.2. Toyota Prius Plug-In Hybrid

The Toyota Prius Plug-in is an extended version of the original Toyota Prius. The first generation of Toyota Prius was introduced to the Japanese Market around 1997 and worldwide 2000 (Toyota 1, 2013; GCC, 2013). By 2003 a second generation was released and by 2009 a third generation was launched (GCC, 2013). Together with the development of the hybrid technology, Toyota has won different prices in environmental branding, e.g. “Best Global Green Brands” (Toyota 2, 2013). In 2012 Toyota introduced their customer segment to a new extended version of the Toyota Prius, the Toyota Prius Plug-in. In contrast to the luxurious Volvo V60 Plug-in, Toyota Prius Plug-in is sold as car with basic equipment with optional additions to customize the vehicle, see figure 30.

As well as the Volvo V60 Plug-in hybrid, the Toyota Prius Plug-in has an internal combustion engine in parallel with an electric motor. In contrast to the Volvo, the combustion engine is powered by petroleum (Toyota 1, 2013).

There are three different driving modes (Toyota 3, 2013):

- “HV” – This is the hybrid mode where the car automatically shifts between petroleum and electricity. Consequently, the fuel consumption is optimized by every driving situation.
- “EV” – This is a pure mode where the car only runs on electricity. Occasionally, the combustion engine assists, in order to retain the performance. The driving range is 25 km on pure electricity.
- “EV-City” – This is a preferable mode for city driving, this mode allows quicker acceleration before the ICE starts.

The Toyota Prius Plug-in is also supplied with an lithium-ion battery on 4.4 kWh. The car is charged with a type 1 car connector J1772, see “Charging Connector”. The charging speed from a discharged battery to a fully charged battery is approximately 90 minutes on a regular domestic/household socket outlet (Toyota 4, 2013). Further, the vehicles inlet is placed on the right-side of the rear, see figure 30 showed above. The charging cable assembly included in the purchase of the vehicle is 5 m (Toyota, 5).

4.3. Chevrolet VOLT and Opel Ampera

Chevrolet VOLT and Opel Ampera are classified as Plug-in Hybrid Electric Vehicles, PHEVs’. The Volvo V60 Plug-in and the Toyota Prius Plug-in contains two parallel power sources supporting the vehicles powertrain. In contrast to them, the Chevrolet VOLT and
Opel Ampera only have one electric motor supporting the powertrain. On the other hand a combustion engine is connected in series, supporting the powertrain when the battery is discharged. The unique technology system is called Voltec-platform and is developed by General Motors, GM, (GM, 2013). The technology system can be found in GM’s own carried car brands – Chevrolet VOLT, but the system is also integrated in the Opel Ampera.

The powertrain contains a chargeable battery, which can be charged externally by plugging it to the grid. As long as the battery is charged, it empowers the electric motor with electricity. In case of the battery gets discharged, a combustion engine will start. This engine is not coupled to a wheel axis, hence it is coupled to an electric generator. This electric generator will continue to supply the depleted battery and electric motor with electricity. The combustion engine purpose is therefore to extend the driving range when the battery is discharged. The Voltec-Platform is categories in a subcategory under PHEV, more known as "Extended Range Electric Vehicle, E-REV (Opel, 2012).

4.3.1. Chevrolet VOLT

The Chevrolet VOLT was introduced in the United States 2011, whereby it was introduced to the European market in March 2012, see figure 31 (Chevrolet, 2013). The manufacturer behind the success is General motors, GM. As mentioned the VOLT is an e-REV, with 4 different driving modes available; Normal, Sports, Mountain and Hold (Chevrolet, 2013).

![Figure 31. Chevrolet VOLT (Chevrolet, 2013)](image)

The current generation of Chevrolet VOLT has a type 1- J1772 connector together with a 6 meter regular mode 2 cable, see figure 32 below. The charging time is approximately 6 h with 10 A/230 V outlet.

![Figure 32. The charging cable (6m) that is included in the purchase of the vehicle. It is adjusted for charging in a domestic/ household outlet 230 V/10 A (Chevrolet, 2013.](image)
4.3.2. Opel Ampera

Opel Ampera is an E-REV based on the same powertrain – Voltec-Platform – as Chevrolet VOLT. Historically Opel is an old German car manufacturer that is in partnership with General Motors, GM, since 1930’s (Autorevloution, 2013). Today GM has a majority share of the company, hence the cars are still commercialized separately from GM brand portfolio. The car is also available at Vauxhall, a British car manufacturer - subsidiary of GM, who is commercializing an identical vehicle under the name of Vauxhall Ampera (Vauxhall, 2013). On the other hand, these vehicles are not available on the Swedish market. Figure 33 below, shows a picture of the current Opel Ampera available on the Swedish market.

The Ampera has been very successful on the market and received over 40 awards within the industry (Vauxhall 2, 2013). The Ampera was the most sold EV in Europe, according to sales figures in May 2012, with a market share on 20 % on sold EVs (Opel, 2012).

![Opel Ampera](image)

**Figure 33. The latest model of Opel Ampera and the exterior of the vehicle (Opel, 2013)**

The Ampera has two major driving modes (Vauxhall, 2013):

- **Battery-Powered Driving mode:** In this mode the petrol engine is off and the electricity is supplied entirely by the battery. The mode enables both low-speed and high-speed driving.

- **Extended-Range Driving mode:** This mode starts when the battery is discharged. The petrol engine activates and supplies a generator with energy, which further supplies the electric motor and battery pack with electricity.

The charging equipment delivered with the vehicle, is a charging cable with a type 1 connector and a mode 2 cable. The charging equipment is identical to the one delivered with Chevrolet VOLT, earlier showed in figure 32. The charging time with 10 A/230 V domestic outlet is approximately 6 hours and 4 hours with 16 A (Miljofordon, 2013).

4.4. Comparison Chart

All the previously mentioned vehicles are within the category of PHEVs, with various attributes and powertrain platforms. In table 6, a comparison chart of the four different models has been presented, in order to clarify the similarities versus the differences.
Table 6. A comparison chart of the four vehicles covered by the study (Toyota 4, 2013; Vattenfall & Volvo Cars, 2013; Opel 1, 2013; Opel 2, 2013; Chevrolet, 2013).

<table>
<thead>
<tr>
<th></th>
<th>Volvo V60 Plug-in Hybrid</th>
<th>Toyota Prius Plug-in</th>
<th>Chevrolet VOLT</th>
<th>Opel Ampera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Speed</td>
<td>230km/h (120km/h in Pure-mode)</td>
<td>180km/h (100km/h in EV-Mode)</td>
<td>161km/h</td>
<td>161km/h</td>
</tr>
<tr>
<td>Performance</td>
<td>285 hp</td>
<td>136 hp</td>
<td>160 hp</td>
<td>150 hp</td>
</tr>
<tr>
<td>Acceleration 0-100km/h</td>
<td>6,9 sec</td>
<td>11,4 sec</td>
<td>9 sec</td>
<td>9 sec</td>
</tr>
<tr>
<td>Combustion Engine</td>
<td>Diesel (215 hp) 5-Cylinder 2,4 litre</td>
<td>Petroleum (99hp) 4-Cylinder VVT-Engine 1,7 litre</td>
<td>Petrol 4 cylinder 1,4 litre</td>
<td>Petrol(86hp) 4 cylinder 1,4 litre</td>
</tr>
<tr>
<td>Battery type</td>
<td>Lithium-ion battery</td>
<td>Lithium-ion battery</td>
<td>Lithium-ion battery</td>
<td>Lithium-ion battery</td>
</tr>
<tr>
<td>Electric motor</td>
<td>50kW (70 hp)</td>
<td>60kW(82hp)</td>
<td>110kW (53kW from gas engine)</td>
<td>111kW (63kW from gas engine)</td>
</tr>
<tr>
<td>Battery capacity</td>
<td>11,2 kWh</td>
<td>4,4kWh</td>
<td>16kWh</td>
<td>16kWh</td>
</tr>
<tr>
<td>Charging time (230 V/10 A)</td>
<td>4,5 h</td>
<td>1 1/2 h</td>
<td>4 h</td>
<td>6 h</td>
</tr>
<tr>
<td>Fast charging</td>
<td>Not possible</td>
<td>Not possible</td>
<td>Not possible</td>
<td>Not possible</td>
</tr>
<tr>
<td>Car Connector</td>
<td>Type 2 - Mennekes</td>
<td>Type 1 - J1772</td>
<td>Type 1 - J1772</td>
<td>Type 1 - J1772</td>
</tr>
<tr>
<td>Driving Range on Pure electricity</td>
<td>50km</td>
<td>16-24 km</td>
<td>80 km</td>
<td>40-80km –</td>
</tr>
<tr>
<td>Total driving range</td>
<td>1200km</td>
<td>N/A</td>
<td>500km</td>
<td>500km</td>
</tr>
<tr>
<td>Electricity consumption</td>
<td>13,5 kWh per 100km</td>
<td>N/A</td>
<td>13,5 kWh per 100km</td>
<td>13,5 kWh per 100km</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>1,9 l per 100km</td>
<td>2,1 l per 100km</td>
<td>1,2 l per 100km</td>
<td>1,6 l per 100km</td>
</tr>
<tr>
<td>CO₂ emission</td>
<td>0 -49 g CO₂/km</td>
<td>0 -49 g CO₂/km</td>
<td>0 -40 g CO₂/km</td>
<td>0 -27 g CO₂/km</td>
</tr>
<tr>
<td>Original Price</td>
<td>Ca. 600 000 SEK</td>
<td>Ca. 360 000 SEK</td>
<td>Ca. 461 000 SEK</td>
<td>Ca. 466 400 SEK</td>
</tr>
<tr>
<td>After Submission</td>
<td>40 000 SEK</td>
<td>40 000 SEK</td>
<td>40 000 SEK</td>
<td>40 000 SEK</td>
</tr>
<tr>
<td>Price</td>
<td>Ca. 560 000 SEK</td>
<td>Ca. 320 000 SEK</td>
<td>Ca. 421 000 SEK</td>
<td>Ca. 426 400 SEK</td>
</tr>
</tbody>
</table>
4.5. The Swedish Vehicle Fleet and The Market

Sweden as a nation favors sustainable development, with several governmental projects running. Internationally, Sweden is recognized as environmental friendly country, which also can be confirmed by the Environmental Performance Index (EPI). Nevertheless, the Yale University in US ranks the index of Environmental Performance (YCELP, 2012). Countries are ranked considering two major perspectives; Environmental Public Health and Ecosystem Vitality.

In the EPI ranking Sweden is ranked as number 9, consequently the top 10 countries in the world (YCELP, 2012). Looking at the national progress on the E-mobility market and industry, Sweden is not keeping the same progress as the other Scandinavian countries and surrounding neighbor countries. For instance, the biggest progress can be located in Germany, Netherlands and Norway. In the category of charging infrastructure – Estonia is the country with the greatest progress (Andrén, 2013).

4.5.1. Current Passenger Car Fleet

Statistics from Statistics Sweden showed that by 2012 the Swedish vehicle fleet consisted a total of 4 447 165 passenger cars. Out of the total car fleet, 603 passenger cars were pure battery electric vehicle (BEV) and 24 349 were hybrid electric vehicles (HEV). Consequently, the total amount of EV's landed on 24 952 passenger cars, representing 5,6 % of the Swedish vehicle fleet 2012, see table 7 below. (SCB, 2013)

Table 7. Passenger cars in use in Sweden, arranged by fuel type and by year 2008-2012 (SCB, 2013).

<table>
<thead>
<tr>
<th>In the end of the year</th>
<th>Petrol</th>
<th>Diesel</th>
<th>Electricity</th>
<th>Ethanol/Ethanol hybrid</th>
<th>Electric hybrids</th>
<th>Gas</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>3 699 221</td>
<td>416 822</td>
<td>129</td>
<td>137 201</td>
<td>13 483</td>
<td>11 974</td>
<td>165</td>
<td>4 278 995</td>
</tr>
<tr>
<td>2009</td>
<td>3 607 248</td>
<td>484 083</td>
<td>157</td>
<td>175 153</td>
<td>16 095</td>
<td>17 850</td>
<td>166</td>
<td>4 300 752</td>
</tr>
<tr>
<td>2010</td>
<td>3 479 607</td>
<td>606 570</td>
<td>190</td>
<td>204 456</td>
<td>19 210</td>
<td>24 973</td>
<td>176</td>
<td>4 335 182</td>
</tr>
<tr>
<td>2011</td>
<td>3 364 196</td>
<td>766 042</td>
<td>366</td>
<td>218 175</td>
<td>21 389</td>
<td>30 992</td>
<td>192</td>
<td>4 401 352</td>
</tr>
<tr>
<td>2012</td>
<td>3 236 814</td>
<td>924 197</td>
<td>603</td>
<td>225 869</td>
<td>24 349</td>
<td>35 121</td>
<td>212</td>
<td>4 447 165</td>
</tr>
</tbody>
</table>
4.5.2. Trend within the Swedish Passenger Car Fleet

By observing the Swedish vehicle fleet over a 10 year period, it shows an increasing trend in total passenger cars per year. In April 2004, the total passenger car fleet was 4 114 364 passenger cars. In April 2008, five years later, the total car fleet was 4 310 040 passenger cars. Consequently, during a five year period, there was an increase of approximately 4,76 % of vehicles on the roads, see table 8 Further information is available in Appendix E.

Table 8. Plot of the yearly change of the Swedish passenger car fleet, over period of 10 year. The table shows an clear trend of a growing passenger car fleet (SCB, 2013).

![Graph showing the yearly change of the Swedish passenger car fleet from 2004 to 2013.](image)

Between April 2009 and April 2010, there was a drop in the passenger car fleet. In April 2013 the car fleet had recovered to a number of 4 512 950 passenger cars. In table 8 above, the total increase during the 10 year period is plotted from April 2004 to April 2013. In conclusion, the final increase landed at approximately on a growth to 9,69 % between 2004 – 2013.

4.5.3. Trends within the Swedish Alternative Car fleet

In the first third of the year 2013 - January to April - there were 87 398 new passenger cars registered, see Appendix F. During the month of April 2013, there were 26 642 passenger cars newly registered. Comparing to the previous year, April 2012, it was an increase with 4,9 % (Trafikanalys, 2013). By end of April 2013, 2,38 % of the new registered cars where electric vehicles – either BEV, HEV or PHEV. Observing the same period last year – January 2012 to April 2012 – the EV share only responded to 0,63% EVs. See further monthly share between 2006-2013 in Appendix F.

The three current major alternative fuels in Sweden are; Ethanol/Ethanol hybrid, Natural Gas and EV (BEV/HEV/PHEV) (Trafikanalys, 2013). Observing the change over the last seven years (2006-2012), table 9 shows the trend of the alternative fuels.
Table 9. The table below shows the progress of the three most popular (Trafikanalys, 2013).

<table>
<thead>
<tr>
<th>Year</th>
<th>Ethanol/Ethanol Hybrid</th>
<th>EV (BEV/HEV/PHEV)</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>26118</td>
<td>2853</td>
<td>3626</td>
</tr>
<tr>
<td>2007</td>
<td>35513</td>
<td>3396</td>
<td>1759</td>
</tr>
<tr>
<td>2008</td>
<td>59024</td>
<td>4247</td>
<td>1387</td>
</tr>
<tr>
<td>2009</td>
<td>40165</td>
<td>3114</td>
<td>6125</td>
</tr>
<tr>
<td>2010</td>
<td>35465</td>
<td>3731</td>
<td>7005</td>
</tr>
<tr>
<td>2011</td>
<td>15203</td>
<td>3112</td>
<td>6618</td>
</tr>
<tr>
<td>2012</td>
<td>5904</td>
<td>3964</td>
<td>5435</td>
</tr>
</tbody>
</table>

Based on numbers from the Swedish Statistics, table 9 shows that during the year of 2008, Ethanol was the most popular alternative fuel type (Trafikanalys, 2013). During the peak period, 59 024 out of 276 344 new registered passenger cars were Ethanol/Ethanol Hybrid driven. This corresponds to a remarkable percentage of 21,4% of the total new registrations in 2008, see Appendix F. After 2008 the fuel trend of ethanol dropped remarkably, hence in 5 years the registration amount had dropped with almost 90%, to 5904 new registered passenger cars 2012.

The E-mobility market has been stable the last few years, with an indication of an incoming trend. Electric Vehicle made a strong start the first third of the current year 2013. 2709 newly registered cars, whereby 122 passenger cars are pure BEV and 1957 passenger cars are HEV/PHEV, see table 10. The total amount of new registered electric vehicles – January 2013 to April 2013 – has already exceeded over 53 % of the total amount of the entire year of 2012.

Table 10. A table over the new registered vehicles distributed over months and fuel type (Trafikanalys, 2013).

<table>
<thead>
<tr>
<th></th>
<th>Petrol</th>
<th>Diesel</th>
<th>Electricity</th>
<th>Ethanol</th>
<th>Electric hybrids</th>
<th>Gas</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 January</td>
<td>5 369</td>
<td>11 067</td>
<td>43</td>
<td>166</td>
<td>469</td>
<td>365</td>
<td>3</td>
<td>17 482</td>
</tr>
<tr>
<td>February</td>
<td>6 046</td>
<td>11 928</td>
<td>26</td>
<td>163</td>
<td>574</td>
<td>405</td>
<td>1</td>
<td>19 143</td>
</tr>
<tr>
<td>March</td>
<td>8 166</td>
<td>14 794</td>
<td>29</td>
<td>287</td>
<td>497</td>
<td>354</td>
<td>4</td>
<td>24 131</td>
</tr>
<tr>
<td>April</td>
<td>9 079</td>
<td>16 610</td>
<td>24</td>
<td>151</td>
<td>417</td>
<td>356</td>
<td>5</td>
<td>26 642</td>
</tr>
<tr>
<td>TOT</td>
<td>28 660</td>
<td>54 399</td>
<td>122</td>
<td>767</td>
<td>1 957</td>
<td>1 480</td>
<td>13</td>
<td>87 398</td>
</tr>
</tbody>
</table>
4.5.4. Current PHEV Car Fleet

In March 2013 there was a total of 840 registered Plug-in Hybrid Electric Vehicle, according to the Swedish Transport Agency and the department of vehicle selection (Granlund, 2013). In total, there were 479 Toyota Prius Plug-in Hybrid vehicles on the roads (57 %), followed by Volvo V60 Plug-in Hybrid Vehicles (30 %) with 252 vehicles. The remaining 13 % are covered by Chevrolet VOLT (4 %) and Opel Ampera (9 %), see figure 34 below.

![PHEV - Passenger Cars on the Swedish Market](image)

**Figure 34.** The Swedish Plug-in Hybrid Electric Vehicle market and the distribution of the four PHEVs (Granlund, 2013).

From 840 registered Plug-in Hybrid Electric Vehicles, 470 PHEV are registered in the "Urban Environment" – Stockholm, Göteborg and Malmö. The remaining 370 PHEV are spread over the country and are in classified in the category "Country Side", see table 11.

**Table 11. Geographical spread of registered PHEV over the country (Granlund, 2013).**

<table>
<thead>
<tr>
<th></th>
<th>Urban Environment</th>
<th>Urban cities</th>
<th>Country side</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stockholm(city)</td>
<td>Göteborg</td>
<td>Malmö</td>
</tr>
<tr>
<td>Volvo V60 Plug-in</td>
<td>82</td>
<td>62</td>
<td>2</td>
</tr>
<tr>
<td>Toyota Prius Plug-in</td>
<td>229</td>
<td>21</td>
<td>13</td>
</tr>
<tr>
<td>Chevrolet VOLT</td>
<td>19</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Opel Ampera</td>
<td>33</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>363</strong></td>
<td><strong>89</strong></td>
<td><strong>18</strong></td>
</tr>
</tbody>
</table>

Further the ownership can be divided into two sectors; Private Sector and Company Sector. The company sector represents the majority of the ownership form, with 83 %.

The private sector corresponds to the remaining 17 %, see figure 35.
Below in table 12, it is shown that only 27 of 252 Volvo V60 Plug-in vehicles are within the private sector, corresponding to only 10.7 percent of the market share of private owned vehicles. In the Toyota Prius Plug-in category, there are 20.9 % of the passenger cars that are private, whereby the category of others only have 13.8 % within the private sector. (Granlund, 2013)

**Table 12.** Distribution of the ownership according to the three pre-defined groups according to the study (Granlund, 2013).

<table>
<thead>
<tr>
<th></th>
<th>Volvo V60 Plug-in</th>
<th>Toyota Prius Plug-in</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Opel Ampera</td>
<td>Chevrolet VOLT</td>
</tr>
<tr>
<td>Total Vehicles</td>
<td>252</td>
<td>479</td>
<td>79</td>
<td>30</td>
</tr>
<tr>
<td>Company Sector</td>
<td>225</td>
<td>379</td>
<td>66</td>
<td>28</td>
</tr>
<tr>
<td>Private Sector</td>
<td>27</td>
<td>100</td>
<td>13</td>
<td>2</td>
</tr>
</tbody>
</table>

Further specifying the sectors, it is seen that the ownership under each sector is divided into either Private Owned/Company Owned vehicles or Private Leased/Company Leased vehicles. The distribution of the ownership share can be seen in figure 36, below.

**Figure 36.** The distribution of the ownership share over the private sector respectively the company sector (Granlund, 2013).
The delimitation of the study focuses on PHEV within the private sector. Accordingly to numbers from March 2013, this responds to a market of 142 Vehicles in total. Further visualizing the private sector, it is seen in figure 37, the distribution of the car models. 71 % of all PHEV drivers in the private sector, are Toyota Prius Plug-in. Further, only 19 % of the drivers are Volvo V60 Plug-in Hybrids owner. Nevertheless, the remaining 10 %, belongs to private owned Opel Ampera and Chevrolet VOLT . (Granlund, 2013)

**Figure 37.** A pie chart showing the percentage distributed on the four car models available (Granlund, 2013).
5. Empirical Investigation of Users

This chapter presents the outcome from the empirical investigation comprising 36 interviews with users of Plug-in Hybrid Electric Vehicles. In order to understand the users’ habits and needs an empirical investigation was conducted, performing telephone interviews with private owners of Plug-in electric vehicle users. Interview question for quantitative and qualitative data collection were asked regarding the users’ car choice and purchase criteria, driving and charging habits, charging solutions and pricing. Moreover, findings presented in this chapter, will be used for further analysis of the users preferences and charging prerequisites. The results are divided into to two major categories; Quantitative results and qualitative results.

The results from the empirical investigation are based on “long interviews” and “short interviews”, conducted using the interview guides presented in Appendix A and Appendix B. The outcome of the long interviews represents both qualitative and quantitative data, further the outcome of the short interviews represents quantitative data with additional observations. The outline of the results for each of the two data gatherings will be presented first using quantitative data, continuing with complement of qualitative data and additional observations. The data will be presented according to the three fields of investigation: car choice and purchase criteria, charging and driving habits and charging solution and pricing.

The respondents’ answers will primarily be presented corresponding to the three respondents groups requested by the stakeholder; Volvo V60 Plug-in, Toyota Prius Plug-in and the group of Opel Ampera and Chevrolet, Others. The 36 respondents are distributed among the three groups as illustrated in figure 38. Worth notifying is that the Others group is a too small sample to be representative for the group as a whole.

![Distribution of respondents](image)

**Figure 38. Illustrating the distribution of respondent.**
5.1. Demographics

Demographical data was gathered in order to get quantifiable data about the users. Table 13 presents social data about the respondents in each group. Regarding the total number of respondents; 86 % of them live in villas, 92 % drive a private owned PHEV and 92 % uses it as their primary car. Regarding the total gender distribution; 86 % of the respondents are male drivers and the 14 % represent female drivers, whereby all female drivers are represented in the Toyota group.

Table 13. Demographics over the 36 respondents categorized by car model

<table>
<thead>
<tr>
<th></th>
<th>V60</th>
<th>Toyota</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of respondents</td>
<td>12</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Gender</td>
<td>100% Male</td>
<td>75% Male, 25% Female</td>
<td>100% Male</td>
</tr>
<tr>
<td>Age spread</td>
<td>21-80 years</td>
<td>39-83 years</td>
<td>55-78 years</td>
</tr>
<tr>
<td>Average age</td>
<td>52 years</td>
<td>57 years</td>
<td>69 years</td>
</tr>
<tr>
<td>Median age</td>
<td>49 years</td>
<td>60 years</td>
<td>72 years</td>
</tr>
<tr>
<td>Housing</td>
<td>83% Villa</td>
<td>85% Villa</td>
<td>100% Villa</td>
</tr>
<tr>
<td>Persons in household, average</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Ownership</td>
<td>92% Private owned, 8% Private leasing</td>
<td>90% Private owned, 10% Private leasing</td>
<td>100% Private owned</td>
</tr>
<tr>
<td>Duration of ownership, average</td>
<td>2 months</td>
<td>5 Months</td>
<td>8 months</td>
</tr>
<tr>
<td>Primary car</td>
<td>92% Yes, 8% No</td>
<td>95% Yes, 5% No</td>
<td>75% Yes, 25% No</td>
</tr>
</tbody>
</table>

Other occupational forms are represented by 14 % of the respondents, whereby 11 % of the respondents live in apartments and the remaining 3 % lives in a row house. The 8 % of the respondents which PHEVs are not private owned have subscription cars, private leasing. The respondents are between 21-83 years old and their age distribution among the groups is presented in figure 39 below.
5.2. Quantitative Data Results

The quantitative research was made on 36 respondents. The respondents were categorized into groups according to their car model. The result of the quantitative data collection is presented in three sub-chapters according to the focus area about the users Car choice and Purchase criteria, Charging and Driving Habits, Charging solution and Pricing.

5.2.1. Car Choice and Purchase Criteria

The interests that drove the respondents’ purchase of their current PHEV are illustrated in Figure 40. Within the Volvo V60 group, the technology interest is the main driving factor in their car choice, rated to be of a 44 % importance level in their purchase decision. Technology is also the main interest affecting the respondents in the Others group. However, within Toyota, environmental interest is the primary driver in their car choice, valued to an importance level of 44 % in their car choice.
Compiling the rating of all respondents purchase interest and criteria, shows that environmental interest is the main driving factor on behalf of the 36 respondents. Technology interest is later rated as the second driving factor, lastly economical interest is rated to be third driving factor in their car purchase decision. The overall percentage on each interest is illustrated in figure 41 below.

**Figure 41. Illustrating the distribution of interests rated compiled from all three respondent groups, which affected the respondents’ car purchase decision.**

### 5.2.2. Charging and Driving Habits

Home is the main charging place for 92 % of the respondents, where 72 % of the drivers have their own garage and 22 % a private outdoor parking. Table 14 shows the respondents current home parking and charging situation.

**Table 14. The home parking and charging situation within the respondent groups.**

<table>
<thead>
<tr>
<th>Respondents parking &amp; charging situation</th>
<th>V60</th>
<th>Toyota</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking Situation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garage</td>
<td>75%</td>
<td>65%</td>
<td>100%</td>
</tr>
<tr>
<td>Private outdoor parking</td>
<td>17%</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>Public rental parking</td>
<td>8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rental parking</td>
<td></td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Main charging place</td>
<td>100% Home</td>
<td>85% Home</td>
<td>100% Home</td>
</tr>
</tbody>
</table>

The respondents experienced difficulties in assessing their electricity consumption in daily driving compared with their usage of fossil fuels. Total 81 % of the respondents could assess their electricity consumption in daily driving and 53 % of the respondents consider themselves to have a realistic ambition, a potential, to drive more on electricity.
Of those respondents who were able to estimate their consumption, Figure 42 presents the outcome. Daily consumption corresponds to the actual percentage driven on electricity, whereby the potential consumption is an estimation made by the respondents themselves. The group of others have a different propulsion technique, E-REV, consequently the outcome from them are based on their electricity consumption from the battery, when it has been recharged from the outlet and not by the range-extending ICE.

![Graph showing appreciated current and potential electricity consumption in daily driving.](image)

**Figure 42.** Shows the assessment of respondents’ daily and potential usage of electricity vs. fossil fuel in daily driving.

### 5.2.3. Charging Solution and Pricing

The respondents were asked if they know about home charging stations, such as the ones showed in current charging equipment. As seen in figure 43, 50% of the respondents answered that they are familiar with charging boxes for home appliance, the rest are not.

![Table showing knowledge about home charging boxes.](image)

**Figure 43.** Illustrating the knowledge among the groups about home charging solutions.
All of the Volvo V60 drivers of them knew about home charging stations, in contrast to the Toyota group in which only 30 % knew about such solutions. Furthermore, the respondents were asked if they had considered purchasing an extra charging cable and 75 % of the respondents have considered doing so as illustrated in Table 15.

Table 15. Showing the interest of buying an extra cable.

<table>
<thead>
<tr>
<th>Considered buying an extra cable</th>
<th>V60</th>
<th>Toyota</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>75%</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>25%</td>
<td>70%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Furthermore, investigating their interest in knowing about their electricity consumption it was revealed that the majority, 83 % of the respondents, would like to have the cars consumption from charging specified on the households’ electricity bill, as illustrated in table 16 below.

Table 16. Respondents interest in specified post for the cars consumption on the electricity bill.

<table>
<thead>
<tr>
<th>Specification on the electricity bill</th>
<th>V60</th>
<th>Toyota</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>92%</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>No</td>
<td>8%</td>
<td>25%</td>
<td></td>
</tr>
</tbody>
</table>

In order to understand the users’ interest in current charging offers the respondents were introduced to a charging offer without pricing knowledge. This charging offer involve a charging station installation of it, inspired by Vattenfall’s charging offer concerning the Wallbox, as presented in “current charging equipment”. Respondents were introduced to the features and performance of the station such as: the charging station was equipped with an attached cable and provided means for maximum household charging of 16 A. Moreover they were introduced to the benefits of such installation: control of the households’ electric grid and upgrading of cables. Then they were asked to rate if the product would add value to their charging experience, by rating it on the scale presented in figure 44. Furthermore, 50 % of the respondents answer that this product would not add any value to their current charging experience or situation.
Figure 4. Respondents’ assessments of a charging offer without pricing knowledge, if it would add value to their current charging experience. The charging offer was inspired by Vattenfalls Wallbox charging offer.

To gain understanding about their price sensitivity regarding such offer, they were asked to price the same charging offer described, which description can also be found in the interview guides Appendix A and Appendix B. The respondents priced the charging offer regarding what they considered to be a low price, acceptable price, expensive price, or a too expensive price for the offer. The median value from the answers on the scale is presented in figure 45 below.

Figure 45. Presents the respondents pricing of a described charging offer, inspired by Vattenfalls Wallbox charging offer.

After the users had priced the offer they were informed about the actual price of the charging offer between 10 000 SEK and 15 000 SEK. This was done in order to understand their perception regarding the price of the described charging offer and value proposition. One of the respondents did not answer, and it was shown that three of Volvo respondents had already bought such an charging offer. The result was that 72 % of the respondents would Not at all be interested in the charging offer for the actual price. This outcome correspond to 90 % of the Toyota group, 33 % of the Volvo group and 100 % of the Others
Group, see figure 46. However, 94% of the respondents believe that the described charging offer, would add the most value at home.

![Assessment of charging offer with pricing knowledge](image)

**Figure 46.** Respondents’ assessments of a charging offer, if it would add value to their current charging experience, inspired by Vattenfalls Wallbox charging offer.

Investigating where the respondents expect to find such a charging offer described. The majority, 75% of the respondents, expect to find such offers of charging stations for home usage at the car manufacturer, retailer. Secondly, 17% of the respondents would turn to the energy suppliers and 8% would turn to other actors such as: Electricians, Internet/EBay, or retailers like Biltema & Claes Ohlson, see figure 47.

![Bar chart showing charging solutions](image)

**Figure 47.** Shows which actors the respondents consider that should provide charging solutions.

### 5.3. Qualitative Data Results

This chapter presents the qualitative data gathered from the interviews with 12 respondents, using the interview guide in Appendix B. Six of the respondents represent the Volvo V60 group, six respondents represent the Toyota group. Further, the result from the qualitative data collection will also be categorized by the car models, and consequently in the three following sub-chapters about: their *Car choice and Purchase criteria, Charging
and Driving habits, Charging solution and Pricing. The respondent group of “Others” is disregarded in the qualitative results, because the sample of the group consisted of only one respondent. Consequently, the sample is considered to be too small to be representative and is therefore left out of this chapter “Qualitative Data results”.

5.3.1. Car Choice and Purchase Criteria

In order to understand the respondents, how they reason and what motivates them in their car purchase, questions were asked about their previous cars, their purchase interest, if they had considered their charging situation before purchasing and their desired next car. Here follows the empirical findings:

The Volvo group respondents' indicated that they value performance in their car and mentioned previous car models, such as; Land Rover, Saab 9.5 Bio Power, Volvo XC Diesel, Volvo S60, Volvo S90 and a cabriolet, sports model. When they decided to purchase their current car, Volvo V60 Plug-in Hybrid was considered as the only option for them. Half of the respondents express that the performance and variety of the driving was a powerful factor influencing their car choice. Due to the fact, that the car provides different options of driving modes and still has high performance and power when requested.

The Volvo V60 respondents had all considered their charging opportunities, when deciding to purchase their car. Indications were given that the respondents take responsibility, in educating themselves about the car and charging. This is mainly done out of personal interest, but partially since they could only receive limited information from the car retailers and pointed out that they experienced difficulties in accessing the information requested. However, all of the respondents are interested in having a plug-in electric vehicle as their next car, whereby five of them are interested in having a PHEV. Two of them expressed that they will probably change cars within 3-5 years.

Within the Toyota group several respondents have had a Toyota Prius Hybrid (HEV) without plug in function as their previous car. Moreover, Toyota Avensis, Ford Focus (Petrol/Ethanol) and Peugeot 407 are also examples from their previous car models. Indications were given that they mainly consider middle price range vehicles when deciding for a new car. Four of the drivers expressed that there were no alternatives when deciding for the Toyota Prius Plug in. However two of the respondents looked into other models of EVs, but decided for the Toyota as it can uphold conventional driving range and still drive on electricity. Indications were given that the respondents bought the Toyota Prius Plug-in as they want to lower their gas consumption. Two of the respondents state that electricity is the future and wants to be good examples for environmental driving.

The Toyota respondents had all considered their charging opportunities when deciding to purchase their car. If they had any questions about the vehicle they could turn to the car retailer, however only one of them expressed the car salesman to be well informative. They all have a good experience from driving their PHEV and all of the respondents are interested in having a PEV as their next car. Two of them will probably change cars within 3-5 years and would like to upgrade themselves within the technique of PHEVs. Two drivers express that it would be nice with full EVs, but that requires longer driving ranges and shorter charging times that the current BEV models, in order to fit with their car preferences.

5.3.2. Charging and Driving Habits

To understand the PHEV users charging and driving habits, questions were asked about their electric charging situation in terms of charging equipment used, as the one presented in the chapter “Technical specification of charging equipment”, and how they park during
charging. Here follows the outcome of these aspects, including some additional observations from the quantitative study regarding this matter.

The Volvo V60 respondents are all the primary drivers of their PHEVs. All of them use the car in their daily travel to friends, supermarket, doctor and etcetera. Three of respondents are currently employed and drive their car on daily basis in their travel to work, but none of them has charging opportunities at their workplace. Two of them have suggested and encouraged their respective workplaces to install charging stations, since they have no charging opportunities at work. The rest of the respondents are retired and drives thus, as they mentioned, more or less irregularly, in which their daily distances vary up to 50 km. Furthermore, the youngest respondent, express that he always drove too fast before he bought this car, now he drives slower as he wants to drive to the maximum extent on electricity. Another respondent mentions that the electrical fuel type isn't his main fuel, and that it might be due to his occupation on the countryside. All of the respondents express that during summertime, when its optimal conditions for their battery, they will be able to drive more on electricity.

All of the Volvo V60 drivers usually park and charge at night at home. They all plug in for charging as soon as they get home and they all use the mode 2 charging equipment with a type 2 connector, examples of such charging equipment are presented in chapter Technical specification of charging equipment. However, the retired respondents have their cars mostly parked at home daytime, which gives them with the opportunity of charging at other occasions than nighttime as it suits them. All of them are familiar with utilization of smartphones and uses the application Volvo on call for their PHEV, from which they manage pre-warming of the car and get information about the battery status. Five of the respondents have their own garage/carport from where they use the domestic socket outlet, providing 10 A household charging, which is mentioned in chapter Technical specification of charging equipment. The sixth driver has an outdoor parking, on which he installed an ABB engine warmer box, which provide him with charging currents up to 16 A, example of engine warmer box is given in chapter Technical specification of charging equipment. Although, he can only charge with 13 A, household charging, as that is maximum of what the mode 2 charging cable delivered with the car can manage.

Regarding managing the cable, half of the Volvo V60 respondents usually leave the cable hanging at home and bring it along in the trunk, when needed. Two of the respondents mentioned that they occasionally use an extension cable during charging, even though it is not recommended. However they never experienced any issues so far, thus they are not concerned with the recommendations and consider it to be safe. One of the respondents often charge at his partners house where the fuses easily break, but it has never occurred during charging as he sets the ampere strength himself to the lowest level of 6 A, which the hose fuses can bear. This is a function with the mode 2 cable that he appreciates, that he can choose to set the ampere strength according to the circumstances of where he charge. Thus, he often bring the mode 2 cable assembly with in the car.

Further investigating the Toyota group, all of the six Toyota respondents are the primary drivers of their PHEV and use it for daily matters. Further, five of them are currently employed and four of them drive their car on daily basis in their travel to work, where daily distances are mentioned between 11 km to 52 km. One of the respondents is retired and drives more or less irregularly, daily distances are mentioned to vary up to 60 km. All of the respondents have expressed that they expect an increase in battery capacity during summertime, which would enable them to drive more on electricity.

All of the respondents charge mainly at night at home, five of them have got their own garage from where they use the domestic socket outlet, providing 10 A, see figure 48. They
all plug in for charging as soon as they get home and they all use the mode 2 charging equipment with a type 1 connector, examples of such charging equipment are presented in chapter “Technical Specification of Charging Equipment”. Two of the respondents usually leave the cable hanging at home and bring it along in the trunk, when needed. Indications are given that they are interested in their electricity consumption. One of them tried to put up an energy measurer, although the space in the garage was too tight. They are all quite well informed about charging from the vehicle with statistics on how much you’ve charged. One of them mentioned that it is possible for him to know exactly how much electricity he consumes by looking at the cars electricity meter. Respondents indicate that they become encouraged to drive more on electricity by Toyota’s visualization of the PHEV powertrain configuration and how the car alternate between the fuels. A PHEV powertrain configuration is presented in the chapter “Introduction of Car Models and Market Research”.

Figure 48. Toyota respondent’s pictures of charging situation, mode 2 cable and hanging arrangement.

5.3.3. Charging Solution and Pricing

In order to gain further understanding of the users’ perception regarding their cars and charging they were asked to consider the benefits and drawbacks from their experiences, as well as expectations on future charging. Furthermore, their interest regarding an existent charging offer was investigated. The offer used as an example in the interviews was inspired by Vattenfall’s Wallbox presented in the chapter “Technical Specification of Charging Equipment”. Below follows the empirical findings:

Volvo V60 Plug-In Hybrid

Cable: There is a shared meaning in the Volvo V60 group regarding the cable assembly’s inconvenience with the mode 2 communication box, like the one presented in “Technical Specification of Charging Equipment”. Their concerns are mainly about handling the cable and to bring it along in the car. The majority of the drivers want one cable in the car and one hanging at home. Furthermore, one respondent expressed problems with managing the cable during wintertime because grass and dirt gets stuck when the cable freezes.
Half of the respondents requests longer charging cable. Indications are given that there are issues related to the placement of the vehicle inlet, which can be an issue in relation to the vehicle inlets. Moreover, comments are made that the cable is not easily rolled together and that there is a compartment in the back of the trunk destined for the cable, but this respondent state that it probably does not fit into the space that's made for it in the trunk. Indications are given that the respondents want the cable organized to make it convenient, but that it is difficult to accomplish with the mode 2 cable assemblies.

Other concerns are mentioned about the forces that the mode 2 cable assembly weight can bring on the outlet, specifically mentioned by a respondent who has an ABB engine warmers box that "hangs in the air". Another respondent mentions that the Schuko plug has a very unwise shape, as it has got a 90 degree angle, which unable a proper connection of the plug into the outlet, then it does not become fully attached.

Four of the drivers have considered buying an extra cable. Two of them are interested in buying an extra cable due to convenience since they want to be able to leave one cable hanging in the garage and have one in the car. The respondents who have not considered buying an extra cable was because one always leaves his cable at home and thus does not need one, the other person considered it to be too expensive, as he had heard that it would cost 10 000 SEK

Missing functions: Two of the Volvo V60 respondents request higher battery capacity and one of them would like to have a guaranty from the car retailer including a change of battery within 8 years. Another respondent clearly point out that he wants an energy measurer on the socket outlet, in order to know how much he has charged. This information should then be exported to a smartphone application or to the computer. This respondent misses an attached cable at home, and will therefore install a home charging box. Another respondent concerns mentions that the cable assembly should be locked during charging, to prevent it from theft. One of the respondents mentions that when he pre-warms the car from the "Volvo on call" smartphone application, the driver physically needs to adjust a setting in the car whether the car is parked inside or outside. This setting decides whether the pre-warming will be driven from electricity or diesel. Then the pre-warming starts automatically and the driver is not able to stop this from the application. Sometimes he has realized from the Volvo on call application that he had the wrong setting, he needed to run back to the garage, where the car consumes diesel in the garage.

Positives: The respondents enjoy driving on electricity; statements are made regarding cheap, nice and quiet driving and their lowered gas emissions. One of them states that it is “worth” plugging in to be able to drive on electricity. Four of the respondents think the best thing with the car is that it can be charged in a domestic outlet. A statement is made that it is easier to charge from the wall than to go to the gas station.

Perfect scenario: The majority of respondents have shown interest in faster charging than 10 A household charging. One driver remarks that in a perfect scenario, there would be charging possibilities everywhere and also that it is not too expensive on charging places with payment possibilities. For another respondent, inductive charging is considered the best scenario, since the cable is not needed.

Specification electricity bill: The drivers are interested in knowing about their electricity consumption from charging their car. One of the drivers has Vattenfall's Energy Watch, which provides him with an electricity meter and transfer his user information regarding electricity consumption to a smartphone application. Another one would like to have the cars electricity consumption specified on a home charging box, in addition to digital information.
**Charging solution:** All of these respondents have received Vattenfall’s offer regarding the Wallbox, presented in chapter “Technical Specification of Charging Equipment”. Some comment was made from one of them that he did not understand the value proposition and that the charging station fills the same function as the mode 2 charging cable. The most value adding features of a charging station were considered to be an attached cable, and faster charging, implying in more power than provided from 10 A household charging.

**Toyota Prius Plug-In Hybrid**

Respondents of the Toyota group indicated and expressed issues regarding management of the cable. After usage the cable tends to be dirty and soils the trunk when returned in storage package. The respondents made separate comments on request for longer cable, better lightning by the socket outlet. Furthermore, half of the respondents made comments about their awareness of the price of a mode 2 cable assembly. They knew that it is expensive and that they had perceived pricing between 5000 SEK and 10 000 SEK, which turned down their interest.

**Missing functions:** Two of the respondents wants something to remind them of to bring the cable with. Since there are few charging opportunities the cable is left at home and when there is an opportunity, you’ve forgot the cable. Since the cable is considered to be expensive and misses a locking function, one respondent states a request to be able to insure it. The respondents would like to have a more incentives like free parking for EVs and one of them requests a function which shows places where to charge.

**Positives:** Half of the respondents appreciate the lowered gas consumption, electric and cheap driving. Half of the respondents also perceive it convenient to leave their cable hanging at home, when not in use. Other positive comments are made about their short charging times, maximum 90 minutes, that they have a compartment in the back of the trunk destined for the cable. Additionally one respondent was exited that her children are engaged in driving, which benefits the whole family.

**Additional features and benefits:** four of the drivers would like to have a cable that does not become dirty. Half of the drivers would like a longer cable and not have to bring out the cable from the car every time they charge. In addition to that they would like to have a timer function to set the charging. Indications are given that they are interested in knowing about their electricity consumption from charging the vehicle. It is mentioned the value of faster charging and. Moreover it is mentioned interesting if an installed charging station would enable the engine warmer and charging to be ongoing at the same time, without any fuses breaking.
6. Analysis

This chapter presents the analysis of the empirical results, with the objective to understand the drivers in their habits and needs relating to electric charging. Moreover it requires analyze of the prerequisites affecting the users of PHEVs, which is done in relation to other aspects for charging, concerning the critical elements identified in the introduction about the market, vehicles and infrastructure, as illustrated in Figure 49, below. Conclusions are then drawn regarding market potential for a charging offer and recommendations about what approach Vattenfall should take within charging offers. Moreover, this outcome acts the foundation for a conceptual charging offer.

![Electric Vehicle triangle model](image)

**Figure 49.** The Electric Vehicle triangle model shows the relationship between; Market - Users, Infrastructure- Charging Technology and Vehicles-Cars. The picture is a combination of Ståhl (et al, 2013) and Kornberg & Larsson (2012).

The fossil fuel dependence has been taken seriously and through different initiatives actions have been made, as described in the “Introduction”. In line with this, the search for alternative fuels have comprised; Ethanol, Gas, Electricity to mention a few (Trafikanalys, 2013). In 2008 it was a major trend with Ethanol and Ethanol Hybrids, 21 % of all cars registered was Ethanol/Ethanol hybrid, but the trend reduced gradually and are today in line with EVs and Gas Vehicles. In the year of 2012 an upcoming trend was observed, the releases of the first PHEV Vehicles – Is there a new incoming passenger car trend of PHEVs? Possibly, considering the regulation and extreme goals of fossil independency, there need to be remarkable changes in the emissions. Consequently, EV becomes interesting, because the emissions from PEVs can be close to zero.

As stated in the introduction, the Electric Vehicles have had difficult period of breaking through. The pure electric vehicles have struggled in order for the market to adopt it. As mentioned the biggest obstacle has been the fact of the customer experiencing “range anxiety”. This obstacle has been hard to overcome and corresponds to the actual chasm (Schilling, 2010) of the technology life cycle. Moreover, some of the respondents in the empirical investigation had considered buying a pure electric vehicle but neglected it due to the aspect of range anxiety (Khan & Kockelman, 2012). Instead they purchased a PHEV and have not experienced such problems. Almost all of the respondents use their PHEV as the primary car in the household. This indicates that the technology is about to be
accepted enough, to be able to lay the foundation for adoption of early majority (Schilling, 2010) and act a threat to the conventional cars.

6.1. User analysis

Observing the empirical investigation, the qualitative data reveals, that the majority of drivers were determined to buy a PHEV when purchasing their current car. This was strongly pointed out by Volvo V60 drivers, claiming that there was no other alternative or option. Most probably it might be a consequence of the narrow range of PHEV models on the market, considering the models presented in the “Introduction of Car Models and Market Research”. Nevertheless, the Volvo V60 Plug-in Hybrid is the only choice available in the higher more luxurious car segment.

6.1.1. Car and Purchase Criteria

The largest purchase motivating factor among the Volvo V60 drivers is their technology interest, as found in the empirical investigation. With reference to the qualitative data about their previous car ownership, performance and technology are considered to be important motivators in their car purchase. There were 300 prospective buyers who got the opportunity to pre-order the first batch of Volvo V60, as mentioned in “Introduction of Car Models and Market Research”.

All of the Volvo respondents in this study took the exclusive opportunity of buying one, and the qualitative data shows that it was done without hesitation. Further, examine the Volvo V60 Plug-in Hybrid, it has a much higher price comparing to the conventional ICE in the same category. There is still uncertainty in the technology and the potential development of especially the battery. To be able to purchase such an expensive vehicle in the doubtful period of the technology indicates financial independency and risk-taking. Accordingly, the characteristics of these respondents correspond to the category of adopters defined by Schilling (2010) as innovators, pioneers within the new technology, described in the Methodology chapter.

The quantitative data showed that within the Toyota group there is a shared environmental interest affecting their car choice. The qualitative data showed that the main reason of their purchase is the potential of lowered petrol consumption. The lowered petrol consumption is valued by the respondents as both an environmental important aspect, but also as an economical, as they are able to decrease their fuel expenses by driving on electricity. Moreover, their previous cars are mentioned to be in a middle price range and several of the respondents have owned a Toyota HEV before. Even though the PHEV is about 80 000 SEK more expensive than the corresponding HEV, see table 6, the Toyota Prius Plug-in is still directed to a middle cost segment within the PHEV car market. Toyota Prius Plug-in is more directed as a “consumer car”, towards the critical mass, which consequently might call for higher price sensitivity among the drivers, compared with the drivers of the Volvo V60 –Plug-in hybrid.

6.1.2. Charging and Driving Habits

Investigating the charging and driving habits of the respondents, it is consistent that almost all of them charge their vehicle at home, on a private parking area dedicated for their PHEV. Nearly every respondent charges their vehicle during the night hours, though if opportunity is given during the day, they try to plug it in as often as possible. The respondents have showed great interest in driving on electricity and are willing to plug in as often as they can. Overall, the respondents have not expressed any major concerns around the charging habits.
However, every driver’s prerequisites for charging and utilization of the vehicle appear to be unique for each respondent. For instance some respondents experienced the charging cable too short, which is related to the distance between their socket outlets and vehicle inlets. This fact depends upon their different cable lengths, see table 6, placement of their vehicle inlet in relation to the socket outlet at the parking place, which is different in each case. Moreover, this calls attention to individual adaption of charging equipment. The qualitative data showed that drivers use the cable assembly delivered with the car. This might be related to the fact that the cable was delivered with the car, or that they are rather uninformed about the possibilities of charging. Amongst the Volvo V60 drivers, all had heard of a dedicated home charging station, due to the V2 Partnership between Vattenfall and Volvo. Nevertheless, Toyota has a partnership with a charging solution distributed by Leviton, as described in “Technical Specification of Charging Equipment”, though the majority of Toyota drivers are not aware of this additional option.

Further comparisons shown in, see table 6, Toyota Prius Plug-in has the smallest battery with the lowest range, comparing to Volvo V60. However, the quantitative data shows that the Toyota Prius drivers have the highest assessed rate of electricity consumption versus petrol consumption. Moreover they also assessed the highest ambition to drive on electricity. Comparing V60 and the Toyota group, this indicates that Toyota Prius drivers potentially more willingness to put an effort in driving more on electricity, due to their environmental interest.

Moreover, the Volvo V60 group have assessed the lowest electricity consumption, even though they have a greater driving range on electricity that the Toyota drivers. Their future ambition of driving on electricity is also lower than Toyota. Though, their main interest of purchasing the car was the curiosity and technology. This might point out that the electric consumption is not an indicator that is prioritized by the group in general or just that they assess their consumption and ambition more realistically. The qualitative data also pointed out that all the Volvo respondents have smartphones and utilize a Volvo application for pre-warming and some additional information. Whereby they have given indications of a desire to communicate with their charging equipment, in order to monitor and remote the charging,

6.1.3. Charging Solution and Pricing

The empirical investigation showed that respondents had a positive attitude towards the technology and difficulties identifying issues and recognizing future needs and demands. Consequently, this can probably be related to the categorization of them as innovators (Schilling, 2010), that the drivers are already being convinced of the technology and adopted it with the given conditions.

A few respondents from the Toyota group and the majority of the respondents from the Volvo V60 group had considered to purchase an extra set of charging equipment, as shown in the “Empirical Investigation of Users”. The intention is to permanently leave a set conveniently hanging at their home, hence the mode 2 cable assembly arriving with the car ought to be more of a spare cable and always be ready with the car when needed. The respondents expressing the desire of an extra cable had consistently their car parked at several places on a daily basis.

As found in the empirical investigation, the respondents assessed fictitious product offer, inspired by Vattenfall’s offer involving Wallbox, which is described in the “Technical Specification of Charging Equipment”. This product is today valued to 12 000 SEK with installation, but for the respondents it was considered to be too expensive. The problem was that most of respondents could value in an attached cable and faster charging with 16
A charging, (instead of 10 A), but not for the given price. The respondents’ assessment of the value proposition resulted in that half of the given price was considered expensive. The low pricing might have been impacted by lack of knowledge and regarding such technology and installation. However, many respondents request faster charging, but are unaware of the limitations of their current charging equipment and prerequisites, such as described in “Technical Specification of Charging Equipment”.

The respondents established that the most obvious placement for charging equipment would be at the car manufacturer, whereby few responded the energy supplier. Most of the respondents associates the charging equipment as an attribute to the vehicle and expect therefore products to be found with the car retailers and car manufacturer.

### 6.2. Charging Equipment and Industry

In the industry of charging equipment there are, as described in “Technical Specification of Charging Equipment”, different types of charging equipment used for electric vehicles which covers different levels of safety. Firstly, the mode 1 cable assembly which is utilized by plugging it into a domestic socket outlet represents the lowest level of safety. The question is if this product is supported by the car manufacturers? – Probably not, as the PHEV manufacturers have chosen mode 2 cable assemblies to be delivered with their vehicles. Moreover, the mode 2 and mode 1 cable assemblies, presented in “Technical Specification of Charging Equipment”, can only be utilized by plug it in a domestic socket outlet. However, the domestic outlets are not intended to be used for charging of electric vehicles, not the design nor the durability.

A charging station with mode 3 charging is a product designated in its full purpose for charging of electric vehicles, as for instance the KEBA charging station (KEBA, 2013) Installation of it requires a safety inspection of the household’s electric grid in order for the charging to function properly and for the household. The energy supply for the charging station is then upgraded for the intended use, charging of an electric vehicle.

Defining the geographical scope of competition (Porter, 2008) the competitors active with their products of the Swedish market are considered direct competitors, such as the ones presented in “Technical Specification of Charging Equipment”. However, in this analysis, Vattenfall’s potential suppliers can act potential competitors and vice versa. Furthermore, in the current state international competitors have the potential of entering the Swedish market, thus they are considered as potential entrants (Porter, 2008) to the Swedish market. Competitors such as GE (GE 1, 2013) and Bosh (Bosh, 2013) are considered as strong competitors if they would target the Swedish market with their differentiated product offers. Moreover, as the charging stations for electric vehicles is not their main source of revenue. Other competitors would be energy suppliers, however only suppliers of the physical product are covered in this report.

#### 6.2.1. PEV and PHEV Buyers

There are 603 BEV passenger cars registered by the end of year 2013 (SCB,2013) and 840 PHEVs registered to be in use March 2013 (Granlund, 2013). Combining these numbers there should be about 1440 Plug-in Electric vehicles currently in use in Sweden. From the empirical investigation it was found that 94% of the 36 respondents have a private parking place intended for charging. Placing this percent content on the 1440 PEVs in Sweden, there would be about 1350 PEV users with the possibilities of installing a charging station for private use, and then about 790 of them would be PHEV users.
As indicated in the empirical investigation, the buyers mainly use the mode 2 cable assembly and domestic socket outlet, which was included in the package when purchasing their car. Thus they do not “pay extra” for this charging equipment. Meaning that if a charging station with installation offer is sold separately, not included in the car deal, there would be “additional costs” for the customer in order have a charging station installed. Using Vattenfall’s charging offer described in “Technical Specification of Charging Equipment” as an example: The user has paid nothing (included in the car deal) to utilize the cable assembly delivered with the car and the existing domestic socket at home. If so, then the price 12000 SEK for the charging offer is, as in the qualitative data collection, perceived as an expensive “additional cost” in order to be able to charge, especially if the customer is uninformed about the value proposition.

In the empirical investigation, customers have expressed to receive rather poor information about the charging both from the car retailers and related businesses, which is important for them to obtain in order to perceive the value proposition. Especially if the charging station is not included in the car deal, the price of the charging offer becomes obvious for the user and thereby constituting an additional cost. Moreover, the customers of exclusive vehicles assume to receive good service and that information is accessible, regarding their car and charging related issues.

The users’ ability to substitute a charging station is high, based on the findings from the empirical investigation; the majority of users is currently doing it. They know where to regularly charge from domestic outlets and receive the substitution equipment, mode 2 cable assembly, with the car. Moreover, as mentioned they do not have to pay for it in excess of the car deal. As described in the “Introduction of Car Models and Market Research”, the cars are marketed and delivered with this type of equipment and therefore users assume it to be safe and the most appropriate way of charging. Thus, they simply assume the highest safety from the charging equipment. However, if the government would require mode 3 conditions for household charging, users’ propensity to substitute from charging stations would be eliminated.

As described in the “Introduction of Car Models and Market Research” the vehicles technical specification determines the equipment the user can utilize for charging, for instance through the connector faces. The empirical investigation showed that the majority of users charge primarily at home and thus their occupational situation affect their choice of electric vehicle supply equipment they will/can use. This implies that the customers’ way of charging is limited to their car’s charging perquisites and their occupational situation. Moreover, as the empirical results showed that as the respondents consider their car purchase they consider what their charging situation will be like. It indicates that, if they decide to purchase supplementary charging equipment it is done in connection with the vehicle purchase.

The empirical results showed that the respondents want to have a plug-in electric vehicle as their next car. As the technology is in an innovative phase (Schilling, 2010), the technical specification of charging equipment is most likely to change as the respondents buy their next car. If they buy a charging station which is permanently installed at their property, it would be convenient for them to upgrade for new charging equipment as they buy a new car, like the WattStation(GE 3, 2013) described in “Technical Specification of Charging Equipment”. Then they would only have to buy one station to be prepared for changes in circumstances and use the same supplier of charging equipment and services.

The empirical outcome presented characteristics from the respondent groups, which indicated that mainly the owners of the exclusive PHEVs spend money on complements for differentiation and uniqueness, as in the case of their car purchase. This points out that
a charging offer must act a complement to their car in such way, not only for charging but in terms of quality and performance related to their vehicle (Porter, 2008). This respondent group (Volvo) has significant characteristics of being innovators and invest in uncertain technology (Schilling, 2010). Thus it is assumed that they are less price sensitive than the Toyota drivers, however they are price conscious and places demands on what they pay for.

The bargaining power of customers (Porter, 2008) of charging offers is very high. On the Swedish markets the charging stations and installation offers are quite undifferentiated and the customers are few (Porter, 2008). Moreover as the plug in electric vehicle users are innovators (Schilling, 2010), suppliers must please them in order to found the basis for the market and further adoption of the technology (Ståhl et al, 2013).

6.2.2. Suppliers of Charging Equipment and Related Services

In the value chain of permanently installed charging stations there are suppliers of charging equipment, energy suppliers and suppliers of electrician services. The suppliers of charging stations depend on authorized electricians to install their permanent equipment and depend on the energy suppliers to provide their customers with energy. In this case, suppliers are considered the suppliers of charging stations, as Vattenfall is the energy supplier and also provide electrician services.

The chapter “Technical Specification of Charging Equipment” introduces four suppliers of charging stations on the Swedish market, and as earlier described the Swedish PEV charging market is limited. This result in small volumes produced, and high production costs per unit. In this case, the market demand can rapidly be filled by the four suppliers presented here. However, the majority of charging station suppliers presented in this report does not heavily depend on this industry for its revenues (Porter, 2008).

As described in the “technical specification of charging equipment”, there is no standard interface of the connectors for the vehicles, which forces the suppliers to negotiate/adapt to the car manufacturers and the features they decide for. Consequently the customers choose the suppliers that can provide them with the right connector interfaces and other characteristics suitable for their needs.

6.2.3. Competitors

In this study the suppliers of the stations can also act competition, and the competitors differ in their capabilities (Porter, 2008) and power. Competitors of the physical product are the suppliers of the charging equipment. The competing charging stations presented in “Current charging products” provide different features and values.

Attached cable: In empirical findings indications were given that users desire an attached cable to leave at home, and some have arranged their own hanging device. For the charging stations presented in charging technology, the option of having a permanently attached cable, appears as a basic option. The respondents desire to have the cable organized or winded up when not in use. This is solved by some different methods illustrated by KEBA (KEBA, 2013), Home Box (POD Point, 2013) and the GM Voltec (Bosh, 2013). The WattStation (GE 3, 2013) has the feature of attracting the cord into the charging station. This might be a useful feature to prevent issues with freezing cable and dirt accumulation, presented in empirical investigation.

Faster charging: The empirical investigation pointed out the PHEV drivers’ interest in faster charging than 10 A household charging. However, the maximum power that can be supplied from household charging is 16A using either 230 V single-phase or 400V three-phase connection, as mentioned in “Technical Specification of Charging Equipment”. This
indicates that the capacity of a household’s electric grid creates limitations of the charging speed. More power, faster charging (CENELEC, 2011), would require more significant changes of the household’s electric grid. However, the household charging is not only limited by the power supplied by the household but also the equipment used for charging, as presented in “Technical Specification of Charging Equipment”. Moreover as mentioned in the empirical investigation, the Volvo V60s cable assembly, delivered with the car, is limited for charging up to 13 A, which makes the user unable to utilize the maximum power that can be provided from the household.

Looking at the charging stations brought up in “Technical Specification of Charging Equipment” they all have the means for maximum single-phase household charging. Furthermore, none of the international competitors provide the option of three-phase charging with type 2 connector, yet. On national level KEBA (KEBA, 2013) and Park & Charge (Park & Charge, 2012) provide stations with two connector options, type 1 or type 2. As presented in the “Introduction of Car Models and Market Research” the PHEVs have either the type 1 or the type 2 mating vehicle inlet. This means that the customers are limited to charging stations providing their connector interface, as it is fundamental in order for them to utilize it. Thus, they wouldn’t choose a station without their connector interface.

Modularity: The WattStation (GE 3, 2013), presented in “Technical Specification of Charging Equipment” is a charging station which is designed to be easily adapted for the evolving technology and changing demands. It has a modular design which enables the equipment to be upgraded when new regulations and the vehicles charging prerequisites changes. This design would enable the users to utilize the charging equipment even if new regulations occur or if they change to another plug-in electric vehicle with different technical specification. Both changes are likely to occur as it is an innovative time (Schilling, 2010) for this technology and as the empirical findings showed that all respondents would like to have a plug in electric vehicle as their next car. Thus the charging technology will develop, and the respondents will buy new PEVs with new prerequisites for charging.

Communication services: The empirical investigation showed that respondents are interested in receiving updates about their charging and electricity consumption. Further, indications were given that there is an interest to be able to remote the charging from other devices. Both the Home box (POD Point, 2013) and the WattStations (GE 1, 2013) provide software services for their users, in order for users to monitor their charging and view usage data online. With the software WattStation Connect (GE 2, 2013) users can manage issues of charging remotely, but this product is not yet released on the Swedish market. Such communication services such, user portals and billing systems can act complements for the charging station and increase the value for the user.

Substitutes: As mentioned in "Introduction of Car Models and Market Research" the vehicles are delivered with a mode 2 cable assemblies, and as the empirical investigation showed, this equipment is commonly utilized, in combination with an engine warmer outlet or domestic schuko outlet. This substitute (Porter, 2008) equipment does not possess the performance that can be offered from a permanently installed charging station, in terms of power and safety, as mentioned in “Technical Specification of Charging Equipment”. However, as it is delivered and included as part of the car deal this combination of equipment acts the main substitutes for a charging station. Nevertheless, the domestic outlets are not intended for charging of electric vehicles and the technology is in a developing phase. Thus, if the PEV technology will prosper, charging stations designated for electric vehicles can, by performance and aid from stakeholders, overcome the mode 2 charging equipment.
6.3. Conclusion

The purpose of this study is to understand the PHEV users’ charging habits and needs, in order to address if there is a market potential for charging offers for PHEV users. Moreover, the study has been conducted to give strategic recommendations regarding Vattenfall’s involvement within the charging infrastructure. Here are the conclusions drawn from the analysis, dedicating answers to the research questions.

- There is a market potential for charging related offers for PHEV users. However, the current PHEV market share is less than 2.5% of the total car market in Sweden. Thus, the recommendation is given; to focus on the PHEV drivers to stimulate the market segment, without excluding other plug in electric vehicles.

The conclusions made about the PHEV users’ needs and requests regarding a charging offer

- **Product**: The users request faster charging (more power than 10 A household charging) and the convenience of an attached cable to leave at home. Moreover, they wish to receive data about their cars electricity consumption, and to be able to monitor and remote their charging. They assume safety and appropriate service.
- **Price**: The market for dedicated charging equipment is narrow in this early phase of adoption, which limits the customers’ possibilities to benchmark such products. Observing the competition and the empirical findings, regarding the users’ interest and awareness of charging solutions and offers, it is assumed that the customers’ pain of threshold for a charging offer is related to their information about the value proposition.
- **Placement**: As the users’ first introduction to the vehicle is at the car retailer, they will turn to the car retailer in matters of charging equipment.
- **Promotion**: The customers are in the need of accessible information and educated persons to talk to about charging their vehicles on electricity.
- **Prerequisites**: The technology is in a developing phase, thus a charging station should be able to allow upgrade of charging equipment for future demands. Users have different prerequisites for utilization of charging equipment in terms of technical specification of the vehicles and intended charging place, which should be considered in a charging offer.

There are five key product factors to consider in a charging station: faster charging (power), attached cable, electricity meter, communication and upgrade of charging equipment.

**A strategic approach for Vattenfall**

- The current charging offer is too expensive for the value it brings to the customer. The value must be raised through either by lowering the costs or by differentiating the offer. Vattenfall, as an energy supplier, must provide the consumers with an offer involving their distinctive capabilities. Thus they should focus on a strategy offering their exclusive services. Considering the competition and market this can be done through differentiation of the offer. Making the charging station more advanced considering the five functional factors. Whereby Vattenfall is able to motivate their services through installation, energy contracts, and communication and billing services.
7. Future Recommendation for Vattenfall

This chapter presents and serves as a recommendation and guidance for Vattenfall in their approach of the PEV customers. The aim of this chapter is to give Vattenfall recommendations regarding their involvement in the development of a solution for home charging. The recommendations are based on the outcome of the analysis and developed from needs and preferences identified from the PHEV users.

Electro-mobility is an upcoming trend, where the customers value sustainability, convenience and new technology. Electric vehicles are a part of a world associated with clean power. The industry of E-mobility is a way of reaching sustainable transportation. As important sustainability is in the matter, consequently safety is. As the customer base is introduced to the market of E-mobility, consequently people are interacting with the electric supply systems and should be considered as equally important as any other component of the electric system.

Plugging a vehicle to the electric grid is still unknown and fascinating for many people. It is a new habit to adopt and it is important that people feel safe and have a good user experience connected to the actual charging situation.

7.1. The Target Market

The core value of the charging solution is to supply an electric vehicle with electric energy from the current electric grid. The charging solution addresses therefore all owners of Plug-in Electric Vehicles, PEV. The target market should be all customers that are willing to utilize the electric grid as a power supply to their vehicle.

The charging solution should further target sales on the Business-to-Consumer market, B2C. The solution should initially be limited to Sweden, whereby on a long-term perspective enter the Scandinavian neighbor countries.

7.1.1. Target Segment and Target Customer

The target segment for charging solution is Plug-in Electric Vehicles intended for private use, regardless the ownership form. The targeted segment is assumed of owning private property, which in the future can be intended as charging place. The driver wants to be a missioner for the EV technology and willingness to drive on electricity.

The target customer is a middle aged technology interested PEV driver. The customer has a passion for his/her PEV and the latest accessories for his/her car. The customer comfortable with smartphones and wishes communicate with his car and belonging charging equipment. The target customer wants receive updates about ongoing charging from the smartphone and computer.

- The customer searches for **convenience of an attached cable**, organized at his home parking, whereby the cable is always clean and ready to be plugged in.
- The customer desires a charging experience that **complements and increases** the value of the PEV. The PEV is often a high performance car, due to technology interest. The customer **wants to increase the whole user-experience** of his car.
• The customer is seeking for optimum performance available for home charging. The customer values interaction and performance, in terms of charging speed and communicational intelligence.
• The customer assumes the highest safety and reliability on his charging solution. The customer expects availability of service and support – and warranty insurance, in case of damage or future upgrade of the charging equipment.

7.2. Functional Need and Product Requirement

Given the conclusion from the analysis and chosen target customer, five functional concerns were recognized. The functional concerns are identified as value-adding factors for PHEV users and a future product – a charging solution for home appliance, see figure 50.

Figure 50. The target customers functional needs regarding a home charging station.

The functional concerns and the customers’ preferences are transferred into a list of requirements, as shown in table 17. The list of requirements serve as an indication of the requirements a charging solution for home appliance should fulfill, in order to increase the value proposition.

Table 17. Requirements for development of charging station.

<table>
<thead>
<tr>
<th>Charging station requirements</th>
<th>Requirements</th>
<th>Prior; Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>The station has the standard features for mode 3 charging.</td>
<td>Must; (IEC, 2010)</td>
</tr>
<tr>
<td>Safety</td>
<td>The cable and connector, belonging to the charging equipment, can be locked onto/in the charging station, to prevent thievery.</td>
<td>Must</td>
</tr>
<tr>
<td>Cable and connectors</td>
<td>The charging station is available with type 1 connector.</td>
<td>Must</td>
</tr>
<tr>
<td>Cable and connectors</td>
<td>The charging station is available with type 2 connector.</td>
<td>Must</td>
</tr>
<tr>
<td>Speed</td>
<td>The charging station enables a charging currents up to 16 A (230V, 1-phase), (400V, 3-phase).</td>
<td>Must</td>
</tr>
<tr>
<td>Case C – Charging</td>
<td>The cable is permanently attached to the electric supply equipment, with a vehicle inlet connector in the detached end.</td>
<td>Should</td>
</tr>
<tr>
<td>Modularity</td>
<td>The station is modular to enable upgrading of charging equipment. i.e cable and connectors.</td>
<td>Should</td>
</tr>
<tr>
<td>Electric meter</td>
<td>The station devises an energy meter with software means for digital data transfer.</td>
<td>Should</td>
</tr>
<tr>
<td>Engine warmer</td>
<td>Engine warmer: the station provides a engine warmer outlet.</td>
<td>Should</td>
</tr>
<tr>
<td>Manageability</td>
<td>The charging station has a hanging function for the cable, to enable untangled organized hanging of the cable.</td>
<td>Should</td>
</tr>
<tr>
<td>Cable</td>
<td>The charging station is available with cable lengths of: 2, 4, 6, 8, 10 m.</td>
<td>Should</td>
</tr>
<tr>
<td>Communication</td>
<td>The station is provided with software for wireless communication.</td>
<td>Should</td>
</tr>
</tbody>
</table>
7.3. Product – Charging Offer

The main product for the given target customer is the actual purchase of their vehicle and the whole driver experience. The charging solution for home appliance is a complementing product that enhances their total user experience of the PHEV.

The future product offer for home charging should cover four essential areas, interacting both products and services, see figure 51. As the safety is the main priority, the first offer is based on a recommendation for the PEV drivers to check their electric grid. This will be offered in a power grid control service for all PEV drivers. The actual product offer will be offered through differentiation of a charging station, provided with more features and functions for uniqueness. The unique selling point is an integrated system with cloud base services connected to an application for smartphones, furthermore an access to an internet based home page for the system. The offer is covered with a support and service center, as the heart of the package proposal. The main selling points are; safety, convenience and intelligence. The offer is illustrated in figure 51 below.

Figure 51. Illustrating the product offer and the interaction between product and services from Vattenfall.

7.3.1. Power Distribution Grid Control

e-check – This is a power distribution grid control service, which is today offered as an pre-service in existing the Wallbox offer named: Health-Check (Vattenfall & Volvo Cars, 2013). To enable the utilization and installation of charging equipment or to enable safe charging from a domestic socket outlet, it necessitates a control of the electricity grid - e-check. This is a power distribution grid control service conducted by an authorized electrician from Vattenfall. By performing an e-check the safety of the household electricity grid and the related fuses are controlled, in order to assure the customer for a safe introduction of the PEV in the household. The requirements of the process are found in Table 18 and followed by a scenario description of the e-check, illustrated in figure 52.
Table 18. Requirements on the electrician’s execution of the power grid control.

<table>
<thead>
<tr>
<th>Vattenfall</th>
<th>Requirement</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit</td>
<td>Electrician conducts a visit to the customer’s property.</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Electrician performs a functionality control of the electrical grid for the intended charging place.</td>
<td></td>
</tr>
<tr>
<td>After the functionality control is performed</td>
<td>The electrician recommends upgrading of cables and fuses if needed for the cases: • Mode 2 charging conditions. • Mode 3 charging conditions.</td>
<td></td>
</tr>
<tr>
<td>If upgrading of the property’s electrical grid is needed</td>
<td>The electrician makes the customer an offer for upgrading the electrical grid to appropriate: • Mode 2 charging conditions • Mode 3 charging conditions, including installation of charging equipment.</td>
<td></td>
</tr>
<tr>
<td>Demonstration</td>
<td>The electrician has a demonstration example of the charging station</td>
<td></td>
</tr>
<tr>
<td>Demonstration</td>
<td>The electrician gives the customer the option to have a demonstration of the mode 3 charging equipment by the electrician.</td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td>The electrician gives the customer the option of having printed material with information about Vattenfall’s home charging offers.</td>
<td></td>
</tr>
<tr>
<td>Appointment</td>
<td>The electrician offers the customer the option to have a demonstration of the mode 3 charging equipment by the electrician.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The electrician offers the customer to make an appointment with the electrician for upgrading of the property’s electrical grid to either case a. or case b.</td>
<td></td>
</tr>
</tbody>
</table>

**Scenario:** A Vattenfall electrician conducts a visit at the intended property for charging of PEV, in scheduled agreement with the customer. The electrician performs a functionality check of the property’s power distribution grid for the intended charging place. The electrician recommends upgrading of cables if needed, suitable for the customers charging objectives. The electrician gives the customer an offer for upgrade of cables to appropriate standard or for installation of a charging solution, if requested. Furthermore, the customer is offered to have a demonstration of the charging solution, with related communication services and printed material about Vattenfall’s home charging offers. Moreover, the customer can make an appointment with the electrician for upgrading/installation of charging equipment, see figure 52.

![Diagram](image)

**Figure 52. Illustration of scenario for e-check. Pictures taken from Faktabank Fordon Plus (2013), Jansson (2008); Vattenfall (2013) and KEBA (2013).**
7.3.2. The Charging Equipment

e-charge – The requirements presented in Table 18 are to be highly considered, when developing a charging solution. The charging station e-charge aims to reach the target customer and satisfy the functional needs and given requests. The e-charge is a home charging station developed to provide the user with functionality, through its intelligent technology. Below are the functional characteristics of the e-charge charging station described, moreover defined in figure 53.

✓ Faster Charging
The e-charge charging station, has the maximum performance for household charging in terms of power. The station enables charging power up to 16 A using 230 V single-phase or 400 V using three-phase connection. The station has the performance to enable charging power up to 32 A using 400 V three-phase connection. However, the charging speed is automatically adapted to the circumstances, regarding the maximum power supplied by the household's electric grid and the charging capacity of the vehicle.

✓ Attached cable
The charging solution in provides the option of a fixed cable like Case C charging, with the security mode 3, described in the “Technical Specification of Charging Equipment”. Further, a hanging device is attached that is aimed for the organization of the cable, when not in use. The charging solution is optional with mode 2 and Case B. The cable is also equipped with a locking function, in order to reduce thievery.

✓ Electricity Meter
The electricity meter is integrated in the hardware of the charging solution, standard edition. The electricity meter is providing data in the purpose of monitoring. The received data is the interpreted and displayed for the customer through software. The software can easily be accessed by a users’ account, via a smartphone app or a computer.

✓ Engine warmer outlet
The charging solution provides an engine warmer outlet as it is essential, hence the vehicle battery needs assistance during the cold Scandinavian winter days.

✓ Communication
The charging solution has related software. The charging equipment is wirelessly connected to a user platform, with a linked user account. The user can monitor, access and control the charging unit from his/her smart phone via an app or via login on to the webpage from a computer.

✓ Upgradeable and Modular
The most important characteristic of the e-charge is that it modular hardware assembly, in order to enable upgrading of charging equipment for changing demands. In case of the customer changing car and having new connector and vehicle inlets, the charging station can easily be upgraded. This should also ease for the customers to freely elect favorable attributes for a personalized charging solution. In addition, the e-charge has upgradeable software. The e-charge is connected to a cloud based service, which facilitates a user account, with personal information of the charging habits, express and progress over time.
7.3.3. Cloud Based Network Platform

The charging solution should be equipped with software, *e-change*, which enables two way communications between the user and the actual charging station. The software should preferably be able to provide communication with the vehicles internal system as well. This enables Vattenfall to illustrate for the users how cheap it can be to charge and drive on electricity.

The software should be a cloud based platform, providing an account for all the customers. The account should be easily accessible via an application and smartphone, compatible with both iPhone and Android. The user account should also be available via the internet to access through a computer. The application should be integrated with the application and platform system of Energy Watch, a product and service provided from Vattenfall for monitoring of the household electricity consumption (Vattenfall, 2013), see figure 54.

Energy watch displays the electricity costs and the distribution of the households’ electricity consumption. The *e-change* however, puts additional focus on the electric vehicle and its electric charging, whereby the user is also able to monitor and remote the charging of the vehicle.

✔ **Monitor and remote**

The user can start, pause and stop the charging from the application. A necessity to enable start of charging is that the charging equipment is properly connected. The application will inform the user if any errors occur during charging. Furthermore, the user can set a timer for the charging from the application, whereby the timer can be set to start charging or it can be set for when the charging should be completed.
The applications provide the user with information about ongoing charging and charging status: the application displays if the charging ready to start, when the charging is ongoing and when the charging is completed. The user receives an error message if the equipment is not properly connected. Likewise, if an error occurs during charging, the user receives an error message within 3 minutes. Moreover it displays, like the Energy Watch, the power supplied by the charging station outlet.

The application should enable the user to view the current vehicle battery status, in terms of: how many kWh the battery is charged with and how many km the vehicle can drive on electricity with the current battery status. Moreover, it should display in time, how many minutes the vehicle can drive with the current battery status and velocity.

✓ **Charging and energy data**

The user is able to view charging periods through the application and historical events of charging from the e-charge. Moreover the user can display the specific electricity costs for charging of the vehicle. The user is able to remote the charging to differ occasions during the day, as the energy prices vary. Monthly costs with different energy contracts can be calculated through the application, similar to the energy watch.

✓ **Maps of charging points**

The application provides an updated service of locations where to charge, appropriate for the users charging equipment. Thereby, it enables the user to view the nearest suitable charging point. Furthermore the user can select to view the smartest way to drive to a destination to maximize the electric driving. This charge locations service is connected to the applications social network, where drivers can make comments on the charging places.

✓ **Service and Support**

The application provides a Service and Support site for charging of EVs. Through this site the user can address issues and request help from the support team, whereby the user can request to receive help via email or phone. If the user has asked for help, Vattenfall’s service and support team will contact the user as soon as possible through the requested contact form, email/phone, within 24 hours.

![Figure 54. A snap shot from the interface of Vattenfalls application, belonging to the product Energy Watch. Pictures taken from Vattenfall (2013) and Apple (2013).](image-url)
7.3.4. Service and Support

The Service and Support is an administrative unit that intends to assist as first line support for the customers, in the matter of booking e-check and coordinate the electricians. The first line is also responsible of receive enquires about the charging offer and simply provide the user with support and service. The unit should also conduct follow ups and provide the customers’ the ability to evaluate their charging experience. Moreover, the unit should also accommodate insurances, reclamation and fraud. Follow up and support the customer in the utilization of the software. The support and service are to be available on telephone, e-mail, through social media and the user account.

7.4. Pricing

The pricing needs future work of benchmarking, in order to get better foundation of where competitors are placed according to Vattenfall's own desired price positioning. The customer of the product will set be in order to communicate uniqueness and value in order to take a high position in the market of differentiated charging offers. The E-station is preferably retailed as an accessory to the vehicle at the car retailer, in order to further motivate a higher price range.

7.5. Placement and Promotion

The largest impact Vattenfall have as a supplier of the charging solution, in excess of the software, is the promotion and placement. To be able to increase the sales and the actual revenue, the awareness of the product needs to increase remarkably. The current customers have poor knowledge about the charging technology market and the products existing. It is important to enhance the value proposition of the charging solution, in order for the customers to become more inclined to invest in a charging solution. The awareness and availability of the charging solution should be communicated through E-Commerce, but also most importantly available and demonstrated In Store.

- In Store: The product offer should be placed in store primarily at the car retailer, together with the PEV and if possible at the OEMs for demonstration.
- E-commerce: Naturally, the product offer has to be available for on Vattenfall's homepage for interest application and order, but also available on the web.

7.5.1. In Store

The car retailer is considered to be the customers’ first and natural entrance to the electric vehicle market, therefore the product offer should be available at the PEV car retailer for demonstration and promotion. Figure 55 illustrates the roadmap scenario for the customers’ introduction to Vattenfall’s charging offer available at the car retailer. Below follows a scenario describing the customer experience at the retailer.

Scenario: A potential customer walks in to the car retailer and shows interest in a Plug-in electric vehicle. An educated salesman answers the customers’ questions regarding the cars performance, optional features and accessories, including charging. The salesman informs the potential customer about the most convenient and appropriate way of charging the PEV, which include a demonstration of the e-charge. The salesman provides the customer with a brochure, explaining Vattenfall's charging offers and related services. The brochure has a QR-code, which can be scanned through the customer’s smartphone, giving the customer a direct link to Vattenfall’s home page with charging offers for PEVs.
The customer reflects and considers the potential car purchase and the complementing charging offer, in a safe and calm environment at home.

The customer returns to the car retailer, when he is ready to make purchase of the vehicle. The customer and salesman create the sales agreement for the car. At this point, if the customer has not already checked the home power grid, customer should be offered opportunity to apply interest in e-check and e-charge. In the next step, the customer is contacted by an electrician from Vattenfall, within two working days, whereby they should schedule a time for an e-check. The customer is given verbal information about the charging offers and the opportunity to ask questions of interest. The electrician should understand and determine whether the customer’s objective is to charge with a domestic socket outlet or to be given an offer for installation of e-charge.

![Diagram of the process](image)

**Figure 55.** Illustration of scenario for in store promotion at the car retailer. Pictures taken from Dailyworth (2013), CFC (2011) and Marco (2013).

### 7.5.2. E-commerce and Campaigns

The charging offer should be available on Vattenfalls webpage, as for the partner car retailers webpages. The information about the offer should be easy to access on the internet. The offer should be a first search hit, if the customers are searching for information on the web. As customers approach Vattenfall, the steps from the initiated contact to the product installed at the customers property should be short, clearly and concisely. By having few clicks from thought to action the customer will not have time to hesitate or regret their choice. As the first contact is initiated with Vattenfall, it needs to be followed up the entire period as customer.

In order to create awareness and a positive word of mouth, communication campaign should be performed utilizing ongoing EV projects and for product placement and digital communication campaign. In this communication campaign direct marketing should be
performed to bloggers and opinion leaders such as “Gröna Bilister”. Social media, such as facebook, homepages and networks for EV interested persons should be used. This in order to get to know the customers better and to generate interest around charging and Vattenfall’s future charging offer.

The charging offer should be an easily integrated complement to the Plug-in Electric Vehicle. The E-mobility should be promoted as a lifestyle and whole user-experience aimed for the environmental friendly and sustainable driver and family.
8. Discussion

This chapter presents a discussion of the study. The discussion also questions the field of investigation, the chosen methodology, the working process and the reliability of results. The aim of the discussion is to generate new and different perspectives for the reader of the study, hence contributing with viewpoints to be considered in future studies.

The industry of E-Mobility is a highly discussed and debated matter, as it is in a developing phase. Large effort is required from all the stakeholders, in order to get the industry and technology to perform and develop. During the last decade different stakeholders have made huge investments in the electrical vehicle fleet. Car manufacturers have struggled to push the limits with pure electricity driven powertrain, but also with the battery technology and the actual adoption of the future drivers. During 2012 Sweden was introduced to the powertrains of PHEV, subsequently the models have been released with short interval from the different car manufacturers. The popular combination of combustion engine and electric motor attracted more car manufacturers, who want to gain market shares. Meanwhile, it is believed that the E-mobility and the vehicle fleet are in a situation, an internally challenging consideration and conflict. The PHEVs and the rest of the E-mobility is actually the largest new entrance on the automotive industry in modern time, as an extension of the vehicle range. Nevertheless are they to grow and potentially become the largest threats towards the standard combustion engine.

As known, the combustion engine contains a large amount of components and further supported with large market of spare parts and services. The aftermarket for combustion engine is believed to be threatened by the introduction of electric motors. Could it be that the loss of profits on the aftermarket is not worth the development and front-end technology? The automotive industry is developing the largest threat targeting their main market segment towards conventional passenger cars. On the other hand, restriction on European level forces them to produce environmentally favorable powertrains, whereby if the car manufacturers do not follow the guidelines, receives financial penalties. Is the e-mobility an upcoming trend? Is it worth taking the risk, in order to gain the first movers advantage on the market?

Lately, the society has been aware of the consumption of the fossil fuel and knows the actual consequence of the usage and what the emission causes on our nature. In order to be able to make a change, it has to be implemented on international level and executed accordingly on national level. On European level restriction has been set, these to create pressure on the car manufacturers and steer them towards a more environmental friendly range of passenger vehicles. Moreover, the Swedish government works on creating a market for EVs, by trying to lower the barriers for the customer to enter. On Swedish national level, one have decided to set a goal on an actual vehicle independent car fleet by 2030, this has been announced, with an incentive on 40 000 kr for "environmentally friendly vehicles". Further observing the neighbor countries, Sweden is falling behind on the progress towards electrification of the vehicle fleet. In order to reach this goal, they have to convert all the 4,5 million vehicle on the road in less than 17 years. Hypothetically; this would mean that they need to turn over approximately in a pace of 4 500 000 cars/17 years, which equals more than 260 000 cars per year, subsequently over 20 000 cars a month – Reachable? Yes, but then they definitely need to make some changes and increase the incentive to increase the pace of conversion to EVs. This most probably needs to be done on national level. To gain market share it is believed that incentives can remarkably increase the sales of EVs and charging solutions – with the outcome of larger market shares. Nevertheless, even when the vehicle is purchased it is important to satisfy the
customers and bring the value propositions forward, in order for the word of mouth to remain positive and converting more potential buyers.

8.1. The Study

As electrification of vehicles is in a turbulent phase of development, information and sources have a short validation date, and the industry and standards can change over 2 weeks, which results in new conditions and limitation affecting the result. For instance, the 30th of May 2013, nationally large stakeholders agreed on a future standard for charging equipment to be introduced by 2017. This standard considered public charging stations, whereby they are set the standard to be mode 3 and type 2 connector (Wingfors, 2013). These changes and development have affected the progress of the thesis work and confirms the instability and the early phase E-Mobility is currently in, consequently created difficulties during the observation and study.

Collecting updated information and literature and has been challenging. It required significant efforts in the beginning of the study to grasp the area and frame the scope. In order to retain the most update information available the pre-study needed to be comprehensive involving interviews and meetings with many different stakeholders and experts. Nevertheless, the pre-study was very important for the further work and understanding of the field.

Further, the sources of information is also highly dependent on getting to know the key professionals within the industry, in order to get further contacts and interview the right people. As mentioned, the comprising pre-study was necessary in order to conduct the investigation; however with limited resources, there was less time was available for the actual compilation of results, analysis and recommendations. Nevertheless, as of today no other study has been found, on the same target group. This increases the difficulty of benchmarking other studies and validation and confirmation of the reliability of method and results.

8.1.1. Empirical Investigation and Findings

The study and the empirical investigation is based on 36 respondents, whereby 13 of them were interviewed using the long interview guide (see appendix B) and the remaining using a short interview guide (see Appendix A). It is believed that the respondent group and the empirical data collection were too comprising, given the time limit and information access. During the statistical data collection it was noticed that the data became saturated, while on the other hand some of the questions in the qualitative interview were too vague. This resulted in a hard compilation of empirical investigation. In the future the qualitative data collection should have been made as observation of users in action, instead of telephone calls. In this study a large quantity of respondents was requested by the company. A smaller qualitative data sample could have resulted in a deeper research of their actual needs and habits, nevertheless increase the quality of the qualitative data collection. An example could be; to follow a couple of respondents in their daily life and daily use of the vehicle, which could have contributed to new findings. Occasionally, the users had hard time sharing their experiences, something that is probably related to the duration of the respondents' ownerships.

Since the respondents had not driven the car for a full year, they had not experienced all the seasons with their cars and problems that might appear in relation to different weather conditions. If they would have driven their cars for more than a year, maybe it would have enriched the results from the empirical investigation with additional valuable knowledge. Further it is believed that the respondents, after a year, would have had time
to get to reflect over the new technology and eventually experience the silent needs and request they have regarding charging.

The outcome of the future recommendations is naturally highly influenced of the fact that the study and field of investigation is in an early face. The users have not driven their cars for long and the drivers have mostly utilized their cars during wintertime. They were mainly positive towards the PHEV technology, but as the battery and the electric motors performance decreases with the reduction of the temperature this might have affected their answers and perception about the technology.

Further it was experienced, that the respondents had hard time estimating personal values and habits regarding this area. As the analysis brought forward, the lack of knowledge was probably the strongest factor of hesitation in answer. Another hesitation factors are most probably the fact that the interview was made over the telephone, and in some cases as the pricing; they have never heard about or seen the product in focus. The awareness is definitely one of the biggest fall downs, as it is hard to convert a market into buying a product that it is not even aware of.

The recommendation of the pricing has been difficult to set. The access of Vattenfalls pricing and procurements have not been there. Further, as the users had hard time to actually appreciate the value of a scenario given charging offer, described over a telephone interview. This can probably be connected to the fact that it is a new industry for them and that it currently creates difficulties for the users in benchmarking the charging offers and the value proposition.

The recommendations from the study are based on the assumption that there is a market potential for charging offers for PHEV drivers. This is only a forecast based on historical sales figures, governmental objectives regarding to lower the emissions of our vehicle and the respondents acceptance of the new technology. If any of these parameters would change drastically in this immature phase of the technology, this forecast might be proved wrong. However at the moment, the electric vehicles seem to have a promising future at least for a few years to come.

As the technology is in a developing phase the target customer was chosen by the characteristics of an innovator. The Volvo V60 respondent group, was the group best corresponding to the characteristics of an innovator. Thus, their prerequisites acted the basis for a target customer. This is a narrow user group to target, but as the market prerequisites were analyzed, it was realized that these customers have a high bargaining power as innovators. This implies that it is essential for the actors involved in E-mobility to satisfy this customer group in order found a greater adoption of this technology. The aim of the charging offer is to attract all PEV users with private properties through the e-check, which is something that is recommended to perform in order to charge at home. Thus, this session should moreover be conducted in order to increase the awareness about safe charging and charging offers. Thereby it might act an introduction for a larger group of potential customers of Vattenfalls services and charging related products.

Reliability

In order to manage the large data of empirical investigation, the interviews were not transcribed. During the qualitative data collection, notes were taken. Due to the request of a large sample of interviews, the time period limited the possibility to transcribe all of the 36 interviews. The data has been interpreted in an iterative process, thus, the risk of data loss increases, which affects the reliability of the results.
8.1.2. Limitation and Scope

As identified in the introduction, this industry is highly depended on their three factors and the actual balance of them; Users, Vehicle and Charging Technology. As the industry is in an innovative phase, the environment is surrounded of risk and hazards. The atmosphere is unexplored, which made it difficult to find credible, scientific literature to support our findings with.

The unexplored industry created difficulties to set delimitations in an early stage, which increased the scope of the study. The positive aspect is that a holistic picture is easier to illustrate and explain, but on the other hand the actual quality of work becomes compromised. Overall, the main purpose and core product of Vattenfall is electricity, the charging station are just a distributional channel of electricity. The purpose of the charging stations is to provide the users with the best charging solution, for their convenience on driving and charging with electricity, instead of petroleum. The outcome of this study is only valuable and fulfills its purpose, when assumed that all PHEV drivers are willing to utilize the ability of using electricity as fuel source. Hypothetically, if the regulatory framework regarding emissions is further sharpened it might force car manufacturers to only manufacture and sell PEVs and PHEVs. However if the framework does not require from the drivers of PHEVs to drive on electricity, the drivers can chose, if they want, to drive exclusively on petroleum.

8.1.3. The Future Recommendation

Vattenfall should definitely use their distinctive capability, being an energy supplier, and provide the customers with features and attributes connected to a charging solution utilizing the capabilities. As an example; provide green and clean electricity source for unpolluted charging, in order to reach the clean driving. The customer should receive a feeling of inhesion and supporting a cleaner community and city. As the industry evolves and grows, the competition will increase. Vattenfall is not an producer of the hardware and components of charging solution, and should therefore aim to value-add the product with their key features as a energy supplier, in order to lock up the future customers from switching to an another product.

The future recommendation given is not a complete answer to the future outcome, it is more of an a visualization and creative idea of what can be strived for in a new product offer. The recommendation and roadmap can be concluded to nine key points. These key points are important for future work, research and field study within the industry of E-mobility.

- Benchmark all suppliers available on the charging technology market. All the potential competitions today could be future suppliers of tomorrow.
  - Review and validate KEBA as a supplier, hence perform a benchmark on supplier, in search of a better contract and purchase price of product with subcontractor. I.e. GE.
- Increase the awareness among the speculators of E-mobility, current PEV drivers and potential customers.
  - Initiate contact with drivers in an early stage to increase awareness of charging technology and Vattenfall as a supplier
  - Create collaborations with projects and car dealers – to be the first contact in charging solutions
- Improve Webpage
  - Simplify access to information and enquires on the web page and decrease the amounts of click on the webpage, per purchase
  - Search Engine Optimization – SEO
✓ Improve selling points and increase value proposition
  o Justifying the pricing and visualizing the actual cost reduction and
    awareness/control customer gains of installing the charging solution
✓ Campaigns and Incentives
  o Beneficial electricity agreements – attract them to change to Vattenfall as
    an electricity supplier by connecting beneficial electricity deals to the
    future charging offer
  o Green electricity – package deals with Vattenfalls service such as Energy
    Watch
✓ Integrate communication and increase the level of intelligence of the charging
  equipment.
✓ Leave space for continuous improvement an enable upgrading of the future
  charging offer.
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APPENDIX A

This is the “Short interview guide”, used for empirical investigation of plug-in hybrid electric vehicle drivers and for the quantitative data collection.

Enkätmall – Kort intervju av användare av Plug-in Hybrider

Hej mitt namn är NAMN EFTERNAMN, vi är två studenter som skriver examensarbete vid Kungliga Tekniska Högskolan inom elbilar och laddningsinfrastruktur med fokus på användarna av laddhybrider. Den här enkätintervjun kommer att ta ca 10-15 min och kommer att genomföras i tre steg, Frågorna är uppdela i generella frågor, laddningsvanor och framtida laddningslösningar. Vill du delta anonymt så går det bra. Respondent anonym ( )

STEG 1 Generella frågor

1. Intervjuenummer __________
2. Datum __________________________________________________________
3. Nuvarande bil (modell, drivmedel) _______________________________________
4. Hur länge har du haft din nuvarande bil? ___________________________
5. Namn & telefonnummer _____________________________________________
6. Ålder ______________________________________________________________
7. Antal i hushåll ______________________________________________________
8. Bostad _____________________________________________________________
   • Villa
   • Radhus /parhus
   • Lägenhet
9. Är detta er förstahandsbil?
   • Ja
   • Nej
10. Är din laddhybrid:
    • Privatägd
    • Företagsägd
    • Leasingbil
11. Varför köpte du din nuvarande bil? Ranka i vilken 1-3 de alternativ som stämmer bäst in på varför du köpte bilen. 1= mest överensstämmende
    • Teknikintresse
    • Miljöintresse
    • Ekonomiskt intresse- incitament / förmån

STEG 2: Laddningsvanor

12. I din vardag, hur skulle du procentuellt säga att fördelningen är mellan drivmedelsanvändningen - Eldrift/Diesel-Bensin? dvs. hur mycket kör du på elektricitet i din dagliga köring?
   • 0% el
   • 20% el
   • 40% el
   • 60% el
   • 80% el
   • 100% el
   • Annan % uppskattning________________________
13. Hur är din parkering där du laddar? (Ringa i de alternativer som stämmer bäst överens med respondentens parkeringsplatser)

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<th>Arbetet</th>
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STEG 3: Framtida laddningslösning

14. Givet din bilns begränsningar, vad anser du anser vara en realistisk ambition att köra på el (total köring/månad)?
   ▶ 25% el
   ▶ 50% el
   ▶ 75% el
   ▶ 100% el
   ▶ Annan % uppskattning

15. Har du övervägt att köpa en extra laddningskabel?
   ▶ Ja
   ▶ Nej

16. Skulle du vilja se din bils elförbrukning separat på elfakturan?
   ▶ Ja
   ▶ Nej

17. Känner du till laddboxar för hemmabruk?
   ▶ Ja
   ▶ Nej

Framtida laddlösningar – Prissättnings scenario

18. Nu så kommer jag så beskriver egenskaper för ett paketerbjudande för laddbox.

Laddboxen installeras av en elektriker i hemmet, på carport eller i garage. Elektrikern ser över hemmets totala elförbrukning, så att inga propper går under laddning. Laddboxen innehåver viss kommunikation, som kontrollerar att båda enheter, bilen och uttaget, är intakta innan strömmen släpps på. Om kabeln tas ur ena änden finns alltså ingen som helst ström i den och det kan inte bli gnistbildning. Det går snabbare än att ladda från ett 10 A uttag (13-16 A). Kabeln är fast installerad i
boxen och hänger på laddboxen. Skulle en sådan här produkt tillföra värde för dig?

- Inte alls
- Möjligt
- Troligt
- Högst troligt
- Definitivt

19. Var skulle denna lösning tillföra mest värde för dig?

- Hemma
- Annan plats

20. För detta värdeerbjudande ovan, vad anser du det skulle vara viktigt för dig, anges prismässigt en engångssumma i antal kr enligt följande kriterier:

- Lågt pris
- Acceptabel pris
- Dyrt
- För dyrt

21. På marknaden finns det olika laddningserbjudanden för hemmabruk, liknande det tidigare beskrevet. Dessa rör sig i en priskategori mellan 10-15000 SEK, skulle överväga att köpa en sådan produkt:

- Inte alls
- Möjligt
- Troligt
- Högst troligt
- Definitivt

22. Vid köp av en laddbox till hemmet, vilken ägandeform skulle du föredra?

- Privatköp engångssumma
- Privatköp, avbetalning
- Leasing avtal i samband med bilen
- Hyra, månadsabonnemang

23. Vilken av följande aktörer tycker du ska förse dig med den här lösningen?

- Biltillverkaren
- Elaktörer ex. Fortum, Vattenfall, E.ON
- Bostadsrättsföreningen
- Offentliga sektorn
- Annan aktör___________

Tack så mycket för att du deltog i studien. Detta resultat kommer endast att användas som statistiskt underlag och ej publiceras med namn. Vill du ta del av resultatet? Mail:

Skriv till ni några frågor så får ni gärna återkomma till detta nr. XXX XXXX

Tack så mycket och ha en fortsatt bra dag!
APPENDIX B

This is the “Long interview guide”, used for empirical investigation of plug-in hybrid electric vehicle drivers and for the qualitative data collection.

Intervjumall – Långintervju av användare av Plug-in Hybrider

Hej mitt namn är NAMN EFTERNAMN, vi är två studenter som skriver examensarbete vid Kungliga Tekniska Högskolan inom elbilar och laddningsinfrastruktur med fokus på användarna av laddhybrider. Den här intervjun kommer att ta ca 45-60 min och kommer att genomföras i tre steg. Frågorna är uppdelade i generella frågor, laddningsvanor och framtidiga laddningslösningar. Vill du delta anonymt så går det bra. Respondent anonym (   )

STEG 1 Generella frågor

24. Intervjunummer __________
25. Datum ____________________________________________________________
26. Namn & telefonnummer ____________________________________________
27. Ålder ____________________________________________________________
28. Antal i hushåll ______________________________________________________
   Familj (partner, barn, djur) __________________________
29. Bostad ____________________________________________________________
   Villa
   Radhus /parhus
   Lägenhet
   (var, bostadstyp) __________________________________________
30. Nuvarande bil (modell, drivmedel) _________________________________
31. Hur många bilar finns i familjen?_____________________________
32. Är detta er förstahandsbil?
   Ja
   Nej
33. Vem är den primära förare av er laddhybrid och hur använder denna i er dagliga körning?
   Uppskattningsvis km daglig körning?
   Respondenten
   Hem till arbetet ______, antal km____,
   Annan körning______
34. Är din laddhybrid:
   Privatägd
   Företagsägd
   Leasingbil
35. Hur länge har du haft din nuvarande bil? ____________
36. Vilken var din föregående bil (modell/drivmedel)?
37. Hur länge och var brukar din bil stå Parkerad under ett normalt dygn (Hemma, arbetet, annan plats... ex.)
   _____ timmar/dygn, vid plats_______________________
   _____ timmar/dygn, vid plats_______________________
   _____ timmar/dygn, vid plats_______________________
38. Vid köpet av er laddhybrid, vilken bilmodell (och drivmedel) var det främsta alternativet, vid inköpsställfälle?
39. Varför köpte du inte den alternativa bilen (drivmedel)?
40. Varför köpte du din nuvarande bil? Ranka i vilken 1-3 de alternativ som stämmer bäst in på varför du köpte bilen. 1= mest överensstämmande
   Teknikintresse
   Miljöintresse
Ekonomiskt intresse - incitament / förmån

41. Vilken bil vill du vara din nästa bil (drivmedel)?

STEG 2: Laddningsvanor

42. I din vardag, hur skulle du procentuellt säga att fördelningen är mellan drivmedels användningen - Eldrift/Diesel-Bensin? dvs. hur mycket kör du på elektricitet i din dagliga körning?

   - 0% el
   - 20% el
   - 40% el
   - 60% el
   - 80% el
   - 100% el
   - Annan % uppskattning______________________

43. Hur/Var och När laddar du din bil? exempel:

   NÄR: tidpunkt/dygn: 13-15, dagtid
   VAR: vid plats: hemma garage
   HUR: Utrustning: Kablage som förvars i bagageluckan, vanligt eluttag/laddstation etc.

   _____ tidpunkt/dygn, vid plats___________________Hur:
   _____ tidpunkt/dygn, vid plats___________________Hur:
   _____ tidpunkt/dygn, vid plats___________________Hur:
   _____ tidpunkt/dygn, vid plats___________________Hur:

   Jag har aldrig laddat

44. Hur är din parkering där du laddar? (Ringa in de alternativ som stämmer bäst överens med respondentens parkeringsplatser)

<table>
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<tr>
<th>Hemma</th>
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<td>Allmän parkering (trottoar)</td>
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</tr>
</tbody>
</table>

Minimitid för laddning:

   - 0-0,5h
   - 0,5-1h
   - 1-1,5h
   - 1,5-2h
   - 2-2,5h
   - 2,5-3h<
45. Uppskattningsvis, hur lång tid uppskattar du att tar det att ladda ditt batteri till max (10 A< Uttag)?
46. Visste du vilka laddningsmöjligheter du hade när du köpte bilen, samt vilka alternativ hade du? (Hemma, arbete och annan plats, fanns det någon att prata med om bilen)

**STEG 3: Framtida laddningslösning**

47. Vad är negativt med din nuvarande parkering och laddningutrustning? (1=mest negativt)
   - 1.
   - 2.
   - 3.
48. Givet din bils begränsningar, vad anser du anser vara en realistisk ambition att köra på el (total körning/månad)?
   - 25% el
   - 50% el
   - 75% el
   - 100% el
   - Annan % uppskattning______________
49. Finns det någon funktion som du idag saknar/önskar i din laddning för att kunna köra mer på el? (hemma/på arbete/annan plats)? Dvs. vad hindrar dig från att uppnå din ambition att köra på el?
50. Vad är bra med din nuvarande parkering och laddningutrustning? (1=mest positivt)
   - 1.
   - 2.
   - 3.
51. I ett perfekt scenario, hur skulle du ladda din bil?
   (plats, utrustning, säkerhet, tidpunkt etc.)
52. Har du övervägt att köpa en extra laddningskabel?
   - Ja
   - Nej
   - Om Ja- Vet du hur mycket den kostar och varför anser du att du behöver en, vet du även vilka kontaktdon skulle den ha?
53. Skulle du vilja se din bils elförbrukning separat på elfakturan?
   - Ja
   - Nej
   - Varför, varför inte?

**Framtida laddlösningar - Prissättningssenario:**

54. Känner du till laddboxar för hemmabruk?
   - Ja
   - Nej
55. Nu så kommer jag så beskriver egenskaper för ett paketerbjudande för laddbox:
   - Inte alls
   - Möjligt
   - Troligt
   - Högst troligt
   - Definitivt
56. Var skulle denna lösning tillföra mest värde för dig?
57. För detta värdeerbjudande ovan, vad anser du det skulle vara värt för dig, ange prismeget en engångssumma i antal kr enligt följande kriterier:

- Lågt pris
- Acceptabelt pris
- Dyrt
- För dyrt

58. På marknaden finns det olika laddningserbjudanden för hemmabruk, liknande det tidigare beskrivet. Dessa rör sig i en priskategori mellan 10-15000 SEK, skulle överväga att köpa en sådan produkt:

- Inte alls
- Möjligt
- Troligt
- Högst troligt
- Definitivt

59. Vid köp av en laddbox till hemmet, vilken ägandeform skulle du föredra?

- Privatköp engångssumma
- Privatköp, avbetalning
- Leasing avtal i samband med bilen
- Hyra, månadsabonnemang

60. Vilken av följande aktörer tycker du ska förse dig med den här lösningen?

- Biltillverkaren
- Elaktörer ex. Fortum, Vattenfall, E.ON
- Bostadsrättsföreningen
- Offentliga sektorn
- Annan aktör___________

61. SCENARIO, bilpaket eller inte: om det skulle vara obligatoriskt enligt standarder (biltillverkare) att ha en laddbox till din bil för hemmaladdning. Skulle du vilja köpa den i ett paket med din bil eller skulle du vilja köpa den själv, separat hos annan återförsäljare?

- I paketpris med bilen
- Separat produkt

   - **Följfråga separat pris:** Om du jämför laddboxen med andra tillvalsmöjligheter, vad är den då värd för tilläggskostnad?

   **Svar:** ________________________________

36. Slutligen: Skulle någon av följande funktioner vara intressant för dig i din laddning?

- Du slipper plocka ut ditt kablage ur bilen varje gång du ska ladda.
- Kabeln blir inte smutsig.
- Kabeln har en räckvidd på 7-10m.
- Kabeln ligger inte på marken under laddning.
- Det tar 2/3 av tiden att ladda upp ditt batteri till max, jämfört med laddning i ett 10 A hushållsuttag.
- Hushållets elförbrukning är balanserad så att ingen propp går i huset/byggnaden under laddning av bilen.
- Du kan ställa in en timerfunktion för när bilen ska laddas.
- Du kan styra bilens laddningsrutiner från din mobil.
- Du kan få elförbrukningen för din bil redovisad separat på elfakturan.
- Din laddstation lyser upp när du närmar dig den.
- Kabeln är organiserad när den inte används och smidig att ta fram för laddning.
- Du kan kommunicera med din laddtrustning, ex. starta, stoppa pausa, samt information om pågående laddning.
- Du har en fast installation av en laddstation hemma/ på arbetet/annan plats, med en kabel fast i ena änden. Den lösa änden hänger organiserat och är redo att pluggas in i bilen.
62. Var skulle dessa ovanämnda funktioner tillföra mest?
   (Skriv 3 i rutan där det tillför mest)
   - Hemma
   - Arbetet
   - Annan plats

Tack så mycket för att du deltog i studien. Detta resultat kommer endast att användas som statistiskt underlag och ej publiceras med namn. Vill du ta del av resultatet? Mail:
Har ni några frågor så får ni gärna återkomma till detta nr. XXX XXXX

Tack så mycket och ha en fortsatt bra dag!
APPENDIX C

This is a brochure dedicated as advertisement and information for the private B2C-Market, when promoting the wallbox.
Snabbare och bekvämare laddning


Snabb laddning
Med en laddbox laddar du snabbt och bekvämt. Laddboxen tillåter snabba laddhastigheter än ett vanligt eluttag och vid installationen uppraderas kablar och säkringar för att minska risken för elstörningar i hemmet.

Säker laddning

Snyggst och enkelt
Vattenfall Baspaket 12000 kr*

**Laddbox**
- Snabbare laddning med aktiv säkerhet.
- Belgård laddning i vardagen med fast kabel.

**Installation och servicegaranti**
- När du köper laddbox sköter vi uppradgiring av säkringar och kablar samt installation.
- Vattenfall garanterar att du får en problemfri laddning.

*Baspaket är främtitet för dig som bor i omfanlighet med egenkår eller garage. Det förutsätter att du har en hushållticket på minst 20 A och ett högavstånd av minst 1,5 meter från vägg. För mer information och vilket besök Vattenfalls hemsida. Observera att priset kan komma att ändras över tid.*

Få ut mer av din laddbox med Vattenfalls tillval

**Timbaserat rörligt ölpris**
Ellpriset varierar över dygnet. Med tidstraff kan du utan extra kostnad, följa din elförsörjning och styra den till dygnets billigaste timmar.

**100 % Vind**
100 % vindel från Vattenfalls vindkraftverk Lilgrund. Både för hushålet och elbilen.

**Solel**
Solceller på taket laddar din elbil. Sex paneler, totalt 10 m² solceller, motsvarar 650 kör mil per år. 25 års effektgaranti.

Mer information finns på vattenfall.se/laddaebilen.

Beställ laddbox och tillval på vattenfall.se/laddaebilen
**APPENDIX D**

This brochure contains information about Charging Stations from KEBA, hence the available product offer and technical specification of the charging station.

**KeContact P20 – flexible variations for your specific needs.**

- **KeContact P20 Type 1**
  - 1-phase
  - Up to 7.4kW
  - Up to 32A
  - This charging point is mainly suitable for Japanese and US vehicles.

- **KeContact P20 Type 2 with fix cable**
  - 3-phase
  - Up to 22kW
  - Up to 32A
  - This charging point is mainly suitable for European vehicles.

- **KeContact P20 Type 2**
  - 3-phase
  - Up to 22kW
  - Up to 32A
  - Ideal for public and semi-public applications
  - All e-vehicles can be charged with this product variation.

Please note: Actual charging performance is dependant upon the respective charger in the e-vehicle.

Additional product options for identification and authorization:

- RFID
- Key switch
Technical data

Installation variations
• Wall installation both in- and outdoors
  - optional installation on a pedestal for one or two charging points; also suitable for ceiling installation
• Surface mounted cabling from above or integrated from behind

Electrical data
• Rated current (configurable connected load): 10A, 13A, 16A, 20A, 25A or 30/32A
• Network voltage: 3x 230-400V / 208-240V
• Network frequency: 50 Hz / 60 Hz
• Overvoltage category: III pursuant to EN 60664
• RCD and MCB in house installations
• Potential-free output
• IN enable input for external enabling, e.g. ripple-control receiver
• Socket variations: Type 2 standard socket: 32A / 400 VAC pursuant to EN 62196-1 and VDE-AR-E 2623-2-2
• Cable variations: Type 1 cable with 32A / 230 VAC pursuant to EN 62196-1 and SAE-J1772, Type 2 cable with 32A / 400 VAC pursuant to EN 62196-1 and VDE-AR-E 2623-2-2
• Protection type: IP 54

Standards and directives
• Standards Europe: IEC 61851-1, IEC 61851-22, IEC 62196-2, DIN EN 61439-1, IEC 61439-7, EN 61000-6-1, EN 61000-6-3
• Standards US/Canada: SAE J1772, UL 2594, UL 2231-1, UL 2231-2, CSA 107.1, NEE, CFR

Environmental conditions
• Operating temperature range:
  - at 16A: -25°C to +50°C
  - at 32A: -25°C to +40°C
• Permitted relative humidity: 5% to 95% non-condensing
• Altitude: max. 2,000m above sea level

Colors
• Surfaces in RAL 7016 Anthracite Grey or RAL 7004 Signal Grey
• Design hood available as an extra component in special colors

Functions
• Mode 3 charging
• Operating display (multicolor LEDs) for differing operational status

Options
• Identification using RFID pursuant to ISO 14443 for Mifare product family RFID tags (e.g. Mifare 1K)
• Authorization using a key switch (half-cylinder not included in the scope of delivery)
• GreenPHY PLC modern homeplug
• Ethernet connection (Fu45) for debugging
• Ethernet connection LSA+ clamps for networking with the KeContact M10 (load management system) or for future smart home integration

Dimensions / Weight
• WxD: 240x495x163 mm (without cable)
• Weight: approx. 4.8 kg (variation-dependent)

Recommended installation height
Approx. 1,200 mm

KeContact P20 corresponds with current standards and the demands of e-vehicle manufacturers.
APPENDIX E

This appendix shows the total amount of active passenger cars, on the road, registered in April in Sweden over 10-year period. M= Month and 04= April.

Reference (SCB,2013)

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M = Month
04= April

Senaste uppdatering: 20130502 09:30
Hämtad: 20130515 21:00

Källa: Trafikanalys

Kontaktperson: Tina Sehalic, Statistiska centralbyrån (SCB)
Phone: +46 019-17 66 26
Fax: +46
e-mail: Tina.Sehalic 2scb.se
Anette Myhr, Trafikanalys
Phone: +46 010-414 42 17
Fax: +46
e-mail: anette.myhr@trafa.se

Sort: antal

Datatyp:
Referenstid: Beståndsstat avser den sista resp månad och inreg avser inreg under hela månaden

Databas: Statistiska centralbyrån

Intern referenskod: TK1001A1
**APPENDIX F**

This appendix is made by the writers of the report and served as basic data for Tables within the report. The material is from the Swedish transport agency. The table reflects the amount of new registered cars shown per month and divided into fuel types.

Referens: (Trafikanalys, 2013)

Tabellen är en egengjord utifrån siffror från Fordonsstatistik (Trafikanalys, 2013)

Skapad 2013-05-15

**Personbil**

Nyregistreringar av personbilar efter drivmedel

New registrations of passenger cars by fuel

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<th></th>
<th>Petrol</th>
<th>Diesel</th>
<th>El</th>
<th>Ethanol</th>
<th>Electric hybrids</th>
<th>Gas</th>
<th>Övriga</th>
<th>Total</th>
<th>VE</th>
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|   |       | 122  | 1 957| 87 398 | 2,38% | 1,69% | 0,88% |

**Anmärkning:**

Bensin - bensindrivna fordon som endast har ett bränsle
Diesel- dieseldrivna fordon som endast har ett bränsle
El- eldrivna fordon som endast har el som drivmedel
Etanol/etanolhybrid - de fordon som har etanol eller E85 som första eller andra bränsle
Elhybrid/laddhybrid - de fordon som har el som andra drivmedel
Gas - de fordon som har naturgas, biogas, välgas eller metangas som första eller andra drivmedel