



CHALMERS

Insights into battery electric vehicle adopters' transition to electromobility

Master of Science Thesis

in the Management and Economics of Innovation Program

JONATHAN STENSON
GUSTAV OLSSON

MASTER'S THESIS E 2017:083

Insights into battery electric vehicle adopters' transition to electromobility

JONATHAN STENSON
GUSTAV OLSSON

Examiner: Magnus Persson
Tutor: Siri Jagstedt

Department of Technology Management and Economics
Division of Innovation and R&D Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2017

Insights into battery electric vehicle adopters' transition to electromobility
JONATHAN STENSON, GUSTAV OLSSON

© JONATHAN STENSON, GUSTAV OLSSON, 2017.

Master's Thesis E 2017:083

Department of Technology Management and Economics
Division of Innovation and R&D Management
Chalmers University of Technology
SE-412 96 Göteborg, Sweden
Telephone: + 46 (0)31-772 1000

Chalmers Reproservice
Göteborg, Sweden 2017

Abstract

Battery electric vehicles (BEVs) can reduce the negative impact on the environment from the transportation sector. However, the widespread adoption of BEVs is low due to a range of customer purchase barriers. Earlier research has mainly focused on quantitative aspects of customer's purchase intentions, hence missing out on gaining a deeper understanding about the adoption process, which needs further analysis. Insights into how BEV-adopters have perceived the transition to electromobility and how they have overcome related barriers are important for understanding and improving the market viability of near-future BEVs. This thesis analyzes Swedish and Norwegian BEV-adopters' transition to electromobility using semi-structured interviews and theory on diffusion of innovation. Findings show that the transition can be troublesome but due to the relative advantages of the BEV, the satisfaction is high and adopters are unwilling to switch back to conventional cars. Adopters have been driven by either a technology interest or environmental concern, and the biggest barrier they had before adopting was regarding battery uncertainties. Test-driving and gaining experience is identified as crucial for discovering the advantages, overcoming range anxiety and taking the decision to adopt. The transition has been proven most difficult in Swedish single-car households with short-range BEVs, due to limited driving range and perceived lack of infrastructure to manage longer trips. Thus, short-range BEVs are insufficient to offer a full mobility solution, or work as first or single cars. However, most BEVs can be found in multi-car households and they normally serve as commuting cars. Near-future customers will continue to be early adopters and to facilitate a decision to adopt they need to be served with appropriate front-runner products; longer range is believed to be important but most of all they need to be offered the relative advantages discovered in this study. To address the mainstream market a full mobility solution will be key.

Keywords: electromobility, electric vehicles, innovation-decision process, diffusion

Acknowledgements

We have come to realize that this thesis not only symbolizes the end of an era, but the beginning of the next. As we close one chapter of the book called life, we are eager to open and move on into the next chapter.

This thesis has given us invaluable experience from an exciting industry that is facing great change. Several people have been involved in the process, to whom we would like to express our gratitude. Of course, we would like to thank our tutor Siri Jagstedt for continuous support and guidance. We also wish to show gratitude to our industry supervisors, without whom this would have never been made possible. Finally, a special thanks to all those who were willing to participate in the interviews.

Gothenburg, Sweden, June 2017

Jonathan Stenson and Gustav Olsson

Table of content

1. INTRODUCTION	1
1.1. BACKGROUND	1
1.2. PROBLEM BACKGROUND	2
1.3. PURPOSE	2
2. FRAME OF REFERENCE	3
2.1. EVOLUTION OF ELECTRIC CARS AND BARRIERS OF THE SUPPLY SIDE	3
2.2. CUSTOMER PERCEPTIONS AND BARRIERS OF THE DEMAND SIDE	4
2.2.1. ECONOMICAL ASPECTS	5
2.2.2. INFRASTRUCTURE AND CHARGING	7
2.2.3. MOBILITY AND RANGE	7
2.3. SUMMARY OF BARRIERS	11
2.4. DIFFUSION OF INNOVATION	13
2.4.1. TECHNOLOGY ADOPTION LIFE CYCLE	16
2.5. SCOPE	17
2.6. RESEARCH QUESTIONS	18
3. METHOD	19
3.1. RESEARCH STRATEGY	19
3.2. RESEARCH LAYOUT	20
3.2.1. PRE-STUDY	20
3.2.2. DATA COLLECTION	22
3.2.3. DATA ANALYSIS	25
3.3. TRUSTWORTHINESS	27
4. EMPIRICAL FINDINGS	29
4.1. RATIONALES FOR PURCHASE	29
4.1.1. CONCERNS FOR THE ENVIRONMENT	30
4.1.2. TECHNOLOGY INTEREST	31
4.1.3. TOTAL COST OF OWNERSHIP	31
4.2. MOBILITY NEED AND RANGE	32
4.2.1. MANAGING LONGER TRIPS	33
4.2.2. DIFFERENCES BETWEEN GOTHENBURG AND OSLO	34
4.2.3. SINGLE-CAR HOUSEHOLDS	35
4.2.4. RANGE ANXIETY	36
4.3. ECONOMICAL ASPECTS	37
4.3.1. RESIDUAL VALUE	39
4.4. INFRASTRUCTURE AND CHARGING	40
4.4.1. THE EXPERIENCE OF CHARGING IN COMPARISON TO REFUELING	41
4.5. BATTERY LIFETIME AND UNCERTAINTIES	42
5. ANALYSIS	45
5.1. THE KNOWLEDGE PHASE AND PRIOR CONDITIONS	45
5.1.1. BATTERY UNCERTAINTY THE BIGGEST CONCERN BEFORE ADOPTING	46
5.1.2. TECHNOLOGY ENTHUSIASTS MORE CONCERNED THAN OTHERS	48

5.2. THE PERSUASION PHASE	49
5.3. THE DECISION TO ADOPT	51
5.3.1. BEV-ADOPTERS FOCUS ON TOTAL COST OF OWNERSHIP	52
5.4. THE IMPLEMENTATION PHASE	54
5.4.1. SHORT-RANGE AND LONG-RANGE BEVS	54
5.4.2. MANAGING LONGER TRIPS	55
5.4.3. OVERCOMING RANGE ANXIETY TAKES (NO) TIME	56
5.4.4. INFRASTRUCTURE AND CHARGING	57
5.4.5. TESLA'S SUPERCHARGER NETWORK IS PERCEIVED SUPERIOR	58
5.5. THE CONFIRMATION PHASE	59
5.6. EVALUATING THE TRANSITION	60
6. CONCLUDING DISCUSSION	63
<hr/>	
6.1. MANAGERIAL IMPLICATIONS	65
6.2. FUTURE RESEARCH	66
REFERENCE LIST	67
<hr/>	
APPENDIX	I

1. Introduction

In this chapter, the background of the study is presented. Then, after having specified the problem background, the purpose is laid forward to give the reader an understanding about the aspiration of this study.

1.1. Background

The transportation sector and related greenhouse gas emissions are growing (IEA, 2016) thus tightening regulations have been incorporated. According to Knupfer et al. (2017) non-emission vehicles are necessary for automakers to be able to comply with tightening regulations and avoid penalty payments. Hence, automakers are forced to develop and offer non-emission vehicles, where battery electric vehicles (hereinafter referred to as BEVs) offer a promising solution (Bühne et al., 2015). A substantial reduction of local emissions in urban areas can be achieved and recent studies further prove that BEVs can lower global greenhouse gas emissions from the transportation sector on a global level (Nealer et al., 2015). As seen in Figure 1.1, a life cycle analysis was made, concluding that even though the extraction of lithium for the battery is dirty and that electricity comes from a grid consisting of 70 percent coal; BEVs are more eco-friendly than conventional cars on a global life cycle level.

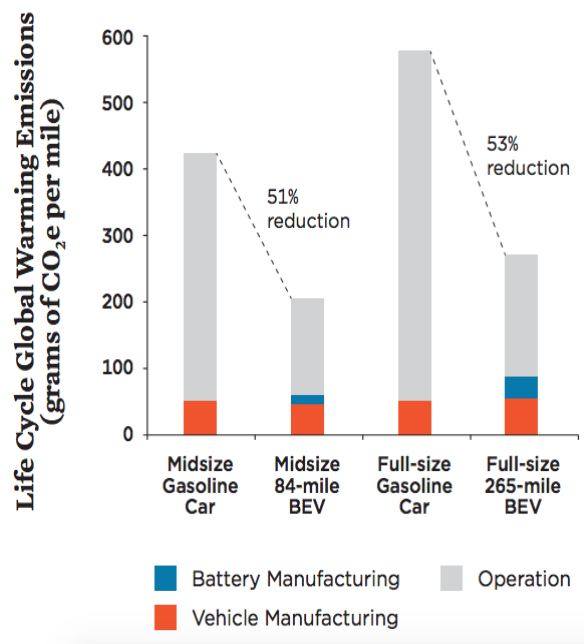


Figure 1.1 Showing the difference between a conventional car and a battery electric vehicle (BEV) in terms of emitted emissions from a life cycle perspective (Nealer et al., 2015).

The history of electric vehicles reaches as far back as to the beginning of the 19th century (Høyer, 2008), although major technological advancements have taken place in recent years (Lebeau et al., 2013). Due to these technological advancements and some scale related economical gains, battery costs have decreased by 80 percent over the last seven years (IEA, 2016). Despite the fact that BEVs are becoming less expensive to buy, they only account for a mere half percent of annual sales of passenger cars in Europe (ibid).

1.2. Problem background

Even though research suggest that around 90 to 95 percent of all conventional cars could be substituted by low range affordable BEVs at any given day, in any type of city and climate (Kahn and Kockelman, 2012; Needell et al., 2016), the widespread adoption of BEVs is low, or even lower than anticipated (Manners, 2014) and as a consequence automakers that have entered the BEV market are losing money (Graham et al., 2014). Earlier research has shown that the weak diffusion is due to a range of customer purchase barriers, the major ones being the high purchase price, limited driving range and insufficient infrastructure. However, there is a gap in research focusing on qualitative aspects of the diffusion process of BEVs. Earlier research has focused on quantitative data collected from non-adopters, hence missing out on gaining a deeper understanding about the process. Insights on how BEV-adopters have perceived the transition to electromobility and how they have overcome related barriers are important for understanding and improving the market viability of near-future BEVs.

1.3. Purpose

Against this backdrop, the following purpose has been specified. The purpose of this study is to investigate BEV-adopters transition to electromobility to gain a better understanding of their purchase drivers and adoption barriers.

2. Frame of Reference

This chapter aims to provide the reader with theoretical knowledge about relevant notions for the study. Firstly, a synthesis of previous research about electric vehicles and related barriers that hinders a widespread diffusion is presented. Secondly, a summary of the barriers is concluded. Thirdly, theory on diffusion of innovation is explained, which will form the basis of the analytical framework used in the study. Finally, the scope of the study is explained and the chapter concludes with a research question.

2.1. Evolution of electric cars and barriers of the supply side

The electric motor has been around for as long as the internal combustion engine (Høyer, 2008). Electric cars were even more popular than conventional cars during the late 19th century (Yu et al., 2011). However, due to technical limitations of the electric motor and decreasing oil prices, which paved the way for conventional cars, electric vehicles disappeared from the market for over 50 years (ibid). The internal combustion engine became the dominant design as described by Utterback (1994), due to its superiority in terms of range, speed, cost and surrounding gasoline infrastructure (Dijk, 2016).

In the 1990s, electric vehicles returned. Dijk (2016) explains this by the increasing environmental issues that led to more regulations and higher taxes on conventional cars, which increased the cost for both automakers and customers. Furthermore, national and international projects were initiated to explore the possibilities of electric vehicles. Other political measures, mainly stimulating the supply side with for instance R&D funds, were also undertaken to ramp up the development of electric vehicles. Although many electric vehicles concepts appeared, very few were commercialized (Yu et al., 2011). Dijk and Yarime (2010) argue that investments in electric vehicles spurred the development of conventional vehicles, which became more efficient and got better performance, making them even harder to substitute.

Technological change is often a hardship for companies. Dijk and Yarime (2010) explain the barriers the supply side is facing. Due to heavy investments in plants, technology and infrastructure for conventional vehicles, automakers and the oil industry are locked-in. Nevertheless, since 2005, the number of electric car manufacturing firms has exploded and Dijk and Yarime (2010) show that there were almost 50 firms

worldwide in 2010, many of which were new entrants in the market. Yet, sales remain modest and the authors explain this by the fact that the industry has not settled upon a dominant design, in terms of battery and architecture. Moreover, by comparing the industry with other cases, Dijk and Yarime (2010) find another obstacle hindering the electric car market from gaining momentum to be the lack of a “front runner”. Lately, technological advancements and decreasing battery prices has brought the market potential back to life (Knupfer et al., 2017).

2.2. Customer perceptions and barriers of the demand side

Electric vehicles have had a hard time gaining customer acceptance. In a study by Lebeau et al. (2013), a comparison was made between general customers (who had indicated that they had a low level to medium level of knowledge about electric vehicles) and customers with higher knowledge about electric vehicles. On the overall ranking about purchase barriers for buying BEVs, no differences could be found. One of the barriers mentioned in earlier research is the fact that electric vehicles have not been emotionally appealing for the general public (Moons and Pelsmacker, 2012). For a technology to gain legitimacy it usually imitates the old technology, which it replaces (Rogers, 2003). Design is according to Grant (2010) one of the key success factors in the automotive industry and would explain partly why electric vehicles did not become a commercial success. The design of BEVs, in comparison with a conventional car, is still considered by customers as a disadvantage (Lebeau et al., 2013).

The car market is highly segmented and there is a large variety of models and brands to choose from. According to Kotler and Armstrong (2006), buying a car is one of the most complex customer purchases since it requires the customer to be highly involved and well informed. Except for the different segments and sizes of vehicles, such as SUVs, compacts and sedans there are also different categories in the respective segment with for instance small-, midsized- and large SUVs. Furthermore, every car can usually be configured with different motors, colors etcetera. Thus, making the purchase rather complex with all the different choices of models, different add-ons and settings. Moreover, some argue that emotions are the most determinant factor of a car purchase (Moons and Pelsmacker, 2012). Heyvaert et al. (2015) and Lebeau et al. (2013) found the limited supply of BEVs, both in terms of brands and models, to be an issue for the customer, albeit not the most concerning one. Except for Tesla with its Model S and X, the rest of the automakers are targeting the compact segment, which account for 21

percent of the European car market (Jato, 2016). To this segment belong BEVs such as the Volkswagen e-Golf, BMW i3, Nissan Leaf and the Renault Zoe.

2.2.1. Economical aspects

BEVs have a high fixed cost, the purchase price, but a low variable cost, cost per kilometer (Lebeau et al., 2013). Even though battery prices have fallen drastically during the last years, several studies, both near term and earlier in the past, identify the purchase price to be amongst the largest barriers for a widespread adoption of battery electric vehicles (e.g. Curtin et al., 2009; Young et al., 2009; Power, 2010; Lieven et al., 2011; Carley et al., 2012; Egbue and Long, 2012; Krause et al., 2013, Lebeau et al., 2013; Delang and Chang, 2013; Böhne et al., 2015; Heyvaert et al., 2015).

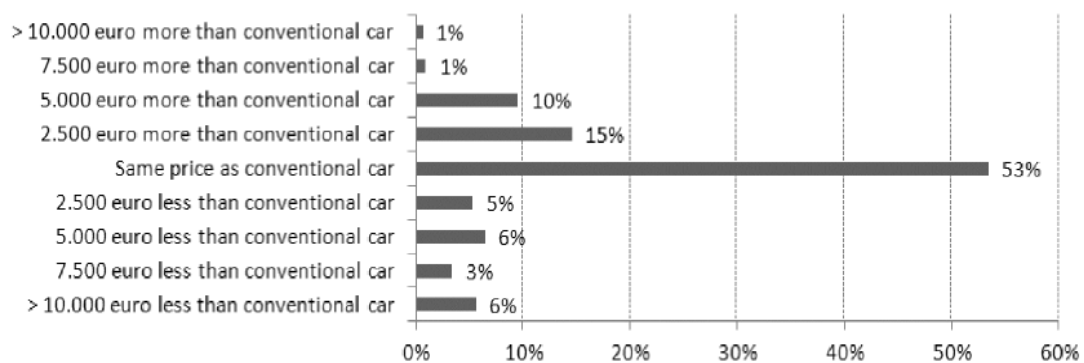


Figure 2.1 Showing the willingness to pay for a BEV (Lebeau et al., 2013).

How important price is of a certain product varies for different kinds of customers (Rogers, 2003). Price is not as important for early adopters of a new technology as it is for the bigger mainstream market, which is in line with what research about electric vehicles show (e.g. Lieven et al. 2011; Knupfer et al., 2017). Lebeau et al. (2013) state that battery electric vehicles are on average 15 to 30 percent more expensive than a similar conventional car. However, research show that customers of clean-tech in general do not like to pay a premium price (Larson et al., 2014). As can be found in Figure 2.1, 50 percent of the respondents in a study carried out in Belgium wanted the BEV to be priced at the same level as a conventional car (Lebeau et al., 2013), albeit around 20 percent wanted the BEV to be cheaper due to the disadvantages such as the limited driving range. Another study shows that the interest in buying a BEV is big, and if the price were to be the same as a conventional car 69 percent would consider buying a BEV (Heyvaert et al., 2015). Larson et al. (2014) discovered that the total cost of

ownership is rarely considered when buying a car. As seen in Figure 2.2, when potential BEV customers in Canada were informed about the savings that comes from lower fuel consumption and maintenance, then 50 percent would be willing to pay a premium of \$2500. This shows that when getting an understanding of the savings using a BEV compared to using a conventional car the respondents were willing to pay a higher premium price.

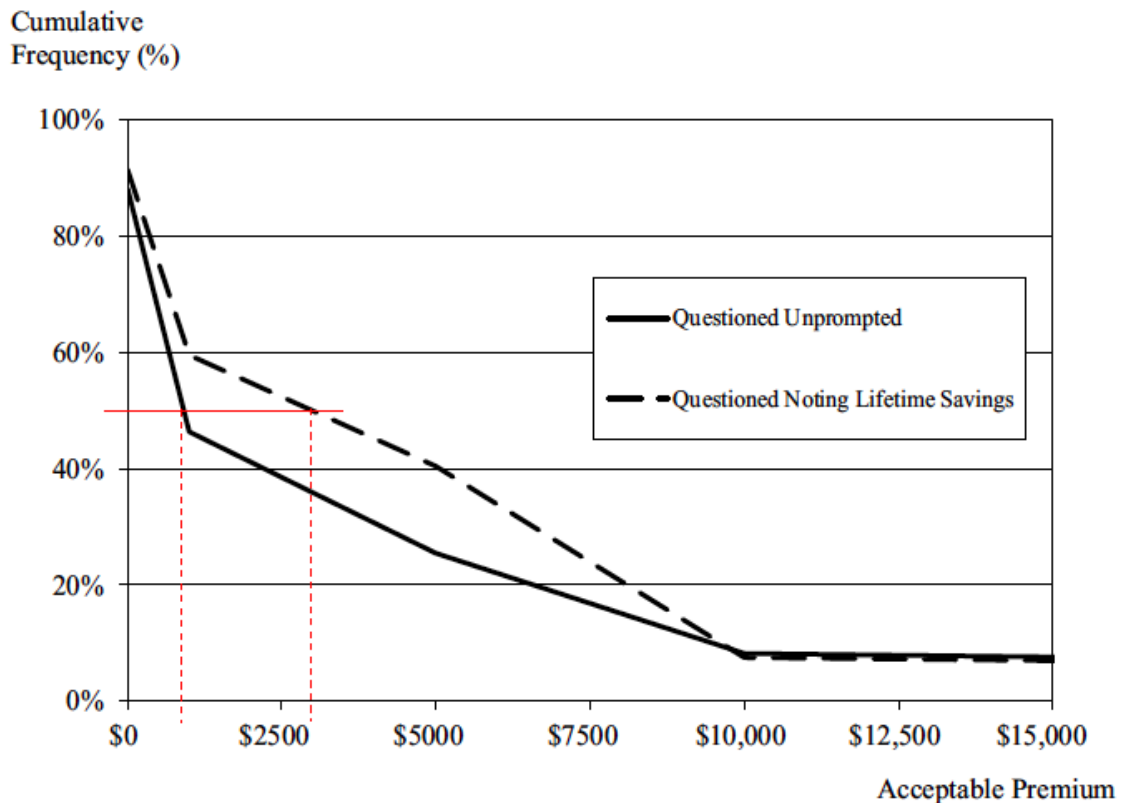


Figure 2.2 Showing the willingness to a pay a premium for a BEV. When informed about the lifetime savings people were willing to pay more (Larson et al., 2014).

The total cost of ownership varies depending on in which country the calculation is done due to different electricity prices and taxes. Calculations have been made where a BEV would be 10 times as cheap to run as a conventional car (TonySeba.com, 2017), whilst others are a bit more modest, counting on a reduced fuel cost of around two thirds (Lebeau et al., 2013). In Sweden, fuel savings can amount to over €1000/year (€0,15/kWh, 1,6kWh/10km, 15 000 km/year), due to high taxes on fossil fuel and cheap electricity.

BEVs have not been available long enough for people to know what can be expected with residual value (National research council, 2013). The conventional car has a

residual value that is fairly easy to predict, at least up until now. Estimates from automakers show that BEVs will probably have a lower residual value mostly due to uncertainties regarding the life length of the batteries (ibid.). Lebeau et al. (2014) show that residual value uncertainty is one of the disadvantages of BEV. In their study in Belgium slightly less than 80 percent thought of this as a crucial, very important or important disadvantage.

2.2.2. Infrastructure and charging

Long recharging time and lack of charging infrastructure were one of the negative associations potential BEV customers stated in an Internet survey carried out in the U.S. (Egbue and Long, 2012). Infrastructure for charging came in at third place of the biggest concerns, as 17 percent ranked this their top concern. The study did prove a strong correlation between driving range and charging time (Egbue and Long, 2012). Respondents were more willing to charge during a longer period of time if the driving range was long and vice versa. Even though 30 percent was unsure about what they think about charging, 30 percent thought it would be less convenient than fueling a conventional vehicle. This is in contrast to what Lebeau et al. (2013) found in their large-scale survey in Belgium, where charging was actually seen as one of the biggest advantages when it could be done at home or at work, thus eliminating the need to go to a gas station. Moreover, a large majority said they would be fine with a charging time of four to eight hours. However, for longer trips than the regular commuting, charging infrastructure was seen as a major barrier for adoption and 91 percent wanted a full recharge within 30 minutes (Lebeau et al., 2013). With today's fast chargers this is possible, although it might have a negative effect on the battery lifetime (Choi and Lim, 2002). A European study by Buhne et al., (2015) shows that the one most important factor to improve for a potential BEV customer to buy a BEV would be to increase the charging infrastructure.

2.2.3. Mobility and range

Several studies, for instance Egbue and Long (2012) and Heyvaert et al. (2015), show that range is the most limiting factor and the biggest perceived barrier for customers in general. If it is not the biggest barrier then it usually comes in at second after the purchase price, as in the case of Delang and Cheng (2013) and Lebeau et al. (2013). Delang and Cheng (2013) study the people's attitudes towards BEVs in Hong Kong.

Why the range was not the biggest concern is believed to be because of the short distances driven by the people of Hong Kong (ibid).

Whilst a regular car can drive around 1000 km (60 liters fuel tank, 6 liters/100km), the electric car has a range about 100 to 200 km (Lebeau et al., 2013). Although this number has radically improved during the last couple of years due to technical advancements. For instance, the Renault Zoe had an official NEDC¹ driving range of 210 km when it was introduced in 2012/2013 with its 22kWh battery (Renault, 2017). In 2016, the capacity of the battery had almost doubled to 41 kWh without changing the volume of the battery, giving the Zoe an official NEDC driving range of 400 km, (ibid).

Since batteries are negatively affected by coldness, so is the driving range of the electric vehicles (Kim et al., 2008). Renault states on their webpage that customers under normal conditions will get approximately 200 km at winter times (Renault, 2017). Nevertheless, at perfect conditions the new Zoe would get around 400 km, as seen in Figure 2.3. However, that would only be around half of how long a regular car can drive using one tank of fuel.

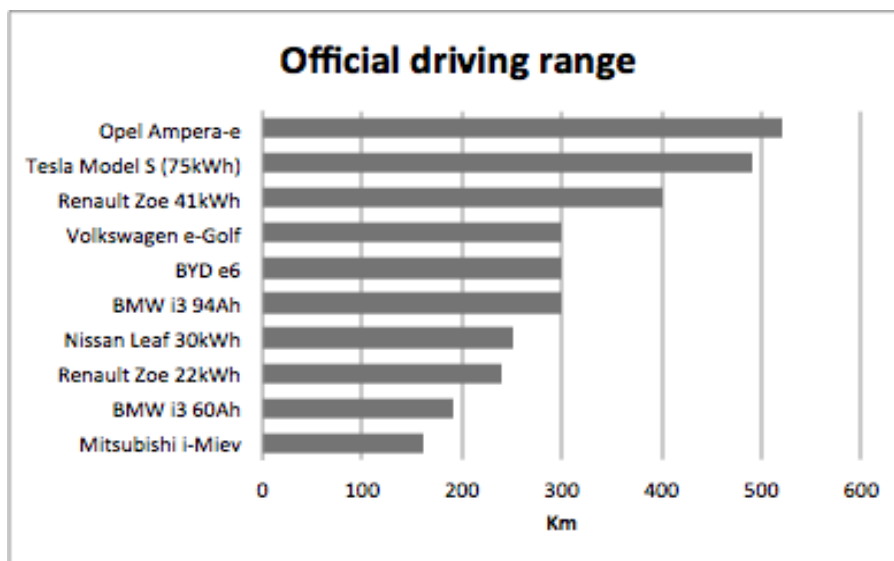


Figure 2.3 Showing official driving ranges of different BEVs. The Renault Zoe is a proof of late technological development, where the capacity of the battery doubled in three years.

Lieven et al. (2011) state that the most limiting factor for a future of electric vehicles is the battery, hence the driving range. The authors tried to find for whom the electric vehicles would be most appropriate and thus most widely adopted. The study, which was carried out in Germany, found that convenience, durability and range are important

¹ NEDC is a European measurement and reflects the driving range under perfect conditions.

criteria for most vehicles (Lieven et al., 2011). They further found that customers of small city cars were very price sensitive while range was not a grand issue. On the other hand, customers of family cars and VANs were less price sensitive but cared much more for the driving range (Lieven et al., 2011). Moreover, the results show that only 23 percent ranked range as an important issue for their secondary car compared to 54 percent for first cars (Lieven et al., 2011). At the time being, 2011, the authors estimated the potential market share of electric vehicles for secondary cars to 6 percent and for first cars to 4 percent.

Jakobsson et al. (2016) investigate if multi-car households are better suited for BEVs, since these households have higher incomes and would therefore be more likely to afford the higher price tag of a BEV. On the other hand, higher income is correlated to higher annual mileage (Jakobsson et al., 2016), making the BEV less suitable. The study by Jakobsson et al. (2016) compares the suitability of different driving ranges of the BEV as both first car and as second car. When the need of a BEV is not sufficient, e.g. for longer trips than the possible driving range, a cost for adoption were included (for instance the cost of renting a car).

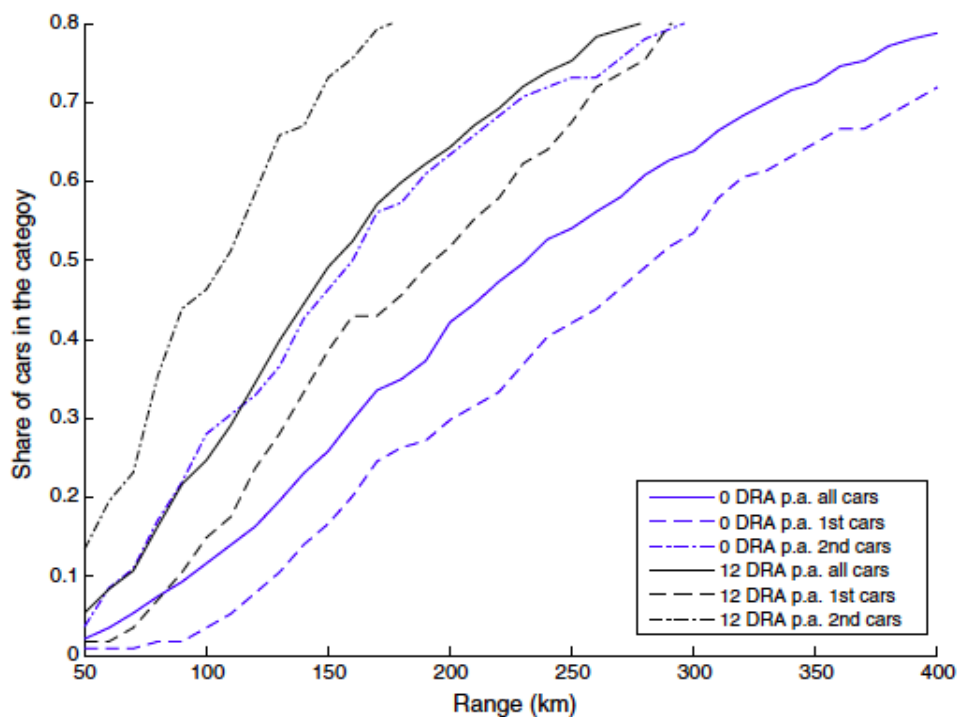


Figure 2.4 Showing the share of vehicles w.r.t. the needed range with zero adaptations (blue), as well as 12 adaptations (black) per annum (Jakobsson et al., 2016). (For color interpretations, the reader is referred to the web version of this thesis.)

Jakobsson et al. (2016) conclude that BEVs are technically and economically best suited for second cars in two-car households. As seen in Figure 2.4, if a BEV has a driving range of 220 km, 70 percent of the two-car households would never need to adapt their driving of their second car, which can be compared to if the BEV is used as single car or first car, then the needed driving range would be 390 km (Jakobsson et al., 2016). If these first car or single car owners accepts adaptations 12 times a year, i.e. once a month, 250 km would be sufficient. Considering the total cost of ownership, the biggest savings for a first car and second car would be achieved with a battery (manufacturing cost of \$300/kWh) that has a driving range of 150 km and 100 km respectively (Jakobsson et al., 2016).

Pasaoglu et al. (2013) analyzed the driving patterns in six different European countries, where results show that the average driving distance range between 40 km (UK) to 80 km (Poland). Egbue and Long (2012) got results consistent with earlier research findings. According to the respondents of their survey, a large majority (87 percent) travelled less than 64 km per day, however, the desired driving range of a BEV was on average 344 km. Lebeau et al. (2013) found that a 300 km driving range would only be appealing to roughly 30 percent of potential customers, whereas 70 percent would be satisfied with a range of 500 km. Egbue and Long (2012) conclude that there is a large gap between what the customer wants and what the customer really needs.

2.2.3.1. Range anxiety

This gap between what the customer wants and what it needs has come to be explained by the psychological phenomenon anxiety, or more specifically range anxiety. Egbue and Long (2012) defines this as “the fear of being stranded in a BEV because it has insufficient range to reach its destination”. Researchers have found this phenomenon to negatively affect customer’s purchase intentions of buying a BEV (Franke and Krems, 2013). Rauh et al. (2015) further investigates how individual differences affect range anxiety and how to mitigate it. They design an experimental field study to compare experienced BEV drivers with inexperienced BEV drivers and to examine how range anxiety is expressed on a cognitive, emotional, behavioral and psychological level (ibid).

Rauh et al. (2015) defines range anxiety as “a stressful experience of a present or anticipated range situation, whereby the range resources and personnel resources available to effectively manage the situation (e.g., increase available range) are perceived to be insufficient”. Studies show that coping mechanisms to deal with this stress is not by learning by experience but rather avoiding it to happen (Franke et al., 2012a). BEV drivers develop a comfort zone of how long they can drive without feeling stressed. Thus, one plausible way of reducing range anxiety could be to increase this comfort zone (Rauh et al., 2015). Results from their study demonstrates that experienced drivers are less threatened by the situation, they are more confident, they do not look at the battery display as often as inexperienced drivers and they get less stressed, thus showing an overall lower level of range anxiety. Moreover, experienced BEV drivers drive more efficiently and do not consume as much energy as inexperienced drivers, which give them a longer possible driving range (Rauh et al., 2015). Experience is proven to be effective when it comes to reducing range anxiety. After only three weeks, range anxiety is no longer perceived as a major concern (Nilsson, 2011) and after three months, the comfort zone has increased (Franke et al., 2012b). As a way of overcoming barriers of range anxiety, Rauh et al. (2015) suggest that new BEV customers should be taught relevant knowledge and skills about driving electric vehicles, such as factors influencing range, eco-driving, how to save energy and range competences.

2.3. Summary of barriers

There are a number of barriers when adopting BEVs, ranging from residual value to lack of information and uncertainty of technology as well as a low BEV supply.

The purchase price for BEVs today is still higher than that of similar conventional cars, even though the gap has decreased over time. A high purchase price together with an uncertainty regarding residual value this constitutes the majority of the barriers relating to economics since the actual use of a BEV has a lower cost than that of a conventional car. The high purchase price may have a correlation with the low BEV supply, which is another barrier that also influences the design of the BEV currently for sales, which are not seen as having a similar design as the conventional cars.

Table 2.1 Summary of major purchase barriers identified in pervious research.

Major barriers	Identified by
High purchase price	Curtin et al., 2009; Young et al., 2009; Power, 2010; Lieven et al., 2011; Carley et al., 2012; Delang and Cheng, 2013; Jakobsson et al., 2016; Lebeau et al., 2013; Egbue and Long, 2012; Bühne et al., 2015; Heyvaert et al., 2015
Limited driving range	Needell et al. (2016), Jakobsson et al. (2016), Lebeau et al. (2013), Egbue and Long (2012), Rauh et al. (2015), Bühne et al. (2015), Heyvaert et al. (2015), Lieven et al. (2011)
Lack of charging infrastructure	Needell et al. (2016), Lebeau et al. (2013), Bühne et al. (2015), Heyvaert et al. (2015)
Long charging time	Jakobsson et al. (2016), Lebeau et al. (2013), Heyvaert et al. (2015)
Low BEV supply	Lebeau et al. (2013), Bühne et al. (2015), Heyvaert et al. (2015)
Uncertainty residual value	Lebeau et al. (2013), Heyvaert et al. (2015)
No charging at home	Delang and Cheng (2013), Lebeau et al. (2013), Heyvaert et al. (2015)
Lack of information	Delang and Cheng (2013), Lebeau et al. (2013), Heyvaert et al. (2015)
Uncertainty of new technology, resistance to change	Lebeau et al. (2013), Egbue and Long (2012)
Design	Lebeau et al. (2013), Heyvaert et al. (2015), Moons and Pelsmacker (2012)

Charging a BEV is different from re-fueling a conventional car and concerns are raised regarding the charging time, the lack of a proper charging infrastructure (Lebeau et al. 2013), especially in comparison with the network of gas stations, and the possibility to charge at home specifically when living in an apartment. The limited driving range is another barrier that might hinder the potential buyers to adopt since it differentiates substantially from a conventional car (Egbue and Long, 2012; Jakobsson et al., 2016).

The interest of doing research about BEVs seems to have risen during the 2010's, since most of the sources of previous research date less than five years back in time. Most of them were actually less than five years old and this makes the field of BEV and the knowledge about the barriers of the potential buyers quite novel. There is a possibility that previous research has missed out on some details of the barriers or some view of the problem that potential buyers might have.

Another notation is that the great majority of the studies conducted within the field up until this day has been of a quantitative research strategy. Studies of quantitative nature are good at showing general conclusions of the populations with a statistical significance. However, they may have a shortage regarding the knowledge depth within each barrier. For example, several studies argue that range anxiety might just be a bad excuse for not wanting to change their behavior. But it could also be that the range anxiety is due to lack of knowledge or that the person has not experienced it yet, which would make it an uncertainty rather than an excuse for not wanting to change behavior.

2.4. Diffusion of innovation

The electrical cars are an old technology as discussed in the subchapter evolution of electric cars and barriers for the supply side. However, as Knupfer et al. (2017) state the recent technological advancements and decreasing battery prices has brought the market potential back to life. Stuart (2000) argues that diffusion of innovation theory is appropriate to use when doing research in the area of technology diffusion and adoption. This study focuses on barriers to adoption from conventional cars to BEVs, which is driven by different individuals perceptions and preferences, which ultimately leads to a decision to adopt a BEV, in this study, or to reject it. The innovation-decision process (Rogers, 1983) focus on the adopter, which is also the focus of this study, and can be used to explain and understand how an individual's process of innovation works. Rogers's innovation-decision process, as seen in Figure 2.5, is one of the most popular adoption models and has been used countless of times during research of technology diffusion and adoption (Sahin, 2006; Dooley, 1999).

Rogers (1983, p. 5) defines diffusion as “the process by which an innovation is communicated through certain channels over time among the members of a social system”. The model, used to explain and understand how an individual's process, works

in five different and sequential steps: 1) *Knowledge*, 2) *Persuasion*, 3) *Decision* 4) *Implementation* and 5) *Confirmation* (Rogers, 1983).

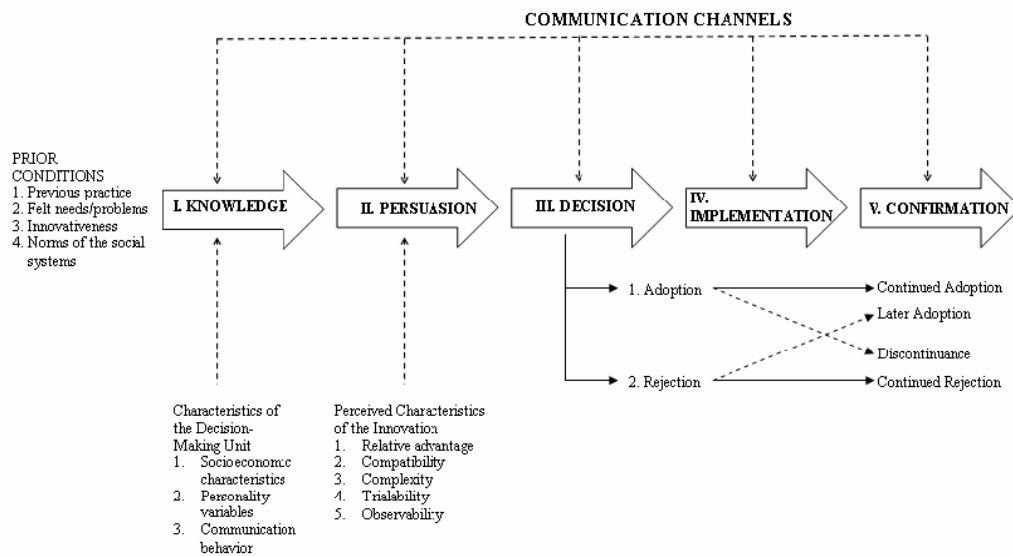


Figure 2.5 An illustration of the innovation-decision process (Rogers, 1983).

The first step, knowledge, is reached as soon as the individual discover the new technology or innovation and typical questions are “*What is this?*”, “*How does it work?*” and “*Why does it work?*”. These questions leads to three distinct types of knowledge. The first type, awareness knowledge, refers to the individual's knowledge of an innovation’s presence (Sahin, 2006). According to Rogers (1983) the awareness knowledge stimulates the individual to seek the two other types of knowledge of an innovation; 1) *how-to knowledge* and 2) *principles knowledge*.

The second type, how-to knowledge, concerns information that is essential for the individual to be able to understand how to use the new technology in an adequate manner. Rogers (1983) argues that the how-to knowledge is crucial to obtain before the first trial of the innovation and the higher complexity of the innovation the higher amount of how-to knowledge is needed.

Lastly, the third type, principles knowledge, is knowledge about how an innovation works and why. Rogers (1983) states examples as to proper be able to structure a basis for family-planning one must understand how the fundamentals of human reproduction works. For an individual to adapt to the new technology the principles knowledge is not

necessary. However, to prevent misuse which may lead to a discontinuance of usage this knowledge is important (Shahin, 2006).

The second step, persuasion, occurs when, and explains how, an individual forms either a positive or a negative attitude toward the innovation. However, a positive or negative attitude does not automatically imply an adoption or rejection. (Rogers, 1983). There are five distinctive characteristics of innovations that Rogers (1983) identifies as 1) *Relative advantage*, defined as “the degree to which an innovation is perceived as being better than the idea it supersedes” (p. 213), 2) *Compatibility*, defined as “the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters” (p. 223), 3) *Complexity*, defined as “the degree to which an innovation is perceived as relatively difficult to understand and use” (p. 230), 4) *Trialability*, defined as “the degree to which an innovation may be experimented with on a limited basis” (p. 231) and 5) *Observability*, defined as “the degree to which the results of an innovation are visible to others” (p. 232).

An individual may find an innovation to have a relative advantage, good compatibility, a low degree of complexity, easy access to trial and a high degree of visibility of the results and still have difficulties to adapt to this new technology. However, when an innovation seems favorable from these characteristics it might help to speed up the diffusion process (Rogers, 2003).

During the third step, decision, a choice to adapt or to reject the innovation is made by the individual. A decision to adopt is according to Rogers (1983) a realization by the individual that “make full use of an innovation is the best course of action available”. Rogers (1983) argues that an innovation that can be tried partially before fully adoption to it has a quicker adoption time than those that cannot. Most individuals tend to not adopt an innovation if trialability is not possible before the decision has to be reached.

A decision to adopt to the new technology has to be taken during the decision step. However, this does not hold true for the decision to reject, which can be made during all stages up until the decision step is completed (Rogers, 1983). Eveland (1979) makes a separation of two different kind of rejections; 1) *Active rejection*, which refers to consider the innovation and to try it out but reject it nevertheless, and 2) *Passive*

rejection, which is for the individual to never seriously considering the use of the new technology.

The fourth step, implementation, often takes place directly after an individual has decided to adapt the innovation and regards the actual use of the innovation. Reaching the implementation step does not mean that the individual has no uncertainties or worries about the innovation and it is often different to actually use the innovation in contrast of what the individual thought it would be like. Rogers (1983) states that several questions, such as “Where do I obtain this new technology?”, “How do I use it?” and “What operational problem can be encountered and how do I solve them?”, makes the individual to continuously be active in the search for information.

The implementation step can continue for a while and it often depends on what kind of innovation type it is. At some point the innovation loses its novelty while the degree of uncertainty for the individual gets reduced, which Rogers (1983) refers to as routinization or institutionalization. This in turn constitutes the end of the innovation-decision process for most individuals, while a few continue toward the step of confirmation, which refers to when the individual seeks support for her decision. Rogers (1983) argues that if the individual is exposed to information and arguments that contradict her decision the decision may be reversed which leads to the stop of use of the new technology. The confirmation step can go on for an unlimited time period or until the innovation-decision process for the individual ends (Rogers, 1983).

2.4.1. Technology adoption life cycle

Rogers (2003) divides the members of a social system into five categories on the basis of innovativeness, i.e. how fast a member adopt a new idea or a certain innovation. The categories are innovators, early adopters, early majority, late majority and laggards, which are shown in the normal distribution in Figure 2.6, also called the Technology adoption life cycle. According to the High-Tech Marketing Model, the way to go about and develop a high-tech market is to work the curve from left to right, focusing first on the innovators and growing that market to then move on to early adopters and so on (Moore, 2001). If momentum is lost, there is a great risk of losing the advantages that come from having a leadership position, more specifically the primary sources of profits, which are made during the middle to late stages of the curve (Moore, 2001).

Technology Adoption Life Cycle

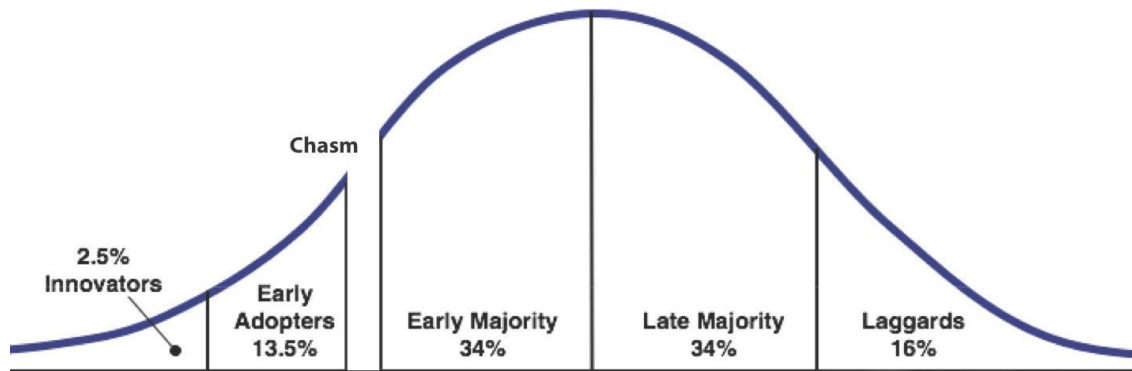


Figure 2.6 The Technology adoption life cycle shows how the members of a social system are categorized by their level of innovativeness (Moore, 2001).

According to Moore (2001), innovators are obsessed with new technology and they oftentimes seek to obtain the technology before it has even hit the marketplace. Innovators are important to persuade, since their endorsements are key if the rest of the herd shall follow. However, innovators often want the product for free in return. Early adopters are also early to adopt new technology, as the name suggests. However, they are less enthusiastic than innovators but they find it easy to understand and see the benefits of new technology (Moore, 2001). Early adopters are visionaries and not price sensitive and they do not need any input or references to adopt new technology. The early majority on the other hand, bases their decisions strongly on others and their references. They want the product or service to be tested and proved effective at increasing the productivity (Moore, 2001). Late majority and laggards are followers and skeptics.

2.5. Scope

This study focuses on the automotive industry and car users transition to electromobility. The study does not focus on trying to find new types of barriers, rather it tries to find explanations for why the barriers are perceived as hinders and how they have been reduced or coped with.

Geographically the scope will be limited to Europe and more precisely Gothenburg and Oslo. Norway and Sweden are demographically and economically similar but none are optimal for the usage of BEVs due to hilly terrains and cold weather, which is unfavorable for the driving range of the vehicle (Kim et al., 2008). Interestingly, the market share of BEVs in Norway is approximately 16 percent (OFV, 2017), while the

same measure in Sweden is 0,7 percent (SCB, 2017). Oslo and Gothenburg have different external environments and therefore macro factors may influence the auto industry and individuals in different ways. For example, in Norway there is a higher degree of subsidies for electric cars than conventional ones (IEA, 2016). Also there is some other advantages with driving an electric car, as not having to pay for the congestion tax and be able to drive in the car line normally only available for buses and taxis which help to reduce the time it takes to drive the same distance as it would take driving a conventional car.

The authors believe that a comparative study between two different cities will result in a deeper understanding of the issue at hand or if it is simply the effect of political measures. Another argument relates to the access for the authors to both get in contact with different interviewees but also to be able to conduct face-to-face interviews.

The study has tried not to focus on enthusiasts that would do anything to adjust their situation to this new technology. However, it is hard to draw a specific line and be able to completely sure that the line has not been crossed. Therefore, there might be interview subjects that others would define as enthusiasts when the authors do not.

2.6. Research questions

Earlier research has focused at the mainstream market and non-adopters, meanwhile this study will focus on getting an understanding of those who have adopted BEVs. The purpose of this study is to investigate BEV-adopters transition to electromobility to gain a better understanding of their purchase drivers and adoption barriers. The purpose will be achieved by answering the following research questions:

“What are BEV-adopters’ rationales for purchasing battery electric vehicles?”

“What are the perceived barriers of adoption?”

3. Method

This section aims to provide the reader with an outline of how the study has progressed. First, the research strategy is explained, then the research strategy and the different phases of the study. Phase one consists of a pre-study, which contains a study of previous research and ends with a workshop with industry experts. The data collection, interviews, is the main part of phase two and lastly the analysis makes up phase three. The chapter ends with a discussion of trustworthiness of the study.

3.1. Research strategy

Research strategy consists of two main methods, qualitative and quantitative (Eriksson & Wiedersheim-Paul, 2008). The reason of choosing research strategy is to evaluate and choose which of the methods that are best suitable to answer the study's purpose (Denscombe, 2003). The quantitative method is mostly used to interpret numerical information with purpose of finding correlation of statistical studies of large data sets. Many quantitative studies use survey and other similar methods to collect large data sets enough. The qualitative method is according to Patel & Davidsson (2003) often based on interviews and interpreted analysis. Eisenhardt & Graebner (2007) argue that this kind of method are more unfolding in the sense that it creates tendencies to patterns that is based in phenomena and underlying logical arguments.

This study has a qualitative research strategy and aims to reach a deeper understanding of a specific and well-defined phenomenon. The reason behind this is that the authors of this thesis want to provide with a deeper understanding of the perceived barriers, which hinders adoption of BEVs. The majority of the earlier research studying this topic has had a quantitative strategy. However, researcher do encourage further research to explore the subject more in depth (Moons and Pelsmacker, 2012; Ziefle et al., 2014), which is another argument behind the decision for the chosen strategy of this study.

An abductive method observes a problem situation and tries to deduct a natural cause of the problem and during this study data were collected, compiled and then analyzed (Patel & Davidson, 2003). This study has not used a strict abductive method, however it has been using an iterative method with elements similar to an abductive method.

3.2. Research layout

The research study consists of three different main phases; 1) Pre-study, 2) Empirical study 3) Analysis, which together leads to a concluding discussion and future research. It will start out with a wide scope guided by barriers found in previous research and slowly progress towards a more narrow focus along the way.

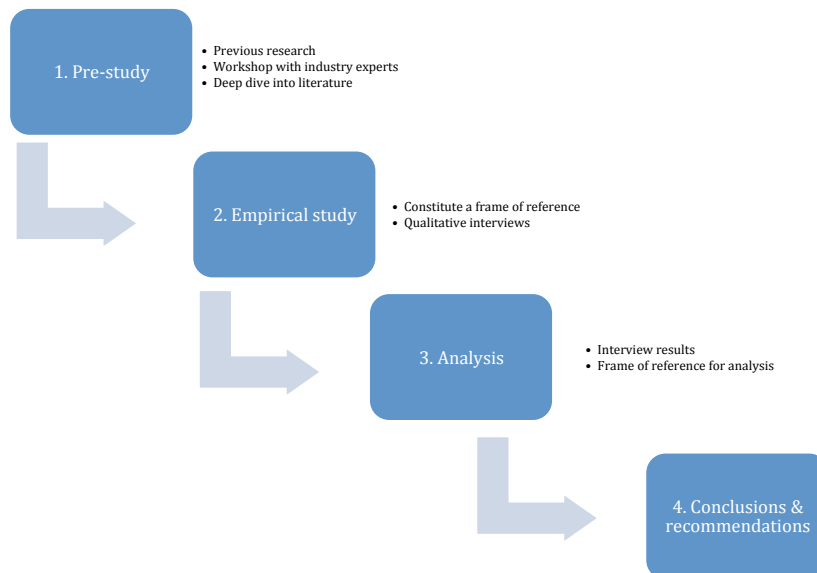


Figure 3.1 Showing the overall research layout of the study.

3.2.1. Pre-study

Phase one, a pre-study was conducted with a study of previous research surrounding electrical vehicles and barriers for customers to buy and use such cars. Simultaneously, in the first phase, a dialogue with supervisors, both at Chalmers and at a automaker, were held in order to be able to set an accurate scope and to progress in the right direction.

During phase one discussion with industry experts, from the automaker and different institutes, mainly RISE Viktoria (research institute within applied information technology) and Chalmers, were contacted and consulted. These discussions function as a form of guidance for the authors since these actors are experienced within the electric vehicle area. Phase one ended with a workshop with industry experts within the electric vehicle area from the automaker.

The purpose of the workshop was to validate and improve conclusions of which barriers the further study should focus on and to get insights from industry experts to build a

steady foundation for phase 2, the data collection. The workshop therefore acted as a validation of work done so far and also as guidance and help onwards when the interview questions were formulated. Lastly, the workshop helped to set the direction of the study, for example that people of a demographical type of being in a pre-family or family situation with a steady income was of highest interest to conduct interviews with.

During the workshop the authors had decided, in consultation with supervisors, to take the role of being facilitators rather than being workshop participants. The decision to not record the workshop was taken to ensure that the participants felt comfortable to speak freely. One of the author therefore acted more as a note taker while the other took more responsibility to facilitate the workshop to ensure that each topic got enough focus to gain new insights.

An agenda based on themes, such as *Identifying and understanding barriers*, *Ranking and prioritizing barriers* and *Overcoming barriers*, rather than in high detail was decided well in advance of the workshop. The agenda together with an explanation of the purpose of the workshop were sent out with the workshop invitation a couple of weeks before it was held. The introduction consisted of a brief explanation of the authors' background and the reason behind the study. The agenda and purpose with the workshop was also communicated. Lastly, the theoretical framework, suggested method and time frame was presented and validated with the participants.

The barriers found in previous research was explained to ensure that all participants had enough understanding of what had been found so far to be able to participate in the discussion. This was also a way to safeguard that the authors had understood the barriers correctly themselves since the participants has been working with similar topics regarding electrical vehicles.

During the discussions regarding *Identifying and understanding barriers*, *Ranking and prioritizing barriers* and *Overcoming barriers* A3 paper with all barriers written within a grid was used together with post-it notes, both pre-marked ones to rank barriers and empty ones that could be written on. The authors believe that by getting the participants physically involved instead of just sitting there discussing might help to stimulate a higher interest and level of participation.

The workshop participants discussed that *High purchase price*, *Long charging time*, *Design*, *Limited driving range*, *No charging at home*, *Lack of charging infrastructure* and *Uncertainty of residual value* were barriers of high relevance to research further while the *Low BEV supply* and *Uncertainty of new technology* were probably of some relevance as well.

The workshop also showed that there might be a point to talk in terms of three different areas, *Economics*, *Mobility need* and *Product need*, rather than talking about all barriers just separately since there was during the workshop a clear overlap between some of the barriers and also sometimes hard to tell which discussion that belonged to exactly which barrier while the disarticulation of the three areas are more distinctive. The three areas were therefore considered and used as a foundation when creating the interview questions.

3.2.2. Data collection

Phase two consisted of a deeper dive into literature, in order to explain certain behavior and the diffusion of innovation, in this case the BEV. Furthermore, an interview study, with semi-structured interviews and open-ended questions, were held in order to dig deeper into the different barriers but also to, endeavor into new aspects of the barriers that previous research has not caught onto (Easterby-Smith et al., 2015). A semi-structured way of conducting the interviews were chosen due to the fact that the authors wanted to understand the interview subjects' view of the certain area and also how and why they have built their way of understanding and responding to the barriers (ibid).

When compiling the interview questions the authors started with previous research, the findings and what kind of questions these studies had asked. To get satisfying answers there need to be a variety of different questions, ranging from easy starting questions about demography to open questions about what the perceived barriers are. Discussions with supervisors and especially the workshop assisted in the interview script creation where industry experts got the chance to weigh in with their experience within electric vehicles.

During the process of creating the interview questions two different test interviews were held after encouragement of the supervisor. The first interview helped to reform quite large parts of the questions while the other one assisted with the polishing of them. The

authors also got the chance to act as interviewers, which helped to increase the smoothness and interplay before the first real interviews were held.

3.2.2.1. Interviewees

Earlier research suggested to interview and further understand the perceived benefits of customers that have already adopted a BEV (Ziefle et al., 2014). An understanding of what kind of barriers they saw and how they overcome those barriers was expected to be part of the outcome. When first deciding whether non-adopters should be interviewed or not a decision to include them were reached. However, the authors realized that it was difficult to get non-adopters to participate in the study while the opposite was true for the adopters. The reason behind this might be that the BEV users are a bit proud of having adopted a BEV and therefore are more prone to participate while the conventional car users might not have similar incentives. This, alongside with the fact that the interviewed non-adopters had similar thoughts and answers that the adopter, lead to a decision to focus only on the ones that had adopted.

The interviewees that were included in the study mostly belong to a group that includes the majority of the population of Gothenburg and Oslo demographically which is people with a middle to high income that are in a pre-family or family situation lifestyle.

The subjects live in the city or in the proximity and a majority of them live in houses while a few of them living in apartments. The focus has been on subjects that own a model like Tesla S60, Nissan Leaf, BMW i3 and similar models and not focused on the owners that have one of the most expensive and advanced models since the authors believe them to be less price sensitive and perhaps driven by differ. However, when it comes to the three Tesla owners the models have been Tesla Model S 85 and Tesla Model S 90D which might not be perfect in line with the author's best-case scenario wishes since the owners is believed to be less price sensitive than of those who own for example a Nissan Leaf.

Table 3.1 Showing the number of interviewees, their respective BEV, their situation and country of origin.

Interview subject	Household	Country
Tesla Model S owner #1	Family	Sweden
iMiev owner #1	Post-Family	Sweden
BMW i3 owner #1	Family	Sweden
Tesla Model S owner #1	Family	Sweden
BMW i3 owner #2	Family	Sweden
Nissan Leaf owner #1	Family	Norway
iMiev owner #2	Family	Norway
Tesla Model S owner #3	Family	Norway
Nissan Leaf owner #2	Post-Family	Sweden
BMW i3 owner #3	Family	Sweden
Renault Zoe owner #1	Family	Sweden
iMiev owner #3	Family	Sweden
BMW i3 owner #4	Pre-Family	Norway
Nissan Leaf owner #3	Family	Sweden

Table 3.1 shows the interviewees and what kind of BEV they have. In order to get in contact with them the authors had several different approaches. Firstly, reaching out to the authors' network, to get the word out that there was an interest in finding people that had access to electric vehicles. Via the authors and the supervisors combined networks a total of ten interview subjects were found. The supervisors network was used at a late stage when it was clear that the number of interviewees needed a couple more to be satisfying for the study.

Secondly, the authors wrote notes, briefly explaining what kind of master thesis it was about and asking the receiver to email or give one of the authors a call, and posted them at parked cars around Gothenburg. While putting these notes at electric vehicles the

authors also talked with people and asked if they would care to be of assist in the study. A surprisingly high percent of the notes got answered, above 80 percent of them.

3.2.3. Data analysis

The interviews were recorded and transcribed in order to safeguard a good result and they act as the foundation for the empirical data in this study. Bryman & Bell (2014) argues that recording the interviews is helpful since the interviewers can focus at the interviewee at hand rather than focusing on taking notes. The recording therefore serve an important purpose when analyzing the data since it is possible to go back and hear the actual interview instead of having to rely solely on the notes taken.

The authors held the majority of the interviews together but to not burden the interviewees more than necessary the interviewees were the ones to decide when and where the interview should be held, after a primal suggestion from the authors. This in turn lead to double bookings and the authors decided to split up and hold these interviews separately. To ensure that both authors had as much information and knowledge as possible from the interviews the person transcribing and interviewing an interviewee was different.

After carefully transcribing each interview the process of mapping them together began were the authors had the focus of the study in mind when first sifting through the recorded interviews. The previous research was revisited and various categories were decided from the barriers that were derived from previous research. The workshop with industry experts and discussion with supervisors acted as support in the authors' decisions of how to divide the different categories such as: *Reasons for buying a BEV, Battery lifetime and uncertainties, Residual Value, Infrastructure, Economic calculation, Cost of Electricity, Environmental aspect, Mobility need and Range, Change of driving patterns and behavior + Range anxiety, Difference charging and refueling.*

When the categories were decided the step of coding commenced and all transcribed interviews were printed out and the authors divided them equally and used markers to highlight the sections that corresponded with the various categories. During this process, the authors realized that there was a need to add some categories due to the interesting information that the interviewees had given that did not fit into one of the

pre-decided categories. The following categories were added: *Managing longer trips + Be able to reach destination on zero to one charges, What need to happen for the general public to buy a BEV*. Several categories were found to be unnecessary or overlapping with others. These categories were therefore excluded: *Positive associations with BEV, What do you value most with having a car, Why did you not buy a BEV earlier*.

The findings were then summarized under each category and made sure that it was clear which interview subject had said what and at the same time ensured that their own words and meaning followed through while making it easy to process for the authors. During this process the authors discovered ways to narrow the number of categories down.

After the summarization part was completed the authors used a whiteboard to link the categories with each other as well as with theoretical concepts. The supervisor from both Chalmers and the Company read the report, with a focus on the analysis, and gave feedback for improvements. The feedback lead to a rework by the authors regarding both structure of analysis and a slightly more narrow focus in the analysis and concluding discussion. This was an iterative process where the authors got feedback several time which lead to further improvements.

3.3. Trustworthiness

In order to assess a qualitative research study Bryman and Bell (2014) propose two different criteria; trustworthiness and authenticity. Trustworthiness is in turn built upon four different sub criteria; credibility, transferability, dependability and confirmability (Bryman and Bell, 2014).

Credibility refers to the study being conducted in good practice and that the research findings should be submitted to the interviewees, the latter is also called respondent validation (ibid.). The interviewees will all get the full report sent to them, all of them were interested enough to actually ask for it themselves. This goes well in line with the respondent validation where the researcher should invite the interviewees to read and question the report, which according to Bryman and Bell (2014) has become popular for qualitative researcher over the years. The reason behind inviting the interviewees is to ensure that the findings actually are derived from what they have stated during the interviews.

According to Bryman and Bell (2014) another way of ensuring credibility is to use triangulation. This study has used two different types of triangulation, investigator and theoretical triangulation. The investigator triangulation has been used by having two different authors doing the research in consultation with supervisors both from the industry and the academy. Furthermore, during the literature study several different sources have been read and presented in order to ensure a broad foundation for this study, which goes well in line with the theoretical triangulation (Björklund and Paulsson, 2003).

Bryman and Bell (2014) argue that the nature of qualitative studies, which often are interviews or similar studies of a rather small group of individuals, encompass the findings to be quite contextual. Therefore, one should try to use what is called thick description which is to use a high degree of details when writing about of the findings (ibid). During this study it has been central to ensure openness by describing thoroughly step for step in the method what has been done and how. Also the authors of this study have tried to retell the stories of the interviewees in great detail, one example of this is the quotes which is used to ensure transparency and that the reader can get the words of the interviewees.

During a research study it is important that the authors try to leave out their own personal values and thoughts as much as possible to ensure a confirmability of the study (Bryman and Bell, 2014). Since the authors of this study have a keen interest in the topic and have been very involved throughout the research it has been tough to try to exclude much of their own insights into the study in a proper way. The supervisor at Chalmers and Company has been of great value during this process, especially the supervisor from Chalmers that has been keen to understand where the authors might have influenced the findings more than appropriate. This has in turn lead to a better understanding of how a qualitative research should be conducted and a reduction of the authors' own values and perceptions. Bryman and Bell (2014) state that it is of crucial importance that the authors act in good faith during the study and the authors has along the whole research tried to achieve this and been open to learn from the more experienced supervisors.

One part of authenticity is according to Bryman and Bell (2014) fairness, which refers to whether or not the study contains a fair representation of different viewpoints among the interviewees. When conducting this research the authors interviewed, after contemplation with the supervisor from Chalmers, new interviewees as long as they contributed with at least a shard of new insights. When the interviews led to almost the same answers as anyone before them had told the authors felt confident to stop interviewing more people. The findings from the interviews contain certain similarities with each other, but at the same hand several of different views in many aspects.

4. Empirical findings

In the following chapter, empirical findings from the interviews are laid forward. The chapter starts with showing rationales for purchase. Then the mobility need of the interviewees is presented. Thereafter the focus turns to the economical aspects of BEVs, which is followed by a presentation of the interviewees' view of the infrastructure and charging. Lastly the battery lifetime and uncertainties are discussed.

4.1. Rationales for purchase

As can be found in Figure 4.1, six out of 14 interviewees acquired their BEV before 2015. However, one Tesla owner is already on his second Tesla, which he acquired recently. Fifty percent therefore acquired their first BEV before 2015 while the other half is spread out from 2015 to 2017 for their first time of adoption.

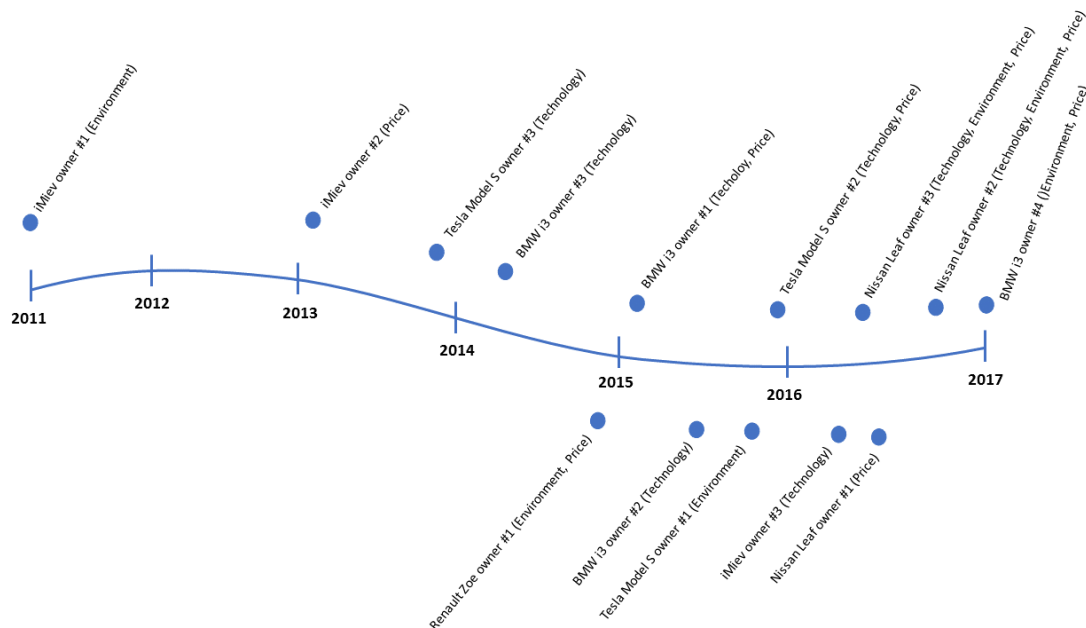


Figure 4.1 Timeline showing the time of purchase, what kind of BEV that was purchased and the rationale for purchasing a BEV in parenthesis.

When discussing about the reasons for buying, the interviewees were asked if they could imagine going back to a conventional car, and the answer was in almost every case that they would never again buy fossil fuel car. In some cases the reason was the care for the environment but mostly the interviewees were very satisfied with what their BEV offered.

Interviewees from Gothenburg mention several reasons for why they have adopted or bought a BEV. Four of the contestants are self-employed entrepreneurs and have bought their cars as part of a leasing contract through their respective companies, i.e. as a company car. Three of those four has a BMW i3. The BMW i3 can be equipped with a range extender, which is a small motorcycle engine that when turned on is used to charge the battery, giving the car some extra kilometers of range when needed. One of the interviewees has chosen to add this option to his car and even though he is not very fond of it being turned on, due to the increase of the noise in the cabin. Furthermore, he states that he would never buy the BMW i3 as a pure BEV without the range extender.

4.1.1. Concerns for the environment

One of the Tesla Model S owners said he has a great interest in cars and that he also owns a motorcycle. Nevertheless, he states that the main reason for buying an electric vehicle is due to concerns for the environment, and maybe because he is a bit impulsive he admitted. After test-driving the Model S, he ordered one directly when coming home.

“I have a technology interest, but also I do care about the environment. I’m not a tree hugger but I do think about those little things, like recycling and so on. And the electric car is part of it.” - Nissan Leaf owner

Two of the interviewees have a Nissan Leaf and for both of them, the environment aspect has been an important driver for adopting the new technology. Even though one of them bought the car after a sequence of events. First, she says, my husband’s employer buys a Tesla, then my brother does, so it came closer and closer. Then after receiving a gas bill of approximately 3000 Swedish kronas, she had enough and started to look for alternatives. They then got to borrow a Leaf for a weekend from their local car dealer, which sealed the deal.

The environment aspect was also of utmost importance for the Renault Zoe owner and Mitsubishi iMiev owner and the main reason for buying a BEV. The Renault Zoe owner used to have a Volkswagen Polo with a consumer leasing contract. In the end of the leasing period, Volkswagen had just been caught cheating with their diesel engines, which is why they looked for other alternatives. After a test drive of the Renault Zoe, even though they had more alternatives, which they had planned to test drive, they

signed a new leasing contract the same day.

4.1.2. Technology interest

The three Swedish BMW i3 owners all have in common that they like new technology and cars that stand out. One of the interviewees specifically got the car with the purpose to market and position his engineering consulting firm as a frontrunner when it comes to technology. Another reason that is mentioned for buying the i3 car in that case was the fact that the performance of the car was in a certain interval equal to a BMW M3, which at the time was the top performance car in the BMW line up. He then argues that he got a top performance car for the price of a well-equipped family hatchback (BMW 1-series). One of the other interviewees wanted an automatic gearbox that was more fuel-efficient than its comparable manual gearbox, which in the end narrowed it down to only two cars to choose from, one of which was the i3.

“It’s not really the environment aspect that gets me going, rather it’s a more modern way of building something that is to last for a very long time”

- BMW i3 owner

In Oslo, one of the interviewees had a Mitsubishi iMiev, one had a Nissan Leaf, one had a BMW i3 and the last one had a Tesla Model S. All of which were bought or financed privately. The Tesla owner was the only one who did not care as much about the savings, but rather what he got as added value. His main reason for buying a BEV was his interest in technology, not cars, but technology. He says there was some degree of uncertainty related to buying the car but on the other hand there was a lot of advantages in terms of acceleration, handling, noiseless ride etcetera to the price of his old car, a BMW 5-series.

“The Tesla has everything I had in my old BMW 5-series, and a lot lot more.”

- Tesla Model S owner

4.1.3. Total cost of ownership

In Oslo, the main reason for buying a BEV, which is common for almost all interviewees, is the low total cost of ownership. Most of the interviewees have compared the cost of a similar conventional car to a BEV and discovered that they can

save 2000 to 3000 Norwegian kronas a month since BEVs do not have to pay VAT, yearly taxes are subsidised, service and maintenance costs are cheaper, and they do not have to pay any road tolls. One of the interviewees says that when looking at buying a BEV in Oslo, the preferences for a certain car brand disappear. Furthermore many of them see advantages of having a BEV since they save a lot of time going to and from work, since they are allowed to use the bus and taxi lane, and thus do not have to get stuck in traffic during rush hours. In general the concern for the environment is not a reason for any of them to buy a BEV, although they state that it is of course important but it rather comes as a bonus.

In total there are six interviewees that have the BEV as a company car, two of which is the Tesla Model S. They all mention the low benefit value as an advantage of having a BEV as a company car. They draw parallels with equivalent combustion engine cars such as the Porsche Panamera, which is claimed to have a benefit value of around 20 000 Swedish kronas, meanwhile the Tesla has a benefit value of 6500 Swedish kronas.

4.2. Mobility need and range

The majority of the interviewees, or 12 out of 14, lives in a house, which can be seen in Figure 4.2. The other two lives in apartments, one in Oslo and one in Gothenburg. All of the interviewees are in some sort of family situation; most of them have kids living at home. 10 of the BEVs can be found in a multi-car household and the remaining four are used as the only car. Nine out of 10 BEVs of the multi-car households are used primarily to commute to and from work, running errands and picking up the kids after school, thus being the car that is used most of the time.

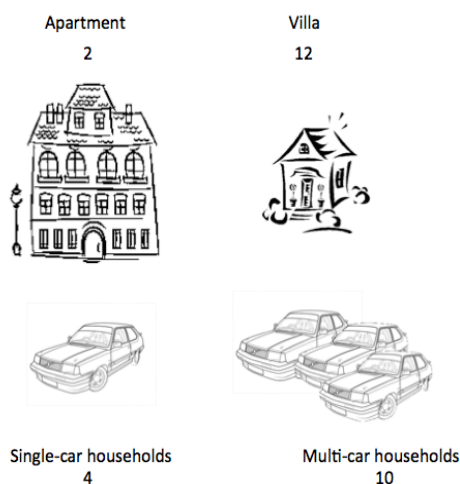


Figure 4.2 Showing how the cars are divided between type of households.

4.2.1. Managing longer trips

The one BEV that is being driven most milage per year is one of the Tesla models. The owner commutes to his work in Gothenburg from his home, which is situated in Borås 75 kilometers east of town. The milage related to commuting amounts at 40 000 to 50 000 km a year and in the total the car is driven around 60 000 km a year. The Tesla has been driven through Europe when on vacation but also to the north of Sweden, Åre, to go skiing. The interviewee says that when going on longer trips the driving range between charges is about 200 km. During the trip to Åre, they had to stop five times in total, but that was not considered bothering. Tesla's own supercharging network is placed with a distance of an average 200 km, which coincide with the actual need for charging. According to the interviewee this means that you drive for two to three hours then you have a paus for about 30 minutes depending on how much battery that is left.

“It’s actually very nice, it is not the usual stress you have when you go in a conventional car. You feel much more at peace.” - Tesla Model S owner

One of the other Tesla owners is a self employed lawyer and has a customer base stretching from the very south of Sweden to far up north, which makes the milage of work related trips amount to over 45 000 km including 10 to 20 trips to Stockholm on a yearly basis. For that reason, the owner says that he could not have had any other BEV since a long range is essential. The Tesla that he has is a Model S 90D, which has a real range of around 350 to 400 km. At the time of the purchase, there was no bigger battery pack, but if there were he would have gotten it. The interviewee is clear to state that it works perfectly fine with the range he has, but at the same time he would not mind having at least the double. Except for the family house in Uddevalla they have also a house south of Gothenburg, which is primarily used during summers.

When going on those longer trips, the interviewee says that it is super easy, due to the supercharging network and the car's information system, which tells you where, when and how long you need to stop to have a certain amount of battery left when reaching the destination. On a trip to Stockholm, he needs to stop in halfway to charge for about 15 minutes to have 20 percent battery left at the final destination. Which works great since then you have driven a couple of hours and you need to stop anyways for a coffee break or visit a restroom. Nevertheless, according to this Tesla owner, to take a break always takes longer time than only 15 minutes, and he states that he has never once had

to wait for the car to finish charging.

4.2.2. Differences between Gothenburg and Oslo

Many of the other interviewees in Gothenburg have around 30 to 50 km one way to work. Since they have cars such as Nissan Leaf or BMW i3, which have real driving ranges of 100 to 150 km, they all say it works perfectly fine for the everyday driving, especially since the car is always fully charged when leaving for work in the mornings. However, most of the interviewees have friends and family situated 120 to 200 km away, to whom they drive one to two times a month. Since most of these BEVs belong to multi-car-households, with one BEV and at least one conventional car, almost everyone use the conventional car when going on these longer trips. For most of them, the threshold range for when they rather use the conventional car is for journeys longer than 50 to 70 km. One of the BMW i3 owners has driven the car a couple of times to Strömstad, which is about 180 km from Gothenburg. He states that even though it is a short journey that normally does not require you to stop when taking the conventional car, it works fine to take a break. However, stopping more than once would be unacceptable. Especially since the risk of not being able to charge, due to that the charging station is occupied or out of service, increases for every stop you have to make according to the interviewee.

The interviewees in Oslo all lives around 15 km from work. One of them, with the iMiev, drives on a regular basis to his parents in Fredrikstad, 120 km south of Oslo. They also have a Volkswagen Tiguan that they use when travelling outside of Oslo, which includes going to their house in the mountains, since the range of the BEV is very limited. The interviewee states that it is possible to take the BEV since there are two fast charging stations on the way. However, due to the high demand of those one would have to stand in line and wait, which would prolong the time of the journey substantially. For them to have a BEV as a long haul car they would need at least 240 km of real driving range in any condition.

“A BEV with a range of 500 km, like the Opel Ampera-e, would be sufficient to only have one car. That would mean 240 km of range in the winter and then we would be able to reach all the destinations we want.” - Mitsubishi iMiev owner

4.2.3. Single-car households

The BEVs that belong to single-car households consists of two Nissan Leaf, a BMW i3 and a Renault Zoe. One of the Leaf owners kept the old car during a period of three months before going all electric. That is explained by the fact that he was unsure about the technology and how to use the BEV. The old car was then sold when the related uncertainties had gone down and due to that he very seldom went on longer journeys. The interviewee argues that it would be cheaper to rent a car those few times, but yet that had not been done. The other Nissan Leaf owner has had the car for more than a year and has still not gone on any longer trips with the car, even though they used to. The interviewee is aware of that there are two fast charging stations on the way to the coast, to where they used to go, but has avoided to go. Stopping every 120 km to take a coffee break and wait for the car to charge for about 30 minutes feels too troublesome. The longest ride they have managed is to the interviewee's sister 70 km one way, which is a bit of a stretch according to the interviewee. On the way home they had to drive very economically, turn of the air condition and so on to be able to get home.

“We had 10 percent left when we got home. We had to turn of the heating, but left the heated chairs on because they run on another battery. Though, at times, we had to turn on the heating to get rid of the condensation (to be able to see out the windows).”

- Nissan Leaf owner

In the case of the Renault Zoe, which has a battery pack of 22 kWh and a driving range of 130 km, it goes around 10 000 to 15 000 km a year. The car is said to be used two to three times a week for going to work or driving the kids to activities. During those times, the car is driven 20 km one way. Otherwise, due to that the house is close to city centre, the family uses public transport or bikes. The family is member of a car sharing fleet, whose cars are used when going to IKEA or similar. The family has for a long period of time, even before adopting to a BEV, used rental cars to go to family and friends far away

The last BEV in the one-car-households is the BMW i3 in Oslo, whose owner lives in an apartment. The car is mostly used to and from work, which is some 15 km away. Once a month the interviewee goes on longer trips, which usually takes three hours to drive with a conventional car. Taking the i3, the owner has to make two stops on the way to charge and the journey now instead takes four and a half hours. The interviewee

states that it works, but that he would preferably have longer range, which is why he has now ordered the new i3 with 50 percent longer range. “Taking the stops works fine especially when you have some company”.

4.2.4. Range anxiety

When the interviewees are asked what they think about their BEVs and how they use them, most say that they are very fun to drive and that their way of using the car has changed. One of the Tesla owners say that when driving on longer journeys he drives more calmly, but that the number of longer trips done are still the same as before with the conventional car. Several others say that they drive more calmly, or economically to save on the battery or due to the fact that the BEV is very quiet and stimulates a less stressful way of driving. On the other hand, most of the interviewees mention that they drive more aggressively after stop lights due to the rapid acceleration that is available.

“The range anxiety is completely gone now. In the beginning I turned off the heating to get some extra range, but I don’t do that anymore. I feel more confident and more relaxed now.” - Mitsubishi iMiev owner

Two interviewees say they drive more now than they used to do since it is so much fun, one is the Tesla Model S owner and the other is the Nissan Leaf owner. The Nissan Leaf owner further explains that the distances driven more are short distances and that long distance trips are still avoided due to the limited driving range. One of the Nissan Leaf owners in Norway claim that the family can not use the car as much as before due to the limited driving range. Before, they could go up to their cottage in two cars; one car leaving on Thursday with the kids and the other leaving after work on Friday. Now the whole family has to go together, and the flexibility has somewhat gotten worse.

On the topic of range anxiety and perceived stress during driving, they all have their own remarkable stories. Some of the interviewees say that their range anxiety disappeared after the first drive or during the first week. Which applies both for BEVs with short range and longer range. Most say they feel more confident and relaxed after a while when they have gotten to know the car and how it works. One interviewee states that her comfort zone has increased over time. Initially, she wanted to have at least 50 percent left of the battery when reaching the destination, but now she is more confident and can drive the car until the battery is almost empty.

“It was only in the beginning I was afraid about the range, then you learn that 10 km is 10 km. Truth be told, it is actually more trustworthy than a conventional car. As soon as it hits red in a conventional car, the panic hits you and have to start looking for a gas station, even though what you have left (range) is more than than what you have in a BEV when fully charged.” - BMW i3 owner

4.3. Economical aspects

There are in total five company cars, the other ten are bought or financed privately. Of the ones that have been bought privately, two have been brand new at the purchase, and the rest have been bought used on a second-hand market.

Most of the interviewees with a company car know what the car cost them every month. In a leasing contract all the costs are normally included in terms of depreciation, services etc. One of the BMW i3 drivers calculated that it was cheaper to privately buy out his previous company car and get a new i3 than only having the previous company car as a lease. Another BMW i3 owner says that BEVs are very beneficial to drive and have as a company car, even though the purchase price is much higher. Then the cost of electricity is about one to two Swedish kronas per 10 km according to the owner. The iMiev owner had also calculated the cost of electricity to about 1 Swedish krona per 10 km, since his electricity bills have increased by 150 Swedish kronas per month after buying the BEV and he drives it about 1500 km per month.

“My colleague made a cost analysis and said it was cheaper with electric cars, and so I bought the argument..” - BMW i3 owner

One of the Tesla Model S owners says he sat down one day and calculated the total cost of ownership and he compared it with his previous company car. At the time he was not able to choose a Tesla as a company car, but when he showed the calculation for his boss that it would be equivalent to what he was already driving, then they changed the company's regulation. He also made a deal with the company that if he could charge at work, then he would not request compensation for any work related travel expenses, which he calls a win-win. He further argues that it was not important that it would cost him less money a month but rather that the equation was possible, for his personal economy and for the company's. He also says that the equation is improved by the fact

that he drives 6000 km on a yearly basis, and that it is great to get rid of the related gas bills. The other Tesla owner, the lawyer, says he did not think much about the costs at all, although he does mention what the car costs him in terms of leasing costs, beneficial value and saved fuel costs.

“It was about making the calculation add up, and even though it would only be a break-even, it’s definitely more fun to drive a Tesla than a 3-series estate.”

- Tesla Model S owner

Several others of the interviewees that have bought their BEV privately, claim they have made a thorough total cost of ownership analysis, including everything from road taxes, depreciation, services to running costs. The owner of the Renault Zoe draw a quick conclusion that he used to pay 2200 Swedish kronas per month for his old Polo plus gas costs of about 1500 Swedish kronas per month, thus that would justify the higher leasing costs of the Zoe, which is about 3500 Swedish kronas a month. But when talking about the cost of electricity, he then says that it was not thought of initially and might come as an unpleasant surprise, since that costs are sort of more hidden now. One of the interviewees from Oslo compared the Leaf to other conventional cars and hybrids and the Leaf came out as the smart choice. Several of the interviewees in Oslo claims that they save 2000 to 3000 Norwegian kronas a month by driving a BEV compared to a conventional car.

Two of the BEV owners have not done any kind of calculation and say that the purchase price was the most important thing. One of them chose to finance the car by taking a loan, which gave her an overview of the monthly costs. The other interviewee says that they have not done a calculation but he is sure they have saved a lot of money in comparison of a conventional car that one has to refuel all the time. When it comes to the cost of electricity it has not been thought of. One of them only looked it up because she assumed it would come a question about it during the interview. Otherwise she says it feels like it is insignificant.

“No, I would not say it has become more expensive (the electricity bill). It almost feels like you drive for free.” - BMW i3 owner

4.3.1. Residual Value

To determine the actual total cost of ownership one has to take into account depreciation, which is based on the car's residual value. Whilst some of the interviewees believe the residual value will be comparable to conventional cars others are more skeptical. A BMW i3 owner says he would not have bought a BEV privately due to the drop in value, i.e. the low residual value. One of the interviewees in Oslo, with the Nissan Leaf, bought his car when it was one year old, and at the time it had already lost 15 to 20 percent of its initial price.

The Swedish iMiev owner bought his BEV when it was four years old. A new car would cost 360 000 Swedish kronas and he bought it for 90 000 Swedish kronas, which is a decrease in value of 75 percent. He argues that he would not buy a new BEV, in that case as a company car, but otherwise he thinks it is smart to buy an almost new car after the first couple of years of money destruction.

“It has dropped tremendously. In four years it had lost 75 percent of its value. That’s just crazy.” - Mitsubishi iMiev owner

Two BMW i3 owners say that the second hand market is unsure and that the cars will drop 50 percent in value during the first three years. However, one of them say that he might not sell the car but rather buy a new battery pack. Other interviewees say that the residual value is not important since they will use the car until it can be scrapped. The Norwegian iMiev owner say that the total cost of ownership is lower if you buy a used car than to lease a new one, due to the fast battery development. However, for the very same reason, the owner of the Renault Zoe has chosen to get his car on a consumer lease program. He states that this means he would not need to think about the residual value and selling the car, which he always hated because one never gets what one expect and after three years he will get a new car with better battery capacity and thus longer driving range.

The Tesla owners agree that the market is uncertain. One of them discusses if the other automakers will start selling comparable BEVs, how good the value of the Tesla will be. In Oslo, the Tesla owner argues that the residual value of a Tesla is just as any other car; in fact it might be even better. The price of a Tesla is not country based but rather in direct relation to the dollar. Since the dollar has had a strong development during the

last couple of years, the purchase price has increased. Which means that the cars are more expensive now than when he first bought the car in 2013.

4.4. Infrastructure and Charging

10 out of 14 interviewees always charge at home for their everyday driving, whilst four charge at work. When talking about the infrastructure for going on long haul trips, both iMiev owners say it is not sufficient, neither in Sweden nor in Norway. They say that even though the situation has improved, one would still need a BEV with longer driving range. As it is now, it is uncertain if the car will make it to the next charging station. On the other hand, a BMW i3 owner in Oslo says it works perfectly fine and that the infrastructure along the motorway E6/E18 to Trondheim and Kristiansand is well developed, but on the countryside it is worse.

“Regarding Tesla, it is really the hat off. The range they’ve managed to get is more than enough, and the infrastructure as well.” - BMW i3 owner

Two of the Tesla owners say that the infrastructure is good enough and that the superchargers are placed out in a smart way that coincide with their coffee break pattern, i.e. every 200 km. Furthermore, they say that Tesla’s chargers can charge at a higher pace than the others, as long as there are not too many cars using the same station, then the speed decreases. The interviewees that not own a Tesla also mentions, despite not having any experience of it, that Tesla’s supercharging network is superior and well developed. A BMW i3 owner states that the Swedish infrastructure is so severely undersized and that if BEVs even become a percent of the total car park this will be a huge problem. Another issue brought up by the same interviewee, is the fact that the charging stations are sometimes out of service. This affected the interviewee when he went on a yearly conference in south of Sweden. He had then planned to make a stop on the way to charge. However, the charging station did not work and the provider told him that they were not able to fix the problem the very same day. Thus he had to go and rent a car in that city, which cost him a lot of money and he did not make it in time for the start of the conference.

“There is one thing one does not think of, and that is that most people that have a BEV live in a house and can easily charge at home. But if you live in an apartment, then it does not work at all.” - BMW i3 owner

Two of the Norwegian BEV drivers say that the infrastructure is good in Norway, especially around Oslo. One says that it is not an argument for not buying a BEV, and that the fast charging network will continue to expand. A Swedish BMW i3 owner says that the problem is not really the fast charging stations and how well developed that network is, since 95 percent of all charging is carried out at home. However, that is mostly only possible for people living in houses but very hard, or even impossible, for those living in apartments in the city. The interviewee further expands on the topic of charging on the route and compares it to a conventional car, meaning that you will spend less time at charging your BEV than you spend at a gas station. According to the interviewee this is due to that those few times you stop to charge your car, maybe 10 to 12 times a year, will only last for about five to 15 minutes to get that extra bit of range that will get you to your final destination. Or even so, if one had to charge the battery for 45 minutes it would still be less time than you spend on a gas station accumulated over a year, since you have to go to the gas station every week. On the other hand, a Nissan Leaf owner comments that when she sometimes has to go to a fast charging station she will charge for about 20 minutes and that will get her an extra driving range of about 70 km. But going to a gas station takes only five minutes and that will get you 700 km of driving range.

4.4.1. The experience of charging in comparison to refueling

One of the challenges, which according to some is an advantage, is the fact that one has to charge every night at home. According to an iMiev owner this implies more scheduling and planning and one can never forget to plug in when coming home since one needs the battery to be fully charged when leaving for work the next morning. Otherwise there is a risk that one cannot make it home again after work. A Swedish Nissan Leaf owner is talking about the same thing. He explains that sometimes when he gets home from work he would only have a couple of kilometers left of driving range. In the case of an emergency, for instance that his kids would need to go to the hospital, the range might not be sufficient since it normally takes the whole night to get the battery fully charged.

One BMW i3 owner further says that it is very hard to remember and quite troublesome to plug in the cable etcetera, but that you get used to it. Whilst others claim this to be an advantage, since always leaving with a fully charged battery is a security. A Tesla owner says that it is much easier to charge than to refuel, since that is something one

automatically does when getting home. When it comes to refueling, this is much more time consuming and stressful. The interviewee says that refueling is often an extra activity, one you might become aware of when you get home, then you have to make an extra trip to the gas station, or your wife might ask you to fill up her car and so on, which he finds bothering. Going to the gas station also implies paying a large amount of money on fuel, which was the very reason for why a Nissan Leaf owner bought a BEV, since that cost becomes very real and painful.

“It’s extremely nice not having to go to the gas station anymore.”

-Tesla Model S owner

Two of the BMW i3 owners say that charging is much more convenient than refueling. One says that when he has to go to the gas station he gets dirty and his hands smell like oil afterwards, he has to press his PIN number and choose the right pump and then he has to wait outside in the cold while his lungs get filled with carcinogenic substances. When charging the BEV it is just to plug in and it will take care of itself.

4.5. Battery lifetime and uncertainties

All interviewees seem to be well informed about the battery and a lot of them mentioned the uncertainties related to the battery. One of them has downloaded an app in which he can see and monitor every individual cell in the battery, which he believes is a relief. He thinks the greatest risk of buying an electric vehicle is the uncertainties of the battery lifetime and its capacity. His iMiev has now run over 50 000 km and according to the app the battery is still as if it were completely new. He states that since he now has more insights and experience from having a BEV and knows that the battery will last for many years, he is now less uncertain about the technology. He would even want to buy rather than lease a BEV since he now trusts the technology.

“There are still great uncertainties with the batteries. You don’t really know how long an electric vehicle can be used.” – Nissan Leaf owner

On the topic of batteries and battery lifetime, one interviewee says that he has read about a guy who has driven a Tesla for over 300 000 km and that the capacity of the battery only has decreased some percent. Furthermore they have eight years of warranty, which seems sufficient. He initially thought that the battery capacity would

decrease more substantially. He then draws a parallel to his phone, which usually only is good for around 1000 cycles of recharging than it is garbage. If that were to apply for the batteries that are incorporated in BEVs, they would only be good for about three years, which would be totally unacceptable for such an expensive product that normally can be used for some 15 years at least. Fortunately that is seemingly not the case.

“It has been shown that the batteries last longer than the car’s lifetime, so it does not seem to be as with the batteries for mobile phones.” - BMW i3 owner

Another interviewee also draws a parallel to her iPhone, whose battery already after two years is soon in the need of a swop out. However, when it comes to her Nissan Leaf, she is not worried. Before buying the car, she had made some research about batteries and their cells. She felt at peace with the eight-year warranty and when she asked about how much it would cost to swop out a single cell, which is possible for the Leaf, the salesman had replied that he did not know since no one had done it yet. She says that the salesman helped her overcome a lot of the concerns she had beforehand. The interviewee further states that swapping out the whole battery would cost around 50 000 Swedish kronas, which seems as a reasonable price.

The two Swedish BMW i3 owners know that they can change the whole battery pack for a cost of 70 000 Swedish kronas, which they state is an outrageous amount. For that kind of money they could buy a whole new car. On the other hand, they do believe, as a result of the decreasing prices of batteries, that it will become cheaper in the future and more realistic. One argue that if cars would be built in the future the way the BMW i3 is built (with plastic and carbon fiber), cars could run for much longer than conventional cars of today. Then also having the possibility of swapping out the battery would mean that the car could easily prolong its lifetime by the double of a normal car. However, the interviewee adds that it has been shown that the batteries of today already outlive the age of the car.

Most of the interviewees say that their BEVs have indicators in the car that tells them the status of their battery. One of the interviewees’ car is over six years old and he states that he has not noticed that the capacity has decreased, maybe only during the winter. According to the owner it used to be able to run for around 5 to 10 km extra during the winter. A BMW i3 owner says that since the car is on a lease, he is not worried at all

about the battery. Others see opportunities in the second hand market due to the skepticism of the general public, which makes the car drop in price and become more attractive.

5. Analysis

In this chapter, a review of the empirical findings is made and presented. The empirical findings are analyzed and discussed using Rogers's innovation-decision process presented in Chapter 2.

5.1. The knowledge phase and prior conditions

This phase is characterized by that the potential adopter identifies a need, problem or interest that catalyze the process in which the adopter starts to look for solutions and ultimately becomes aware of the innovation and increasingly so acquires knowledge about it (Rogers, 2003).

By analyzing the empirical data, three types of subsets regarding the interviewees purchase drivers were identified. The first one consists of BEV-owners that have a concern for the environment, which has been a returning subject for several interviewees. Four of the interviewees stated that this was the main reason for which they purchased their BEV. Several of the interviewees argued that the BEV is more environmentally friendly, both locally and globally, even though some were unsure about the latter. The second subset consists of interviewees with an interest in technology, which eight stated as their main reason for buying. Almost all subjects in this group said that they do believe BEVs are more environmentally friendly but that this has not been the reason to buy such a car, but rather it comes as a bonus. Instead their main reason for becoming familiar with electric vehicles was their interest in technology or cars. The third and last group of BEV-adopters, are those that prioritized price and found electric cars to be cost efficient. A majority of this group is from Norway, where three of the interviewees said that price was the only reason for buying a BEV. Otherwise, they would have bought another car, with another badge and with a higher comfort.

One could argue that some of the interviewees could be categorized as innovators due to their strong interest in technology and that they have not really seen any barriers in adopting this technology. If the price however is emphasized one could argue that these interview subjects should belong to a later category, either early adopters or the early majority. Since the market share of BEVs in Sweden is around 1 percent, it would be hard to argue for anything else than that these people are early adopters. However, in Norway, where the market share is about 17 percent, the interviewees that emphasized

low price could belong to the early majority, which in a normal distribution starts at 16 percent (Rogers, 2003).

Due to the fact that most interviewees are early adopters and have a strong interest in technology, they are believed to be more persistent in acquiring knowledge than a normal customer. Many of the interviewees had read a lot about electric cars online, compared them and talked to dealers about this new technology. Even though a majority is believed to have had a deep understanding about the product at the time of the purchase, many stated that the uncertainties were high initially.

5.1.1. Battery uncertainty the biggest concern before adopting

At this stage in the process, uncertainties are normally high (Rogers, 2003). A vast majority of the uncertainties that the interviewees mentioned, which are shown in Table 5.1, is regarding the battery. This is independently if the car is a long-range or a short-range BEV.

The battery uncertainty is significant. Several interviewees even compared the BEV battery to a mobile phone battery. When drawing such parallels it is usual that they derive from past experiences. They stated that a mobile phone starts to degrade after two years and after three years the battery is basically dead. In this case it was clear that the interviewees had developed a good understanding for the problem. They mentioned that mobile phone batteries normally last for around 1000 cycles of charging. As with a mobile phone, BEVs are charged every night and thus three years would amount to around 1000 cycles. Now, mobile phones are usually replaced after three years or at least is the battery. But cars are normally in service for a much longer period of time, sometimes for 20 years, and thus the concerns were most likely regarding the lifetime of the BEV, which at the time was unknown. It would then be logical to question investing a large amount of money in a technology whose expected lifetime is unknown. Furthermore, replacing the battery of the BEV can cost around 20 percent of the initial price.

When going to dealers, the interviewees became aware of that most dealers offers eight years of warranty for the battery, which was comforting but yet the uncertainties appeared to remain. One of the technology enthusiasts dealt with the uncertainty by obtaining an app in which he could monitor every cell in the battery.

Table 5.1 Showing the interviewees' concerns before adopting. A majority of the concerns was regarding the battery uncertainty.

Subject	Main barrier before adopting
Tesla Model S owner #3	Battery capacity degrading, Untested technology
BMW i3 owner #3	Battery lifetime
Tesla Model S owner #2	Residual value, Comfort
Nissan Leaf owner #2	Battery uncertainty
Mitsubishi iMiev owner #3	Battery uncertainty
Nissan Leaf owner #1	Uncertainty new technology, Battery lifetime
Nissan Leaf owner #3	Range
BMW i3 owner #1	Uncertainty new technology
BMW i3 owner #4	Battery uncertainty
Tesla Model S owner #1	Uncertainty regarding Tesla as a company

As can be found in Table 5.1, the most common barriers that were synthesized in the frame of reference, such as high purchase price, limited driving range and lack of infrastructure are more or less absent in this study. The interviewees have most likely identified these barriers but they have managed to overcome them in this knowledge stage. Driving range is believed to not be a barrier due to the fact that the range of the long-range BEVs are sufficient and that most short-range BEVs are part of multi-car households and mainly used for commuting. Range was only found to be a barrier in one case, Nissan Leaf owner #3, where the BEV was used as the single car. As a result, the owner kept his old car during a period of time, thus having two cars initially. Infrastructure was most likely not a barrier for the interviewees since the majority lives in houses. As found in the empirical findings, one BMW i3 owner, argued that the charging network is not a real problem since almost all charging is carried out when the car is at home or work. The two BEV-owners living in apartments had the possibility to charge at work, thus eliminating that barrier. When it comes to the barrier high purchase price, it appears to be solved through leasing or buying a used car, after the initial price drop.

One of the concerns before adopting that was found in the data is regarding the residual value. As explained in the frame of reference, this is a common barrier, mostly due technology advancements, making older technology less attractive. The National research council (2013) states that one of the problems with BEVs is the residual value, which they in turn explain largely by the uncertainty regarding the batteries and their expected lifetime. In contrast to those who can be found in Table 5.1, some of the interviewees stated that the battery uncertainty was an opportunity for them since the residual value was affected, making the car more affordable to buy. However, while this paved the way of overcoming the price barrier, it is clear that the battery uncertainty remained, and some stated that they still see this as a barrier. Rogers (1983) argues that it is common to still have doubts of the technology when entering the phase of using it and the battery uncertainty is a good example of that.

5.1.2. Technology enthusiasts more concerned than others

By comparing the three groups of BEV-owners, or their purchase drivers, to the uncertainties presented in the previous subchapter it is clear that those who had an interest in technology were also the ones being most concerned regarding the new technology and battery uncertainties. Surprisingly, those who were categorized in the environment group did not mention that they had any concerns at all beforehand. In the group of low cost seekers no clear trend could be identified since some expressed that they had concerns whilst others did not. Nevertheless, the most interesting part is that the most concerned ones could be found in the technology enthusiast group. Maybe they had acquired more knowledge and were thus more aware of the risks than the others. That would imply that information about the battery and its respective uncertainties is something negative. Yet, the interviewees in this study are all adopters of BEVs, thus they went through with the purchase anyway. It could be that this group of early adopters is more willing to take risks.

5.2. The persuasion phase

During the persuasion phase in Rogers's innovation-decision process, uncertainties are reduced by informing customers about the advantages of the BEV, which if successfully managed results in a decision to adopt. In this study, before taking the decision to adopt, a vast majority has taken a test-drive or even borrowed the car over a weekend and in some cases a whole week. This is what is referred to as trialability in the persuasion step. Several interviewees stated that they bought or signed the papers for the car the same day, after having test-driven the car. Furthermore, many of the interview subjects mentioned this as being the tipping point in their process of taking the decision to adopt. One of the interviewees was on his way to test-drive another, fossil fuel car, but after test-driving the BEV he signed the papers immediately. Another interviewee stated that his BEV, a BMW i3, looked like a "*shitty car*" and that he was very skeptical beforehand, but after having test-driven it, he got very convinced that this was the right car for him. By driving it he realized what Rogers (2003) refers to as relative advantages, such as the instant acceleration and noiseless ride. Thus, in the process of buying BEVs, trialability seems to be of utter importance for discovering the relative advantages, which ultimately leads to a decision to adopt.

Regarding the level of compatibility of the BEV, this would depend on if the BEV is to be used as a first car or second car. Many of the BEVs included in this study are short-range BEVs and thus compatible with previous experience and existing needs in the usage as a second car or commuting car. However, the only BEV that is compatible as a first car is the Tesla Model S, which has a sufficient range to be used more or less like a conventional car. The two remaining characteristics of the BEVs that are important knowledge for convincing potential buyers to adopt are complexity and observability. When it comes to complexity, it has already been stated in the frame of reference that the buying process of cars is among the most complex there is. However, the interviewees were almost unanimous in stating that buying a BEV was not harder than buying any other car. This could be a consequence of what was discussed in the knowledge phase, that a majority was very well informed and had acquired a deep understanding of the product beforehand. This might be a characteristic of early adopters and could imply that the early majority will find the buying process more complex. Nevertheless, the product itself is said to be very easy to use, since there are no gears and it is always fully charged when leaving home. Ultimately, the degree of observability is found to be low in general, since cars are sold at dealers, which are

normally situated in the outskirts of the cities. One could argue that on the roads, the observability is better in Oslo since the market share is substantially higher. The five characteristics of the BEV are summarized in Table 5.2, as described by the interviewees.

Table 5.2 The five most important characteristics of an innovation to diffuse successfully (Rogers, 2003).

Characteristic	Applied to BEV
<i>Relative advantage</i>	Instant acceleration and good handling, noiseless and peaceful ride, fully charged when leaving home, low running costs, zero emissions
<i>Trialability</i>	Have been crucial for discovering the relative advantages and adopting
<i>Complexity</i>	High complexity in the buying process but comparable to buying conventional cars, low product complexity
<i>Compatibility</i>	Short-range BEVs compatible as commuting cars, Long-range BEVs (Tesla) fully compatible
<i>Observability</i>	High in Oslo, Low in Gothenburg

5.3. The decision to adopt

This section deals with the decision to adopt a BEV, the third step in the innovation-decision process. When considering acquiring a BEV the interviewees started out with an environmental or technical interest, which led them to take the BEV into consideration instead of only looking at conventional cars. When moving closer to the decision the environmental and technical aspects were however not the only reasons for making the purchase.

Basically there are two types of customers; those who have a company car or benefit car and those who have bought it privately. Everyone who has a company car has it on a lease, but there are two BEV owners in the other category that also has it on a lease, a consumer lease. Thus, leasing has been the most common setup for financing the BEV. The purchase price is an important aspect for both types of customers when acquiring a car since it sets the upper limit for what they can afford. Two of the interview subjects stated that they would have wanted to buy a more expensive car with higher comfort such as the Volkswagen e-Golf or a Nissan Leaf, but settled with a cheaper car due to this upper limit. Interestingly, whilst these BEV-owners compared different types of BEVs, Tesla owners were only interested in buying a Tesla. For those who have the car as a company car, the purchase price is the most important criteria since it has to fit within the company agreement.

There is a clear difference between those who buy and those who lease the car when it comes to the investment horizon. A leasing program is normally three years, and so is these customers' horizon, but a majority of the others said they will have the car until it has to be scrapped. It is possible that the long investment horizon is because of the nature of the electric car; it does not need as much maintenance since there are fewer moving parts and should function for much longer than a conventional car.

Regarding the customers who have bought their BEVs privately (excluding consumer leases), everyone has bought used cars that have been in traffic for two to three years. Some argued that this purchase ideology takes advantage of the initial price drop, hence decreasing the expected depreciations and lowering the total cost of ownership. With this in mind, the diffusion of BEVs seems to be more complex than regular business to customer sales. Rather, the diffusion of the BEVs in this study had to pass a leasing program before there was any change of ownership and closure of a deal.

As seen in the previous subchapter, the battery uncertainty was identified as the main purchase barrier. Here, when taking the decision to adopt, a majority has chosen to lease their BEV. It can be argued that when leasing, there is no initial investment thus no capital is tied up and this would be a way of overcoming high purchase prices. Moreover, with leasing the customer does not own the car and consequently does not take any risk. Thus, leasing seems to be a smart choice to both overcome the purchase barrier but also mitigating the risk of the battery.

5.3.1. BEV-adopters focus on total cost of ownership

The BEV-owners included in this study have in almost every case made an economic calculation, or a total cost of ownership analysis. Since the purchase price is higher than that of a conventional car, making a total cost of ownership analysis is preferable since the running costs are lower for a BEV. Having a longer investment horizon would improve the situation since the purchase price is spread out over a longer period of time. In the case of the interviewees, they said that this calculation for a BEV was equal to or less than for a conventional car. As seen in the frame of reference, making the costs become comparable to a conventional car is important to increase the market viability of BEVs and reach out to the mainstream market. Findings from this study is to some extent quite extraordinary since these BEV-owners are innovators and early adopters, for whom normally the price is not as important as for the mainstream market (Rogers, 2003). However, what do argue for the fact that most interview subjects still belong to this category is that they are more persistent and innovative in making the calculation add up. For instance one of the interviewees made a deal with his employer so he could charge for free at work.

The ones focusing especially on costs and stated that it was their main purchase driver are centralized to Oslo. Due to subsidies such as reduced VAT and road taxes, several interviewees stated that they save 2 000 to 3 000 Norwegian kronas a month in comparison to a conventional car. Thus the price barrier in Norway seems to be completely teared apart. Yet, not everyone in Norway drives a BEV, which must mean that eliminating one barrier is not enough for the mainstream market. The Tesla owners stand out from the rest of the BEV-owners. They argued that it was not necessary for the calculation to benefit from the transition but rather it had to be reasonable, or at least

almost add up, considering all the benefits that comes from the Tesla such as quick acceleration and design.

When it comes to the electricity cost some of the interviewees excluded it, or rather forgot to include it, in their total cost of ownership. This may lead to the total cost of ownership looking better for the BEV than it actually is, and might come as an unpleasant surprise after taking the decision to adopt. Several subjects stated that the electricity cost somewhat disappears since it is merged with the electricity cost of the house. Others simply did not include it since they could charge for free at work, which makes more sense since they do not bear this cost themselves. However, many of the interviewees did include it and had calculated the cost per ten kilometers to be between 1.5 to 2 Swedish kronas, which is noticeably lower than the cost for fuel to a conventional car. Although this could be seen as a hidden cost, one of the interviewees with a consumer lease stated that although it might not add up in the end due to the added cost of electricity, the BEV comes with certain qualities that are worth paying a premium for.

5.4. The implementation phase

The mobility need concerns the everyday usage and whether the driving range of the vehicle fulfills that need. This section deals with the implementation phase in Rogers's innovation-decision process (2003) and how the BEV-adopters have managed to live with this new technology.

5.4.1. Short-range and long-range BEVs

Most of the BEVs in this study can be found in a multi-car household, which according to Jakobsson et al. (2016) is where BEVs are best suited. When one talk about multi-car households, one talk about first cars and second cars, where the first car is the car being used the most. The first car is also normally an all-round car, a larger car that fits all needs. These are norms that seem to change in multi-car households that have a BEV. It is clear from the empirical data that BEVs are normally bought as a second car, a smaller car, but since it does all the commuting it is the car being used the most, hence being the first car. Instead, when dealing with BEVs it becomes increasingly more suitable to talk about long distance cars and short distance cars or the everyday car. Most of the interviewees in this study have short-range BEVs, typically first generation BEVs, but there are also those who have long-range BEVs, i.e. Tesla.

The interviewees' usage depends highly on how far they live from work, since commuting accounts for the majority of the annual mileages. As shown in the empirical findings the distance to work varies a lot. One cannot see any clear similarities between what type of car (long-range or short-range) the interviewees have and how long they have to work. In Oslo, one of the interviewees had a long-range car despite the short distance to work. What is clear, though, is that interview subjects with long-range BEVs do go on longer trips and are not afraid of taking the car in such situations. However, all of the interviewees are happy with the range their respective BEVs offer, and that they suit the intended purpose perfectly fine. As described in the frame of reference, it is not unusual that a majority of the subjects in a survey answer that they want more than 300 km, sometimes more than 500 km. Meanwhile, a majority in this study owns short-range BEVs with a driving range of 100 to 160 km and is satisfied with this. Thus, there seems to be a gap between BEV owner's perceptions and what the mainstream market wants.

Since buying and using a BEV is said to require a mentality change and the way of using the car changes by experience, interviewees were asked if they had changed their way of driving, as described in the empirical findings. Almost all interviewees stated that their driving has changed; driving more aggressively at stoplights, taking advantage of the instant acceleration of the BEV, but during cruising they argued that they drive more calmly and economically to extend the range. When it comes to the perceived driving patterns and if they have changed – some drive a lot more, and have not refrained from going on any longer trips. On the other hand, some drivers said that they drive less due to the limited driving range of the BEV. It is not safe to say that this only applies for long-range and short-range BEVs respectively, but a longer range does help. Short-range BEV-owners may drive more but within their comfort zone, whilst long-range BEV-owners drive more in general.

5.4.2. Managing longer trips

As mentioned in the frame of reference, 95 percent of the daily driving is normally within 160 km. This section will analyze the interviewees' way of managing the remaining five percent of the times.

Most interviewees were in agreement that stopping once during longer trips is acceptable or not even bothering, but rather the opposite. Instead of having to desperately search for a place to eat or refuel when the time comes, this is already planned beforehand, thus making the trip less stressful. However, even though this way of traveling brings some positives, always having to plan for when to stop is said to be a mental barrier by some. Nevertheless, the interviewees often mentioned that if the trip does not last for more than two hours on motorway, it should not be necessary to stop. This would mean that for BEVs to be used during longer distances, a driving range of at least 220 km would be needed, which most of the BEVs in this study cannot manage. Driving longer than approximately 600 km in one day is seen as too much and in combination with preferring to stop once during longer trips makes 300 to 350 km driving range reasonable for a BEV to have if it is to be used as most conventional cars are today.

As for those with a short-range BEV in this study, they seem to manage longer trips where adaptation is necessary in different ways; 1) by having another car in their household, 2) renting a car during those adaptations or 3), in some cases longer trips are

avoided. Avoiding longer trips is not a viable long-term solution and will eventually lead to dissatisfaction since it takes away a great part of the value offer and the reason for having a car. Having a long-range car as a complement is probably the most convenient solution, however it is also the most expensive one. Renting a car when needed is applied in some cases, with the argument that it gives flexibility and is not as expensive as buying a long-range BEV or a second car. Surprisingly, many of the interviewees found in multi-car households, do suggest this as a solution for those who cannot afford having two cars, yet they are not willing to rent a car themselves. Thus, there must be additional barriers when it comes to renting cars.

Interestingly, the four cars being used in single car households in this study are all short-range BEVs, of which two belong to the group where longer trips are avoided. It might be so that these households have fewer resources to cope with the changes that come with the transition to going fully electric. Since they have short-range BEVs, the transition is believed to require more effort to change since the BEV cannot offer a full solution to their needs. It is only one of the four households that takes the BEV on longer trips, and that is done in Norway where the infrastructure is perceived to be well developed. This BEV-owner now needs to deal with stopping twice to charge, making the trip last for four and a half hours rather than previous three. It seems that changing behavior, i.e. stopping to charge and thus extending the travel time by 50 percent, is so demanding and thus understandable that some households rather avoid those situations. However, this might be due to the two stops that are necessary when the desired amount of stops is maximum one. Although, it is unclear why these households do not try solve the issue at hand by for instance borrowing the neighbor's or a relative's fossil fuel car, which is a cheap alternative for those with limited resources.

5.4.3. Overcoming range anxiety takes (no) time

Despite the fact that most of the interviewees stated that driving electric is less stressful, almost everyone has encountered stressful situations, to what in the frame of reference is referred to as range anxiety. In most cases, these situations occurred during their first trip or during the first week, then range anxiety was not longer considered an issue, which is considerably faster than what earlier research show (three weeks). However, there is a variation, as in the case where it took the driver three months to overcome range anxiety issues and consequently did not sell his previous conventional car until he

felt secure. On the other hand, other factors might have prolonged the time frame, such as limited time to get rid of the conventional car.

There is also doubt if the range anxiety has really been overcome by all the adopters like they say they have. It is obvious that by experience the drivers feel more secure and confident in handling the car. As previous research suggest, minimizing range anxiety can be done by increasing the comfort zone of the driver. In almost all cases, the comfort zone has increased as a result of learning to handle the car. One interviewee even stated that he thinks the BEV is trustworthier than a regular car, when it comes to calculating the driving range. Thus to some extent range anxiety issues have been dealt with. On the other hand, some stated that they still avoid longer trips, which rather proves the opposite; that range anxiety still exists.

5.4.4. Infrastructure and charging

Driving a BEV almost implies that you must charge it at home during the night or at work during the day to get around. This is a different behavior than is needed with a conventional car where refueling takes place mostly when it is really needed. A Nissan Leaf owner described it as with a BEV you charge whenever you have the opportunity, which you do not do with a conventional car. The charging need is an obstacle to a few of the interview subjects where most see it as more convenient than refueling. This goes well in line with the different views of Egbue and Long (2012), that stated that 30 percent thought it would be less convenient to charge than refuel, and Lebeau et al. (2013), that found the charging to be one of the biggest advantages since it eliminated the need to go to a gas station. One example of this is the BMW i3 owner that said that charging is more convenient; when he used to refuel a conventional car he had to go and get his hands dirty and waiting outside regardless of the weather. Most subjects said that connecting the charger every time you get to your destination quickly became a normal habit, which indicates that the new charging behavior is easy to adopt during Rogers (1983) implementation phase.

Most of the interviewees charge at home, a few at work, and the majority never or rarely uses their BEV for longer trips. The Tesla owners are however exceptions and two of them use it fully as a substitute for a conventional car when it comes to what distances they are travelling with it. When charging at home or work the interviewees are perfectly fine with charging times in accordance to the findings of Egbue and Long

(2012) that stated that 70 percent would be fine with charging times of four to eight hours at home.

When not charging at home or at work one mostly charge using public charging stations installed in the road infrastructure. There seems to be differences between Norway and Sweden where the interview subjects from Norway are overall more satisfied than the Swedish ones. For Sweden, at least, the infrastructure is still seen as a barrier by most of the interview subjects. This suggests that it needs to be improved, but it can also have its explanation in Rogers (1983) implementation step where there still can be an ongoing period of doubt of the new technology and its surroundings. Taking the purchase decision and moving into the implementation phase where the BEVs are used in their everyday-life has lowered the uncertainty level of the charging infrastructure of the subjects in this study. For example, most interviewees say that they had more doubts of if the infrastructure worked before having the opportunity of trying it out. So, even though the infrastructure seems to be far from satisfying enough for all when going on longer trips, getting experience from using a BEV reduces the uncertainty.

5.4.5. Tesla's supercharger network is perceived superior

Buhne et al. (2015) shows that the most crucial factor to improve to get more people to buy BEVs is to improve the charging infrastructure. When it comes to this study the perception about how well organized the charging stations are differs depending on what type of car they have, more specifically if it is a Tesla or not. The Tesla owners are very satisfied with the distribution of charging stations when they go on longer trips. For example, the Tesla owners stated that the superchargers were placed in vicinity that feel natural to them since they normally want to take some form of small break after approximately 200 km. If this is done by purpose by Tesla it is a smart way of meeting their customer's needs rather than forcing them to change their behavior. Another example of this are non-Tesla owners that, despite not having any experience of it, said that Tesla's supercharger network is well developed and superior to the others. These perceptions may be derived from the company's way of communicating. After all, even though statistics show that Tesla's network is about half the size of other fast-charging networks in Sweden (Laddinfra.se, 2017), the most important thing is what the customer perceives to be best, even though it is not the case.

5.5. The confirmation phase

In general the interviewees are satisfied, and Rogers's confirmation rate would be classified as very high; many say they will never go back to conventional combustion engine cars and everyone say that they will continue to buy electric vehicles. One of the Tesla owners, which seems to be the group that are most pleased, is already driving his second Tesla and two others of the interviewees are waiting for their second generation BEVs to be delivered. Although a majority say this is because of the rapid acceleration of the BEV, the noiseless ride and the ease of use, the underlying root cause might not only be the relative advantages. In the end of the day, the BEV is not a fully developed solution since its limited driving range intrude on the value offer; flexibility. The root cause might be that the interviewees are innovators and early adopters. What sets them apart from the majority is that they are pleased with buying a product that solves 80 percent of the problem (Rogers, 2003).

It has been shown that longer trips are sometimes avoided for BEV-adopters with short-range BEVs, which is not a viable long-term solution and will probably lead to dissatisfaction since it takes away a great part of the value offer and the reason for having a car. Yet so far these households, or BEV-adopters, are very pleased. Nevertheless, most of the interviewees with a short-range BEV purchased them in order to commute, hence a longer driving range than the commuting distance would be unnecessary, and thus this is believed to be the reason for why these interviewees are satisfied with the range of their BEVs, since the car fulfills that specific need.

An issue that seems to have been overcome in this stage is the battery uncertainty, which for many was the main barrier to adoption. The interviewees referred to reports that recently have come out showing that the battery degrading has been better than expected, even though some uncertainties remain about how long the lifetime of the battery is. The ones who felt most reassured that the battery is no longer a big uncertainty are those who have had the BEVs for a longer period of time and been able to see the degrading themselves. The one who was most concerned about the battery before adopting, the iMiev owner that has an application where he can monitor the battery, said he feels more and more confident since the car has now run for 50 000 km and is more than five years old, and the capacity is still 100 percent. It seems that experience and time is important for gaining trust in the technology. Some of the

interviewees even stated that they feel safe buying a BEV rather than leasing it, as a consequence of overcoming battery uncertainties.

5.6. Evaluating the transition

During the knowledge phase, the interviewees studied and read news about electric cars, giving them a good base to stand on. Their interests in BEVs can be derived from three causes; interest in technology, concern for the environment or seeking cost efficient transportation solutions. At this stage, the biggest uncertainty was the battery and the ones being most concerned were technology enthusiasts, which can be linked to that they had studied the subject and become more aware of the risks.

During the persuasion phase, test-driving has been proven crucial for discovering the relative advantages of the BEV and consequently adopting. At the time of taking the decision to adopt it was important for all interviewees to consider the total cost of ownership. Tesla owners only compared Teslas, and wanted the calculation to make sense. The other BEV-owners compared all kinds of BEVs and it was important for the calculation to become as good as, or in Oslo better, than that of a conventional car.

When entering the implementation phase, battery uncertainties remained, which according to Rogers (2003) is normal. During the implementation phase, the ease of use and compatibility has been proven to differ between BEVs as well as between households and cities. The transition has been proven easiest for Tesla owners, whose cars are long-range BEVs, meaning less need for adaptation, and in combination with a well developed charging network makes longer trips as easy as with a conventional car. Those short-range BEVs that are part of multi-car households where the BEV function as a commuting car or second car also seems like a smooth transition, where there is always a long-range conventional car available for long distance trips. Where the transition has been proven difficult is in single car households in Gothenburg, where longer trips are avoided as a consequence of limited driving range, range anxiety and a poor developed infrastructure for charging. General trends have been identified, such as the BEV-adopters take advantage of the instant acceleration but drive economically during cruising to save energy and extend the driving range. Moreover, almost all BEV-adopters drive more; the ones having short-range BEVs drive more within their comfort zone and the ones having long-range BEVs drive more in general. Furthermore, by

gaining experience from driving the interviewees have extended their comfort zone and overcome most range anxiety issues.

The confirmation rate has been classified as high, where all interviewees are satisfied, which has already led to continued adoption by some. Tesla owners seem to be more satisfied than the others, which would be logical since they are identified as having had the easiest transition.

6. Concluding discussion

In this chapter, a concluding discussion will be laid forward and conclusions will be drawn in order to answer the research question and thus achieve the purpose of the study. Moreover, managerial implications and proposal for future research will be presented. The research questions are defined as follows: “What are BEV-adopters’ rationales for purchasing battery electric vehicles?” and “What are the perceived barriers of adoption?”

This study has investigated BEV-adopters’ transition to electromobility using Rogers’s (2003) innovation-decision process to identify important insights regarding purchase drivers and barriers in each part of the process of adopting BEVs. Interviews were done with BEV-adopters as a mean to gain a deeper understanding of the process.

Following the analysis, it can be argued that the transition has been easiest for Tesla owners, due to the long driving range and well developed infrastructure. On the other hand, where trips have been avoided and where it seems like the transition has been proven more challenging, are in single-car households in Gothenburg. These findings strengthen the conclusions of Jakobsson et al. (2016) who argue that BEVs are more suited for multi-car households.

Earlier research focusing on the mainstream market suggests that the high purchase price, the limited driving range and the lack of infrastructure are the biggest barriers of adoption. However, results from the interviews show that this was not the case. The analysis indicates that the BEV-adopters are early adopters and consequently this means that they do not have the same barriers as the mainstream market. One reason is that early adopters are fine with buying a high-risk product that does not solve the whole problem (Rogers, 2003). However, what is aligned with earlier research findings about the mainstream market, e.g. Lebeau et al. (2013), is that most of these BEV-owners do not want the car to cost them more than a conventional car. Due to the fact that these BEV-owners have focused on the total cost of ownership, and that they have proven persistent in finding solutions for making the calculation add up, the costs became comparable to conventional cars, which could explain why the high purchase price was not mentioned as a barrier.

Range anxiety related to commuting and everyday usage seems fast and easy to overcome. It has been proven that by gaining experience from driving, the interviewees

have extended their comfort zone and overcome most range anxiety issues. However, in some cases longer trips were avoided, which strengthens the conclusions of Franke et al. (2012) that find one coping mechanism for range anxiety to be avoiding those situations. In terms of driving range, the results from this study are different from earlier research findings. BEV-owners in this study were satisfied with the offered driving range, a majority ranging from 100 to 160 km. Meanwhile, earlier research, e.g. Egbue and Long (2012) and Lebeau et al. (2013), show that the mainstream market wants driving ranges of 300 to 500 km, considerably longer than the early adopters in this study. Thus, there is a gap between BEV-adopters' perceptions and what the mainstream market wants. It might be because of that the BEVs in this study function as commuting cars or second cars, whilst earlier research have been investigating the market potential for first cars or long distance cars. In that respect, findings and insights from this study can explain why approximately 300 km would be sufficient for a long-range car. Driving longer than 600 km in one day was seen as too much and in combination with preferring to stop once during longer trips makes 300 to 350 km driving range reasonable.

This study can conclude that the main barriers perceived beforehand by the BEV-adopters included in this study were uncertainties related to the battery, which stated above has not been the case in earlier research. Moreover, the adopters were driven by a technology or environmental interest. The ones being most concerned were technology enthusiasts, which could be explained by the fact they were more aware of the risks. However, by time the uncertainty was handled and by some not longer considered as an important issue. Nevertheless, in some cases the uncertainty was so significant that the owner wanted to measure every cell in the battery, which helped him cope with the uncertainties and trusting the technology. Thus, transparency and supporting owners with data about the condition of the battery might help to reduce battery uncertainties. However, most effective would be to inform and give the customer driving experience at an early stage of the process and thus decreasing the risk of rejection.

6.1. Managerial implications

This study shows that experience of using a BEV is crucial for overcoming the barriers of adoption. Test-driving is not only important for discovering the relative advantages of BEVs but also it helps to polish off the barriers to a degree where the potential buyers feel comfortable with making the purchase decision. Since this is not only a complex process, but also a product with lots of uncertainties, offering aspirant buyers to test-drive or borrow a BEV over a weekend should be complemented with a specially trained sales force to address the areas of uncertainties and purchase barriers. Nevertheless, there are still some uncertainties about the battery and range that remain after the adoption. Over time, by gaining more experience, these barriers fade away completely and when that occurs, there is no turning back to using conventional cars. Thus, automakers have a great opportunity in winning returning customers and ensuring future profits.

An important aspect is that the perceptions are sometimes more important than the reality, as seen with the example of Tesla's charging infrastructure compared to other charging infrastructures. Thus, due to the fact that most charging takes place at home, automakers should instead of investing in infrastructure adequately communicate and inform potential customers about the existing infrastructure and where to find the chargers in an easy way. A suggestion is to learn from Tesla's way of communicating and implement a similar smart navigation system in near-future BEVs. Furthermore, it seems like a good idea for automakers to observe the way Tesla has organized their network considering that even the non-Tesla owners are talking about its superiority.

This study can further conclude that most BEVs on the market today are considered perfectly fine to be used as second cars, and BEVs in this study were mostly used as commuting cars. However, they are insufficient to offer a full mobility solution, or work as first or single cars. Near-future customers will continue to be early adopters and to facilitate a decision to adopt they need to be served with appropriate front-runner-products; longer range is believed to be important but most of all they need to be offered the relative advantages discovered in this study, for instance quick acceleration. However, to address the mainstream market a full mobility solution will be key. For automakers to maximize the market potential, a BEV with 250 km of range could serve as both a second car and a first car, but only if first-car-customers are offered a service for adaptation, e.g. a rental car, those 12 times a year that will be needed. Then, it

becomes important to consider the fact that there might be additional barriers when it comes to renting cars, and such a solution might not be very successful unless the service of renting is made easy and accessible. Based on the reasoning of the interviewees, a long-range car should be able to manage 550 to 600 km with one stop on the way, thus a driving range of 350 km with rapid charging possibilities could be a viable solution.

6.2. Future research

This study has focused on early adopters to BEVs and how these people have coped with the perceived barriers with the BEV in regard to a conventional car. For the BEVs to overtake the conventional cars as the main technology early and late majority must adopt as well. How to make the leap from early adopters to early majority is a potential area for future research.

The authors believed that potential buyers would use the same comparison methods as with conventional cars, for example comparing different brands and favor some over others. During this study a different way of comparing BEVs has been identified, where the potential buyers used to compare different brands and models. The early adopters in this research has deviated from this historically used behavior and compared BEVs only with other BEVs and included brands that they normally do not consider. Will the early and late majority use the same comparison methods for BEVs as the early adopters?

Reference list

Bryman, A., & Bell, E. (2014). *Business Research Methods 3e*. Oxford University Press.

Bühne, J., Gruschwitz, D., Hölscher, J., Klötzke, M., Kugler, U. & Schimeczek, C. 2015, “How to promote electromobility for European car drivers? Obstacles to overcome for a broad market penetration”. *European Transport Research Review*, vol. 7, no. 3, pp. 1-9.

Carley, S., Krause, R.M., Lane, B.W, Graham, J.D. (2012). *Intent to purchase a plug-in electric vehicle: a survey of early impressions in large U.S. cities*. Proceedings of the 31st USAEE/IAEE North American Conference, Austin, TX. http://www.usaee.org/usaee2012/submissions/OnlineProceedings/Intent_to_purchase_SCarley_USAEEconf.pdf. [Accessed 16 March 2017]

Choi, S.S. and Lim, H.S., 2002, “Factors that affect cycle-life and possible degradation mechanisms of a Li-ion cell based on LiCoO₂”, *Journal of Power Sources*, Vol. 111, pp.130–136.

Curtin, R., Shrago, Y., Mikkelsen, J., 2009. *Plug-in Hybrid Electric Vehicles*. University of Michigan, Ann Arbor. http://www.ns.umich.edu/Releases/2009/Oct09/PHEV_Curtin.pdf. [Accessed 6 March 2017]

Delang, C.O. and Cheng, W-T., 2013, “Hong Kong people’s attitudes towards electric cars”. *Int. J. Electric and Hybrid Vehicles*, Vol. 5, No. 1, pp.15–27.

Denscombe, M. (2003). *The good research guide: For small-scale social research projects*. Maidenhead, England: McGraw-Hill/Open University Press.

Dijk, M. & Yarime, M., 2010, “The emergence of hybrid-electric cars: Innovation path creation through co-evolution of supply and demand”. *Technological Forecasting & Social Change*, vol. 77, no. 8, pp. 1371-1390.

Dijk, M., 2016, "Electric revenge after 100 years? Comparing car market patterns around 1900 and 2000". *Int. J. Automotive Technology and Management*, Vol. 16, No. 2, pp.147–168.

Dooley, K.E., 1999, "Towards a holistic model for the diffusion of educational technologies: An integrative review of educational innovation studies". *Educational Technology & Society* 2 (4), 35-45

Easterby-Smith, M., Thorpe, R. & Jackson, P. (2015). *Management & Business Research*. Fifth edition. London: SAGE Publications

Egbue, O. & Long, S., 2012, "Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy*, vol. 48, pp. 717-729.

Eisenhardt, K. M., & Graebner, M. E., 2007, "Theory building from cases: Opportunities and challenges". *The Academy of Management Journal*, 50(1), 25-32.

Eriksson, L. T., & Wiedersheim-Paul, F. (2008). *Rapportboken: Hur man skriver uppsatser, artiklar och examensarbeten*. Malmö: Liber.

Eveland, J., 1979, "Issues in Using the Concept of 'Adoption of Innovation". *Baltimore, Maryland*, Paper presented to the American Society for Public Administration. O(N)

Franke, T., Neumann, I., Bühler, F., Cocron, P., & Krems, J. F., 2012a, "Experiencing range in an electric vehicle: Understanding psychological barriers". *Applied Psychology: An International Review*, 61, 368–391.

Franke, T., Cocron, P., Bühler, F., Neumann, I., & Krems, J. F., 2012b, "Adapting to the range of an electric vehicle: The relation of experience to subjectively available mobility resources". In P. Valero Mora, J. F. Pace, & L. Mendoza (Eds.), *Proceedings of the European Conference on Human Centred Design for Intelligent Transport Systems* (pp. 95-103). Lyon, France: Humanist.

Franke, T., & Krems, J. F., 2013, "What drives range preferences in electric vehicle users?". *Transport Policy*, 30, 56–62.

Gallagher, K.S. and Meuhlegger, E.J., 2011, "Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology". *Journal of Environmental Economics and Management*, Vol. 61, pp.1–15.

Graham, J., Cisney, J., Carley, S. and Rupp, J., 2014, "No Time for Pessimism about Electric Cars". *Issues in Science and Technology*.

Grant, R.M. (2010). *Contemporary strategy analysis: text and cases*, 7.th edition, John Wiley & Sons, Hoboken, N.J.

Heyvaert, S., Coosemans, T., Van Mierlo, J. and Macharis, C., 2015, "Electric vehicle attitudes and purchase intention: a Flemish case study", *Int. J. Electric and Hybrid Vehicles*, Vol. 7, No. 1, pp.83–100.

Høyer, K.G., 2008, "The history of alternative fuels in transportation: The case of electric and hybrid cars". *Utilities Policy*, vol. 16, no. 2, pp. 63-71.

Jakobsson, N., Gnann, T., Plötz, P., Sprei, F. & Karlsson, S., 2016, "Are multi-car households better suited for battery electric vehicles? - Driving patterns and economics in Sweden and Germany".

Jato. 2016. *SUV takes over as the Best-Selling Segment in Europe for the first time*. [ONLINE] Available at: <http://www.jato.com/suv-takes-over-as-the-best-selling-segment-in-europe-for-the-first-time/>. [Accessed 26 March 2017].

Kahn, M. & Kockelman, K. M., 2012, "Predicting the market potential of plug-in electric vehicles using multiday GPS data". *Energy Policy* 46, 225233

Kim, B.G., Tredeau, F.P. and Salameh, Z.M., 2008, "Performance evaluation of lithium polymer batteries for use in electric vehicles", *Paper presented at the Vehicle Power and Propulsion Conference (VPPC)*, 3–5 September, Harbin, China, pp.1–5.

Knupfer, S., Hensley, R., Hertzke, P., Schaufuss, P., Laverty, N. and Kramer, N.,(2017), “Electrifying insights: How automakers can drive electrified vehicle sales and profitability”. *McKinsey - Advanced Industries*.

Kotler, P. & Armstrong, G. (2006) *Principles of marketing*, 11.th edn, Pearson Prentice Hall, Upper Saddle River, N.J.

Krause, R.M., Carley, S.R., Lane, B.W., Graham, J.D., 2013. “Perception and reality: public knowledge of plug-in electric vehicles in 21 U.S. cities”. *Energy Policy* 63, 433–440.

Nilsson, M., 2011, “Electric vehicles: An interview study investigating the phenomenon of range anxiety”. Retrieved from http://www.elvire.eu/IMG/pdf/An_interview_study_investigating_the_phenomenon_of_range_anxiety_ELVIRE-2.pdf

Larson, P.D., Viáfara, J., Parsons, R.V. & Elias, A. 2014, “Consumer attitudes about electric cars: Pricing analysis and policy implications”, *Transportation Research Part A: Policy and Practice*, vol. 69, pp. 299-314.

Lebeau, K., Van Mierlo, J., Lebeau, P., Mairesse, O. & Macharis, C. 2013, “Consumer attitudes towards battery electric vehicles: A large-scale survey”, *International Journal of Electric and Hybrid Vehicles*, vol. 5, no. 1, pp. 28-41.

Lieven, T., Mühlmeier, S., Henkel, S. and Waller, J.F., 2011, “Who will buy electric cars? An empirical study in Germany”, *Transportation Research Part D*, Vol. 16, pp.236–243.

Manners, D., 2014, “Why worry about the lack of electric cars?”. *Electronics Weekly*. ProQuest Central

Moons, I. & De Pelsmacker, P., 2012, “Emotions as determinants of electric car usage intention”, *Journal of Marketing Management*, vol. 28, no. 3-4, pp. 195-237.

National Research Council, 2013, *Transitions to Alternative Vehicles and Fuels*. National Academies Press, Washington.

Nealer, R., Reichmuth, D. and Anair, D., 2015, "Cleaner Cars from Cradle to Grave - How Electric Cars Beat Gasoline Cars on Lifetime Global Warming Emissions". Union of Concerned Scientists, Washington

Needell, Z., McNerney, J., Chang, M. and Trancik, J., 2016, "Potential for widespread electrification of personal vehicle travel in the United States". *Nature energy*, vol. 1. Macmillan Publishers Limited.

OECD/IEA., 2016, "Global EV Outlook 2016 Beyond one million electric cars". Paris: International Energy Agency.'

Pasaoglu, G., Fiorello, D., Martino, A., Zani, L., Zubaryeva, A. & Thiel, C. 2014, "Travel patterns and the potential use of electric cars - Results from a direct survey in six European countries", *Technological Forecasting and Social Change*, vol. 87, pp. 51-59.

Patel, R., Davidson, B. (2003), *Forskningsmetodikens grunder*. Lund: Studentlitteratur.

Power, J.D., 2010, "Drive Green 2020: *More Hope than Reality?*". J.D. Power and Associates/McGraw-Hill, Westlake Village.

Rauh, N., Franke, T. & Krems, J.F. 2015, "Understanding the Impact of Electric Vehicle Driving Experience on Range Anxiety", *Human Factors: The Journal of Human Factors and Ergonomics Society*, vol. 57, no. 1, pp. 177-187.

Renault. 2017. *Nya Zoe*. [ONLINE] Available at: <https://www.renault.se/bilar/personbilar/nya-zoe.html>. [Accessed 29 March 2017].

Rogers, E.M. (1983) *Diffusion of innovations*. Third edition. New York: The Free Press.

Rogers, E.M. (2003) *Diffusion of innovations*. Fifth edition. New York: The Free Press.

Sahin, I. 2006, "Detailed review of Roger's Diffusion of Innovations theory and educational technology-related studies based on Roger's theory". *The Turkish Online Journal of Educational Technology*, vol. 5, no.2, article 3

Tony Seba. (2017). *The electric Vehicle Disruption - End Of Oil by 2030*. [Online Video]. 17 March 2016. Available from: <http://tonyseba.com/>. [Accessed: 16 February 2017].

Utterback, J.M. 1994, "Mastering the dynamics of innovation: how companies can seize opportunities in the face of technological change", *Harvard Business School Press*, Boston, Mass.

Young, W., Hwang, K., McDonald, S. and Oates, C.J., 2009, "Sustainable consumption: green consumer behaviour when purchasing product". *Journal of Sustainable Development*, Vol. 18, pp.20–31.

Yu, A.S.O., Silva, L.L.C., Chu, C.L., Nascimento, P.T.S. & Camargo, A.S. 2011, "Electric vehicles: Struggles in creating a market", pp. 1.

Ziefle, M., Beul-Leusmann, S., Kasugai, K. & Schwalm, M. 2014, "Public perception and acceptance of electric vehicles: Exploring users' perceived benefits and drawbacks", pp. 628.

Appendix

Interview guide

Introduction. The interviewers make a brief explanation about the project.

Starting questions

- How is your life situation? Can you tell us about yourself?
 - What is your occupation?
 - What is your highest education level?
- Interest in cars?
 - Are you one of the first in your circle to buy a new model when it comes out?
 - How much knowledge would you say you have about BEVs?

Product

- What car do you currently drive?
 - How do you use your BEV? (Second car, only to work, weekends?)
 - What other car do you have, and why?
 - How often do you purchase a new car?
 - How much do you drive on a daily basis?
 - Do you experience any change in the way you use the car after the change to a BEV?
 - If so, how?
- How is it now? Are you satisfied with your car situation? Why/why not?
 - What do you value the most when it comes to having a car?
- Do you think that a BEV is more environmentally friendly than a conventional car?
- What aspects are most important for you in the purchase decision?
- How do you find facts and information?
 - How do you prefer to get information?
- Is there anything you would like a BEV to do/have that would improve your experiences? (Another size, more practical etc.)
- What do you think needs to happen for the general public to buy a BEV?

Mobility (Charging time, infrastructure, range, charge at home/work?)

- How do you perceive charging vs. refueling? Where do you charge?
- How often do you go on longer trips? How important is it for you to reach that destination without charging?
 - How do you manage longer trips?
- What is the threshold range for a BEV in your opinion?
 - What situations constitute your threshold range?

Financials (Price, Residual Value, TCO)

- To what extent did you consider the purchase price when buying your car?
- Did you do a financial calculation when taking the decision? The financial cost or TCO?
 - Own it yourself or only leasing?
 - Do you think about the electricity bill?
 - To what extent were you read up on the taxable benefits and taxation rules when deciding?
 - What were the alternatives?
- How often do you normally buy a car?
 - How long do you plan to have the present car before buying a new one?
 - Do you have any concerns regarding selling your BEV in the future?
- Why did you end up buying a BEV?
 - Did you have any concerns before acquiring it?
 - Why didn't you buy a BEV earlier than you did?
 - Would you go back to having a conventional car?
 - How do you think the BEVs will progress in the future?
 - Why?
- Would you buy a new BEV? Why/Why not?
 - Any advantages? Disadvantages?

Concluding questions

- What do you think about this offering (battery included in the price or battery leasing)?
- What do you think about this offering (car rental included)?