Future Users of Plug-in Hybrids and Battery Electric Vehicles

Characteristics of the future early adopters and early majority in the Netherlands

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SUMMARY

One approach to reduce the greenhouse gas emissions in the transport sector is to change transportation modes to become more electric. The scope of this research is on the Plug-in Hybrid Electric Vehicle (PHEV), the Electric Vehicle with a Range Extender (EREV) and the Battery Electric Vehicle (BEV). BEVs are the most desirable form of passenger cars, because of their zero tailpipe emissions and their potential of 100% reduction of CO$_2$ emissions.

The slow adoption of the electric vehicles (EVs) can be explained by using the adoption curve of Roger (2003). In this adoption curve the adopters are categorized into five categories on the basis of the moment when they adopt an innovation. The five categories from first to last adopters are: Innovators, Early adopters, Early majority, Late majority and Laggards.

This research aims to identify the factors that may accelerate the three markets (EV, charge infrastructure and energy) relevant for PHEVs, EREVs and BEVs in the Netherlands. The focus is on the requirements of the future users (early adopters and early majority) of PHEVs, EREVs and BEVs.

The main research question is:

What are the characteristics of the early adopters and early majority of Plug-in Hybrid Electric Vehicles and Battery Electric Vehicles and what are their requirements to the Dutch EV market, charge infrastructure market and energy market?

To answer the main research question, literature is studied, two discussion groups on LinkedIn are followed and eight open interviews were used to collect data and to perform the analysis.

The biggest issue in the EV market is the range problem and the need to increase the range of the EV. PHEVs and EREVs are often considered as a solution to the range problem.

The price of the EV is highly dependent on the battery and is likely to remain expensive in the next decade. More development in batteries is needed to make the EVs more attractive with better performance and lower prices.

The number of (quick) charging poles is increasing, but there are still more (public) charging poles needed to obtain a nationwide coverage. The majority of the Dutch population does not have the ability to charge at home in a safe way and is dependent on public charging poles. Quick chargers can reduce the fear of the limited range and lower the threshold at car users to purchase or use an EV. But quick charging has a big impact on the battery and reduces the lifetime of the battery. Battery swapping stations and inductive charging may be attractive alternatives for the users. It is more user-friendly, because it takes away the need for charging by wire and slower charging times. But they are very expensive and large investments are needed.

The peak demand when a lot of cars are (quick) charging will be a problem and will have a big impact on the electricity grid. The smart grid concept has to be more applied, where electricity production and consumption will interact with each other to prevent electricity shortage or surplus. EVs will be important for this application with controlled charging.

The early adopters will be the middle and higher class lease drivers, with a detached house or having the ability to charge at home. Also companies which are pursuing sustainability objectives or authorities with an example function will be the early adopters of EVs. When the EV gets more technically developed, more individuals will drive electrically also and they will be the early majority.

The most common and important requirement to drive an EV is the financial aspect. This includes arrangements like lower or no tax addition, no road tax, lower total cost of ownership, getting paid by the employer and the increasing cost of driving conventional cars. Eventually the total costs of ownership of the EV should be lower than the conventional car without the tax advantages.

The need of the early adopters and early majority will require a tailor-made solution. The right vehicle for the right trip. The need to own a private vehicle will shift towards the need to have access to mobility. In this case the user can go from A to B, without having to be the owner of the vehicle.
SAMENVATTING

Elektrische auto’s (EV’s) kunnen de uitstoot van broeikasgassen in de transportsector verminderen. Het doel van het onderzoek is om inzicht te krijgen hoe EV’s aantrekkelijker gemaakt kunnen worden. Drie vormen van elektrische auto’s worden hierbij beschouwd: Plug-in Hybrid Electric Vehicle (PHEV), de EV met een Range Extender (EREV) en de Battery Electric Vehicle (BEV).

De langzame adoptie van EV’s zou verklaard kunnen worden met behulp van de adoptie curve van Rogers (2003). In deze adoptiecurve worden de adopters gecategoriseerd op basis van het moment waarop iemand een innovatief product aanschaft. De vijf adoptiecategorieën van eerste tot laatste kopers zijn: Innovators, Early adopters, Early majority, Late majority and Laggards.

Het doel van dit onderzoek is het identificeren van de factoren die de drie markten (EV, laadinfrastructuur en energie) van PHEV’s, EREV’s en BEV’s in Nederland kunnen versnellen. Hierbij ligt de nadruk op de eisen van de toekomstige gebruikers (early adopters en early majority).

De centrale onderzoeks vraag voor dit onderzoek is:

Wat zijn de kenmerken van de early adopters en early majority van de Plug-in Hybride Electric Vehicles en Battery Electric Vehicles en wat zijn hun eisen op de Nederlandse elektrische automarkt, laadinfrastructuur markt en energie markt?

Om de centrale onderzoeks vraag te beantwoorden is literatuur bestudeerd, zijn twee discussiegroepen op LinkedIn gevolgd en zijn acht open interviews afgenomen om gegevens te verzamelen en te analyseren.

Het grootste probleem in de EV markt op dit moment is de actieradius. Een toename van de actieradius van de EV is nodig. PHEV’s en EREV’s worden hierbij vaak gezien als een oplossing voor het actieradius probleem.

De batterijen voor elektrische auto’s zal duur blijven in de komende tien jaar en meer ontwikkeling in batterijen zal nodig zijn om de EV’s aantrekkelijker te maken met beter prestaties en goedkoper te maken. Want de prijs van de EV is sterk afhankelijk van de batterij.


Het smart grid concept moet meer worden toegepast, waarmee de elektriciteit productie en consumptie op elkaar worden afgestemd. Met behulp van gestuurd laden kunnen EV’s van belang zijn voor deze toepassing.

De early adopters zullen de midden- en hogere klasse leaserijders zijn, met een vrijstaand huis of met de mogelijkheid om thuis te kunnen laden. Ook bedrijven die duurzaamheidsdoelstellingen hebben en instanties met een voorbeeldfunctie zijn de early adopters. Als de EV meer technisch ontwikkeld is, zullen ook meer particulieren elektrisch gaan rijden en zij zullen de early majority zijn.

Het meest genoemde en belangrijkste vereiste om een EV te rijden betreft het financiële aspect. Dit geldt voor regelingen zoals lagere of geen fiscale bijtelling, geen wegenbelasting, lagere totale kosten, bijdrage van de werkgever en de stijgende kosten van het rijden van conventionele auto’s. Uiteindelijk zullen de totale kosten van de EV goedkoper moeten worden dan de conventionele auto zonder de fiscale voordelen.

De behoefte van de early adopters and early majority zal mobiliteit op maat zijn. Dan verschuift de behoefte om je eigen mobiliteitmiddel te bezitten naar de behoefte om toegang tot mobiliteit te hebben. In dit geval kan de gebruiker van A naar B, zonder zelf de eigenaar van het voertuig te hoeven zijn.
1 INTRODUCTION

The transport sector accounts for about 19% of the global energy use and 23% of energy-related Carbon dioxide (CO\textsubscript{2}) emissions in 2008. It is predicted that the energy use and emissions of the transport sector is going to increase in the future by nearly 50% by 2030 and more than 80% by 2050 (OECD/IEA, 2009). CO\textsubscript{2} is a greenhouse gas (GHG) which occurs naturally, but their atmospheric concentrations increased over the last 250 years due to human activities. The increase of CO\textsubscript{2} concentrations in the atmosphere is primarily caused by the use of fossil fuel and the effects of change in land use (IPCC, 2007).

The emissions from the transport sector mainly result from the use of fossil fuels with internal combustion engines (ICE). Another issue with the use of fossil fuels is the limited stock of the oil reserves, which will probably be depleted before or within the next century (McKinney, Schoch, & Yonavjak, 2007). Other disadvantages of the increasing transport sector are: traffic jams, air pollution and less traffic safety. ICE generates tailpipe emissions of pollutants as PM\textsubscript{10} (Particulate Matter), NO\textsubscript{x} and VOCs (Volatile Organic Compounds) which are harmful to human health especially in urban areas (Offer, Howey, Contestabile, Clague, & Brandon, 2010).

In the Netherlands, the CO\textsubscript{2} emission from road traffic was 33.8 Mton in 2010. In 1990, the CO\textsubscript{2} emission was 25.5 Mton. That is an increase of 25% in 20 years (CBS, 2012). Travelling with the passenger car is the most popular travel mode by Dutch people. People in the Netherlands travelled in total 183.6 billion kilometers in 2010. Of this total, 135.1 billion kilometers is done by 7,622,353 passenger cars (CBS, 2011a; CBS, 2011b). People use their cars because some developments make the use of private cars more attractive and sometimes necessary. Reliable motor vehicles and the corresponding infrastructure (roads, petrol stations, and traffic regulation) became more available. Higher incomes increased the car ownership and car use. Urban sprawl increased the need to travel. People need their cars for living, working or shopping, but people also presume the availability of a car when making choices on their living, working and shopping. (Steg, 2007)

Table 1 - Total numbers and percentages of different kinds of passenger cars in the Netherlands on January 1, 2011 (CBS, 2011b).

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Gasoline</th>
<th>Diesel</th>
<th>LPG</th>
<th>Only electricity (BEV)</th>
<th>Elec. + gasoline</th>
<th>CNG</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>6,170,127</td>
<td>1,297,113</td>
<td>211,455</td>
<td>523</td>
<td>55,303</td>
<td>912</td>
<td>114</td>
</tr>
<tr>
<td>Percentage</td>
<td>79.76%</td>
<td>16.77%</td>
<td>2.73%</td>
<td>0.01%</td>
<td>0.71%</td>
<td>0.01%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Fossil fuels are the primary energy sources for the Dutch passenger cars (Table 1). One approach to reduce the GHG emissions in the transport sector is to follow the order of the Trias Mobilica (based on Trias Energetica): 1.) Prevent transportation, 2.) Change transportation and 3.) As efficient as possible fossil fuel use in the mobility system.

In this research, the scope remain on the electric vehicle (EV). The different kinds of EVs can be distinguished in the following categories (DHV, 2009):

- **Micro hybrid**: Electric when stationary (start-stop, reduction potential fossil fuel 5-10%).
- **Mild hybrid**: Electric when stationary and accelerating (reduction potential 10-20%).
- **Full hybrid**: Driving autonomous on low speed (reduction potential 25-40%).
- **Plug-in hybrid (PHEV)**: Some tens of kilometers electric, then as full hybrid (for example with a range extender).
- **Battery electric vehicles (BEV)**: Operating 100% electric (reduction potential 100% with electricity from renewable sources). The different charge techniques are:
  - Normal charging (NC) in 6 to 8 hours;
  - Quick charging (QC) in less than 1 hour;
  - Battery swapping (BS) in less than 5 minutes.
BEVs are the most desirable form of passenger cars, because of the zero tailpipe emissions and the potential of 100% reduction of CO\textsubscript{2} emissions. The electricity can be produced from biomass, wind-, solar- and nuclear energy and decarbonised fossil fuels (Campanari, Manzolini, & García de la Iglesia, 2009; Offer et al., 2010). Within the EVs, the scope remains on EVs with a plug. These are the PHEV and the BEV.

### 1.1 Problem definition

EVs could be a way for a more sustainable mobility, but there are some issues to take into account. Sustainability consists of three elements: Ecology, Social and Economy (Glavič & Lukman, 2007). These three elements can also be divided in eleven themes (Figure 1).

![Schematic overview of sustainability](IVAM, 2012)

Figure 1 – Schematic overview of sustainability (IVAM, 2012).

Compared to the ICE cars, EVs has some drawbacks. In the Ecological element, some materials (for example lithium) are more needed and used in the EVs. Lithium is needed for the Li-ion battery which is considered to be the most favorable technology regarding to the power density, energy density and efficiency (Campanari et al., 2009). This also requires different disposal measures. EVs are also more dependent on the electricity grid and the emissions from power plants burning fossil fuels (coal and natural gas).

In the social element, EVs can have some inconveniences compared to the ICE. For example the shorter cruising range (from ±800km with ICE to ±150km with BEV) and longer and more often charging periods. Also EVs have a substantial higher purchase price. This element could be very important for a successful introduction of the EV.

In the economical element, changes in road taxes and fuel taxes could appear. In some cases, new electrical infrastructure is needed which will cost money. There are also some technical challenges. Batteries have to be large, heavy and expensive for a reasonable range, because of the relatively low energy density of batteries. A range of 200 km requires around 150 kg of lithium ion cells. (Offer et al., 2010)

At this moment the adoption of EVs is slow. This can be explained by the S-curve based on the adopter categorization on the basis of diffusion of innovation (Rogers, 2003). On January 1\textsuperscript{st} 2011, BEV had a market share of 0.01% (Table 1). According to the adopter categorization, this means that EVs are in the adopter category ‘Innovators’ (Figure 2).

![Curve with adopter categorizations and S-curve of market share](Wikipedia, 2012)

Three markets can be distinguished within the EV sector: EV market, charge infrastructure market and energy market.
1.2 Research aim
This research aims to identify the factors that may accelerate the three markets (car, charge infrastructure and energy) of PHEVs and BEVs in the Netherlands. The focus is on the requirements of the future users (early adopters and early majority) of PHEVs and BEVs, with the emphasis on passenger cars.

1.3 Main research question
The main research question is:

What are the characteristics of the early adopters and early majority of Plug-in Hybrid Electric Vehicles and Battery Electric Vehicles and what are their requirements to the Dutch EV market, charge infrastructure market and energy market?

1.4 Sub questions
To answer the main research question, seven sub questions have been formulated:
1. What kinds of PHEVs are available and what are their characteristics?
2. What kinds of BEVs are available and what are their characteristics?
3. How can the demand side of the three markets of the PHEVs and BEVs (EV, charge infrastructure and energy) be described?
4. Which groups of users of PHEVs and BEVs can be distinguished and what are their characteristics?
5. Who will be the early adopters and early majority of EVs in the future and what are their characteristics?
6. What are the main pros and cons of the future groups of users to switch to PHEVs and BEVs?
7. What has to be done to overcome the bottlenecks and to accelerate the adoption of EVs?
2 METHODOLOGY

Sub questions 1 and 2 and partially sub questions 3 and 4 are answered with a literature study of scientific articles and information provided by governmental and non-governmental organizations which are involved in the development of PHEVs and BEVs and their three markets (Chapter 4). Sub questions 3 and 4 (partially) and 5, 6 and 7 are answered by a qualitative study in two phases: an orientation phase and a strategic refinement phase.

In the orientation phase, discussion groups on LinkedIn are used (Chapter 5). In the last decade, the use of social media has strongly increased on the internet and is still increasing very fast. LinkedIn is a social networking website for people in the professional environment. Within LinkedIn people can form and join discussion groups on a certain subject. This can result in an interesting and useful data, which may or could be a new method of gathering information for research. There are also active discussion groups about electric vehicles where EV users and experts give comments in the discussion groups. First, an overview of the relevant discussion groups and their activity is made. Secondly, a selection is made of discussion groups to analyze. Then, an overview is made of relevant discussions and comments in the selected discussion groups in the period of January, February and March 2012. This results in a large amount of data. To analyze all this data, the method as described in the book ‘Kwalitatief Onderzoek’ (‘Qualitative Research’) by Baarda et al. (1995) is used. This method includes the following steps:

1. Selecting information on relevance.
2. Splitting the relevant text into fragments.
3. Labeling of the fragments.
4. Ordering and reducing of the labels.
5. The determination of the validity of the labeling. When a preliminary labeling system is established, it is important to verify that this scheme is valid when new data is added from more or less equivalent persons, situations or processes. The labeling has to be applied so far on this new data to check if the labels cover the new data. If this is not the case, then the labeling should be adjusted so that it is an adequately dense coverage. If it is a fairly fundamental change, the coverage should be checked again on the basis of new data. During this research, the labeling schemes are not verified with new data, because of the limited available time.
6. The defining of the key labels.

More details of these steps can be found in Baarda et al. (1995).

At the end of the orientation phase the LinkedIn analysis are evaluated for the second phase: the strategic refinement phase.

In this phase a new plan for doing open interviews has been made (Chapter 6). The participants are more strategically selected to get better and more refined answers to the research questions. Respondents are selected from the car market, the charge infrastructure market and the energy market. They are also selected in the adopter categories of innovators and early adopters. A topic list is made and used during the interview (Appendix 6). The interviews are recorded on a voice recorder and transcribed to text. These elaborated texts are analyzed in the same way as the data from LinkedIn as described above, with the method from Baarda et al. (1995).
The research methods are schematically shown in Figure 3.

Figure 3 - Scheme of the methodology
3 GROUPS OF USERS

On the basis of when individuals first begin using a new idea over time, they can be classified into adopter categories. Each adopter category consists of individuals with a similar degree of process to adopt an innovation. This is an easier way of describing users of a system instead of describing each individual. A method of categorization that is most widely accepted is the method proposed by Rogers (2003). The adopter distribution over time tends to follow a (bell-shaped) normal frequency distribution. Figure 4 shows the normal frequency distribution divided into five adopter categories: Innovators, Early Adopters, Early Majority, Later Majority and Laggards. Including the approximate percentage of individuals by laying of the average time of adoption (\( \bar{x} \)) and its standard deviations (sd). Pronounced breaks do not occur between the five categories, but there are some important differences between them, which are described below. (Rogers, 2003)

**Innovators**

Inovators are not afraid of taking risks. It is almost an obsession and they have a desire for the rash, the daring and the risky. They have a high interest in new ideas and have their social relationships around the world. An innovator has also the ability to absorb the possible losses from an unprofitable innovation, where it can be very helpful to have control of substantial financial resources. Another prerequisite is the ability to understand and apply complex technical knowledge. At the time he or she adopts, the innovator has to cope with a high degree of uncertainty and has to accept an occasional setback when a new idea proves unsuccessful. Innovators have a gatekeeping role in the flow of new ideas into a system and the diffusion process.

**Early Adopters**

Compared to innovators, early adopters are a more integrated part of their local social system. They have the highest degree of opinion leadership in most systems and are considered by many following adopters to be “the individual to check with” before adopting a new idea. Early adopters are respected by their peers and are often responsible for the success of an idea to the critical mass. Uncertainties about a new idea are decreased by early adopters by adopting it and to evaluate the innovation to near peers. They make innovation-decisions and put their stamp on a new idea to earn esteem of colleagues and to have a central position in their communication networks.

The socioeconomic characteristics of early adopters are that they are no different from later adopters in age, have more years of formal education than later adopter, have a higher social status, have a greater degree of upward social mobility and early adopters have larger-sized units (e.g. farms, schools, companies).

**Early Majority**

The early majority frequently interacts with their peers, but in most cases they are not holding the position of opinion leadership in their social system. They adopt new ideas, just before the average member of the system. This makes them an important link in the diffusion process. They may think carefully and slowly before the early majority completely adopts a new idea. Their innovation-decision period is relatively longer.

**Late Majority**

There may be two reasons why the late majority adopts a new idea. It may be an economic necessity and it may be the result of increasing peer pressure. They are skeptical and cautious in approaching...
innovations and do not adopt a new idea until most others in their system have already done so. Before the late majority is convinced to adopt a new idea, the weight of system norms must definitely favor an innovation and most of the uncertainty must be removed.

**Laggards**
Laggards process almost no opinion leadership and are the last in a social system to adopt. Most of them are near isolated in the social networks and interact primarily with others who also have relatively traditional values. The past is their point of reference. The innovation-decision process of the laggards is relatively lengthy. From the laggard’s view of point, the resistance to innovations may be entirely rational. They must be certain that a new idea will not fail. The laggard is forced to be extremely cautious in adopting new ideas, because of their precarious economic position.

The main differences between the earlier and later adopters of innovations are the socioeconomic status, personality variables and communication behavior. From 10 percent adoption to 20 percent adoption is an important part of the curve. It is often impossible to stop the further adoption of a new idea at this point.
4 EV, CHARGE INFRASTRUCTURE AND ENERGY MARKET

4.1 EV market

There were 3,537 electric vehicles in the Netherlands at the end of May 2012, 2,700 of which were passenger cars (Agentschap NL, 2012). Figure 5 and Table 2 show the growth in the number of electric vehicles on the road in the Netherlands. In particular, the increase in the number of EREV and PHEV is conspicuous.

![Growth curve electric vehicles](image)

**Figure 5 - Growth curve electric vehicles in the Netherlands** (Agentschap NL, 2012)

**Table 2 - Recent numbers of different kinds of electric vehicles in the Netherlands** (Agentschap NL, 2012)

<table>
<thead>
<tr>
<th>Type vehicle</th>
<th>31-12-2011</th>
<th>31-03-2012</th>
<th>30-04-2012</th>
<th>31-05-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger car (BEV)</td>
<td>1,124</td>
<td>1,418</td>
<td>1,446</td>
<td>1,517</td>
</tr>
<tr>
<td>Passenger car (EREV &amp; PHEV)</td>
<td>15</td>
<td>580</td>
<td>785</td>
<td>1,183</td>
</tr>
<tr>
<td>Company car &lt;3500</td>
<td>164</td>
<td>295</td>
<td>318</td>
<td>344</td>
</tr>
<tr>
<td>Company car &gt;3500</td>
<td>21</td>
<td>22</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Bus</td>
<td>91</td>
<td>90</td>
<td>89</td>
<td>89</td>
</tr>
<tr>
<td>Three wheeler</td>
<td>191</td>
<td>210</td>
<td>243</td>
<td>286</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>96</td>
<td>91</td>
<td>94</td>
<td>95</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,702</strong></td>
<td><strong>2,706</strong></td>
<td><strong>2,997</strong></td>
<td><strong>3,537</strong></td>
</tr>
</tbody>
</table>

The objective is to have about 200,000 electric cars in the Netherlands in 2020 (Agentschap NL, 2012). This is 2.6% of the current number of passenger cars. The number of EVs in future will be very dependent on the strategies of the automotive sector and the contribution of governments, charge infrastructure providers, lease companies and providers of new service concepts (DHV Group, 2011).

The EV market can be characterized as follows (DHV Group, 2011):

- Currently the emphasis is on two kinds of EVs: small city vehicles and bigger far more expensive models.
- There is a remarkable variation in attitude towards electric driving of manufacturers.
- Some manufacturers see PHEV as the stepping stone, others bet on BEVs.
- Batteries will remain expensive in the next 5 to 10 years.
• (Really) quick charging is an option within 5-10 years.
• Wireless technology is an antidote to range anxiety.
• Smart grid and smarter connected vehicles are to revolutionize the way we use electricity.
• Battery switching may be an attractive alternative.

Figure 6 - An overview of some EVs which are available on the European market (DHV Group, 2011)

4.1.1 Conventional Vehicles
Conventional vehicles are driven by Internal Combustion Engine (ICE) which uses fossil fuels, like gasoline and diesel (Figure 7). (Agentschap NL, 2012)

4.1.2 Plug-in Hybrid Electric Vehicles (PHEVs)
A PHEV is driven by an electromotor or by an ICE or by a combination of the electromotor and ICE (Figure 7). The electromotor is powered by a battery. The battery can be recharged by plugging the battery to the electricity grid. A PHEV can drive around 20 to 40 km full electric, after which the ICE takes over. (Agentschap NL, 2012) The tank-to-wheel efficiency of a PHEV is dependent on the driving patterns, because distances have an influence to the fraction of driving in a PHEV. Short distances results in low fraction and achieve large fuel savings compared to conventional vehicles. Longer distances with the PHEV results in lower fuel savings. Driving behavior also affect the tank-to-wheel energy-use of a PHEV. (Raykin et al., 2012)

4.1.3 EV with Range Extender (EREV)
An EV with a range extender (EREV, Extended Range Electric Vehicle) is always driven by an electromotor (Figure 7). Daily short (commuting) trips of around 40 to 70 km can be done on electricity from the battery. For longer trips (and high speeds above 120 km/h) a range extender can be used. A range extender is an ICE, which works as a generator for the electro motor. (Agentschap NL, 2012; Momoh & Omoigui, 2009) Because the EREV and the PHEV are almost the same, the two labels can be switched or sometimes they are seen as one technology and only one of the two names is used.

4.1.4 Battery Electric Vehicles (BEVs)
A BEV is only driven by an electro motor powered by a battery, which can be recharged from the electricity grid (Figure 7). Dependent on the capacity of the battery, BEVs have a range of 80 to 350 km (Agentschap NL, 2012). Because BEVs are more expensive and have a limited range, their market share is currently very small (Hoen & Koetse, 2012). Also the limited number of different models, shorter range, longer charging time and limited available charging locations are reasons why current car drivers are not driving a BEV (Hoen & Koetse, 2012). The most common positive characteristics of the BEVs are: no noise, no tailpipe emissions and automatic gear (DHV Group, 2011; Hoekstra,
The electromotor of the BEV is simpler than the ICE. That is why the electromotor is more reliable and requires less maintenance (Hoekstra, 2009).

### Figure 7 - Schematic overview of the conventional vehicle with an Internal Combustion Engine, the Plug-in Hybrid Electric Vehicle, the EV with range extender and Battery Electric Vehicle. The sizes of the components are relative.

#### 4.1.5 Current users
The current users of the EV are the innovators. They are more positive to the BEV compared to other car users. The reason for this could be that the innovators are driving less kilometers a year (Hoen & Koetse, 2012).

#### 4.1.6 Early Adopters
The possible characteristics of the early adopters of EVs are (DHV Group, 2011):
- Predictable mobility pattern of the car, limited distance travelled per day (50-150 km).
- Nighttime and intermediate periods available to recharge (at least 30 min in case of quick charging, or 4-8 hrs in case of slow charging) during the day.
- Yet intensive or daily use of the car, the more kilometers the easier the high purchase costs can be recovered (and the lower the relative environmental impact).
- Appreciation of certain comfort aspects, such as the absence of noise, odor and gears.
- Willingness to pay higher total costs, willingness to pay the far higher initial costs.
- Willingness to compromise on choice (look and feel).
- Appreciation of the lower environmental impact (and/or the green image).
- Public (local) authorities
- Professional fleet owners:
  - Utility and energy companies
  - Taxi operators
  - Delivery services
  - Large companies (with focus on Corporate Social Responsibility)
- End-users:
  - City dwellers / commuters, green conscious and flexible.
The negative valuation can be reduced significantly, when the limitations of BEVs can be removed. An increasing range, faster charging time and closer location of charging possibilities are the most important. It could be that they are still on average negatively valued due to unfamiliarity with the new auto technologies and the resulting uncertainty about the performance and ease of use (Hoen & Koetse, 2012).

4.2 Charge Infrastructure Market

There were 1,801 public charging poles, 1,330 semi-public charging poles and 34 quick chargers for electric cars in the Netherlands at the end of May 2012 (Agentschap NL, 2012). Figure 8 shows the number of charging poles in the Netherlands in the last 2.5 years.

Figure 8 - Number of charging poles in the Netherlands in 2010, 2011 and May 2012 (Agentschap NL, 2012)

4.2.1 Normal charging

Charging poles at parking lots is an extra ease for the EV user. The battery charges automatically while your EV is parked. The only extra action the user has to take is to plug the cable between the car and the charging pole. The main advantages of charging at a pole are: you do not need to drive to a pumping station to refuel, with electricity from the pole you can heat your car in the winter and cool down in the summer. (Hoekstra, 2009)

Several grid operators launched in 2009 the foundation ‘Stichting e-laad.nl’. Their goal with e-laad.nl is to install 10,000 in three years to gather experience and to stimulate the introduction of EVs (Stichting e-laad, 2012). If the local government encourages the installation of charging point, they can stimulate a cleaner and quieter city (Hoekstra, 2009).

4.2.2 Quick chargers

Quick chargers can reduce the fear of the limited range of the EV. With a quick charger, it is possible to charge for 200 km range in 10, 20 or 30 minutes. A big issue with quick charging is the battery. Very expensive batteries are needed to be compatible with quick chargers and it still will have an influence on the battery life-time. But there are a lot of developments for better batteries going on at the moment. (Hoekstra, 2009)

4.2.3 Battery swapping

Currently, there are developments in battery swapping stations. With a battery swapping station of Better Place, an empty battery can be replaced with a fully charged battery within 2 minutes. This process can be done full automatically. The EV user only has to drive the EV at the right spot and it is not necessary to leave the car. The price of the EV and the battery are decoupled and the uncertainties at the users about the battery can be taken away. (Better Place, 2012; Hoekstra, 2009)
4.2.4 *Induction chargers*

Charging through induction is wireless. Electrical lines are build into the driving lanes and at the moment an EV is driving above the lines, they will be activated at this point. Right above the road, magnetic fields will be present. Inside the EV, a coil is placed which works as a dynamo to charge the battery. The main advantages of this system are that the EVs can have smaller batteries and never have to stand still for charging. This application is in their infancy and to installation of the infrastructure will be very expensive. (Hoekstra, 2009)

4.3 *Energy Market*

EVs contribute to a better air quality. The electric car uses electricity generated at a central power plant. From that, it reduces the dependency of expensive oil and refueling (or recharging) is cheaper. Above all, EVs have the potential to the transition to the use of renewable sources for mobility. This reduces the emissions from vehicles enormously and it gets even more interesting when the price of fossil fuels increases and the renewable sources are getting cheaper. EVs are growth markets for electricity companies and battery manufactures, but are market loss for oil companies. (Hoekstra, 2009)

When it is possible to get electricity from everywhere through long distances (a super grid), it will increase the possibilities for the use of renewable sources, because renewable sources are dependent on variable weather conditions. There is more wind above the seas and coastal regions and there is more solar radiation in southern Europe and northern Africa. Technically it is possible to transport electricity over long distances with HVDC (High Voltage Direct Current). An example of a HVDC-line is the NorNed-line between Norway and the Netherlands. (Hoekstra, 2009)

There are two options for the Dutch electricity grid to meet the electricity demand. The first one is the ‘copper plate idea’. In this option the electricity grid companies have to install enough cables under the ground to meet to the electricity grid always and everywhere. This requires an enormous investment into the electricity grid. The second option is the ‘smart grid idea’. In this option the electricity demand can be controlled and have a better match with the electricity production. This still requires a lot of money, but will be much cheaper. The EV is an important application in a smart grid to communicate with. Relatively, the EV consumes a lot of electricity. The period to charge the battery of the EV is easy to change to a more convenient period. A passenger car stands still for 90% of the time on average. With a smart grid, EVs can be charged at the moment when there is a surplus of electricity from wind or solar. (Hoekstra, 2009)
5 LINKEDIN ANALYSIS

5.1 Overview discussion groups
First, an overview is made of the relevant discussion groups and their activity on LinkedIn. The activity can be measured by the number of new discussions and new comments in a discussion. An overview of relevant discussion groups and their activity is given in Table 3.

Table 3 - Overview relevant discussion groups and their activity

<table>
<thead>
<tr>
<th>LinkedIn Group</th>
<th>Last week Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Zero Emission Electric Vehicles</td>
<td></td>
</tr>
<tr>
<td>Electric Vehicle Taxi</td>
<td></td>
</tr>
<tr>
<td>Electric Vehicles and Hybrid Electric vehicles test – EV/HEV test</td>
<td></td>
</tr>
<tr>
<td>Electric Vehicles, EV infrastructure and Vehicle to Grid (V2G)</td>
<td></td>
</tr>
<tr>
<td>Hybrid, Electric, PEV, and PHEV Engineering Professional Group</td>
<td></td>
</tr>
<tr>
<td>The Business of Plugging In – A Plug-In Vehicle Conference</td>
<td></td>
</tr>
<tr>
<td>Electric Cars</td>
<td></td>
</tr>
<tr>
<td>Renault Fluence Z.E. owners</td>
<td></td>
</tr>
<tr>
<td>Nissan Leaf owners</td>
<td></td>
</tr>
<tr>
<td>Chevy Volt and Opel Ampera owners</td>
<td></td>
</tr>
<tr>
<td>Electric Vehicles EVs &amp; Electric Scooters &amp; Bikes (LEVs)</td>
<td></td>
</tr>
<tr>
<td>Duurzame mobiliteit</td>
<td></td>
</tr>
<tr>
<td>Elektrisch rijden</td>
<td></td>
</tr>
<tr>
<td>Subgroup: Formule E team</td>
<td></td>
</tr>
<tr>
<td>Subgroup: Elektrische Auto’s</td>
<td></td>
</tr>
<tr>
<td>Zero Emission</td>
<td></td>
</tr>
<tr>
<td>Platform Elektrische Mobiliteit</td>
<td></td>
</tr>
<tr>
<td>The New Motion</td>
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</tr>
</tbody>
</table>

In this overview the activity is categorized in three groups. The discussion groups with less than 5 comments and discussions in a week are considered as not active. The discussion groups with 5 to 20 comments and discussions in a week are considered as a little bit active. In most cases these discussion groups were coupled with RSS-feeds (RSS is a family of web feed formats used to publish frequently updated works, such as blog entries, news headlines, audio, and video in a standardized format). The discussion groups with more than 20 comments and discussions in a week are considered as active. Because of the scope of the research the Dutch discussion groups ‘Elektrisch rijden’ en ‘Zero Emission’ are used for further research.

5.2 Active Discussion Groups (Profiles and Statistics)
These are the profiles of the most active Dutch discussion groups in LinkedIn. The profiles and statistics of the other discussion groups are listed in Appendix 4.

Elektrisch rijden (Electric driving)
This network connects people and professionals who believe in Electric Mobility in the Netherlands and want to work together to make this possible.

Status March 26, 2012
- Created: December 6, 2008
- Type: Professional Group
- Members: 2,995
- Subgroups: 9
- Comments last week: 59
- Discussions last week: 11
Zero Emission

Zero Emission is about electric vehicles. The group is intended for professionals, experts, riders, drivers and anyone who wants to know more about the electric car. Driving without emissions (with sustainable energy) provides a great perspective for the future of mobility. It will not take off itself. The last 50 years there is no greater and more radical change than has been the emergence of the current generation of electric cars.

In this group we will be providing knowledge together and discuss all topics related to the electric car. What is needed for electric vehicles to be a success? And how can we achieve that together? What is already happening now?

We believe that the electric car is essential for mobility in the future. What do you think?

5.3 Labels

In Appendix 5 relevant fragments are listed from the discussions and comments from the discussion groups ‘Elektrisch rijden’ and ‘Zero Emission’ in January, February and March 2012. All these fragments are labeled which define the fragments Table 4.

Table 4 - Head labels and the dimensions of the LinkedIn fragments. The complete table of the labels can be found in Appendix 1

<table>
<thead>
<tr>
<th>Head label</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range problem</td>
<td>Route planning</td>
</tr>
<tr>
<td></td>
<td>Unreliable navigation system</td>
</tr>
<tr>
<td></td>
<td>Range Extender</td>
</tr>
<tr>
<td>Alternatives to EV</td>
<td>Car sharing</td>
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<tr>
<td></td>
<td>Carpooling</td>
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<tr>
<td></td>
<td>OV</td>
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<tr>
<td></td>
<td>Auto borrow or rent</td>
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<tr>
<td></td>
<td>E-Scooter in the city instead of EV</td>
</tr>
<tr>
<td></td>
<td>Electric motorcycle</td>
</tr>
<tr>
<td></td>
<td>Alternative to holidays</td>
</tr>
<tr>
<td></td>
<td>Increasing range</td>
</tr>
<tr>
<td>Acceleration introduction EV</td>
<td>Lower purchase price</td>
</tr>
<tr>
<td></td>
<td>No castles made of air</td>
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<tr>
<td></td>
<td>Less research among drivers</td>
</tr>
<tr>
<td></td>
<td>More quick chargers</td>
</tr>
<tr>
<td></td>
<td>Replacing fixed routines</td>
</tr>
<tr>
<td></td>
<td>Equal to of better than conventional car</td>
</tr>
<tr>
<td></td>
<td>Need for an earning structure EV</td>
</tr>
<tr>
<td></td>
<td>Effort from governments to EV</td>
</tr>
<tr>
<td></td>
<td>Remanufactured car is outdated</td>
</tr>
<tr>
<td></td>
<td>Battery development</td>
</tr>
</tbody>
</table>
## Developments from China

| Survival probability EV                  | EV no financial advantage necessary       |
|                                         | Cheap charging                           |
|                                         | Availability charge stations             |
|                                         | Waiting to current level of the ICE       |
|                                         | Lease company found it difficult          |
|                                         | EV is part of the solution                |
|                                         | Need for focus and strategy               |
|                                         | Interest from population                  |
|                                         | Uncertainty                               |
|                                         | Sustainability                            |

| Price EV                                | TCO EV cheaper                           |
|                                         | Early adopters are not sensitive for costs|
|                                         | EV too expensive for dealers              |
|                                         | EV in terms of profit picture is not of interest to car manufacturers |
|                                         | Owner EV                                  |
|                                         | Price quick charger                       |

| Need drivers                            | Restricted share EV                      |
|                                         | Range problem                            |
|                                         | Charging time problem                    |
|                                         | Direct benefit to user                   |
|                                         | Mobility has become a basis need         |
|                                         | Usability                                |
|                                         | Mobile Apps                              |
|                                         | Use of EV                                 |
|                                         | Charging                                 |
|                                         | Quick charging                           |
|                                         | Reason for electric driving              |

| EV in winter                            | Road holding on slippery roads            |
|                                         | Range in cold weather                     |
|                                         | Comfort in winter                         |

### 5.4 Analysis

#### 5.4.1 Users

Users use their EVs for commuting, because for this purpose the range is not a problem in most cases. The EV is also used as a secondary car besides a conventional car, where the conventional car is used for larger distances.

Mobility has become a basic need. The main needs of the users to the EV are a larger range and less charging time. To make the EV more user friendly, more battery development is needed and wireless charging would be ideal. Wireless charging can be done with induction chargers. The only charging poles which are needed are the quick chargers, because the slow chargers are too slow. Mobile applications can be used with status updates of charging poles, like where they are and if they are available.
There are several reasons why users are driving an EV. Some people drive an EV for the environmental and climate aspects. Others for financial advantages. And some others for the comfort and performances of the EV. It is also stated that the early adopters are not sensitive for the costs. The reasons why someone is not using an EV are the uncertainties about the costs and the ease of use. Also the bad image can disinterest car drivers.

5.4.2 Car

The main problem with the EV is the range. It is very challenging for users to prepare their routes. And it becomes even more challenging when the navigation system does not provide the right information about the location of the charging poles.

EV with a range extender (EREV) is a solution to the range problem and is attractive for lease drivers. But there are discussions about the use of these kinds of cars. Lease drivers are choosing an EREV because of the tax advantage and may use the EREV in another way than for which it is intended. It could be that they use the range extender too often, also for short distances, because they do not charge the batteries as much as possible. The tax addition has to be coupled to the emissions from the EREV. Currently, lease companies are struggling with this issue.

Alternatives to the EV are car sharing, carpooling, public transport, car renting, car borrowing, e-scooters for short distances and electric motorcycles. Another alternative is renting a conventional car for holidays. An issue with car sharing is that the status symbol of the car is too high.

The performances of the EV during the winter are fine. No problems on slippery roads. Only the capacity of the battery is reducing which result in a shorter range. Also the heating is causing a reduction in the range. The cars can be preheated when they are connected to the electricity grid.

To accelerate the introduction of the EV some developments to the car are needed. These are the increase of the range, development of the batteries, lower purchase price, cheap charging and more quick charge possibilities. In short, the EV should have the same or better performances than the conventional car with an ICE. Also an earning structure to the EV is needed. At this moment, the EVs are too expensive for the car dealers and car manufacturers. Some users claim that the total cost of ownership is cheaper, because electricity is much cheaper than fuel. The government should support the users of EV, but eventually this support should not be needed. It is also important that the government is reliable and clear.

5.4.3 Charge infrastructure

At this moment charging is mostly done at the house of the user or at a charging pole in front of the house. Sometimes an extension cord is needed. Charging at work is also done and some users say that charging is easier than refueling.

Quick chargers have more value for the user. A nationwide coverage of quick chargers would be needed. During quick charging some activities for the user in the environment would be needed.

An issue with charging poles is that they disfigure the streets and that they are there for promotion. Another issue is the peak demand when a lot of cars are (quick) charging.

5.4.4 Energy

Sustainable and environmental friendly alternatives to fossil fuels are necessary. Fossil fuels are getting more scarce and expensive. A more expensive and heavier electricity infrastructure is needed, because of the increasing electricity demand from the EV.
6 INTERVIEWS

Eight interviews are done with nine respondents during this research.

The respondents were:
- Joost ter Doest - Founder Rebble - Appendix 7
- Henk Meiborg - Founder Emodz - Appendix 8
- Theo Wolthuis - Founder Mobilectra - Appendix 9
- Ivo Stroeken - Freelancer - Appendix 10
- Magrita Noordmans - Head of Business Development at BAM infratechniek - Appendix 11
- Wim and Alie Kroon - Owners windpark Riedpolder Midlum - Appendix 12
- Joris Kniege - Innovator at Enexis - Appendix 13
- Gertjan Mulder - Teammanager at stichting e-laad - Appendix 14

Table 5 gives a classification of the respondents between expert in the EV, charge infrastructure and energy market and between the adopter categories: innovator and early adopter of the EV.

Table 5 - Classification of the respondents between expert in the EV, charge infrastructure and energy market and between the adopter categories innovator and early adopter of the EV.

<table>
<thead>
<tr>
<th>Car market expert</th>
<th>Charge infrastructure expert</th>
<th>Energy market expert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovator</td>
<td>J. ter Doest; H. Meiborg; T. Wolthuis; W. &amp; A. Kroon; I. Stroeken</td>
<td>G. Mulder</td>
</tr>
<tr>
<td>Early adopter</td>
<td>M. Noordmans</td>
<td>J. Kniege</td>
</tr>
</tbody>
</table>

The interviews are analyzed with the same method as used with the LinkedIn Analysis. First, the irrelevant information is removed. Then the interviews are fragmented. These fragments are labeled which define the fragments. Then, the labels are structured in the following 8 key labels: Current users, Future users, Current EV, Future EV, Current charge infrastructure, Future charge infrastructure, Current energy market and Future energy market. The fragment with their labels can be found in Appendix 7 to Appendix 14. The structured labels can be found in Appendix 2.

6.1 Analysis

6.1.1 Current Users

The current users are a limited and fragmented group. The innovators can be described as people with higher incomes and higher education. Often they are men between the ages of 35 to 50. They are the pioneers and the forerunners of the EV. Also trendy entrepreneurs from the Randstad are driving electric. They are willing to try new things and are willing to do concessions. They have the ability to own two cars and the ability to charge at home or at work. There is also a small group do-it-yourself which convert conventional cars to electric cars. At this moment they are the exceptions and not the mass group. Some companies and governments own an electric car for promotion. Most EVs are business owned and not private owned. A more upcoming group is the lease drivers and people with a car company. All these users are contributing to make the EV successful or unsuccessful.

Innovators are driving an EV, because it is new or it is good for the environment. Lease drivers are driving an EV more often for the financial aspect. They use a PHEV because of the obstacles of the BEV. At this moment no tax addition has to be paid for leasing an EV. Bigger companies are using EV as an experiment or as a promotion tool.

Approximately 80% of the current EVs are used for commuting and business and 20% for private. The average driving distances are approximately 60 to 70 kilometers a day.
Current users experience that there is much unfamiliarity about electric driving among other people. At the same time they get a lot of interest from other people and the current users are willing to share their experience. When people drive an EV for the first time, they always exit the car with a smile. They also experience that you do not have the same freedom compared to the conventional car at this moment. Some (creative) planning is needed before you are driving with an EV. The side effect is that you are driving more efficiently and with fewer kilometers. Current users have a different way of thinking and experience that problems are relative. Experiences from electric drivers are that the EV is nice, easy, quite, smooth, user friendly, comfortable and attractive.

There are no major differences between respondents on the current users of EVs.

6.1.2 Future users

The future users (or the early adopters) are the middle and higher class lease drivers, with a detached house or having the ability to charge at home. Also companies which are pursuing sustainability objectives or authorities with an example function will purchase more EVs. When the EV gets more technically developed, more individuals will drive electric also.

The most common and important reason will be the financial aspect. This includes arrangements like lower or no tax addition, no road tax, lower total cost of ownership, getting paid by the employer and the increasing cost of driving conventional cars. Other reasons are importance of sustainability and good experiences from other EV users.

At first the PHEV and EREV will be used the most and the BEV will come in second. A shift in the secondary cars will happen to be more electric.

The needs of the early adopters are tailor-made. The right vehicle for the right trip. A shift from the need to own mobility may go to the need to have access to mobility. In this case the user can go from A to B, without having to be the owner of the vehicle. The main advantage of this case is that the vehicle can used for the use where it is build for. For example: a small EV can be used for short distances, commuting, in cities and individual transport. A middle class EV for more distance or more people. A PHEV or EREV for longer distances. This also includes the access to other types of transport, like bikes, scooter and public transport. This case is part of the freedom of making choices. So people can still choose to have an own car.

One of the respondents stated that the need to have access to mobility is be present at a small group and most of the people still want to have their own car for the most of their mobility, especially people who are living in the country side. According to the respondent, people have to be pushed by their employers to go from owning mobility to have access to mobility.

The need of the early adopters to the EVs is that they have to be cheaper in purchase (especially smaller models), a larger range, a reliable car, minimal maintenance, no charge problems, comfort, silence, without having to be concerned about the possibilities to drive back and forth and clean.

6.1.3 Current EV

Current purchasing costs of EVs are much higher than the conventional cars, but the fuel costs are lower. The total cost of ownership differs between the different EVs. Some are more expensive than conventional cars and other cost the same or cheaper. For business use the total cost of ownership can be cheaper, because of financial advantages from the government. For private use the total cost of ownership is higher. For short distances and lower speeds it is cheaper to use an EV. The costs for driving an EV are lower, because electricity is cheaper than fuel per kilometer. The electro engine is also more efficient than the ICE.
EVs are clean and have no tail pipe emissions. The Well-to-Wheel efficiency of the EV is also better than the conventional car. Even when the electricity is generated by coal fired power plants. The efficiency will be better when the electricity is generated from renewable sources.

There are various types of EVs, but the supply is limited at the moment. This year there will be a bigger supply of EVs. Also a lot of technologies in the EVs are not standardized.

The EV is often used as a secondary car besides a conventional car, where the conventional car is used for larger distances and more traction for a trailer and the EV for shorter distances. This has to do with the limited range of the current EVs. At this moment partial recharging the EV is often enough and quick charging is not necessary. EVs are functional for commuting, but not for too long distances. Users are thinking more about the route they are going to make and highways are as much avoided as possible.

The EREV can drive full electric for a distance of 60 to 80 kilometers and if the user wants to drive further he can use the range extender or he have to recharge the battery. Currently there is an increase in the purchase of the EREV. This is because of the increase of supply and no tax addition. EREVs are used by people who do not want a second car. EREVs are also considered as an in between solution, because the EREV is a compromise between two technologies. How the EREV are used by lease drivers is dependent on the incentives of the employer, but it is expected that the EREV is getting recharged as much as possible, because of the high fuel prices.

A development at the moment is de decoupling of the car and the battery. So the user buys the car and rent (or leases) the battery. In this way the uncertainty of the depreciation and the life time of the battery can be taken away from the user, because the battery is an unknown factor for most users and a very expensive part of the EV. With the decoupling of the car and the battery, the battery can be used for battery swap stations. There are some different opinions about the decoupling of the battery and the car. Some think it would be very expensive and would be a complex system for the user.

The media is not always positive about the EVs and some EV users say that the information given by the media is not true and not fair, especially about the BEVs. Also the focus of the media is too much on the exceptional use of cars and not on the regular use, because EVs are currently attractive for the regular use and not for the exceptional use.

There is no consistent and clear policy between the governments. Provincial governments have different policies and have different rules for subsidies than the national government. This makes it only more difficult for the future users. Local governments are also not cooperative in some cases.

The developments around EVs are very dynamic and stand really in their infancy. The Netherlands is a forerunner in the use of EVs, but there is still a lot lack of knowledge at the governments. Also the earning structure for the EVs is still unclear at entrepreneurs and businesses.

6.1.4 Future EV

In the Netherlands 80-90% of the people are able to drive EVs. EVs will be a part of the mobility for the users like described in 6.1.2. So, in the shift from the need of owning mobility to the need to have access to mobility. Compared to the other alternatives, EVs are probably having the most potential.

The performance of the batteries will be better, with higher energy density and higher efficiency. Batteries will also be cheaper and the range of the EV will not be a problem anymore.

To make the EV successful, the purchase must be lower or equal to the conventional car. Also more models and supplies are needed. The media has to get more positive about the EVs and the focus should be more and the regular use of the EV. Governments should come with clear and unambiguous regulations and arrangements. The national government should be focusing on stimulating the EV by
financial advantages and the local governments for charging facilities. The success of the EV is also very dependent on the fossil fuel prices.

Obstacles for the success of the EV are the opposition of oil companies, the image of EVs and the supply of second-hand cars.

6.1.5 Current charge infrastructure

Most of the current EV users have the ability to charge at home or at work, but the majority of the population does not have the ability to charge at home in a safe way. People who live in an apartment are dependent on public charging poles.

The most public charging poles are connected to the existing electricity grid and are provided with two charging points. They provide 16 Ampere three phase alternative current (AC). There are different charging pole owners with different charging cards, which is an issue at this moment. There is no earning structure for these slow chargers. Therefore several grid operators launched ‘Stichting e-laad’ to place 10.000 charging poles on public places for free. At this moment there are more charging poles than EVs. It was expected that the price of the charging poles were getting cheaper by now, but due to higher safety regulations this is not the case. Eventually they will get cheaper.

There are not many quick chargers at the moment, but then number of locations is increasing. They can recharge a battery in 20 to 30 minutes for 80%. Quick charging have a big impact on the battery and the most of the batteries are not compatible for quick charging. A bigger investment is needed for quick chargers, because more adjustments are needed in the infrastructure to provide direct current (DC) electricity. Some market parties have an earning structure for the quick chargers.

At this moment there is a battery swap station at Schiphol used by a taxi company. And in Utrecht there is an experiment with induction charging with a bus. The need for the type charging is very dependent on the type of EV.

6.1.6 Future charging infrastructure

Most of the EVs will charge at home. This will have an impact on the electricity grid when the number of EVs will increase. There will be also more public charging poles, which will be covered nationwide.

Slow charging and quick charging will take place beside each other. They also grow more to each other. Slower quick chargers are cheaper and slow chargers can deliver more Amperes. What really is needed with charging poles is an earning structure. Otherwise it will not become a mature market. Also more standardization is needed in the plugs. A proposal is done by some companies for a combo plug. With this plug it is possible to charge slow and quick.

The batteries of the EVs will also be more compatible with quick charging. Quick chargers will also be more available at more locations. For example, along highways and pumping stations. This will also lower the threshold.

There are very different opinions about the future of battery swap stations. The advantages of a battery swap station are that it takes away the need for charging by wire and slower charging times. So it is more user-friendly. Also EVs will have a larger range without battery degeneration. According to some respondents, the battery swap stations are only attractive for regional car fleets. Battery swap stations can also be used as a buffer for the electricity grid. Disadvantages of the battery swap station are it is very expensive and large investments are needed, because a big change in the infrastructure is needed. Also the different kind of batteries of the different car brands will be a problem. For the most users a battery swap station would be unnecessary according to some respondents.
A more user friendly way of charging would be inductive charging. This excludes manual charging. Also this is very expensive and would require a big investment. The efficiency with the transfer of energy needs to be improved to be more attractive.

6.1.7 Current energy market
The current electricity grid is designed for centrally produced electricity by large power plants. The lifetime of the electricity grid is 30 to 50 years. The electricity supply is also very reliable. People are used to have access to electricity everywhere and always.

One development in the energy market is the increase of electricity production from renewable sources (green electricity) to reduce emissions. Another development is the introduction of ‘smart meters’. With these meters data can be collected about the electricity consumption and production per household. Also grid operators are testing what happens when a large number of EVs are charging at the same time. Currently a test is going with controlled charging. EV users have to give a sign (with a smart phone) when they want to use their EV and what the next destination will be. In this way, the system figures out when it is the best time to charge an EV with a minimum level of energy. With this system the electricity demand will be more scattered in certain period of time. An issue with this system is that it requires a behavior change of the users. Grid operators are also testing a battery storage facility.

6.1.8 Future energy market
In the electricity grid of the future more electricity will be produced decentralized by solar panels (on carports), wind turbines, etc. Electricity will be more important in the future, because of the shift from gas to electricity might take place. The use of fossil fuels will decrease and the use of renewable sources will increase. The smart grid application will also increase, where electricity production and consumption interact with each other. EVs will be important for this application with controlled charging. The battery in the EVs can also be used as an electricity buffer.

In short, more electricity production and consumption will take place in the capillaries of the electricity grid. This requires a huge investment in the electricity grid. The smart grid application can reduce the need for big changes in the electricity grid (and also the costs).

The price for energy will increase, but it will also more fluctuate. It will fluctuate more, because it would be more dependent on weather conditions, which is hard to predict. Fossil fuel prices will only increase, because it is scarce and exhaustive. This will also increase the demand for EV.

The environmental awareness and the necessity of the population will also increase. People want to reduce their emissions and want to be less dependent on fossil fuel producing countries and more people produces their own electricity. It is very important that the government makes good choices how they deal with energy market and where the energy is coming from.
7 AGGREGATION

In this chapter the three perspectives Literature & DHV knowledge, LinkedIn and Open Interviews are compared to each other similarities and differences in order to assess important topics. Before this, the three perspectives are putting next to each other in a table which can be found in Appendix 3. In the case of a difference between the three perspectives a deliberated conclusion is made. Only important similarities and differences between the three perspectives are discussed in this chapter. This similarities and differences are distinguished by subject: EV market, Charge infrastructure market, Energy market, Characteristics (future) users, Pros and cons of the future users and Overcoming bottlenecks.

7.1 EV market

7.1.1 Similarities

One of the largest similarities between the three perspectives about the EV is the range problem and that an increase in range is needed.

Another similarity between LinkedIn and the interviews is that EV users need to prepare their routes before driving, because of the limited available range.

From the interviews it can be concluded that the developments in the EV market are very dynamic and that the EV market is still in its infancy. This can also be concluded from the literature which describes that there is a variation in attitude of car manufacturers towards electric driving and the market is dependent on different parties at this moment. For example automotive sector, governments, etc.

In the interviews and on LinkedIn it is stated that there is an increase in the purchase of the EREV, because of the increase of supply and it is a solution to the range problem. It is also attractive for lease drivers, because of the tax advantage. EREVs are used by people who do not want a second car. The EREV is also considered as an in between solution, because the EREV is a compromise between two technologies. According to the literature, some manufacturers see PHEV also as a stepping stone to BEV.

From all the three perspectives it can be concluded that batteries will remain expensive in the next decade and more development in batteries is needed.

It can be concluded from LinkedIn and interviews, that the earning structure for the EV is unclear at the entrepreneurs and businesses. This would have to be solved to convince businesses to adopt EVs. The government should support the users of EV, but eventually this support should not be needed. The policies of the governments should be consistent, clear and reliable.

Another similarity between LinkedIn and interviews are that the total cost of ownership can be cheaper in some cases, because the price of electricity used per kilometer is cheaper than the price of used fuel per kilometer. Only in the interviews it is said that this is dependent on the type of EV you use, if it is used for business or for private use or for what distances it is used.

7.1.2 Differences

On LinkedIn and in the open interviews it is stated that PHEVs and EREVs will be attractive for lease drivers, because of the tax advantage. But they may use the EREV in another way than for which it is intended. On LinkedIn it is stated that it could be that the lease drivers use the range extender too often, also for short distances, because they do not charge the batteries as much as possible. But in the interviews is stated that the use of the range extender is dependent on the incentives of the employer or lease company. It is expected that the EREV is getting recharged as much as possible, because of the high fuel prices. The situation as described in the interviews is more likely to be the case, because
the tax advantage is based on the more environmentally friendly use of the car. The main problem in this situation is a split incentive problem. Who is going to pay the fuel? The driver or the employer? A possible solution for this is to make the tax addition for the user dependent on the emissions of the car. The lease driver gets a limit on his fuel use or emissions imposed by his employer. If he exceeds the limit, than the lease driver has to pay the fuel by himself or he has to pay an extra penalty.

7.2 Charge infrastructure market

7.2.1 Similarities
From all the three perspectives it is clear that more (quick) charging poles are needed and that the number of charging poles is increasing. According the interviews, there will be more public charging poles, which will be covered nationwide.

In the interviews and on LinkedIn it is said that the most current EV users have the ability to charge at home, but majority of the population do not have the ability to charge at home in a safe way and is dependent on public charging poles.

According to the literature and LinkedIn discussions, charging is easier than refueling, because you do not need an extra drive to the pumping station.

From all the three perspectives it can be concluded that quick chargers can reduce the fear of the limited range and lower the threshold at car users to purchase or use EV. In the literature and interviews it is said that quick charging has a big impact on the battery and reduces the lifetime of the battery at this moment, but this might change in the future through more development.

LinkedIn and interviews state that the peak demand when a lot of cars are (quick) charging will be a problem and will have a big impact to the electricity grid.

7.2.2 Differences
Battery swapping stations and inductive charging may be attractive alternatives for the users according to the literature. But the respondent in the interviews are more skeptical about these two technologies. From both it can be concluded that it is more user-friendly, because it takes away the need for charging by wire and slower charging times. But in the interviews it is said that it is very expensive and large investments are needed, because a big change in the infrastructure is needed. In the case of the battery swapping station, the different kind of batteries of the different car brands will be a problem and it is only attractive for regional car fleets with the same EVs (e.g. taxi company).

7.3 Energy

7.3.1 Similarities
All the three perspectives state that sustainable and environmental friendly alternatives to fossil fuels are necessary, because fossil fuels are getting scarcer, are (getting more) expensive and are pollutant. There will be more renewable generated electricity in the future electricity grid according to the three perspectives and the EV market will play a role in this transition.

7.3.2 Differences
According to the literature there are two options for the Dutch electricity grid to meet the future electricity demand. The first one is to install enough cables to meet to the electricity demand always and everywhere, which requires an enormous investment into the electricity grid. The second option is the smart grid idea, where the electricity demand can be controlled and have a better match with the electricity production, which still requires a lot of money, but will be much cheaper than the first option. The literature prefers the second option and describes the important role of EVs in this scenario. On LinkedIn it is only stated that more expensive and heavier electricity infrastructure is needed, which sounds like the first option from the literature. During the interviews both options are
described, but it is concluded that the second option (the smart grid application) would be the best option. In this research, it is concluded that the second option is the better option for the future, because of the arguments which are described in the literature and interviews the pros and cons of the two options. There are no further arguments described on LinkedIn about the first option.

7.4 Characteristics (future) users

7.4.1 Similarities
The descriptions of the innovators of EVs in interviews are quite similar to those described in the literature. They can be described as people with higher incomes and higher education. So they have the ability to absorb the possible losses from an unprofitable innovation and they have the ability to understand and apply complex technical knowledge. They are not afraid of taking risks and are willing to try new things and are willing to do concessions.

The descriptions of the early adopters of EVs in interviews are also quite similar as described in the literature. They will be the middle and higher class lease drivers, with a detached house or having the ability to charge at home, companies which are pursuing sustainability objectives and authorities with an example function. They have more years of formal education than later adopters, have a higher social status, have a greater degree of upward social mobility and early adopters have larger-sized units (e.g. farms, schools, companies).

7.4.2 Differences
Frequently on LinkedIn the terms ‘Innovators’ and ‘Early adopters’ are switched, where the term ‘Innovators’ is not used at all. A characteristic of an early adopter as described on LinkedIn is that they are not sensitive for the costs. This is more a characteristic for an innovator according to the literature and the interviews.

7.5 Pros and cons of the future users

7.5.1 Similarities
A similarity between the literature and LinkedIn is that the innovators use their car for short distances and that this is one of the reasons why they adopt an EV.

Similarities between LinkedIn and the interviews is that the reasons why innovators driving an EV is because for the environmental reasons or for the financial advantages or for the comfort and performances of the EV.

7.5.2 Differences
Earning esteem of colleagues and having a central position in their social networks is according to LinkedIn and interviews less important and is different than the description of early adopters from the literature.

7.6 Overcoming bottlenecks

7.6.1 Similarities
A similarity between literature and interviews is that the BEVs do not have the same freedom compared to the conventional car at this moment and that these limitations have to be removed to have more EVs adopted.

The bottlenecks to overcome, according to all the three perspectives, are the increase in range and faster charging times. A similar bottleneck in the literature and interviews is the unfamiliarity about EVs at people.
7.6.2 Differences

From the interviews it can be concluded that the need of the early adopters and early majority will be tailor-made. The right vehicle for the right trip. A shift from the need to own mobility will go to the need to have access to mobility. In this case the user can go from A to B, without having to be the owner of the vehicle. This is not mentioned in the LinkedIn discussions and literature, but it might be an important development for the adoption of EVs.
8 CONCLUSION, DISCUSSION AND FURTHER RESEARCH

The main research question was:

*What are the characteristics of the early adopters and early majority of Plug-in Hybrid Electric Vehicles and Battery Electric Vehicles and what are their requirements to the Dutch car market, charge infrastructure market and energy market?*

To answer the main research question, seven sub questions have been formulated. These research questions are answered in this chapter.

8.1 Conclusions

8.1.1 Sub questions 1 and 2
What kinds of PHEVs are available and what are their characteristics?

What kinds of BEVs are available and what are their characteristics?

Sub questions 1 and 2 are only answered with literature and are the characteristics of the different EVs are described in paragraph 4.1. For these two sub questions no further conclusions can be made.

8.1.2 Sub question 3
How can the demand side of the three markets of the PHEVs and BEVs (EV, charge infrastructure and energy) be described?

**EV market**
The biggest issue in the EV market at this moment is about the range problem and that an increase in range of the EV is needed.

It can be concluded that the developments in the EV market are very dynamic and stands in their infancy. There is a variation in attitude of car manufacturers towards electric driving and the market is dependent on different parties at this moment. This includes the automotive sector, energy companies and governments.

There are various types of EVs at this moment, but in the most cases they are small city vehicles or bigger far more expensive models. Also the supplies of EVs are limited. At this moment, there is an increase in the purchase of PHEVs and EREVs, because of the increase of supply.

PHEVs and EREVs are often seen as a solution to the range problem. It is also attractive for lease drivers, because of the current tax advantages. But they may use the range extender in other way than it is built for. The lease drivers may use the range extender too often, also for short distances, because they do not charge the batteries as much as possible. This is dependent on the incentives of the employer or lease company and it is expected that the EREV is getting recharged as much as possible, because of the high fuel prices. A possible solution for this is that the tax addition for the user is dependent on the emissions from the car or fossil fuel use. PHEVs and EREVs are also used by people who do not want a second car and is considered as an in between solution, because the EREV is a compromise between two technologies. The range extender is an internal combustion engine which is still running on fossil fuels.

The price of the EV is highly dependent on the battery. The batteries for EVs are likely to remain expensive in the next decade and more development in batteries would be needed to make the EVs more attractive with better performances and cheaper. A development at this moment is de decoupling of the car and the battery. So the user buys the car and rent (or leases) the battery. In this way the
uncertainty of the depreciation and the life time of the battery can be taken away from the user, because the battery is an unknown factor for most users and a very expensive part of the EV.

The total costs of ownership is dependent on the type of EV one uses. If it is used for business or for private use or for what distances it is used. In some cases the total costs of an EV can be cheaper than a conventional car, because the price of electricity used per kilometer is cheaper than the price of used fuel per kilometer.

At first the PHEV and EREV will probably be used the most and the BEV will come in second.

**Charge infrastructure market**

The number of charging poles is increasing, but there are still more (public) charging poles needed which will have a nationwide coverage. More abilities to charge at home are also needed. Most current EV users have the ability to charge at home. But the majority of the Dutch population does not have the ability to charge at home in a safe way and is dependent on public charging poles.

The only extra action the user has to do, compared to conventional cars, is to plug the cable between the car and the charging pole, but an extra drive to a pumping station would not be needed anymore.

The demand for quick chargers will also increase. So, more locations along highways and pumping stations for quick charging would be needed. This requires a big investment, but there are market parties with an earning structure for quick chargers. Quick chargers can reduce the fear of the limited range and lower the threshold at car users to purchase or use an EV. But quick charging has a big impact on the battery and reduces the lifetime of the battery at this moment. This might change in the future through more development as also described in the conclusions of the EV market.

Most public charging poles are connected to the existing electricity grid and are provided with two charging points providing 16 Ampere three phase alternative current (AC). There are different charging pole owners with different charging cards, which is an issue at this moment. There is also no earning structure for these ‘slow’ chargers. Therefore several grid operators launched ‘Stichting e-laad’ to place 10.000 charging poles on public places for free. But this is temporary to give an impulse to the EV market. Eventually, the EV market should be profitable by itself.

Battery swapping stations and inductive charging may be attractive alternatives for the users. It is more user-friendly, because it takes away the need for charging by wire and slower charging times. The range of the EV will be extended with minimal effort from the user. But it is very expensive and large investments are needed, because a big change in the infrastructure is needed. In the case of the battery swapping station, the different kind of batteries of the different car brands will be a problem and it is only attractive for regional car fleets with the same EVs (e.g. taxi company). A problem with induction charging is the low efficiency of the energy transfer to the EV.

**Energy market**

In the future electricity grid, more electricity will be produced decentralized by solar panels (on carports), wind turbines, etc. More electricity production and consumption will take place in the capillaries of the electricity grid. The peak demand when a lot of cars are (quick) charging will be a problem and will have a big impact to the electricity grid. This requires a huge investment in the electricity grid. The smart grid application has to be more applied, where electricity production and consumption interacts with each other to prevent electricity shortage or surplus. EVs will be important for this application with controlled charging. The battery in the EVs can also be used as an electricity buffer.
8.1.3  Sub question 4
Which groups of users of PHEVs and BEVs can be distinguished and what are their characteristics?

The groups of users can be distinguished in adopter categories as proposed by Rogers (2003). This method uses a normal frequency distribution which is divided into five adopter categories: Innovators, Early Adopters, Early Majority, Later Majority and Laggards. The characteristics of these five adopter categories are described in chapter 3.

8.1.4  Sub question 5
Who will be the early adopters and early majority of EVs in the future and what are their characteristics?

The early adopters are the middle and higher class lease drivers, with a detached house or having the ability to charge at home. Also companies which are pursuing sustainability objectives or authorities with an example function will be the early adopters of EVs. This description of the early adopters of EV is quite corresponding with the general description of early adopters from the literature as described in Chapter 3.

When the EV gets more technically developed, more individuals will drive electric also and they will be the early majority. This is probably because the early majority is more cautious in buying new products in general.

8.1.5  Sub question 6
What are the main pros and cons of the future groups of users to switch to PHEVs and BEVs?

The most common and important requirement to drive an EV is the financial aspect. This includes arrangements like lower or no tax addition, no road tax, lower total cost of ownership, getting paid by the employer and the increasing cost of driving conventional cars. Other reasons are importance of sustainability and good experiences in comfort from other EV users (the innovators). Some questions can be made to the tax advantages, because this requires a lot of money from the governments to subsidies all the current and future users. And who is going to pay for that? Eventually the tax advantages should not be needed anymore and the total costs of ownership of the EV should be cheaper than the conventional car.

The main reason why the lease driver drives a BEV, PHEV or EREV is because of the financial advantages. Earning esteem of colleagues and having a central position in their social networks is less important and is different than the description of early adopters from the literature.

The main reason why someone is not using an EV is the uncertainty about the total costs of an EV and the uncertainty about the ease of use.

8.1.6  Sub question 7
What has to be done to overcome the bottlenecks and to accelerate the adoption of EVs?

The need of the early adopters will be tailor-made. The right vehicle for the right trip. A shift from the need to own mobility will go to the need to have access to mobility. In this case the user can go from A to B, without having to be the owner of the vehicle. The main advantage of this case is that the vehicle can be used for the trip where it is intended. A small EV can be used for short distances, commuting, in cities and individual transport. A middle sized EV for distances around 100 kilometers or more people. A PHEV or EREV for further distances. This also includes the access to other types of transport, like bikes, (electric) scooters and public transport. This case is part of the freedom of making choices. So people will still have the choice to own an own car. This will also be the need of the early majority.
The requirement for the EVs are: their purchasing prices have to be lower (especially smaller models), a larger range, a reliable car with minimal maintenance, no charge problems, comfort, silence, clean and no emissions. Moreover, it should be possible to drive without having to be concerned about the possibilities to drive back and forth to a certain destination. Also more models and supplies of EVs would be needed to increase the adoption of EVs. The price of the EV is highly dependent on the battery. So the development of the battery will be important to meet the requirements regarding to the price of the EV. Requirements for the battery are: a higher energy density, lower price and compatible for quick charging.

Currently, the earning structure for the EV is unclear at the entrepreneurs and businesses. This would have to be solved to convince businesses to adopt EVs. The government should support the users of EV, but eventually this support should not be needed. When governments have policies regarding EVs, they should be consistent, clear and reliable. Otherwise users are easily discouraged to adopt an EV. The national government should be focusing on stimulating the EV by financial advantages and the local governments for charging facilities.

A last bottleneck to overcome is that the media has to be more positive about the EVs. Also their focus should be more on the regular use of the EV instead on the exceptional use. Otherwise the right target group would be not informed in a right and honest way.

8.2 Discussion
There are some discussion points regarding to the conclusions.

8.2.1 Qualitative research
This research is a qualitative research. Eight open interviews are done with nine respondents. Respondents had their own space to give answers to the questions. A lot of specific information about the person and the organization where the person is working at, is restricted to a small group of respondents. It gives less room for comparison possibilities. The conclusions of this research are strongly based on this small group of respondents.

8.2.2 Validation
The labeling system is not checked for validity. This means that the labeling system is not checked with new data from more or less equivalent persons. The labeling schemes are not verified with new data during this research, because of the limited available time.

8.2.3 Intersubjectivity
The analysis of the data from LinkedIn and the interviews is not executed by someone else. This means that the analysis is not checked on intersubjectivity. This is not done in this research, because of the limitation of time.

8.2.4 Adopter categorization theory
The theory of Rogers (2003) which uses a normal frequency distribution which is divided into the five adopter categories is based on a situation where the innovation will have a market share of 100% (Figure 2). Probably this will not be the case within the mobility sector. The current full hybrid cars also have a market share below 1%.

8.3 Further research
Some recommendations for further research are the following:

8.3.1 EV market
More research is needed on the ability for users to have access to mobility instead of owning mobility. How are lease companies and employers going to facilitate the access to mobility? To which extent does it have to be tailor-made? What will be the role of the governments? How much financial advantages are needed to accelerate the EV market?
8.3.2 Charge infrastructure market
For the public charging poles an earning structure is needed. Currently stichting e-laad is placing public charging poles for free to stimulate the adoption of EV, but in the future this should be done by a market based operator.

Charging the EV through induction is very attractive for the users, because it takes away the need for charging by wire. Further research is needed about the effects of the magnetic fields to the human health. For example: What would be the effects of the magnetic fields for people who are wearing a pacemaker?

8.3.3 Energy market
Currently, grid operators are testing controlled charging of EVs and using old batteries as stationary electricity buffer. These experiments are part of the smart grid of the future and it is recommended to continue with these experiments on larger scale.

8.3.4 Future users
This research has not included the future Dutch demographic influences. With the increase in aging population, the mobility patterns in the Dutch traffic system could change to shorter distances per ride. The assumption is that older people drive fewer kilometers than younger people. This may apply that older people could be an interesting group for the EV, but further research would be needed for this.
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LITERATURE


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