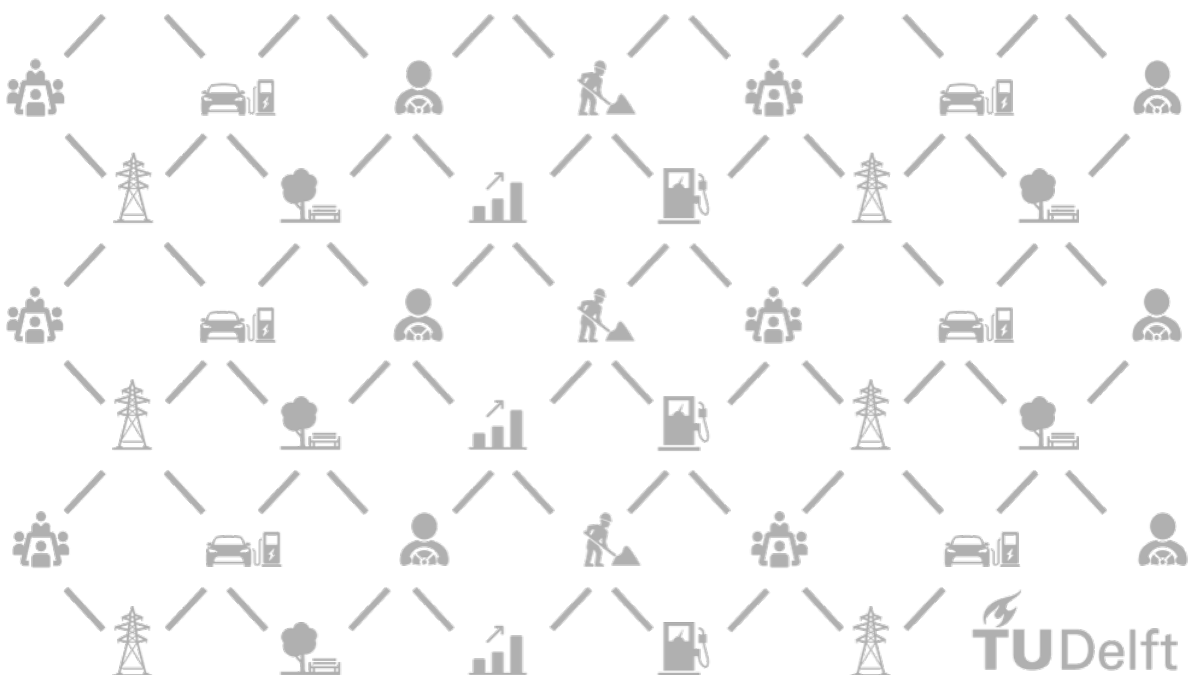




The feasibility of fast charging in Dutch cities

The technological, economical, social and political factors explained

Jorrit Vervoordeldonk



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The technological, economical, social and political factors explained

by

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in partial fulfillment of the requirements for the degree of

Master of Science
in Management of Technology

at Delft University of Technology,
to be defended publicly on Thursday March 1, 2013 at 14:00 AM.

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Executive Summary

The transport sector is a major contributor to greenhouse gas emissions, fossil fuel depletion and urban air pollution. Passenger car transport is responsible for 20 % of global energy consumption and 14 % of greenhouse gas emissions. The introduction of zero emission vehicles such as electric vehicles (EVs) can significantly reduce pollution. To achieve the climate goals agreed upon by the international community, the Dutch government aims for 1 million EVs on the Dutch roads by 2025.

To reach this goal, sufficient charging infrastructure needs to be in place. As 75 % of Dutch households do not have access to private parking, public facilities to charge EVs are essential, especially in cities. There are two different technologies to charge an EV: normal charging and fast charging. With normal charging, the electricity from the grid is converted on-board of the car to the direct current the electric motor needs. With the more expensive fast charging technology this is done in the external charger, allowing charging rates up to 50 times faster compared to normal charging. Fast charging technology is developing rapidly, with charging speeds that allow a full charge in fifteen minutes in 2020. Local governments however, currently mainly support and subsidise normal charging.

Charging infrastructure and fast charging specifically is a topic of interest for many parties. This includes car manufacturers, electricity grid operators, energy suppliers, charge point operators and policy makers. Many aspects are involved as technological development as well as social innovation and the broader paradigm shift towards clean energy and mobility play a role. Currently however, there is no scientific study that combines the technical, economical, social and political perspectives to evaluate the feasibility of fast charging in Dutch cities for current and future context. This research therefore answers the following research question:

To what extent is public fast charging feasible from a technical, economical, social and political perspective in the current and future context of Dutch cities?

An exploratory case study of the major Dutch cities of Amsterdam, Rotterdam, The Hague and Utrecht is performed. The political economy theory on transport innovations by Feitelson and Salomon is used as the theoretical perspective to evaluate the feasibility of fast charging. Desk research, semi-structured interviews and a focus group on consumer preferences are performed to collect the data. The feasibility is determined for both the current situation as for future context. The current context is evaluated to determine the reasons for the current focus on normal charging. For future context, positive and negative developments that influence the feasibility are identified. Moreover, the uncertainties and accelerating factors that influence the adoption are determined.

From the research it is concluded that fast charging is increasingly feasible as a charging solution in Dutch cities. Currently, there is a focus on normal charging in cities caused by the current EVs and charging technology. The developments sparked by larger batteries and faster charging however increase the feasibility of fast charging. As EV adoption accelerates, a more hybrid mix of normal and fast charging solutions is needed in crowded cities to accommodate the charging needs. The increasing industry interest, consumer attitude and high charging capacity make fast charging an important factor in the future public charging infrastructure.

The current focus on normal charging in favour of normal charging can be explained by a number of factors. From the technical perspective, the focus is explained by the fact that the majority of EVs on the Dutch roads nowadays are PHEVs without fast charging capability. Economically, the profitability of fast chargers at low adoption rates is difficult, resulting in low industry interest. Social feasibility is mostly high along the highways, as most early adopters have access to home charging and use fast charging only as a range extender. Politically, a number of factors play a role. Installing normal chargers is a lower risk for municipalities. And as most normal chargers are installed with national subsidies, municipalities solve the problem of charging needs at minimal costs. The growing experience with normal chargers and low impact on decision making procedures increase this focus.

When EV adoption accelerates in the coming decade, public fast charging in cities becomes increasingly feasible. This is primarily because of four factors. First, the faster charge rate will increase the consumer attitude as well as the profitability for market parties. Second, industry interest in fast charging will intensify, bringing down costs, influencing the consumer perception as well as the political feasibility. Third, when EV numbers increase exponentially in cities, fast charging can alleviate pressure on the public space (as it can replace a large number of normal chargers), the grid (as it does not contribute to low voltage grid peaks) and capacity problems (as grid upgrades and installation of chargers are time intensive). Finally, trends in autonomous driving and car sharing increase the demand for quick recharging of EV batteries.

Three main factors are determined that could delay the adoption of fast charging. The existing decision making procedures hinder new installation of fast chargers, since new public space is sparsely allocated and the transition of existing gas stations is difficult. Secondly, the existing (financial) interests and experience with normal charging could affect the sanctioned discourse in such a way that fast charging is not perceived as an effective solution. Third, the consumer preferences are still uncertain in their development. The focus group results indicate a positive development in the attitude towards fast charging, but it is still unclear what the preferred mode of charging will become.

This research contributes to the scientific body of knowledge by combining the technical, economical, social and political perspectives to analyse the feasibility of fast charging. The focus on cities as a location for fast charging is also not yet analysed. Next to that, a number of possible enhancements of the Feitelson and Salomon framework are determined. The effect of co-evolving innovations and the resistance of the existing regime towards new innovations are suggested as additional factors. Furthermore, the actors in the framework can be viewed as accelerators in the adoption process. This can enhance the dynamic capability of the framework. Experts and industry actors can create a snowball effect by affecting consumer preferences, the public perception and decision making procedures.

The managerial contribution lies in the fact that businesses and policy makers can use the insights in developing future strategies and policies concerning charging infrastructure. For fast charging businesses, the insights can be used as argumentation towards local governments. Another contribution for businesses is the identification of the factors that prevent the adoption of fast charging. These hampering factors are positioned in the political context, and fast charging businesses could help in forming new regulations. Also a rough sketch of strategies is provided based on fast or slow transitions in EV adoption and autonomous driving.

The societal relevance can be found in the fact that a more efficient and effective charging infrastructure stimulates EV adoption. This helps to meet environmental goals to reduce GHG emissions, fossil fuel depletion and urban air pollution. Fast charging availability is determined to stimulate EV adoption, and the findings from this study show the relevant factors involved. Next to that, charging infrastructure will have a significant impact on public space and electricity grids in cities in the coming decade. Infrastructure that suits the needs of EV drivers, avoids unnecessary societal costs and creates a pleasant living environment is therefore desirable.

As EV charging infrastructure and especially fast charging, is a relatively new research field, numerous interesting topics for future research can be identified. First of all, as cooperation between stakeholders is necessary in large-scale transitions, a more elaborate analysis on the interests and strategies in the charging infrastructure system could provide new insights. Second, the current scope of the research is limited to Dutch cities. As the percentage of fast chargers in cities is relatively low in the Netherlands compared to other leading EV markets, an international comparison could explain these differences in more detail. Finally, large-scale surveys on charging preferences among Dutch EV drivers and research into the political aspects of the transition of gas stations to charging stations are analyses that would add to the scientific body of knowledge.

Preface

Before you lies my Master thesis as part of the master Management of Technology at Delft University of Technology. This project concludes my time as a student in Delft in which I had the opportunity to explore so many different projects and interests. I am very grateful for the opportunities I have been given during these years. While I started as a 'hardcore' engineer, I have broadened my perspective towards sustainability, education, management and entrepreneurship. I had so much fun building a solar car, designing airplanes, setting up my own start-up and exploring the public sector. I would like to thank all the people I met along the way, who shaped my interests, dreams and with whom I have experienced so much adventures.

When looking for an interesting subject for my Masters thesis, I quickly settled on the sustainable energy sector, looking at electric mobility, solar energy and grid operators. It was so much fun diving into electric vehicle charging infrastructure, as it has so many aspects, The energy transition, autonomous driving, the sharing economy, and urbanisation worldwide all intertwine. The future is uncertain, but exciting for sure. These transitions beautifully coincide in the crowded cities in the Netherlands, with the challenge of providing a comfortable living environment amidst the transition to green and sustainable mobility.

With this report I hope to shine fresh and new light on the public charging infrastructure in the Netherlands. In quickly changing systems, a constant and iterative evaluation of the best technologies and layout of the system is necessary. With this thesis I hope to give a scientific overview of all aspects to take into account when designing charging infrastructure in Dutch cities.

I would like to sincerely thank my graduation committee for all their help during this process. First of all, Joost and all the guys at Fastned. They provided me with valuable information and contacts, while stimulating me to gather my own information. It has been a very warm welcome and the best working environment I have experienced at any company I worked with. Next to that I would like to thank my first supervisor Jan Anne, who is a master in providing constructive feedback with a positive and motivating tone. He has a refreshing attitude, combining sound scientific research with a 'boerenverstand' approach. I would also like to thank Bert and Roland for their feedback on my report and their guidance during the project.

Lastly, I would like to thank all my friends and family for their support. It has been so valuable to have friends and family who have supported me during better and worse times over these years. A special thanks to my roommates Anna, Nico, Jochem and Rosalie for providing a family and keeping me alive. I would also like to thank Edwin, Tom, Eric, Rune, Kristiaan and Rick for their feedback on my report.

I am immensely looking forward to a new period full of adventures. I hope to contribute to making the world a little bit more sustainable by inspiring people with cool, concrete and innovative projects. I hope you enjoy reading this report.

Jorrit Vervoordeldonk
Delft, March 2018

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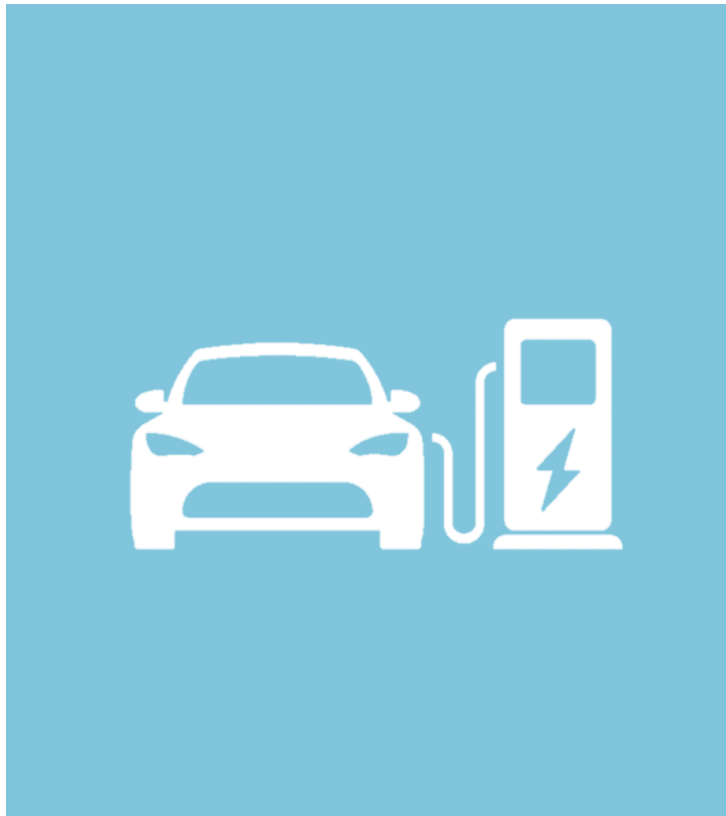
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1 Introduction

Electric vehicles (EVs) are on the verge of a worldwide breakthrough. The adoption rate is increasing because of technological developments and government incentives. In the Netherlands alone, 3 million EVs are expected by the year 2030. In order to charge these EVs, an extensive public charging infrastructure is needed. This master thesis elaborates on the feasibility of fast charging as a solution for public charging in Dutch cities. This chapter introduces the research. First, the problem statement and the scientific and societal relevance are stated. Next, the research objective and question are formulated. These act as a starting point for this research.

1.1 Research problem

The transport sector is a large contributor to greenhouse gas (GHG) emissions, fossil fuel depletion and urban air pollution. According to the International Energy Agency, 28 % of global energy consumption stems from transport and the sector produces 23 % of worldwide GHG emissions (IEA, 2017). The total GHG emissions from the transport sector are predicted to increase by 50 % in 2030 and 80 % in 2050 (IEA, 2013). In the Netherlands, passenger cars account for 70 % of the total energy demand of the transport sector. The introduction of zero emission cars such as EVs can thus significantly reduce GHG emissions of passenger transport (IEA, 2017).

Climate policies, which are introduced worldwide, include goals to stimulate EV adoption. To achieve the climate goals, the Paris Declaration on Electro-Mobility states that EVs should have a 20 % global market share by 2030. This accumulates to more than 100 million cars (IEA, 2017). The Dutch government has also formulated policy to stimulate EV adoption, with the goal of 1 million EVs on the Dutch roads by 2025. Policy measures include the stimulation of Research and Development (R&D) programs, financial incentives for EV owners and charging infrastructure deployment (RVO, 2011).

As a result, the EV stock is increasing in the Netherlands with over 100,000 EVs in 2017. The majority of these EVs is still plug-in hybrid electric vehicles (PHEVs), which combine an internal combustion engine (ICE) with an electric motor. The growth in EVs and charging availability in the Netherlands can be seen in Figure 9. Although the number of EVs is rapidly growing, in 2016 only 1.5 % of the passenger car fleet and 6.4 % of new car sales was electric (RVO, 2017).

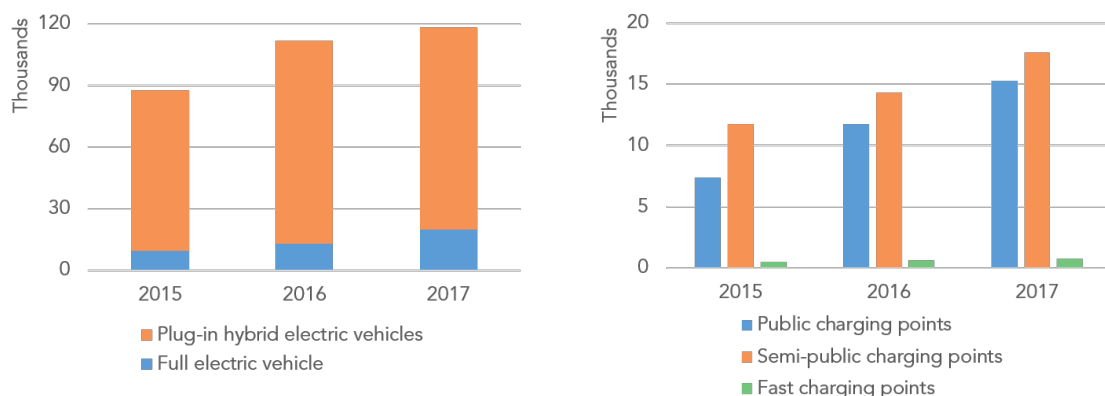


Figure 1: The number of EVs (left) and charging poles (right) in the Netherlands (RVO, 2017).

1.1.1 Charging infrastructure as a barrier to adoption

To reach the goals set by the Dutch government, the barriers to adoption need to decrease. Three important barriers for EV adoption are the availability of charging infrastructure, the limited range of EVs and the high purchasing cost (Liao et al., 2017). The way EVs refuel differs significantly from conventional vehicles, as recharging a battery takes much longer than refuelling. Next to that, customers need to be convinced that there are sufficient charging possibilities available before they purchase an EV (Egbue and Long, 2012; Liao et al., 2017). In a survey among 47,000 respondents, 20 % stated that charging infrastructure is a major barrier to adoption, ranking third behind the high price and the limited range (ING, 2017). The national government highlights that an extensive network of charging stations is crucial for the adoption of EVs (RVO, 2016b).

In order to charge the rapidly increasing number of EVs, a significant expansion of public charging infrastructure is needed (Ecofys, 2016). Currently, there are 15,000 public charge points in the Netherlands, while projections state that over 1 million public charge points are needed in 2030 to keep up with the accelerating EV adoption (Ecofys, 2016). This is a challenge especially in the crowded Dutch cities, where over 75 % of citizens do not have access to private parking and are thus dependent on public facilities (CBS, 2016). In 2014 already, 64 % of urban EV drivers stated there was a shortage of public chargers (G4, 2014).

1.1.2 Normal versus fast charging

Broadly speaking, there are two ways to charge an EV: normal charging and fast charging. With normal charging, the electricity from the grid is converted on-board the EV to the direct current (DC) that the electric motor needs. With the more expensive fast charging technology this is done in the external charger, allowing charging rates up to 50 times faster compared to normal charging (Yilmaz and Krein, 2013). Fast charging technology is developing rapidly, with charging speeds that allow a full charge in 15 minutes in 2020 (IEA, 2017). Policy incentives in cities however are all geared towards normal charging. The four largest municipalities in the Netherlands have all set targets for the number of normal charge points, but no targets are set for fast charging locations (G4, 2014).

EV charging infrastructure and fast charging specifically is a topic of interest for many parties. This includes car manufacturers, electricity grid operators, energy suppliers, charge point operators and policy makers. It combines many perspectives, as it includes technological development, as well as social innovation and the broader paradigm shift towards clean energy and mobility. Consumers, policy makers and the mobility industry need to shift from a fuel station infrastructure towards an industry that supports electric charging. To achieve the goals set by the government, EV drivers need adequate public charging infrastructure, while investors in public charging infrastructure should be able to earn a profit on their investment (Dharmakeerthi et al., 2014).

1.2 Knowledge gap & problem statement

Many uncertainties still exist about the future of EV charging infrastructure, including the charging technology, the charging rate, the charging locations and the impact on the electricity grid. Research is performed into aspects of fast charging, such as the business case (Alhazmi and Salama, 2017; Schroeder and Traber, 2012), the consumer preferences (Liao et al., 2017) and the different stakeholders (Bakker et al., 2014; Neubauer and Wood, 2014). There is no overall analysis yet on the feasibility of fast charging as a solution for charging in cities that combines these perspectives, as is explained in this section.

Many studies focus on the modelling of optimal locations for charging stations. Hess et al. (2012) developed an optimisation model for charging stations based on travel patterns, but did not take fast charging into account as it was still an immature technology. More recent studies by Li et al. (2016) and He et al. (2015) also developed mathematical models for the optimal deployment of charging stations, including fast charging. These models focus on the spatial location and on current EV behaviour. Future developments affecting charging behaviour, as well as customer preferences are not taken into account.

The economical feasibility of fast charging is addressed in a study by Schroeder and Traber (2012) in which the business case is analysed for Germany. The study concludes that the EV adoption rate in 2011 is too uncertain to invest in public fast charging infrastructure, but the market has developed rapidly since in terms of technology and cost. Alhazmi and Salama (2017) developed an economical staging plan for fast charging infrastructure and concludes that investment in fast charging will become attractive when penetration levels of 20 % are reached. This is however done from an electricity grid perspective, and changing customer preferences and scaling effects are not included in the model.

Concerning social feasibility, much research is performed based on customer preferences for EVs. In an extensive literature review by Liao et al. (2017) it is shown that infrastructure availability is crucial for EV adoption, but that in most studies no distinction is made between normal and fast charging. Morrissey et al. (2016) analyse charging behaviour in terms of location, duration and preferred mode of charging based on a large data set from Ireland. This study is specific to the infrastructure availability in Ireland, and therefore make it hard to extrapolate this to other regions.

Bakker et al. (2014) describe stakeholder interests, expectations and strategies by conducting a series of interviews. They provide opportunities and threats for different stakeholders in the changing mobility environment. However, this study only touches briefly on the topic of normal versus fast charging. In another study by Bakker and Trip (2013), policy options to support EV adoption in the urban environment are investigated. EV infrastructure build-up is ranked as the second best way to support EV adoption, but again fast charging is not treated separately.

To summarise, most studies focus on certain aspects of fast charging, or do not make a distinction between normal and fast charging at all. Studies are based on current charging data and customer preferences, which will most likely change when battery size and charge rate will increase. This thesis elaborates on the feasibility of fast charging in cities and combines a technical, economical, social and political perspective.

1.2.1 Problem statement

Following the research exploration and knowledge gaps, the problem statement is defined. For this research the case of Dutch cities is chosen, as is further explained in the scope of this research in Section 1.3.1. The problem statement for this research is as follows:

Currently, there is no study that combines the technical, economical, social and political perspectives to evaluate the feasibility of fast charging in the current and future context of Dutch cities.

1.2.2 Scientific, societal and managerial relevance

From a scientific perspective, the contribution of this research is to fill the knowledge gap in literature in evaluating the feasibility of fast charging in cities. Often in literature no distinction is made between normal and fast charging, and when fast charging is researched, the focus is on one aspect of fast charging. This research combines the technical, economical, social and political perspective. Secondly, as will be explained in Chapter 2, the political economy model by Feitelson and Salomon (2004) is used as a theoretical framework to evaluate the feasibility of fast charging. Potential enhancements to the Feitelson and Salomon framework can benefit the theory, and can be useful in future scientific research using this framework.

The societal relevance can be found in the fact that a more efficient and effective charging infrastructure stimulates EV adoption (Liao et al., 2017). This helps to meet environmental goals to reduce GHG emissions, fossil fuel depletion and urban air pollution. Next to that, a balanced charging infrastructure can result in lower risks for the stability of the electricity grid (Hall et al., 2017).

From a managerial perspective, the outcome of this research can help policy makers and business in making decisions on public charging infrastructure. For policy makers the insights from this thesis can be used in developing future policies concerning charging infrastructure. Investments by local and national governments in public charging infrastructure could be done more efficiently. For businesses it can provide insight into which technology to invest in, and the conclusions can be used when discussing the deployment of chargers with local and national governments.

1.3 Research objective & questions

In this section, the research objective and research questions are stated. The research objective determines the aim of the research. The research objective is as follows:

To determine the feasibility of public fast charging by combining a technical, economical, social and political perspective in the current and future context of Dutch cities.

The main research question is as follows:

To what extent is public fast charging feasible from a technical, economical, social and political perspective in the current and future context of Dutch cities?

Several sub-questions have been formulated to guide the research. The research is split up in a part analysing the current situation and a part where future scenarios are analysed. Therefore, the first four sub-questions are stated as follows:

For the current and future context...:

1. What is the state-of-the art and development of fast charging technology?
2. What is the profitability and market potential of fast charging compared to normal charging?
3. What are consumer preferences for charging in cities?
4. What is the political feasibility of fast charging in cities?

Finally, taking into account that the current political situation is geared towards normal charging, the results are combined to answer the two final sub-questions:

5. How can the current focus of the Dutch government on normal charging in cities be explained?
6. How do future developments affect the feasibility of fast charging in cities?

The sub-questions are answered in order to answer the main research question. Each sub-question is answered in a chapter of this thesis report. The main research question is answered in the conclusion.

1.3.1 Research scope

The research is demarcated to fit the time-frame of a Masters thesis and to be able to conduct an in-depth study. The research is limited by the following criteria:

- The research is limited to passenger cars. Other vehicles such as buses, trucks and trains are thus excluded. As stated before, passenger cars amount to 70 % of energy demand of the Dutch transport sector (IEA, 2017).
- The focus of this research is on Battery Electric Vehicles (BEVs). Unless otherwise stated, the term EV refers to a BEV. Plug-in Hybrid Electric Vehicles (PHEVs) and other EV technologies are discussed, but it is widely recognised that BEVs will become the dominant EV technology in the future (Hall et al., 2017).
- This thesis focuses on large cities in the Netherlands. This scope is chosen because of two reasons. First, the increased need of public charging facilities because of limited private parking. Secondly, since the adoption rate in cities is higher than the national average, cities can be front-runners in developing and testing policy actions (Hall et al., 2017). The term city refers in this case to the region that is under administrative control of a municipality. The focus is primarily on the G4 cities which are Amsterdam, Rotterdam, The Hague and Utrecht.
- The focus of this research is on public charging infrastructure. As in cities, 75 % of citizens do not have access to private parking, public charging infrastructure is essential in cities (CBS, 2016).
- No comparison with other vehicle technologies such as fuel cell vehicles or ICE vehicles is made. This comparison is a research on its own and too comprehensive for a Masters thesis. Moreover, the International Energy Agency considers EVs as the dominant passenger car technology in their World Energy Outlook IEA (2017).
- No alterations of the political-economy model by Feitelson and Salomon (2004) are determined and tested during this research. Possible enhancements are presented as recommendations at the end of this thesis.

1.4 Research approach

Following the research questions and scope, the research design is defined. The research starts with determining the theoretical framework used to determine the feasibility. The research domain of socio-technical transitions is used to determine possible influencing factors on the adoption of innovations. Based on this exploration, a suitable theoretical framework is selected. Next, the four types of feasibility (technical, economical, social and political) are evaluated using desk research, semi-structured interviews as well as a focus group on consumer preferences. The desk research acts as a basis to determine the interview and focus group questions. Combining these four types of feasibility, the current and future feasibility of fast charging in cities is determined and possible improvements of framework are proposed. The research framework is presented in Figure 2, including the relevant chapters and research questions. The sub-questions are answered in the conclusions of the indicated chapters.

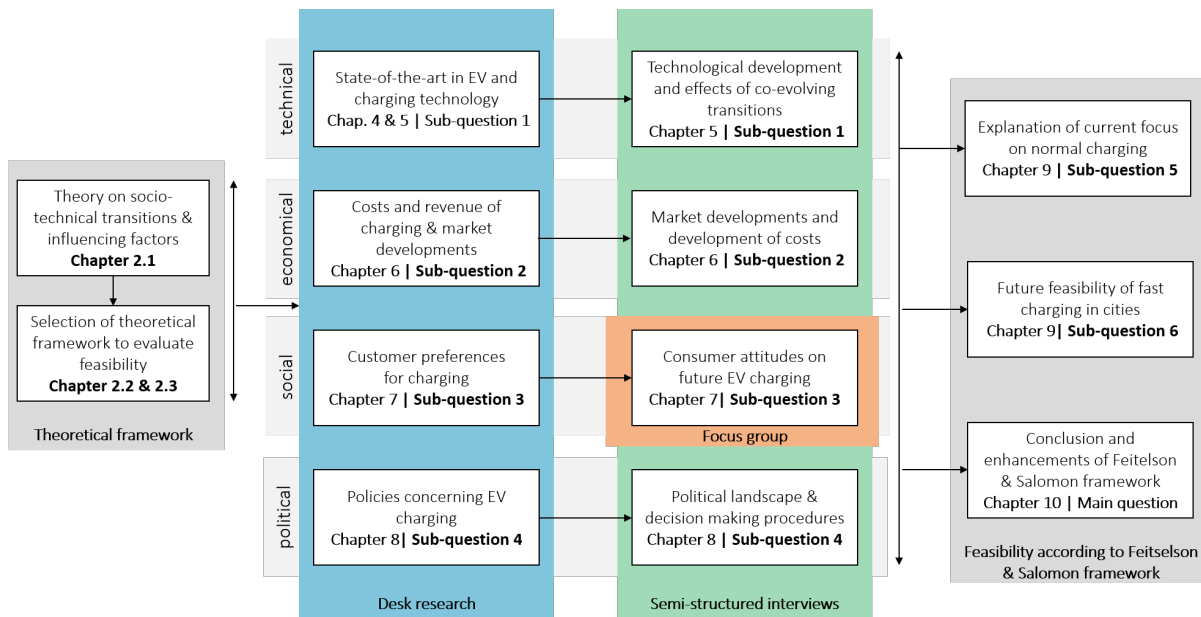


Figure 2: Research framework.

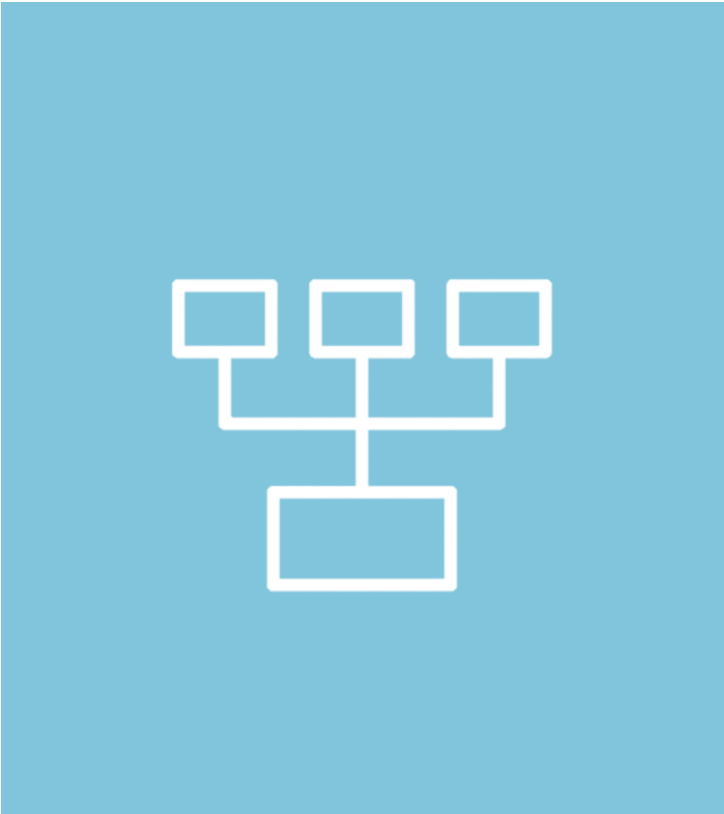
1.5 Structure of the report

The theoretical perspective used in this research is discussed in Chapter 2. Literature on technology diffusion and socio-technical innovation systems are discussed, which provide a theoretical basis for this research. Next, in Chapter 3 the research methodologies used are discussed, which are desk research, interviews and a focus group, as well as the way the data is collected and analysed. Chapter 4 sketches the research context of EV and charging technology and its status in the Netherlands. Next, the four streams of feasibility (technical, economical, social and political) are evaluated. This is done by combining the results from the desk research, interviews and focus groups. The icons and colours used in the report to indicate the type of research method or feasibility are shown in Figure 3.



Figure 3: Icons used to indicate research methods and feasibility type.

Chapter 5 evaluates the technical feasibility by discussing the developments in charging technology. Their effect on the electricity grid and developments such as autonomous driving is also presented. In Chapter 6 the economical feasibility is considered by discussing the business case of normal and fast charging for different future scenarios. Next, in Chapter 7 the social feasibility is presented by discussing existing consumer preference studies as well as the results of the focus group held. Finally, the political feasibility is analysed in Chapter 8 by discussing policies, interviews with policy makers and the influence of interest groups. In Chapter 9 the four feasibility streams are combined to conclude on the current and future feasibility and policy and business recommendations are formulated. Finally, the main research question is answered in Chapter 10, and the contribution of the research and recommendations for future research are given.



2 Theoretical Framework

Technological diffusion is a process which not only involves technological development, but also economical, social and political factors. The interaction of the technology with the system it is positioned in, is crucial for its adoption in society. This chapter presents the theoretical framework used to evaluate the feasibility of fast charging. First, the broader context of innovation diffusion and socio-technical systems is sketched to identify possible factors that determine the adoption of fast charging. For EV charging infrastructure, political factors play an important role, since businesses are dependent on government regulations for the installation of charging infrastructure in the public environment. Therefore, the political economy model by Feitelson and Salomon (2004) is selected as the theoretical framework for this research.

2.1 Socio-technological transitions

The transition of the transport sector from a fossil fuel driven industry towards one based on sustainable fuels requires more than technological development alone. Technological innovations are formed by social and political factors as well (Kline and Pinch, 1996). In order to diffuse in society, organisational and institutional changes are required (Geels, 2002, 2012). The diffusion of an innovation is described by Rogers (1995) as the gradual adoption by society or the market. This diffusion process often occurs in a characteristic S-shaped curve (Rogers, 1995). Before the S-curve takes off, pre-diffusion phases often occur where the technology is improved and adapted through technological innovations (Ortt et al., 2013).

The theory behind socio-technical transitions describes these as processes in which social, economical and political aspects co-evolve (Markham et al., 2010). In socio-technical systems a 'regime' is present, which entails the existing set of rules (Rip, 1995). This regime represents the dominant operating mode within the socio-technical landscape. All actors in this landscape are geared towards this solution, granting stability but also rigidity in the system (Geels, 2002). Radical new technologies are initially excluded and only incremental changes can occur within the boundaries of the regime. Socio-technical systems are path dependent, and often strengthen the existing regime.

The new technology should convince various stakeholders, such as policy makers, consumers and businesses, of its benefits in order to reach diffusion (Rip, 1995). An added difficulty is that a high level of uncertainty is involved in developing new radical innovations as they have to change the current paradigms (Werker, 2003). Socio-technical transitions are thus long-term processes, in which the emerging system is opposed by the existing regime. This can occur both in a passive way, by existing regulations, or actively, by opposing actions by incumbent actors. Despite these opposing forces, sometimes so-called 'windows of opportunity' open which provide opportunities for radical innovations. These windows often emerge when external pressure (e.g. environmental concerns) forces changes in the existing regime (Turnheim and Geels, 2012). Subsidies or regulations by local or national governments can force changes in the system and give the new technological innovation an advantage over existing technologies (Schot, 2016).

When the newly emerged system is building up, it needs to be protected from the hostile market environment. Advantageous policies, funding for research and development (R & D) and societal factors are examples of protection in the pre-commercial market (Smith and Raven, 2012). These actions and the stakeholders that take these protective actions create a 'technological niche' (Schot and Geels, 2007). In these niches, promising socio-technical systems can be developed that are not yet mature enough for true commercialisation (Kemp et al., 2001).

Next to technological development, many iterations are needed to embed the technology in its socio-technical context and make the innovation economically profitable. The length of this adjustment phase varies significantly, as the technology needs to adjust to the context of its new technological landscape (Ortt et al., 2013). To move from a technological innovation towards market stabilisation, often a critical mass of consumers is necessary. This can be difficult, as new consumers do not have experience with the technology yet. They might not understand its potential or perceive the technology to not fit their needs. As a result, often technologies are withdrawn and reintroduced again in this adaptation phase (Ortt et al., 2013).

2.1.1 Relation to EV charging infrastructure

In the case of EVs and specifically charging infrastructure, two socio-technical transitions intertwine. In their study, Schot and Geels (2007) describe the electricity infrastructure and the transport system both as complex socio-technical systems. As a transition in the transport and electricity system is needed in the future because of environmental concerns, transitions theory could provide valuable insights for the implementation of charging infrastructure. From the transitions perspective a number of insights are taken into account when looking at the feasibility of fast charging.

First, when changing from a regime based on fossil fuel (gas stations) to a electricity charging infrastructure, the existing regime could resist the new socio-technical system (Hekkert et al., 2007). Incumbent firms or existing regulations could hamper the introduction of charging infrastructure. Next to that, since normal charging is already further embedded in cities, it is interesting to determine how path dependency plays a role in the adoption of fast charging. Secondly, in order to introduce EVs and charging infrastructure into the transport system, a large-scale transition is needed. To achieve this, many stakeholders such as energy providers, car manufacturers and regulators need to co-operate (Geels, 2012). Thirdly, technological niches need to be protected by stakeholders when they are not yet mature enough (Bakker et al., 2012; Kemp et al., 2001). This can be done for example by government programs or policies (Smith and Raven, 2012). Since charging infrastructure has been subsidised by the government in the past, it is interesting to determine how these technological niches develop in terms of business models and standards. Finally, the configuration is still flexible, especially since the electricity and transport systems are both in transition. Stakeholders might attempt to influence this configuration to align with their interests, especially since new roles are created in the system.

To conclude, a number of potential factors influence the feasibility of fast charging in cities. These factors can influence the adoption and are taken into account during this research. These factors are:

- Resistance from the existing socio-technical regime (e.g. gas station operators, car manufacturers)
- Path dependency (e.g. familiarity with normal charging infrastructure in cities)
- Co-operation between stakeholders to achieve the needed large-scale transition
- Governmental policies and subsidies to protect the technological niche
- The composition of the newly emerging system, and how this is influenced by the interests of stakeholders
- Bounded rationality of new and existing EV drivers
- Technological, societal and political constraints such as battery developments, grid limits or limited public space
- External pressures such as environmental regulations or environmental zones in city centres
- Transition in the electricity infrastructure system (e.g. renewable energy generation) influencing the configuration of the transport system.

In the next section, several socio-technical frameworks are considered as a lens to evaluate the feasibility of fast charging in cities. The factors determined in this section are determined to select a suitable framework.

2.2 Socio-technical innovation frameworks

The previous section has shown that the adoption of a technical innovation is a process involving social, economical and political factors. For the adoption of charging infrastructure in cities, political factors are of critical importance, as market parties are dependent on regulations from national and local governments to install infrastructure in the public environment. A number of theories on socio-technical innovation diffusion are discussed in this section, and the reasons behind selecting the framework by Feitelson and Salomon (2004) are given.

In a paper by Hekkert et al. (2007) the functions of innovation systems theory is introduced. Hekkert et al. (2007) state that innovation systems are a crucial factor in technological change. Newly emerging innovation systems and changes in the set-up of existing systems co-evolve with technological development. In their theory, they focus on functions of innovation systems, processes that are identified to be important for well performing systems. These processes are systematically mapped in a theoretical framework and a method is proposed to analyse historic events. This theory adds to the concept of innovation systems in the fact that it is dynamic; it allows to map processes over time. Next to that, through historic event analysis it allows for attention to the micro-level and the effect of singular events on the course of technological change. The theory focuses on entrepreneurial activities, knowledge creation and knowledge diffusion, while the adoption of charging infrastructure is much more a societal process, with significant involvement of the government. Next to that, the perception of the innovation plays an important role in the charging infrastructure system, which is not a primary focus of the Hekkert et al. (2007) framework.

Ortt et al. (2013) identifies niche strategies for high-tech products in the market formation phase. In their study, actors, factors and functions are identified that influence the commercialisation of new high-tech products. These can form barriers to diffusion, and niche strategies can help to address these barriers. Although this model is appropriate for managers to select a niche strategy in entering the mass market, it is based on a commercial perspective. It is therefore very suitable from the perspective of charging point operators. For this thesis however, a model that combines and explains the adoption of innovation from a more social and political perspective is preferred.

One such theory that has a strong connection between technical and political factors is the political economy model for transport innovations by Feitelson and Salomon (2004). The political economy model by Feitelson and Salomon (2004) states that the adoption of an innovation depends on whether it is seen as technically, economically, socially and politically feasible. It focuses on the conditions that have to be met to increase the chance of widespread technological diffusion in society. The theory states that innovations are developed as a result of entrepreneurship by either industry or by experts and professionals. The second group is called 'policy entrepreneurs', who advance various policy suggestions in which they believe (Kingdon and Thurber, 1984). At specific times usually caused by political changes or a perceived crisis, 'policy windows' occur and ideas become policy proposals. This occurs only when the suggested innovations is perceived as feasible by the public. The focus on political and social factors besides the technology is preferable for this study. Policy and regulations play an important role in the process, as the infrastructure needs to be installed in the public space. Furthermore, the theory is specifically developed for transport innovations, which fast charging is as well. One possible disadvantage is that the changes over time are not apparent in this theory. The theory of Feitelson and Salomon (2004) is a time static snapshot on how factors influence innovation adoption. To allow for a more dynamic analysis, future developments are taken into account to determine the future feasibility. This is explained in more detail in Chapter 3.

Concluding, the political economy model of Feitelson and Salomon (2004) is selected as the theoretical framework for this thesis because of its applicability to transport innovations and the focus on social and political factors in the adoption of innovations. In the next section the political economy model of Feitelson and Salomon (2004) is explained in more detail.

2.3 Political economy model for transport innovations

The model of Feitelson and Salomon (2004) is shown in Figure 4. As stated before, an innovation is adopted if it is perceived to be technically, economically, socially, and politically feasible. The economical feasibility is mentioned as a separate feasibility in their study, but not explicitly shown in the model. The actors are shown in white and the interacting factors in green. In this section the model is discussed shortly.

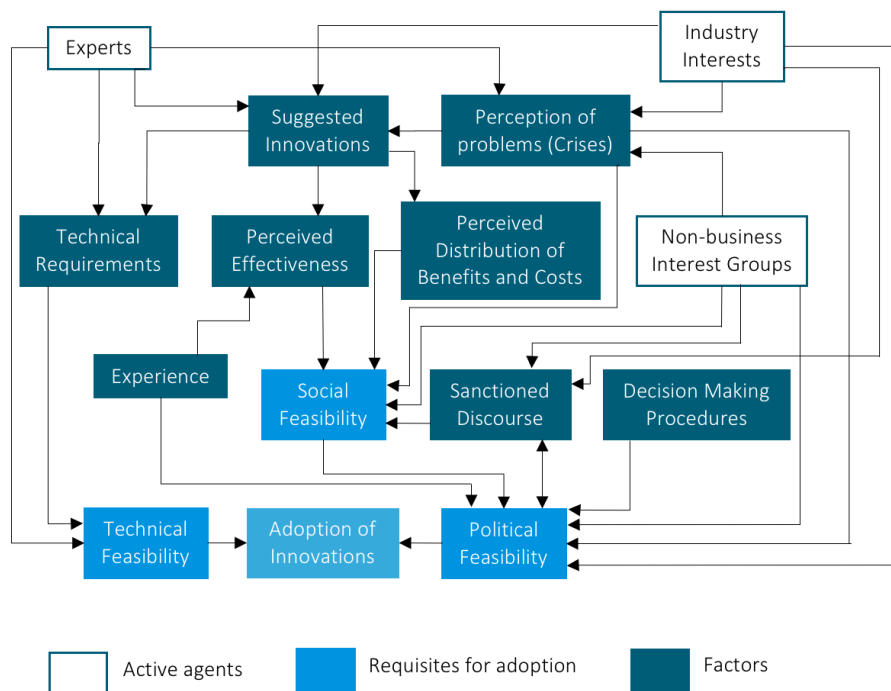


Figure 4: The political economy model for transport innovations (Feitelson and Salomon, 2004)

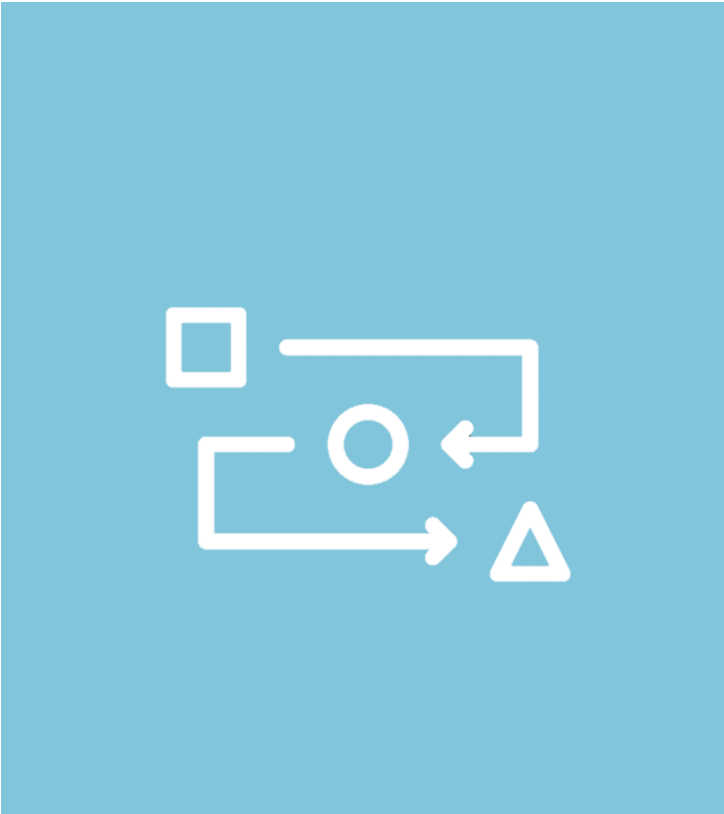
First of all, the innovation has to be feasible from a technical standpoint. That is, it has to be able to work technically and be a solution to the perceived problem. Experts are important actors in the determination of technical feasibility.

Next to that, a suggested innovation must also be economically viable. If the benefits do not outweigh the costs, the suggested innovation will be viewed by society as unrealistic and be termed socially infeasible, even if the technical requirements are met.

Social feasibility is determined as the effectiveness of the suggested innovation in addressing the perceived problems in society (Rienstra et al., 1999). These perceived effectiveness is also influenced by experience with similar policies or innovations. Policy entrepreneurs in the form of industry experts or non-business interest groups can try to influence the social feasibility by altering the 'sanctioned discourse'. This is the argumentation or rhetoric sanctioned by decision makers as politically appropriate.

Political feasibility is also influenced by social feasibility, as politicians take voter preferences into account. Decisions on transport innovations however are usually not topics the public decides their vote on, and are based on existing decision making procedures. Feitelson and Salomon (2004) state that decision makers provide solutions to perceived problems, in a way the support from different groups is maximised and that can be explained with arguments within the currently leading sanctioned discourse. Not all innovations that are politically feasible are adopted however. Sometimes a politically feasible innovation may turn out not to be technically feasible after a while. This occurs when the costs of implementation become clear, often after the 'crisis' is not a high priority anymore for the public. If the cost of implementation is too high, it is possible that innovations ultimately will not be implemented, or implemented in an altered version.

Each of these feasibilities is analysed in the remainder of this thesis. In Chapter 3 the research methods used to achieve this are explained. The broader research domain sketched in Section 2.1 is used as reference and is reflected upon in Chapter 9.



3 Methodology

The research methodology of this thesis is presented in this chapter. The research can be described as an exploratory case study. Using the Feitelson and Salomon (2004) framework, the technical, economical, social and political feasibility is analysed. Desk research, semi-structured interviews and a focus group are performed to collect the data. This data is analysed following the Feitelson and Salomon (2004) framework in the current and future context. First, the research methodology is introduced. Next, the research methods are discussed and finally the validity of the research is discussed.

3.1 Research typology and approach

This thesis can be characterised as an exploratory case study analysing the major Dutch cities of Amsterdam, Rotterdam, The Hague and Utrecht. Case studies are often used when studying a contemporary phenomenon in a real-life context. It is suitable for studying complex social phenomena, which is the case in the adoption of charging infrastructure (Yin, 1994). Characteristics of a case study are many variables and sources of evidence and a theoretical perspective to guide the data collection and analysis (Yin, 1994). This suits this research, as the four feasibilities are influenced by many variables, multiple stakeholders are involved and the Feitelson and Salomon (2004) theory is used to analyse and collect the data. In a case study the used methods can be qualitative, quantitative or both. This study combines both qualitative (interviews, focus group) as quantitative (technical developments, costs and revenues) data. The research approach as shown before is presented in Figure 5.

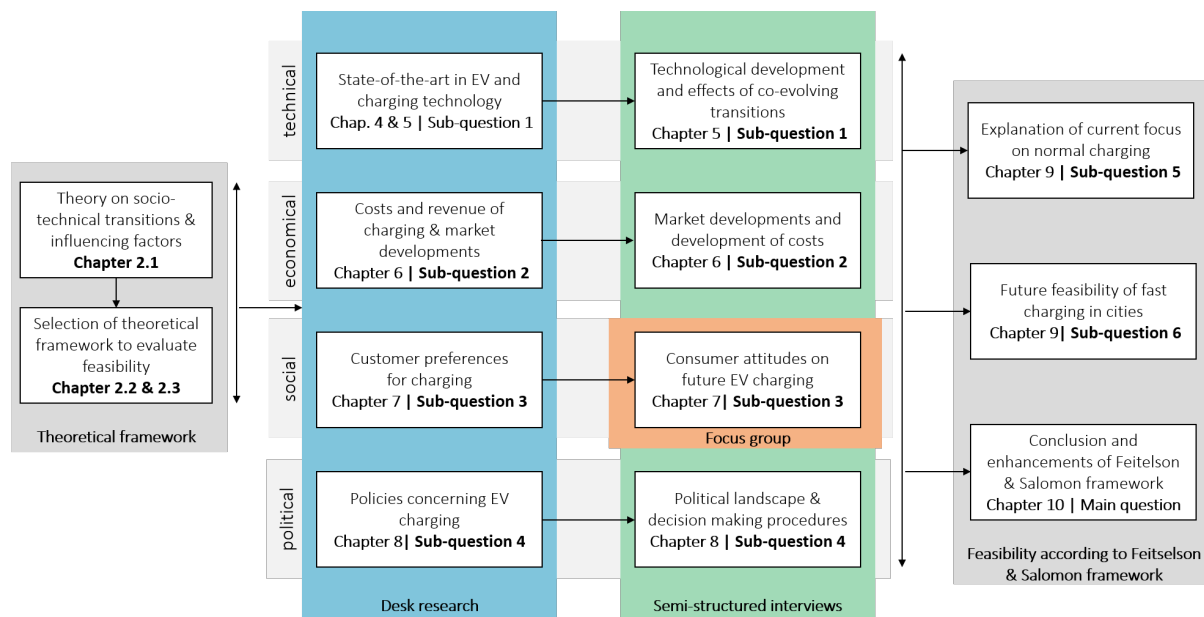


Figure 5: Research approach.

Since one of the drawbacks of the Feitelson and Salomon (2004) framework is that it is a time static framework, the feasibility is not only evaluated for the current situation. The developments in feasibility are evaluated to conclude on the future feasibility. Positive and negative developments that influence the factors from the Feitelson and Salomon (2004) framework are identified, as well as the largest uncertainties that influence the adoption in the future. A reflection on the theoretical context of socio-technical transitions and its dynamic environment is presented in Chapter 9.

This research combines quantitative and qualitative data in reaching the research objective. In each chapter desk research, semi-structured interviews and the focus group are combined, as discussed next.

3.2 Desk research

The first research method used is desk research. Desk research is a research strategy in which material produced by others is used to answer research questions. In a desk research existing material is gathered and reflected upon. The data is often analysed from another perspective than at the time of publication (Verschuren and Doorewaard, 2010). Desk research in scientific and grey literature is carried out during the first phase of the research. Government reports and policy documents give insight in the political feasibility, while scientific literature is used to determine future developments in charging technology (technological feasibility) or customer preferences for charging (social feasibility). Also news and company websites were visited to determine the latest market developments. The data from desk research also acts as an important source of information to set-up the interviews and the focus groups as relevant factors and developments are identified.

Literature is found by doing a systematic search. First, literature reviews are searched using the online search databases Scopus, Google Scholar and Web of Science. The following keywords are used to find relevant scientific articles using AND, OR and NOT statements: 'EV', 'electric vehicles', 'charging infrastructure', 'fast charging' and 'urban environment'. Additional search terms were added to find information regarding one of the feasibilities, such as: 'business model', 'policy', 'consumer preferences'. Reference lists of extensive literature reviews such as the consumer preferences review by Liao et al. (2017) are also used to find relevant literature. Furthermore, policies of Dutch national and local governments are gathered and analysed.

3.3 Semi-structured interviews

To verify the factors identified from desk research, and to get an in-depth overview of the qualitative factors involved, semi-structured interviews are conducted. The insights from the desk research are used to determine the interview topics and interviewees. Semi-structured interviews are selected over unstructured interviews, since semi-structured interviews allow for an in-depth discussion about specific variables of interest. Semi-structured interviews combines a pre-determined set of open questions with the possibility to explore areas of interest in-depth. It allows interviewees to discuss topics that the interviewer did not consider (Sekaran and Bougie, 2009).

A list of the stakeholders in the Dutch charging infrastructure system was compiled from a stakeholder analyses by Bakker et al. (2014) and the first interview held at the TU Eindhoven (Hoekstra and Refa, 2017). An overview of the stakeholders is presented in Table 1.

From this list, a selection was made to interview experts with know-how of the four streams of feasibility in the Feitelson and Salomon (2004) framework. Experts with diverse positions from various stakeholder groups were interviewed to reflect the different interests and roles in the system (Sekaran and Bougie, 2009). The focus is on the municipalities, EV drivers and charge point operators (CPOs), as these are the main stakeholders involved in installing and using the charging infrastructure. Also distribution system operators (DSOs), research institutes and consultants specialised in this field were interviewed. In total, 12 interviews were conducted in the fall of 2018. The interviews were mostly conducted at the work location of the interviewees. When this was not possible (e.g. with the Norwegian EV drivers association) the interview was held via phone call. All interviews were recorded, summarised and approved by email. The insights from the interviews are referenced in this report by their interview number. The selected organisations that are interviewed are shown in Table 2. The stakeholder segment, the name of the organisation and the feasibility stream that is focused on during the interview are shown.

Table 1: Stakeholders involved in Dutch charging infrastructure based on Bakker et al. (2014) and Hoekstra and Refa (2017).

Stakeholder	Abbr.	Role & tasks in EV public charging
EV driver	-	Driver of the EV, user of the charging infrastructure
National government	-	Formulating policy, laws and regulations on a national level
Local government	-	Responsible for public space; placement or permits for charging stations; adherence to policy
Charge point operator	CPO	Placement, maintenance and operation of charging infrastructure
Distribution system operator	DSO	Responsible for grid stability, and thereby the connection of the charging station and the grid
Energy provider	-	Providing and selling electricity to allow charging
Gas station operator	-	Operator of traditional gas station; could also start operating charging infrastructure
Mobility service operator	MSO	Selling and providing charging services to e-driver; ensure that driver can charge anytime, anywhere at different charging providers
Car manufacturer	OEM	Manufacturers of electric cars; major OEMs are also starting to invest in fast charging networks
Consultancies & research institutes	-	Give advice, doing research and carrying out detailed analyses for various stakeholders

Table 2: Interview list.

Segment	Organisation	Technical	Economical	Social	Political
Government	Municipality Amsterdam, The Hague, Dordrecht		✓	✓	✓
Charge point operator	Fastned, Allego	✓	✓	✓	
Research institutes	E-laadNL, TU Eindhoven	✓	✓	✓	✓
Drivers organisation	Elbil (Norway)			✓	✓
Grid operators	Stedin	✓			✓
Consultants	OverMorgen, EVConsult, APPM	✓	✓	✓	✓
Gas station owners	BP Slagboom		✓		✓

The interview set-up is based on the desk research, and the four streams of feasibility stated by the Feitelson and Salomon (2004) framework. Certain stakeholders have more know-how on certain topics, e.g. policy makers are asked about EV policy, and charge point operators about profitability of their chargers. The types of feasibility that are discussed in each interview is also shown in Table 2. The interview set-up is shown in Figure 6.

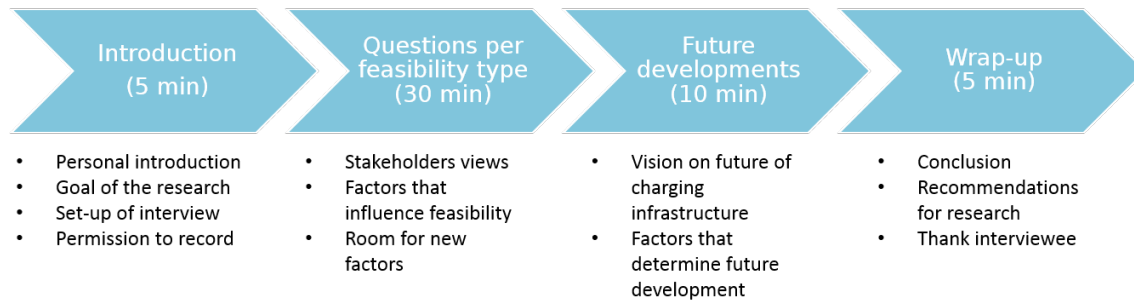


Figure 6: Set-up of the semi-structured interviews.

The set of questions is determined from the initial desk research. Using the Feitelson and Salomon (2004) framework, the factors and actors that determine the adoption of fast charging in the case of fast charging in Dutch cities are determined. This is done by combining academic sources, policy documents and news articles. In each chapter, the insights from the desk research and interviews are combined to conclude on a type of feasibility. The interview protocol and set of questions is shown in Appendix A and summaries of the interviews are given in Appendix B.

3.4 Focus group

In order to get a thorough understanding of the social feasibility, a focus group among EV drivers is executed. A focus group is a qualitative research method, that takes advantage of the communication between participants to generate useful data (Kitzinger, 1995). Focus groups use personal interaction as part of the method and participants are encouraged to ask questions or comment on each others' opinions. The idea is that group conversations can aid participants to clarify their opinions and feelings in ways that would be less accessible in an interview (Kitzinger, 1995). A focus group setting is selected, as group interaction can help in deepening the participants' views and exploring their preferences in charging. The aim of this focus group is to generate ideas and experiences that otherwise might be underdeveloped in an interview and enhance the participant perspectives through debate within the group (Kitzinger, 1995).

Possible disadvantages of focus groups are that group dynamics may silence voices of dissent or that it compromises the confidentiality of the participants. The latter is in this case less important, since charging preferences are not considered confidential. Other possible disadvantages are a bias in the selection of the participants and less control over the session than with interviews (Kitzinger, 1995).

Focus groups generally consists of 6-12 people (Kitzinger, 1995). A homogeneous group of EV drivers with experience in EV charging was preferred, since EV and charging experiences change considerably after experiencing an EV (Liao et al., 2017). The goal of the focus group was not to persuade new drivers, but to determine the charging preferences of EV drivers. Since the charging preferences are likely to differ between private and business EV drivers, a group with experience in both uses was preferred. Minimum EV experience of one year and experience with both normal and fast charging were additional criteria.

For these reasons, the focus group was held at Royal Haskoning DHV, a engineering advisory firm which also advises several organisations on electric mobility. This location was chosen, since it fits the desired participant background: a mix of business and private EV drivers and background knowledge in EV technology. Royal Haskoning DHV is one of the first companies in the Netherlands which is switching its entire lease fleet to full electric vehicles (Royal HaskoningDHV, 2017). In total 9 EV drivers participated, who mostly drove BMW i3 EVs for business purposes. The discussion is guided by the author of this report, and a second observer is present to write down notable quotes and key takeaways. The questions are focused on state-of-the-art EV and charging technology, as these cars and chargers will determine the charging behaviour in the coming years. The session is recorded and summarised. Participants are kept anonymous to guarantee their confidentiality. The focus group is organised on 17 January 2017 at the Royal Haskoning DHV office in Amersfoort, the Netherlands from 12:00 to 13:30. The focus group set-up is presented in Figure 7.

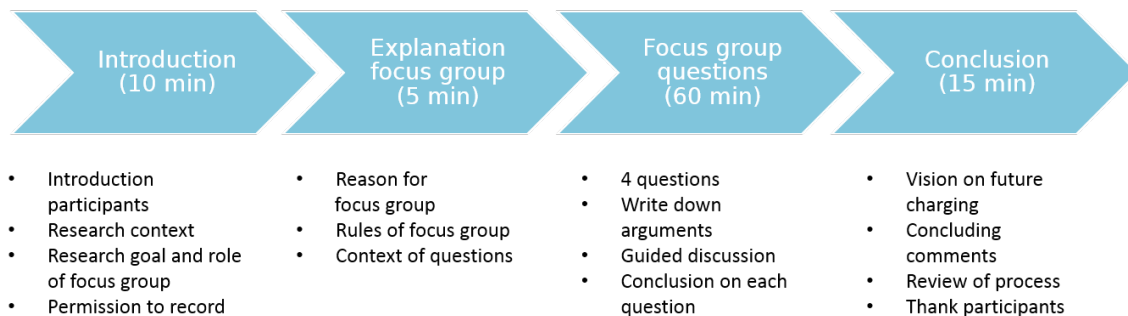


Figure 7: Set-up and planning of the focus group.

The four questions that have been discussed are focused on charging preferences. The questions and context sketched during the discussion are shown in Figure 8. As will be explained in Chapter 4, the context is a reflection of the battery size, charging speeds and driving distances expected in the coming years. Only public charging is discussed, as this is the focus of this research.

Focus group topics:

1. In what way would you preferably charge your EV when using it privately?
2. In what way would you preferably charge your EV when using it as a lease car?
3. At which locations and which opportunities would you use fast charging?
4. What is your vision of the ideal public charging infrastructure in 2025?

Context:

- 80 kWh battery
- 400 km range
- Normal charging: 11 kW
 - Charge 20-100%: 6h
- Fast charging: 175 kW
 - Charge 20-100%: 20 min
- 250 km per week driving
- Only public charging

Figure 8: Discussion topics and context of the focus group.

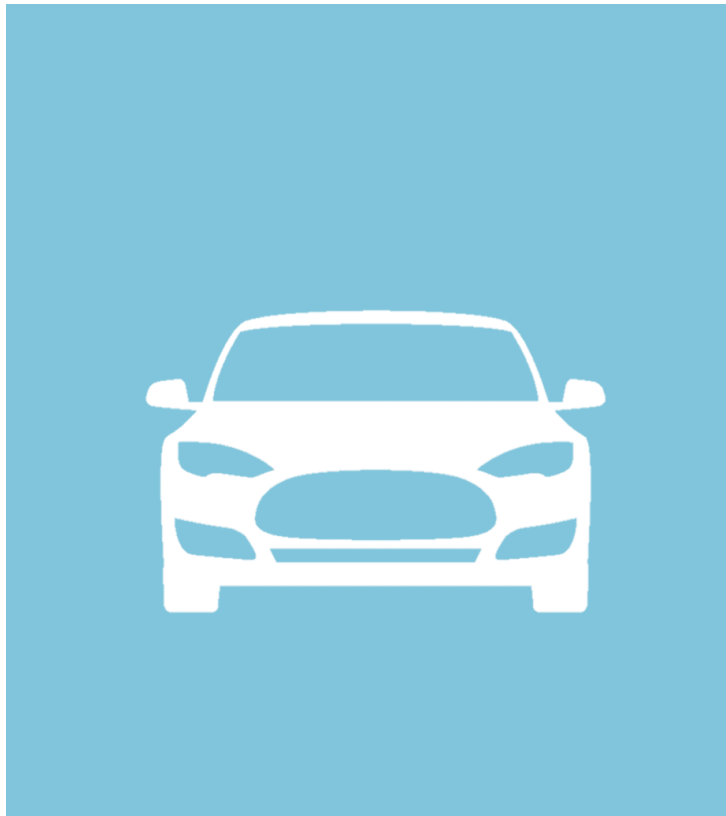
The results have been summarised, send back for feedback and documented in Appendix C. Insights from the focus group are referred to as (Focus group EV drivers, date of focus group).

3.5 Data analysis

The gathered insights are evaluated using the Feitelson and Salomon (2004) framework. The desk research is used as a stand-alone research method, as well as to set up the interviews and focus group. In each chapter, the insights from literature concerning that type of feasibility are combined with insights from the interview and/or focus group. Especially social and political factors are identified by the interviews, as these give room for people's views and relations. The focus group data is primarily used in determining the social feasibility. At the end of each chapter, the insights are bundled to determine the feasibility for the current and future context. In Chapter 9, these are combined to determine the adoption of the innovation. If factors are found that do not fit the Feitelson and Salomon (2004) framework, they are discussed in relation to the broader theoretical context of Section 2.1.

3.6 Validity and Reliability

This research relies mainly on qualitative data gathered during the interviews and focus group. The questions asked and interpretation of the answers by the researcher could influence the results. Therefore the interviews are sent back to the interviewees to check if they correspond with their views. Next to that, triangulation is used in this research where possible. Triangulation is a method that checks if multiple sources lead to the same results (Sekaran and Bougie, 2009). Factors found during the desk research are checked during the interviews, and factors are only stated when mentioned by multiple interviewees. The regular contact of the author with Fastned, a CPO in fast charging infrastructure, could potentially introduce a bias in favour of fast charging. The author has therefore selected a wide variety of interviewees with to gain a complete view of different interests and viewpoints. Finally, reliability is increased by documenting the data to ensure the replicability of the research (Yin, 1994).



4 Research Context: Electric Mobility in the Netherlands

The research context of the case study is sketched in this chapter by explaining EV and charging technology and its current status in the Netherlands. Since the adoption of fast charging is dependent on the system it is positioned in, in this chapter a general overview of the research context is presented. First, a short overview of EV technology and the status of EV adoption in the Netherlands is given, including the development of battery technology. Second, the charging technology is explained together with the current status of charging facilities in the Netherlands. Building on this context, the feasibility is determined in the remainder of this research.

4.1 Electric vehicles: Technology and adoption in the Netherlands

An overview of EV and battery performance is given in this section, as well as the current adoption of EVs in the Netherlands. First, the definitions used to describe the different types of EV throughout this report are stated in Table 3.

Table 3: EV definitions.

Term	Definition
ICEV	Internal Combustion Engine Vehicle, term for all vehicle propelled by a gasoline or diesel engine, or alternative biofuels
EV	Electric Vehicle, used in this report for vehicles with a fully electric power train (with no combustion engine) and a plug-in connector
PHEV	Plug-in Hybrid Electric Vehicle, the collective term for all vehicles with a hybrid-electric power train (with a combustion engine and electric motor) and a plug-in connector

4.1.1 Introduction of EVs on the market

Although the invention of the electric car dates back to the 19th century, advantages of the ICE technology made it the dominant technology for over a century. Its better range and easier refuelling methods gave the ICE car the advantages it still holds nowadays. Rising oil prices and environmental concerns reintroduced interests in EVs in the early 21st century (Westbrook et al., 2001). A new phase of EV development starts in 1997 with the introduction of the HEV Toyota Prius in 1997 of which 18.000 were sold during the first year of production (Toyota, 2009). The development accelerated when Tesla, a newcomer in the automotive industry, introduced the Roadster in 2009. Next, incumbent car manufacturers also start large scale R&D programs and start mass-producing EVs from 2010 onwards (Westbrook et al., 2001). The Nissan Leaf in 2010 and the BMW i3 in 2013 are two recent examples of successfully developed EVs. In the coming years car manufacturers are committing further to EVs because of government regulations and projected advantages over ICE cars. Volvo announced it will produce only PHEVs and BEVs from 2019 onward (Volvo, 2017) and Volkswagen Group is expected to realise thirty new electric models by 2025 (Volkswagen, 2017).

Numerous studies are conducted by research institutions to predict the growth of EVs in the Dutch market. A recent study by Ecofys estimates 3 million EVs in 2030 and 5 million EVs in 2035 (Ecofys, 2016). This is depicted in Figure 9.

The reason for this exponential growth of EV market share can be explained by technological advantages, as well as the need for more sustainable technologies to counter climate change (IEA, 2017). The EV technology is explained in more detail in the next section.

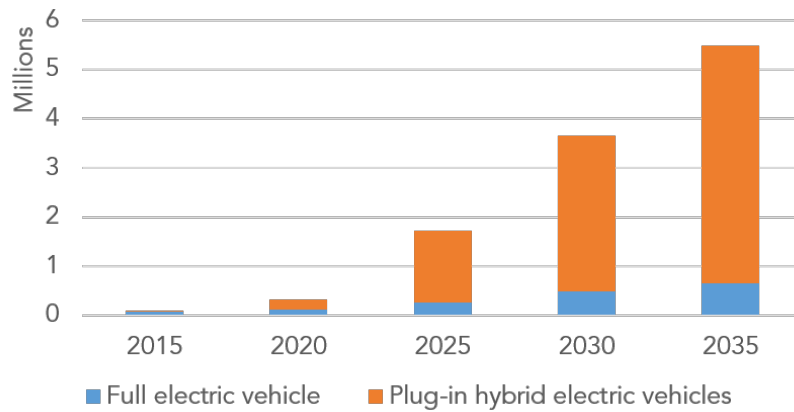


Figure 9: The expected growth in EVs in the Netherlands up to 2035 (Ecofys, 2016).

4.1.2 EV technology

One of the main advantages of an EV is that it achieves a higher energy efficiency than conventional cars. A typical gasoline or diesel engine has an energy efficiency of 25 to 30 %, as most of the energy is emitted as heat. The energy efficiency of an electric motor is significantly higher at around 90 % (Larminie and Lowry, 2003). An electric motor has less energy losses due to less moving parts and less friction. Next to that, the electric drivetrain operates more efficient compared to an ICE drivetrain. An electric motor is also able to recover energy while braking. As a result, an EV is considered a more energy efficient technology than an ICEV (Larminie and Lowry, 2003).

Another advantage of EVs is that it has no tailpipe emission or pollutants such as NO_x and particulate matter. This is especially significant in cities where local air pollution is a problem (van Rijnsoever et al., 2013). For countries depending on fossil fuel imports, replacing ICEVs with EVs can also contribute to reducing oil demand and increasing energy security (RVO, 2011). These advantages of an EV are often important for municipalities and governments in the decision to stimulate zero emission transport. The CO₂ emissions per kilometre driven of conventional gasoline and diesel vehicles are compared to those of EVs in Figure 10. As can be seen, when using green electricity (e.g. produced by wind or solar power), the emission is approximately three times lower than for an ICEV.

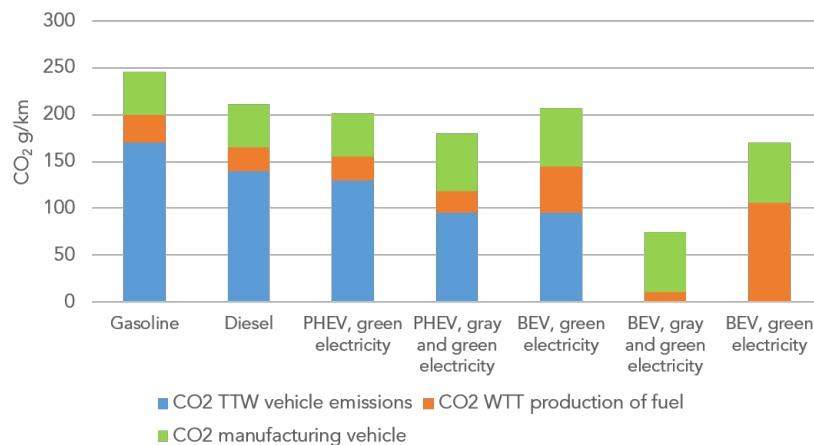


Figure 10: The CO₂ emissions of ICEV and EV technology (RVO, 2017).

4.1.3 The barriers to EV adoption are decreasing

There are a few important disadvantages regarding EVs: the limited range, the high cost of batteries and the long charging time. These are, together with charging infrastructure availability, the most important barriers to adoption (Liao et al., 2017).

The range of an EV is still lower than the range of an ICEV. The reason for this is primarily driven by battery performance: the amount of energy stored per weight unit is limited, and the price of these batteries is still high (Cluzel and Douglas, 2012; Young et al., 2013). This makes an EV less interesting for potential new consumers (Cluzel and Douglas, 2012). Since batteries are used in many technological devices nowadays, significant funding is granted to R & D. Battery development is expected to cause an increase in EV range in the coming years (ARF and McKinsey & Company, 2014; Nemry and Brons, 2010).

Most models of the current generation of EVs, have a range between 150 and 300 kilometres. This range is perceived as insufficient, although the average Dutch driver only drives 35 kilometres a day (ING, 2017). More and more models are entering the market however with a higher range up to 400 to 500 kilometres. The model availability of EVs in 2013 and the expected availability in 2020 is presented in Figure 11.

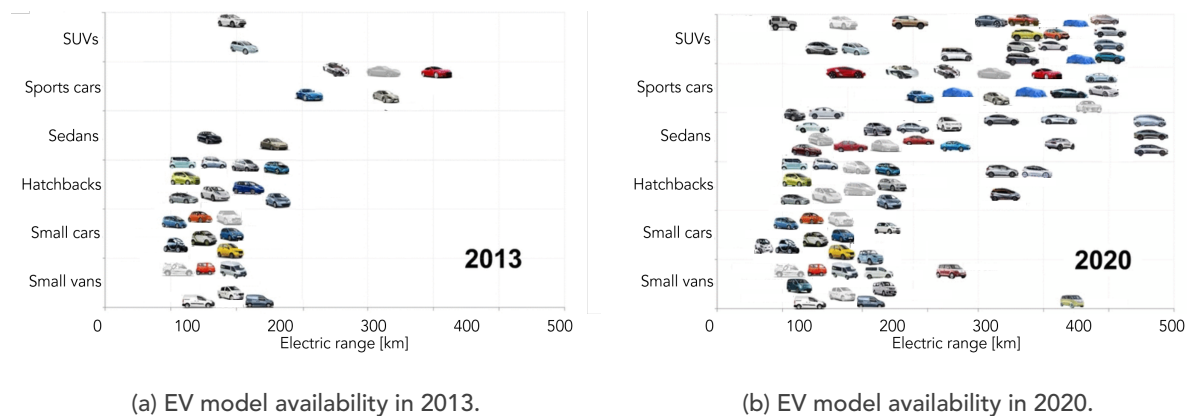


Figure 11: The range and availability of EV models in 2013 and 2020 (BNEF, 2017).

It can thus be expected that in the coming years, more EVs enter the market with a range of 400 to 500 kilometres. This is an important conclusion, as the size of the battery determines how and how often people will have to recharge. In the next section, the technology that has the largest influence on range and cost is described: batteries.

4.2 The key technology: Batteries

As stated before, battery development influences two barriers to adoption: the high purchasing cost and limited range of EVs (Liao et al., 2017; Tsang et al., 2012). To make the purchasing price of EVs competitive with ICEVs, the battery packs installed have limited capacity and therefore the EV has a limited range. The cost of the battery pack of an EV can make up to 50 % of the production costs of an EV. The battery price is therefore recognised as a crucial barrier for large scale EV adoption (Cluzel and Douglas, 2012; Tsang et al., 2012). R&D and mass production are driving the price of batteries down however, from 800/kWh in 2010 to 250/kWh in 2017 (Nykqvist and Nilsson, 2015). This trend is expected to continue, with estimations ranging from 120 to 200 /kWh in 2025, as can be seen in Figure 12. As a result, financial institutions estimate the EV to be cost competitive with ICEVs on total cost of ownership (TCO) around 2024 (BNEF, 2017; ING, 2017).

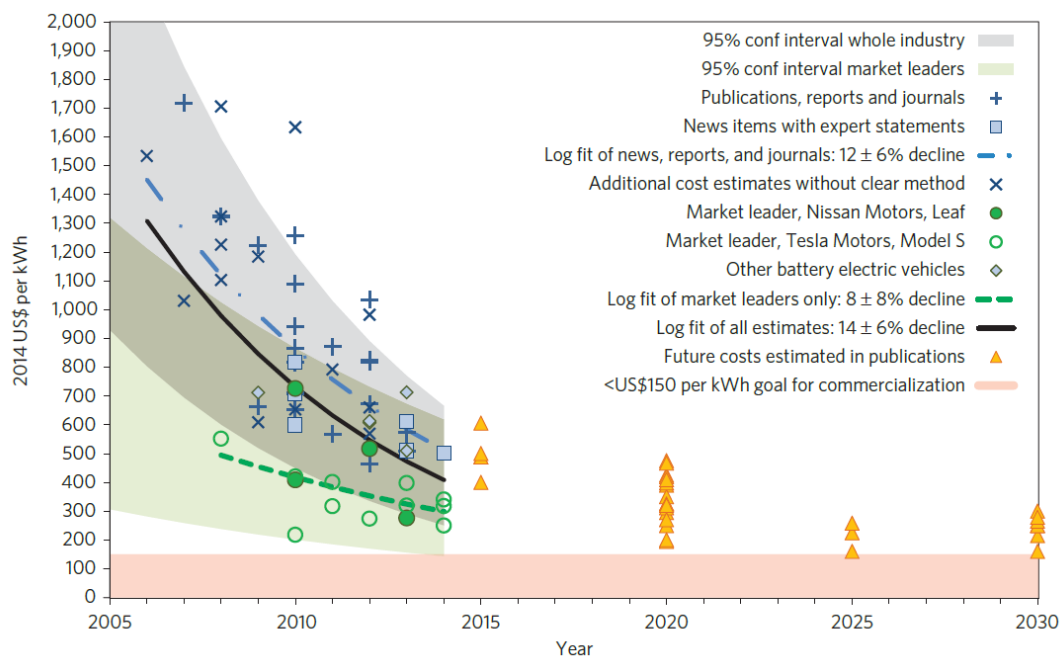


Figure 12: Historical and projected price of Lithium-ion battery packs in EVs (Nykqvist and Nilsson, 2015).

4.2.1 Battery technology and degradation

All EVs in production now are powered by Lithium-ion (Li-ion) batteries. For Li-ion batteries, the limiting performance factor currently is the energy density. Li-ion has a high specific energy of 150 Wh/kg compared to other available compositions, but it is still significantly lower than the 13,000 Wh/kg of gasoline (Young et al., 2013). The element Lithium has a much higher specific energy of 12,000 Wh/kg, but the other materials of which the battery is made have a lower specific energy (Young et al., 2013). Therefore, much R&D funding is focused on increasing the energy density of Li-ion batteries. Current research focuses among other things on material improvement of the electrodes (Cluzel and Douglas, 2012; Hacker et al., 2009).

An important aspect for the application of batteries in EV, and for charging technology, is the battery life. The battery deteriorates over time due to ageing (calendar life) and due to charging and discharging (cycle life). Ageing is caused by chemical reactions between the materials, and can be minimised by temperature control. Over time, this results in a capacity loss. Cycle life is caused by the actual use of the battery, and can be minimised by not completely depleting and recharging the battery (Yilmaz and Krein, 2013). An important aspect when producing EVs is that the battery will not fail before the EV itself will be stopped using (Lunz et al., 2012). There is no academic consensus on practical cycle life yet, since estimates range from a cycle life of 2000 cycles and 7 years calendar life, to 3000 cycles and 12 years calendar life around 2025 (Cluzel and Douglas, 2012). In an EV study by Azadfar et al. (2015), 3200 cycles for current batteries are assumed. New battery technologies are in development as well, but are not expected to reach commercialisation within 10 years (Cluzel and Douglas, 2012). These technologies include Lithium-sulphur (theoretical energy density of 2500 Wh/kg) and Lithium-air (theoretical energy density of 10,000 Wh/kg).

After discussing the EV and battery development, the primary focus of this thesis can be discussed: EV charging technology. This is done in the next section.

4.3 Charging infrastructure: Technology and status in the Netherlands

The demand for EVs is correlated with the availability of charging infrastructure, which shows the importance of developing an extensive charging infrastructure (Liao et al., 2017). An underdeveloped charging infrastructure leads to range anxiety, which is “the fear of an EV driver that the battery will be empty before the destination or a suitable charging point is reached” (Neubauer and Wood, 2014). This anxiety lowers appreciation of EVs, potentially preventing drivers from purchasing an EV (Neubauer and Wood, 2014). In this section the current state-of-the-art in charging technology is discussed. First, the difference between normal and fast charging is explained. Next, an overview of charging infrastructure development is given. Finally, the trends in charging are presented. The definitions of normal and fast charging used in this report are presented below.

Table 4: Charging technology definitions.

Term	Definition
Normal charging (AC)	Charging using alternate current (AC), which is transformed to direct current (DC) needed by the electric motor on-board of the EV. Charging speeds range from 3.3 kW to 43 kW.
Fast charging (DC)	Charging using direct current (DC), which is transformed from the AC of the electricity grid to DC in the external charger. Charging speeds range from 50 kW to 350 kW

The difference can thus be characterised by the position of the AC-to-DC converter. This is visually explained in Figure 13.

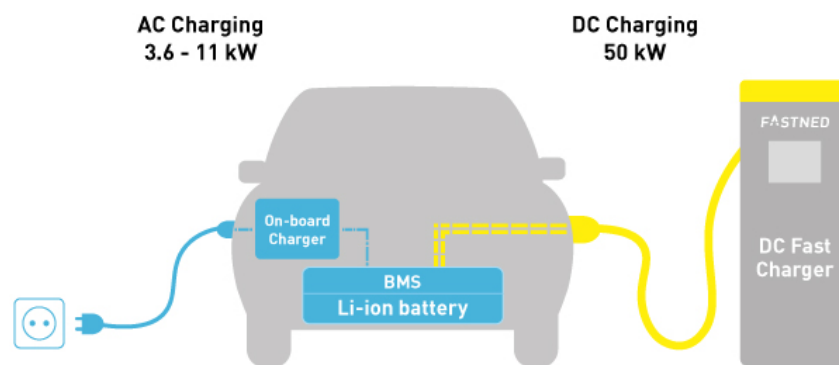


Figure 13: The difference in converter position between normal and fast charging (Fastned, 2016).

4.3.1 Public vs. private charging

There are different locations and opportunities to charge your EV. Some people can charge their EV at home, requiring a private driveway or garage. Only 25 % of the households have private parking in the Netherlands, and this is even lower in urban areas (CBS, 2016). This is called *private* charging. Other locations are destinations such as workplaces or hotels, where several EV drivers use the same chargers. As these chargers can only be used when you work or visit a location, these are called *semi-public* chargers. Lastly, there are chargers that are accessible to everyone, so-called *public* chargers. These are located near people’s homes when they do not own a private driveway or along highways of roads in the city. As mentioned, this thesis is concerned with public charging points.

4.3.2 Normal charging vs. fast charging

Besides the location, there are two options in technology to charge your EV: normal charging and fast charging.

Normal charging uses AC and is done in the Netherlands at speeds of 3.3 up to 22 kW. This means a full charge takes, depending on your battery capacity, between 6 and 20 hours (Yilmaz and Krein, 2013). On-board of the vehicle this is converted to DC to power the electric motor. Faster AC charging rates up to 43 kW are also possible requiring a heavier and more costly on-board converter. Currently, the Renault Zoe is the only EV that supports this option, as this increases the price of an EV significantly. The charging speeds are dependent on the electricity grid at a location, the grid connection of the charger, and the capabilities of the EV itself. The charging speeds in the Netherlands are 3.7 and 7.4 kW for single-phase AC (Level 1 chargers), and 11, 22 or 43 kW for three-phase AC (Level 2 chargers). When looking at the database of public chargers, 11 kW charging points account for 67 % of public and semi-public charging points in the Netherlands, followed by 3.7 kW points with 19 %. The average charge speed based on usage in the G4 cities in the Netherlands is 4.7 kW (Wolbertus et al., 2016).

The second option is fast charging with direct current (DC), Level 3 chargers. In this option, the electricity from the grid is converted to DC by the external charger and the charging speeds start at 50 kW. Current state-of-the-art chargers deliver up to 150 kW and ultra-fast chargers are planned with speeds up to 350 kW in 2020 (IEA, 2017). With these speeds, a full charge can be obtained in 10 to 15 minutes. Most cars however will not be able to charge at these speeds yet, as will be explained in Chapter 5. Porsche is the first car manufacturers developing a car, the Mission E, capable of charging at 350 kW (Porsche, 2017). The fast charger technology requires significantly more expensive hardware, with investments of approximately 20.000 euro for a 50 kW charger. This means fast charging is usually more expensive than normal charging for the EV driver (Schroeder and Traber, 2012).

Figure 14 shows the time it will take to charge a 90 kWh battery from 25 % to 100 % for the different charging solutions. Now the difference in technology is explained, a short overview of the public charging infrastructure in the Netherlands is provided next.

Charging a 90 kWh battery from 25% to 100%	
3.5 kW domestic charger	19 hours
7.0 kW domestic charger	8 hours 30 minutes
11 kW commercial charger	6 hours
22 kW commercial charger	3 hours
50 kW fast charger	1 hour 20 minutes
350 kW fast charger	12 minutes

Figure 14: Time needed to charge a 90 kWh battery from 25 to 100 % (Barclays, 2017).

4.3.3 Deployment of charging infrastructure

The introduction of public charging infrastructure in the Netherlands started with the installation of public charging stations by Stichting E-laad. E-laad is a foundation initiated by several distribution system operators (DSOs) (Hall et al., 2017). The goal was to facilitate the roll-out of public charging stations, while gathering information on charging behaviour. E-laad worked together with approximately 350 Dutch municipalities to install public charging stations. E-laad supplied and installed the chargers and was responsible for maintenance and service. This resulted in almost 3000 normal public chargers in 2014. After 2014, the government stopped the program and each municipality became responsible for managing and installing new charging infrastructure through concessions or permits. Several commercial parties entered the market and started installing infrastructure, often (partly) subsidised by government programs (Rijksoverheid, 2016).

In the Netherlands, there are currently over 11.000 public normal charging points and over 600 public fast charging points (RVO, 2017). The growth of charging points over time is shown in Figure 15.

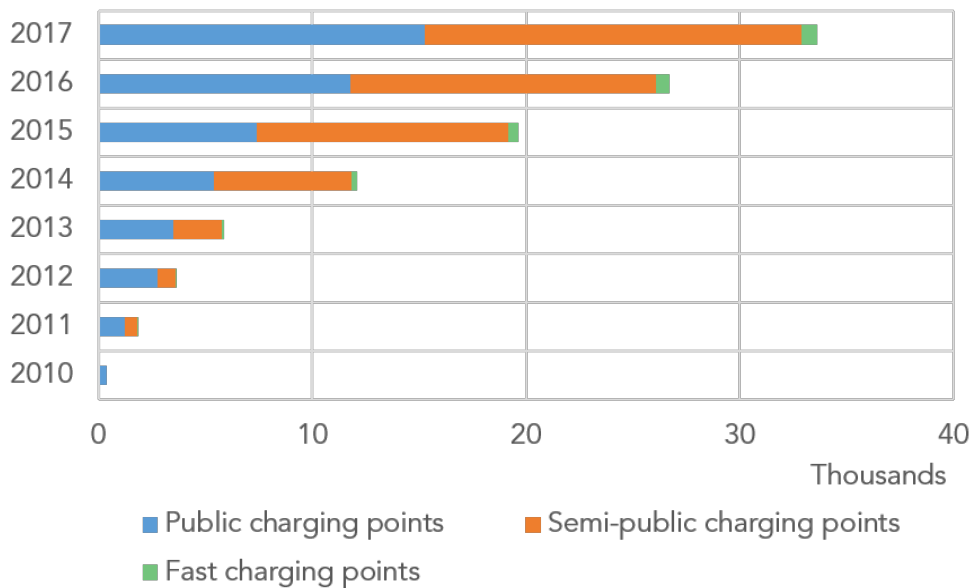


Figure 15: Development in the number of (semi-)public charging points in the Netherlands (RVO, 2017).

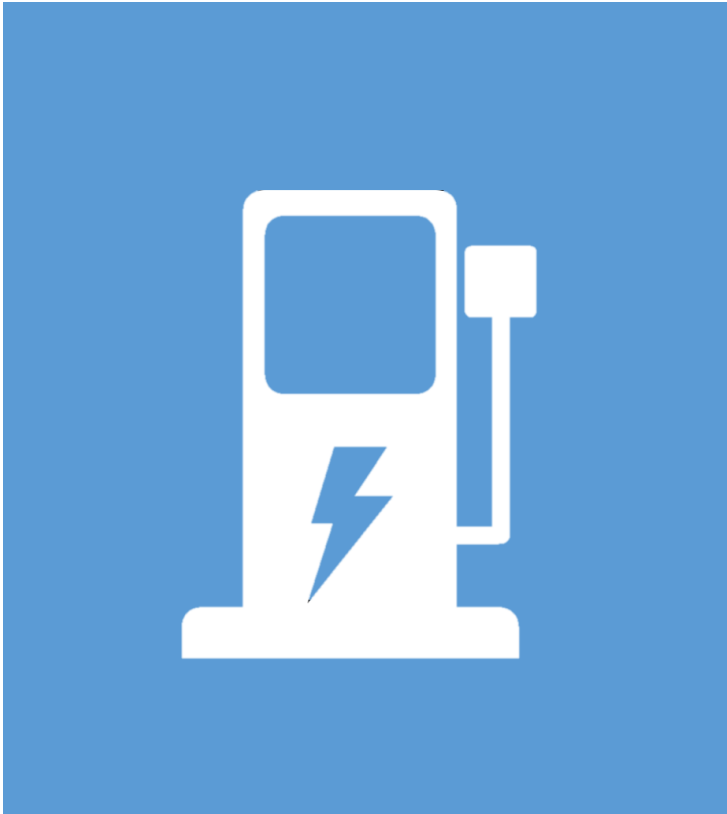
Standardisation

As with every new technology, it takes time before the technology is standardised (van de Kaa et al., 2011). Charging solutions need standards for the connectors, payment and recharging protocols to ensure the inter-operability between cars and chargers. A standardised infrastructure also minimises the cost for charging installation (Hacker et al., 2009). For normal charging, the Mennekes standard is widely accepted by the industry. For fast charging there are still three standards on the market: The European CSS "Combo", the Japanese ChAdeMO and the Tesla Supercharger. In Europe and the US, the CSS is starting to become the standard for fast charging. A final standardisation is projected around 2020 (ARF and McKinsey & Company, 2014). Other standardisation aspects are the communication and payment protocols. In the Netherlands the same protocol is used by all charge points, which means EV users can use any charge point they want. Worldwide, this is not the case yet (ARF and McKinsey & Company, 2014).

4.4 Chapter conclusion

To conclude, the research context of this thesis is that of EV mobility in the Netherlands. In the coming years, barriers to adoption are expected to decrease as range increases and price goes down. This results in an expected 3 million EVs on the Dutch roads by 2035. To charge these EVs, either normal or fast charging technology can be used. Differences in technology include the charge speed and price of charging, where fast charging technology is developing rapidly with charge speeds up to 350 kW in 2020. These developments are expected to change the structure of the public charging infrastructure in the Netherlands. Or as Barclays, a leading financial institution puts it: "It remains to be seen how the market shares develop between local (slow charging) and centralised (fast charging). Growing battery sizes should support a greater uptake of fast charging over time." (Barclays, 2017).

Taking the research context presented in this chapter into account, the technical feasibility of fast charging is discussed in Chapter 5.



5 Technical Feasibility: Fast Charging Development and Grid Integration

Fast charging technology is developing rapidly. In this chapter the technical feasibility in the current and future context is analysed. First, the developments in fast charging technology are discussed. Next, the integration of charging infrastructure in the electricity grid is discussed. Finally, the co-evolving technologies of car sharing and autonomous driving and their effect on charging are evaluated.

5.1 Factors in determining the technical feasibility

Following the Feitelson and Salomon (2004) framework, a number of actors and factors play a role in the technical feasibility of fast charging. First of all, the suggested innovations needs to be able to solve the perceived problem or crisis. Therefore the charging technology must meet the technical requirements to charge the EV. Experts and industry actors influence the suggested innovations, the perception of problems and the technical requirements of these innovations. The factors and actors of interest are indicated by the red dotted lines in Figure 16.

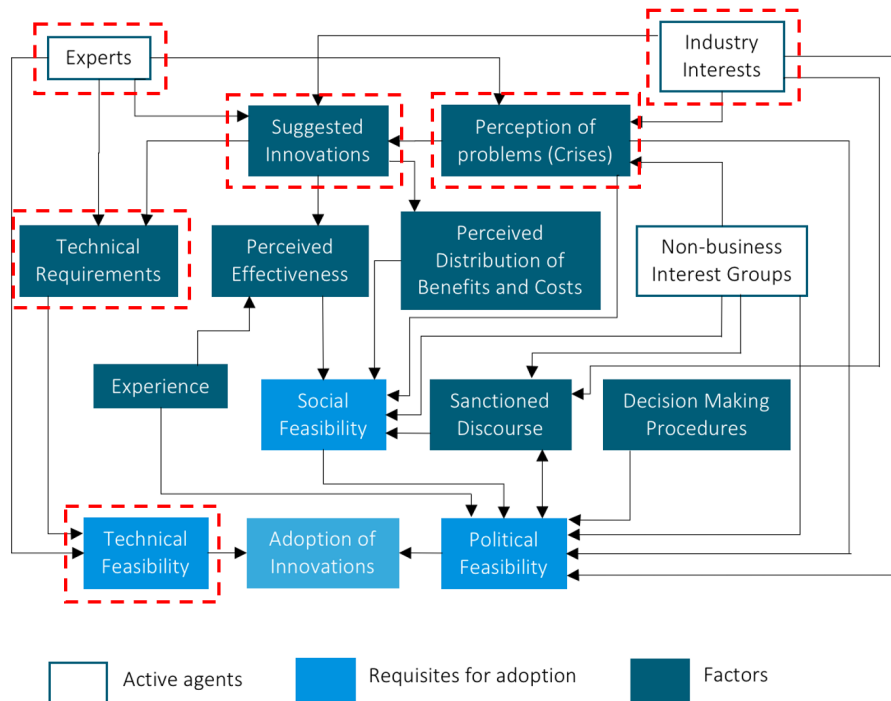


Figure 16: Factors influencing the technical feasibility of fast charging.

Following the desk research, three main factors are identified that influence the technical feasibility. These are discussed during the interviews to verify and enrich the findings. It must be noted however, that for the technical feasibility emphasis is lied on desk research, as this is mainly concerned with aspects that require elaborate scientific research. An overview of the factors, linked to the Feitelson and Salomon (2004) framework and overview of relevant interviews is presented in Table 5.

Table 5: Technical feasibility factors identified from desk research and interviews.

Factor influencing feasibility	Theoretical category	Desk research sources	Discussed in interview
Technical developments in fast charging	Technical requirements, Experts	Yilmaz and Krein (2013) Ahmed et al. (2017) Keyser et al. (2017) Meintz et al. (2017)	1,2,6,7,8,9
Integration with the electricity grid	Technical requirements, Industry interests, Experts	Mauri and Valsecchi (2012) Verzijlbergh et al. (2012) Eising et al. (2014) Sovacool and Hirsh (2009)	1,2,3,4,5,6 7,8,9,10
Adjacent disruptions: autonomous driving and electrification	Suggested innovations, Technical requirements	Ecofys (2016) Chen et al. (2016)	1,2,3,4,5,6 7,8,9,10

5.2 Technical developments in fast charging

The technical developments in fast charging are discussed in this section, as this influences the technical feasibility of the innovation. With this respect three factors are important. First of all, the developments in charging technology show that 350 kW chargers can be made in the future. Secondly, the effect of high charging rates on battery performance is often seen as a risk, but research suggests the effects are minimal. Thirdly, as the combination of the car battery and the charger effect the actual charge rate, effective speeds of 100 to 150 kW are expected in the coming years.



DESK RESEARCH

The majority of currently deployed fast chargers charge up to 50 kW, with the exception of Tesla superchargers which charge at a maximum of 120 kW (Tesla, 2017a). Dutch CPO Fastned has started with installing 150 kW chargers in late 2017 (Fastned, 2016).

Extensive academic and industry research is conducted in increasing this charge speed even further. As a result, ultra-fast charging stations with speeds up to 350 kW are expected in 2020 (IEA, 2017). Currently, refuelling times with a 50 kW fast chargers are 3 to 6 times longer than is normal with gasoline or diesel. Higher charging rates can reduce these times with a factor 3 to 7, in which case the experience becomes similar to gasoline refuelling (Meintz et al., 2017). Most cars however will not be able to charge at these speeds yet. Porsche is the first car manufacturers developing a car, the Mission E, capable of charging at 350 kW (Porsche, 2017). The battery packs and charging power capabilities of the models in the market are shown in Figure 17.

	Existing BEVs	Future BEVs
d.c. charging power	50–120 kW	>400 kW
Battery pack voltage	400 V for passenger vehicles	800–1000 V
Battery pack capacity	20–90 kWh	>60 kWh
Vehicle range	80–300 miles	>200 miles
Charging connector	CCS, CHAdeMO, Tesla	Revised CCS and CHAdeMO or a new XFC connector

Figure 17: Current and future EV and fast charging characteristics (Meintz et al., 2017).

For charging speeds up to 350 kW, developments in battery technology are needed. Among those are the need for new electrode materials which are less sensitive to stress-induced failure. Also new designs for better thermal management and battery pack configurations to accommodate the higher operating voltage are needed (Ahmed et al., 2017). The cables and connectors need to be able support the high amperage (A) of fast charging. An option is to integrate cooling in the cables and connectors in liquid-cooled systems. Current liquid-cooled cabling is able to handle charging currents up to 350 A for dimensions and weights suitable for a cable. Manufacturers are developing prototypes to upgrade the CCS and CHAdeMO protocols and their cables (Meintz et al., 2017).

Concluding, current charge speeds are already up to 100 to 150 kW. To accommodate for speeds up to 350 kW, which resembles the current refuelling experience, chargers need to be developed further. Liquid-cooled cabling and upgraded standards are in development.

5.2.1 Actual charging speed is based on the combination of charger and car

As stated, it is important to consider that the actual charging speed is based on the combination of the battery pack of the EV and the charger. To support 350 kW charging, EV and battery components need to support 800 V charging, which they will not do in the coming years.

It is important to consider that the charging rate is influenced by both the current and the voltage. The charger determines the amperage, and advances in thermal management minimise losses for high amperage. The voltage however is determined by the battery pack of the specific EV (Yilmaz and Krein, 2013). If a charger is advertised as to deliver 50 kW, it therefore does not mean that every car can charge at this speed. When charging is done at 50 kW this is usually done at 400 V and 125 A, as shown in a calculation example below.

$$\begin{aligned}\text{Charging rate} &= \text{Voltage} \times \text{Current} \\ 50 \text{ kW} &= 400 \text{ V} \times 125 \text{ A}\end{aligned}$$

The most common EV battery today is around 400 V when fully charged. When the battery is empty, this voltage is lower, around 320 V (Meintz et al., 2017). The voltage of a battery pack will gradually increase while charging, increasing the charge speed as well. To accommodate higher charge speeds up to 350 kW, the battery pack configuration and components needs to change to accommodate a higher voltage of up to 800 to 1000 V. The current models in the market and their battery pack capability are summarised in Figure 18.

The current can be increased or decreased based on data received from the battery management system by the fast charger. Common fast charge technology today have a maximum current of 125 A. State-of-the-art 150 kW chargers can provide a current of 300 A. For the upcoming 350 kW chargers, it is important to consider that this is based on 930 V and 375 A. Most models on the market in the coming years have batteries operating on 400 V, which means the actual charging speeds are limited to approximately 150 kW. The different combinations of current and voltage that deliver fast charging rates are shown in Figure 19.

Concluding, fast chargers are in development with charge rates up to 350 kW. As the actual charge speed depends on the combination of charger and EV, the charge rate will be around 100 to 150 kW in the coming years due to the limitations of the EVs on the market. Next, the effect of fast charging on battery degradation is discussed.

5.2.2 Effect of fast charging on battery degradation

One concern often associated with these ultra fast charging speeds is the issue of battery degradation. When fast charging negatively influences the battery, the range will decrease and the EV will use utility. If the battery will fail before the EV does, extra costs of battery replacement further increase barriers to purchase an EV. Research however suggests that current batteries do not suffer significantly from fast charging when using battery thermal management systems.

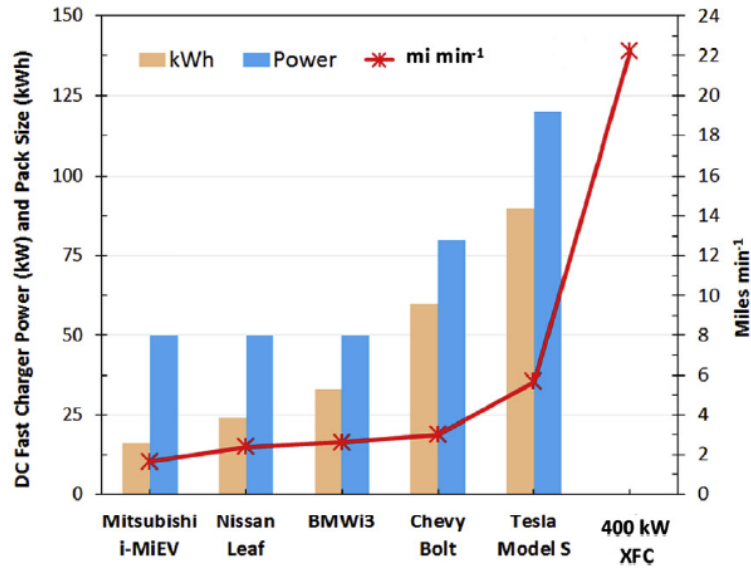


Figure 18: Practical fast charging capabilities of EV models (Ahmed et al., 2017).

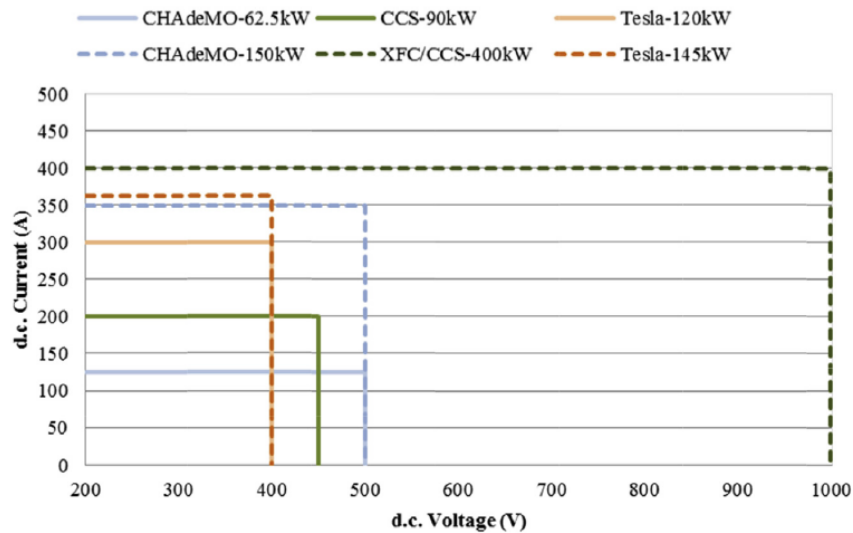


Figure 19: Charging voltage and current for for current and future protocols (Meintz et al., 2017).

The effect of charging rates on battery performance are discussed extensively in literature. New research however suggests that this is not a significant issue for current battery technology. In a survey among 286 Tesla Model S drivers the battery degradation is modelled over time (Tesla, 2017b). The data shows that for the first 80,000 kilometres, most Tesla battery packs will lose about 5 % of their capacity. After that the capacity levels off and battery packs stay above 90 % of their original capacity. Frequent use of fast charging (Tesla calls this Supercharging) appears to not degrade the battery faster and it seems even to be beneficial for the Tesla Model S battery (Tesla, 2017b).

Another study by the Idaho National Laboratory compared the battery degradation of 2012 Nissan Leafs by charging them using 3.3 kW chargers or by 50 kW fast chargers (Shirk and Wishart, 2015). The cars charged with fast chargers showed some additional battery degradation after 80,000 kilometres, but the capacity loss due to fast charging was significantly lower than the overall battery degradation. The research used an extreme use case, as the vehicles were fast charged twice a day. Next to that, the vehicles were driven in Phoenix, Arizona which has a hot climate. It is thus likely that the capacity loss measured is an upper bound for capacity loss (Neubauer et al., 2015). Shirk and Wishart (2015) also concludes that battery thermal management is critical in preventing battery degradation when using fast chargers multiple times. Using different cooling techniques, the battery capacity loss is shown in Figure 20 for a cold (Seattle) and hot (Phoenix) climate.

Seattle Climate 10-Year Capacity Loss, %			Phoenix Climate 10-Year Capacity Loss, %		
Strategy	No Fast Charge	Fast Charge	Strategy	No Fast Charge	Fast Charge
Passive Cooling	17.6	18.1	Passive Cooling	27.0	27.6
Active Cooling	17.3	17.5	Active Cooling	24.4	24.5
Active + Standby	17.1	17.3	Active + Standby	21.0	21.2

Figure 20: Effect of fast charging and cooling on capacity loss in Seattle and Phoenix (Keyser et al., 2017).

INTERVIEWS

This state of the technology is confirmed during the interviews held. All interviewees acknowledged that the fast charging rate will improve in the coming years to approximately 150 kW (Interview 1-12). Some interviewees did also mention the challenges involved in ultra-fast charging (Interview 1,2) and the notion that even if fast charging is available, most EV models on the market could not yet charge on these rates (Interview 1,2,8,9). The expected maximum fast charge rate is around 150 kW according to the interviewees (Interview 1,2,7,8). It was also questioned during the interviews if 350 kW chargers would become viable on a large scale. Consumers would not have the need for charging at these rates as it is more expensive (Interview 1,3) and there could be sufficient charging solutions at lower rates (Interview 2,3).

“Cars that can charge at 350 kW are not on the market yet. Tesla’s can charge at approximately 100 kW, that’s it. In 5 or 10 years the technology will be there.” (DSO, Interview 2)

To conclude, the fast charging technology is capable of charging EVs on the market in the coming years with speeds of approximately 100 to 150 kW. This depends on the charger used, and the configuration of the battery pack in the EV. Battery degradation does not seem to be a major issue when fast charging when appropriate thermal management is taken into account. Next, the integration of charging infrastructure in the electricity grid is evaluated.

5.3 Integration with the electricity grid

As EV adoption increases, the demand for electricity increases as well. The EV batteries need to be charged, and this can have a significant impact on the electricity grid. The feasibility of fast charging is influenced hereby in two ways. First, fast charging can decrease the loads and peaks on the low voltage grid, possibly avoiding significant costs. Secondly, DSOs have labelled EV charging as a possible solution to balance supply and demand in the increasingly electrification of neighbourhoods. So-called ‘smart’ charging is used in this way to determine when the EV charges, or returns energy to the grid. Fast charging does not have this capability, as cars are connected during short periods with high peaks.



Regarding the impact of increased EV adoption on the electricity grid, numerous studies have been performed (Eising et al., 2014; Pieltain Fernandez et al., 2011; Verzijlbergh et al., 2012). A case study for the Netherlands for a 75 % EV penetration scenario in 2040 showed that approximately 50 % of transformers and 18 % of cables need to be replaced in the low voltage network when normal charging is used (Verzijlbergh et al., 2012). This would result in 29 % more costs compared to a no EV scenario. Costs can be reduced to an additional 5 % if controlled 'smart' charging is used however (Richardson, 2013; Verzijlbergh et al., 2012). Because electricity grids are designed for peak demand, efficiently distributing the peaks can greatly reduce the upgrade costs. In cities, additional costs arise since housing and paving is more dense and electricity peaks are more severe. Eising et al. (2014) stated that the adoption of EVs can harm the functioning of the electricity grid in the city of Amsterdam in the short term. An extensive comparison of grid reinforcement costs for regular and smart charging in Dutch cities is not yet available.

Fast chargers, in contrast to normal chargers, are usually connected to the medium voltage (MV) grid. This steers EV charging loads away from the low voltage grids in streets and neighbourhoods. In a study of the impact of fast charging on the grid in Milan, Italy, it was concluded that the voltage drop was only at maximum 2.5 %, and could be termed imperceptible (Mauri and Valsecchi, 2012). Concluding, fast charging steers the loads away from the low voltage grid, possibly avoiding extra costs for DSOs and governments.

Due to the increasing amount of renewable energy however, normal charging can also be seen as an opportunity. In a smart grid the EV can be connected to the grid (vehicle-to-grid, V2G) or possible to a users home. By using the battery the EV, the supply of the demand on the grid could be managed. The EV will thus charge when demand on the grid is low or supply high, and the EV battery can supply electricity to the grid when demand is high or supply low (Sovacool and Hirsh, 2009). Since solar and wind energy cannot be controlled, this is an interesting proposition. V2G solutions are often stated as a solution, but it is still questionable what the technical and economical feasibility of this technology is (Lopes et al., 2011). The hardware involved is expensive, and since battery life is determined by the amount of cycles, using the battery constantly to balance the grid reduces battery life (Sovacool and Hirsh, 2009). Concluding, normal charging has the potential benefit of acting as a 'balancing mechanism of supply and demand' in the increasingly renewable electricity grid. The costs involved and limited revenue possibilities however question the short-term viability.



The conclusions from the desk research are mostly underlined by the interviewees. Recently, the ElaadNL foundation in collaboration with DSO Stedin started a study in the integral costs and benefits of fast and normal charging on the electricity grid (Interview 2). Current estimates of the financial potential are low however. One interviewee mentioned that 3500 euros could be gained for the 800 public chargers in the Hague, but that the software costs involved in organising this would outweigh these benefits (Interview 4). Another interviewee predicts that V2G technology can become feasible in ten years, but that this will happen after the EV boom (Interview 2).

"When an EV charges over night, it uses as much electricity as a household does in 5 days" (Municipality, Interview 4).

“There is some potential in smart charging and V2G technology, but it is not a decisive factor in determining charging solutions” (TU/e, Interview 1)

Other interviewees mentioned that the integration of the charging infrastructure should be seen in a wider context. Interviewees state that heating is expected to become electric in some neighbourhoods, and renewable energy generation will grow (Interview 1,4,5,10). This means that the grid needs to be reinforced anyway in some neighbourhoods, depending

on its specific context. EV charging could be seen as one piece of this puzzle, and taken into account when upgrading the grid for the future (Interview 5).

Concluding, the integration of EV charging in the grid can increase the peak loads significantly. For fast charging this is less of an issue, as fast charging stations are connected to the MV grid. Smart charging is an effective measure to help shave off these peaks, but V2G technology will not be feasible in the coming ten years. In the next section, adjacent disruptions that effect charging are discussed.

5.4 Adjacent disruptions: Autonomous driving and electrification

Technological disruptions such as car sharing and autonomous driving show synergies with EVs. Sharing EVs in cities is an efficient way to improve local air quality, reduce emissions and reduce the costs of mobility. Next to that, shared or autonomous vehicles can reduce barriers to EV adoption such as the high purchase price and infrastructure availability (Chen et al., 2016).



DESK RESEARCH

The Netherlands intends to become a front-runner in the area of autonomous driving. Cars already have Level-2 autonomous systems like adaptive cruise control or systems which help the car keep to its lane (lane assist). There are also some level-3 cars on the road (including the Tesla model S). The term autonomous car often means the development to Levels 4 or 5, where the car is capable of making decisions completely autonomously (RVO, 2017). The car industry has announced bold ambitions in this area over the past year. For instance, Ford announced in August this year that it plans to start producing autonomous cars on a large scale as from 2021. And Tesla is already fitting all the cars it produces with hardware intended to allow for fully autonomous driving (Level 5) within a few years (RVO, 2017).

If autonomous driving breaks through, the up-time of EVs will increase significantly (Hall et al., 2017). A lower number of vehicles is needed, and vehicles will be parked a lower percentage of the day. In a 2012 study, it is expected that each shared, autonomous EV can replace 3.7 to 6.8 privately owned vehicles. When fast charging is used, this number is higher (6.8) when compared to normal charging (5.5) for a 350 km range EV (Chen et al., 2016).



INTERVIEWS

The interviewees also see strong synergies between EV charging and shared and/or autonomous driving (Interview 1,2,3,4,6,10). Interviewees expect this will change the charging landscape significantly and expect charging solutions to be located outside the city centre (Interview 1,2,3,4,7,8). Charging solutions are expected to be fast charging for cars with a high utilisation rate, such as e-taxis (Interview 1,2,6), or slower rates of approx 20 to 50 kW when cars are used less and charge at the city periphery (Interview 2,10).

5.5 Chapter conclusion

To conclude this chapter, the first sub-question is answered: *What is the state-of-the art and development in fast charging technology?*. This question is answered by evaluating the factors and active agents in the Feitelson and Salomon framework that determine the technical feasibility.



CURRENT FEASIBILITY

It can be concluded that fast charging is technically feasible. Fast charging is one of the two suggested innovations for EV charging infrastructure and is currently capable of charging rates up to 150 kW. The technical requirements are met, as fast charging is already used currently and concerns regarding battery degradation are not severe if proper battery thermal management is used. Fast charging reduces pressure on the low voltage grid, but also limits the potential to level sustainable energy production on the grid.



DEVELOPMENTS IN FEASIBILITY

Fast charging technology is developing rapidly and charging speeds are expected to increase to 150 kW and even 350 kW in the future, reducing time needed to charge the battery significantly. Car manufacturers such as Porsche and Tesla are committing to fast charging, showing the industry interests in the technology. The co-evolving transitions in the transport sector of autonomous driving will most likely increase industry interest in the technology.



6 Economical Feasibility: Benefits, Costs and Market Development

The profitability of charging infrastructure is difficult at low adoption rates. To counter this problem and to stimulate EV adoption, governments have subsidised mainly normal charging infrastructure in cities. With increasing EV numbers, industry interest intensifies and charging infrastructure will become economically feasible. To accelerate EV adoption, local governments can grant advantageous location prices and a long contract duration to both normal and fast charging operators. In this chapter the profitability of fast charging and normal charging is evaluated for current and future adoption rates. Furthermore, investments by government and the automotive industry in charging infrastructure are evaluated.

6.1 Factors influencing the economical feasibility

The economical feasibility is not explicitly depicted in the Feitelson and Salomon (2004) framework, but is stated as a separate form of feasibility in their study nonetheless. The economic feasibility is connected to the technical and social feasibility. An innovation will not be considered technically feasible if it cannot pass a cost-benefit analysis. This can be seen in two ways: from a societal perspective and from a business perspective. In the past years, installation of chargers was mainly financed by the government. But since the Dutch government has stated that installing charging infrastructure is a market activity, the business case should be profitable RVO (2017). Next to that, it will also not be considered socially feasible if the perception of the benefits do not outweigh the costs. Industry actors play a role herein, as business only enter the market if a profit can be made. The factors involved in the economical feasibility are indicated by the red dotted lines in Figure 21.

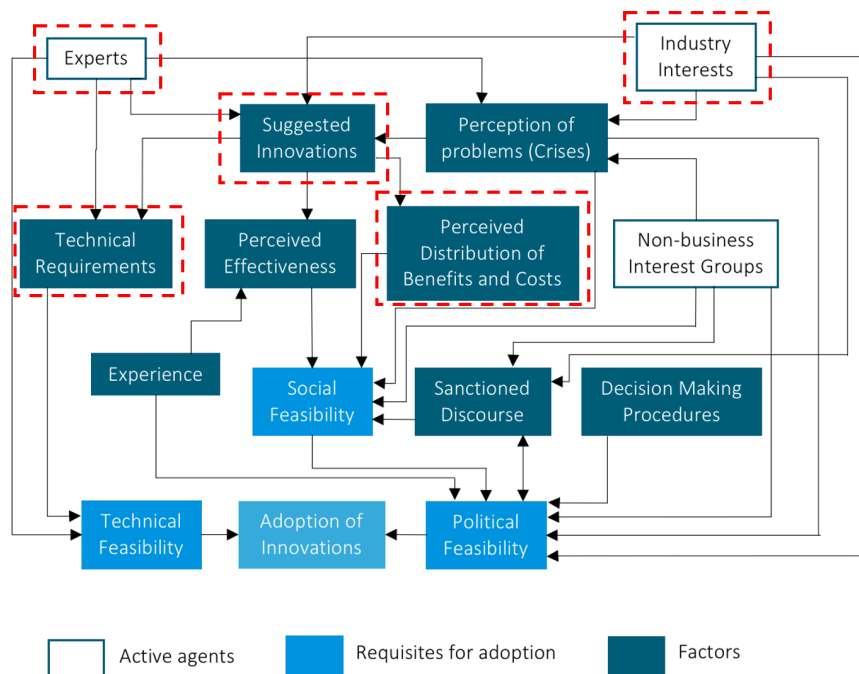


Figure 21: Factors influencing the economical feasibility of fast charging

From these factors and the desk research, four factors are identified that play a role in the economical feasibility. First of all, the perceived distribution of benefits and costs is discussed. Next, the profitability of operating charging infrastructure is discussed. Finally, business models and industry and government spending are evaluated. The factors are summarised in Table 6.

Table 6: Economical feasibility factors identified from desk research and interviews.

Factor influencing feasibility	Theoretical category	Desk research sources	Discussed in interview
Perceived distribution of benefits and costs	Distribution of benefits and costs	Bakker and Trip (2013) Schroeder and Traber (2012)	1,2,3,4,5,6
Profitability of fast charging compared to normal charging	Distribution of benefits and costs, industry interest	Schroeder and Traber (2012) Madina et al. (2016) Alhazmi and Salama (2017)	1,2,3,4,5, 6,7,8,9,10,11
Business models	Industry interest	Román et al. (2011) Madina et al. (2016)	1,2,6,7,8,9,10
Market investment	Industry interest	Tesla (2017b) Fastned (2016)	1,2,3,4,5,7,8

6.2 Perceived distribution of benefits and costs

The perceived distribution of benefits and costs determines if the innovation is deemed feasible by society. The innovation must be able to pass a cost-benefit analysis, and must be viewed as an effective solution economically.



DESK RESEARCH

Dutch government has largely funded early charging infrastructure in order to solve the ‘chicken-and-egg’ problem: if there is no infrastructure no EVs will be sold, but when there are no EVs on the roads no charging infrastructure will be built (RVO, 2015). As fast charging was technically not yet a feasible solution in cities, the subsidies for normal chargers were an effective way to install a first charging network.

Currently, the installation and operation of charging infrastructure is determined to be a market activity by the national government (RVO, 2017). As will be shown in Section 6.3, both normal and fast charging can become profitable, considering two factors. First, the contract duration should be sufficiently long to earn back the initial investment (ranging from 10 to 15 years). Secondly, the location for installing chargers should be provided by municipalities at an advantageous rate. As normal chargers are usually located at parking spots, no rental prices are charged. For fast chargers, a similar construction used as along the highways can be used. Here, commercial parties install and operate fast chargers commercially, but pay a reduced price for the location (RVO, 2011). Also the costs of upgrading the grid because of increased peaks should be taken into account when determining the distribution of benefits and costs of both solutions (Eising et al., 2014).



INTERVIEWS

The interviews showed that the subsidies for normal charging were a logical choice to start up the charging infrastructure in the Netherlands (Interview 1,2,4,7). This however resulted in a better perceived distribution of benefits and costs for normal charging (Interview 6,7,8). As the price per kWh is lower and business did not have to pay the initial investment, the perception of normal charging has been better (Interview 2,5,6).

Taking into account the future developments however, this is expected to change. Costs of upgrading the electricity grid, as well as better fast charging technology change the distribution of benefits and costs (Interview 1,2,7). Currently, a study is set-up to investigate the societal costs of normal and fast charging including grid upgrade costs (Interview 2). Both solutions however can pass a cost-benefit analysis and are concluded to be economically feasible by the interviewees (Interview 1-10).

“Currently, normal charging is subsidised. If fast charging is cheaper from a societal perspective, policy should stimulate fast charging more.” (DSO, Interview 4)

Concluding, both fast and normal charging can pass a cost-benefit analysis. The context of early charging infrastructure has led to a better perceived distribution of benefits and costs for normal charging than for fast charging. The changing context however asks for more equal division of benefits towards normal and fast charging.

6.3 Profitability of public charging

In this section the profitability of public charging are discussed, as this determines if the technology become commercially viable and if industry interests arise.



DESK RESEARCH

To evaluate the profitability of charging infrastructure, the costs and revenues of installing and operating charging infrastructure need to be determined. This is done for the costs and benefits of normal as well as fast charging infrastructure. Three public charging solutions are compared, which have been identified from the interviews to be the most common in the future (Interview 1,2,3,8). For normal charging an 11 kW charger with 2 plugs is selected. For fast charging, two configurations are evaluated: a curbside charger with 2 50 kW chargers and a station-type design with 2 150 kW chargers. The characteristics of the different chargers evaluated are shown in Table 7.

Table 7: Normal and fast charging solutions evaluated for profitability.

	Normal 11 kW	Curbside 50 kW	Station 150 kW
Number of charging plugs	2	2	2
Station lifetime	8	10	10
Load limit (Volt)	230	400	400
Load limit (Ampere)	48 (3 * 16)	125	375
Power limit (kW)	11	50	150
Duration for 20 kWh charge (min)	109	24	8
Max. # of 20 kWh sessions/day (7-23h)	8.8	40	120

6.3.1 Costs

In this section the costs of charging infrastructure is determined, and to see how these costs develop over time. The numbers are gathered from various studies and manufacturer data. The costs are split up in initial investment costs of installing the charger and the exploitation costs during operation of the charger.

The costs of installing a 11 kW public charger are presented in Figure 22 per charge point. Also the yearly operating costs per category are shown. These numbers are based on the benchmark costs public infrastructure presented by the National Knowledge Platform for Public Charging Infrastructure (NKL) (NKL, 2017). As can be seen from Figure 22, the costs have decreased significantly over the past years, and are expected to increase further towards 2020. The largest portion are the hardware costs of the charger.

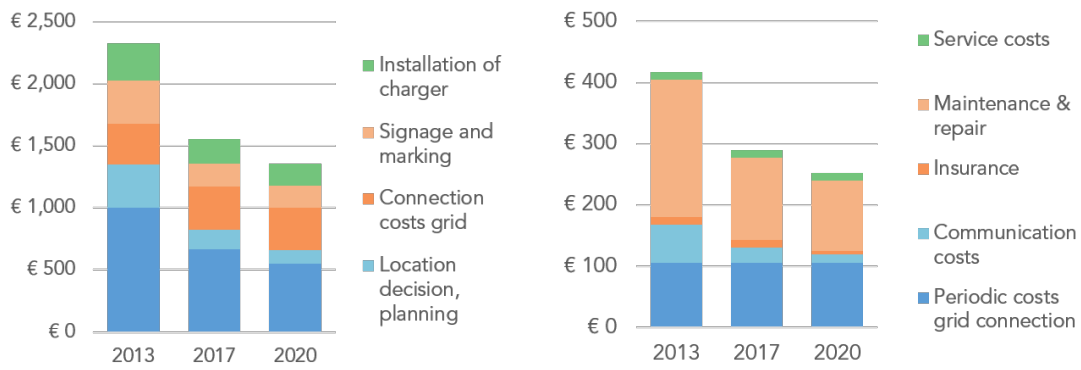


Figure 22: The initial investment (left) and yearly operating (right) costs of a normal charge point (NKL, 2017).

The initial investment and operating costs of fast chargers are significantly higher. The hardware involved is much more expensive, as well as the transformer that is needed. In the case of a charging station, roofing and additional infrastructure are additional costs. The costs of public fast chargers are determined from financial data gathered by de Jong (2016) and checked with fast charger CPO Fastned (Interview 7).

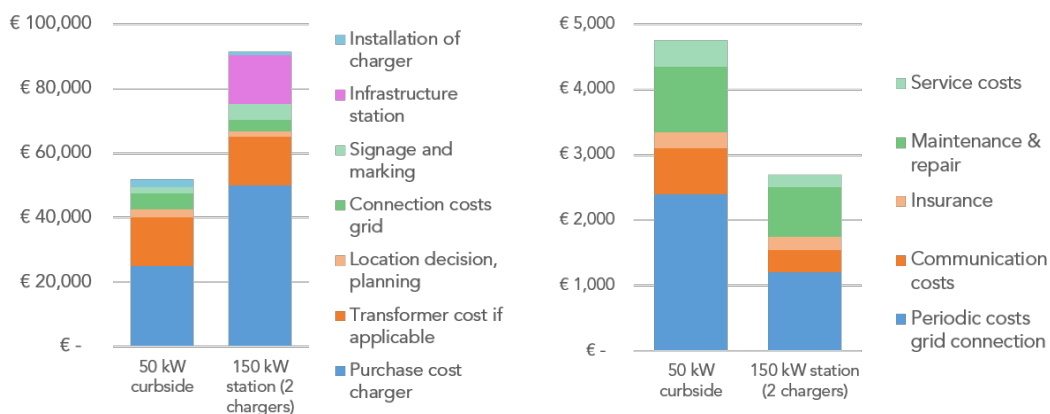


Figure 23: The initial investment (left) and yearly operating (right) costs of a fast charge point (de Jong, 2016).

Next, the revenues through electricity sales are discussed.

6.3.2 Revenue

The revenue of fast charging depends on the usage of fast charging and the price per kWh. A basic framework to determine revenues is shown in Figure 24.

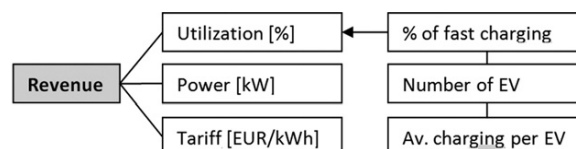


Figure 24: The revenue model for charging infrastructure (Schroeder and Traber, 2012).

For normal charging, once again the number provided by the NKL are used. An increase from 4.3 kWh sold per day in 2017 to 5.9 in 2020, is extrapolated to 2026. From 2020 onward, a 20 % increase per year is expected. A kWh price of 28 cent per kWh is used. For fast charging, the current sales are determined from the Q4 Fastned sales figures in the Netherlands (Fastned, 2016). This is approximately 2 sessions of 14 kWh. This is linearly increased to 14 sessions of 14 kWh in 2023, based on assumptions stated by CE Delft (2017) and EVConsult (2016). The increasing revenue for normal and fast chargers are shown in Figure 25. As can be seen, the higher investment costs are compensated by increased electricity sales, as a faster charge rate means a higher capacity of a charger. Electricity prices of 40 cents / kWh for 50 kW charging and 45 cent/kWh for 150 kW charging are used.

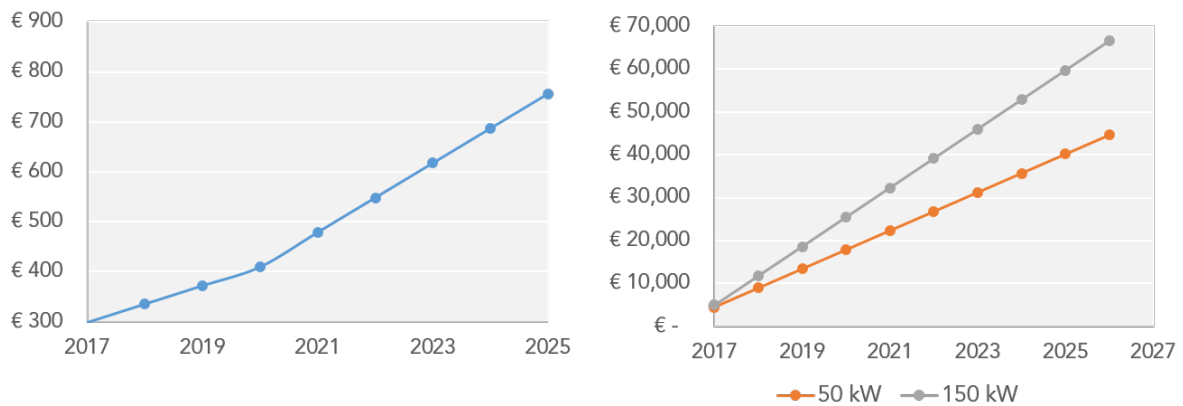


Figure 25: The revenue for normal (left) and fast (right) charging stations.

6.3.3 Profitability

When combining the cost and revenue figures, the total cost of ownership (TCO) can be determined. This is negative in the first years due to the investment costs, but with increased energy use and EV adoption, the sales increase. This is shown in Figure 26.

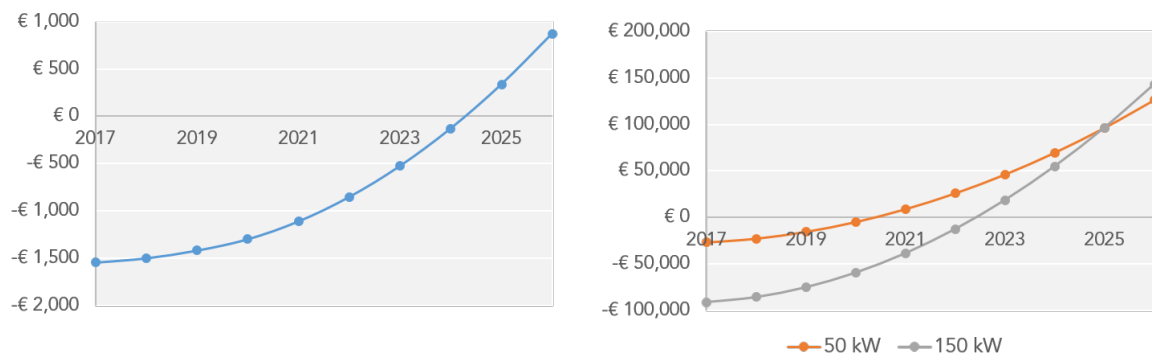


Figure 26: The TCO of normal (left) and fast (right) charging stations.

Concluding, the high initial investment costs of fast charging are made up for by increased sales and scalability at high EV adoption rates. If usage of fast charging stations is much lower however, there is a risk that the initial investment is not earned back. For normal charging break-even is reached after 8 years. The investment is lower, but the expected return is also significantly smaller at 900 euro per charge point. The depreciation period is thus crucial to earn a profit on normal charging.



"The business case of normal charging is difficult, it is hard to earn a profit from only selling kWh's." (Consultancy, Interview 6)

The interviewees have differing opinions on the profitability of normal and fast charging. While some interviewees (Interview 6,7,10) mention it is difficult to earn a profit with normal charging, others (Interview 8,9) said that at good locations you can earn back your investment in 7 to 8 years. All interviewees agreed that the increasing charging rate and EV adoption affect the profitability of fast charging positively (Inter-

view 1-10). The profitability is however dependent on the uptake of fast charging, car sharing and autonomous driving which are unclear yet (Interview 1,2,4,6).

During the interviews, municipalities also mentioned that the maximum price per kWh is important to take into account (Interview 3,4,5). If electricity costs approach the costs of gasoline (on a per-kilometre basis), electric vehicles become less financially attractive. The viability of an electricity price-based business model depends on the cost per kilometre of driving on electricity versus gasoline. When gasoline costs approximately €1.40 per liter, electricity should be priced €0.36 per kWh to be cheaper than driving with gasoline in the same vehicle. This example calculation is for the 2016 Chevrolet Volt, achieving 5.6 L/100 km on gasoline versus 0.2 kWh per km in electricity consumption (Interview 10). Therefore it is important to monitor kWh prices as the market matures.

"Amsterdam limits the price of charging, to keep it competitive with driving on gasoline. Therefore charging cannot be more expensive than 28 cent / kWh." (Municipality, Interview 4)

Concluding, the business case will increase and become positive with increasing use and EV adoption. The high initial investment costs of fast charging facilities are counteracted by increased capacity and kWh sales in the future. It is therefore important that concessions or permits for operating infrastructure are given for longer periods of time (10 to 15 years). The revenue however is sensitive to use of the chargers, and therefore still has significant risk.

6.4 Business models

Besides electricity sales, a number of other ways exist to increase profitability of charging infrastructure. These are discussed in this section.



The most common business model for public charging infrastructure is to sell electricity with a sufficient margin to recover the initial investment cost of the charging infrastructure. Another option is to base the business case on increased retail sales. Because public electric vehicle charging still requires longer than ICEV refuelling, charging stations may represent a way to attract new customers. In this way, selling electricity could be complemented by increased sales from other products. A study in California found that when EV drivers stopped to charge at a fast charging station next to a retailer, 50% of drivers shopped during the charging, and among those shopping, the average expenditure was about €15 (Nicholas & Tal, 2017). As the market continues to grow, greater use of this model may benefit drivers and businesses alike.

Advertising revenues are another option on which to base a charging station business model. Gasoline stations already have increasingly integrated advertisements on pumps and signage; EV charging stations could offer a similar opportunity for advertising. Such an idea is most appropriate for high-traffic, high visibility locations such as malls, restaurants, and busy highway rest areas (Hall and Lutsey, 2017).

Automobile manufacturers could also fund charging stations by integrating their overall EV deployment and infrastructure into their unique customer proposition. To fuel future sales of their electric vehicles, automakers have an interest in creating a robust charging infrastructure network (Hall and Lutsey, 2017).



INTERVIEWS

Interviewees also mentioned other interests for businesses. In the broader energy transition, business parties are interested in securing their position. Large incumbent parties can be interested in securing EV clients in order to sell other goods or use the EV as an asset on the electricity market (Interview 2,3,6,8). Even if they do not make a profit, it can still be interesting to see where the market is going (Interview 2,6,7).

Concluding, there are different models and ways to earn money operating charging infrastructure. Additional ways to earn money besides selling electricity can increase profitability. It is important to keep the price of charging compatible with gasoline prices in this transition period. Next, the profitability of normal and fast charging are discussed based on the electricity sales business model.

6.5 Market investments

Finally, industry interest can increase the adoption of fast charging. As more parties are interested in fast charging, this can bring down costs as well as influence the political feasibility.



DESK RESEARCH

Increased market interest in fast charging can be seen. Car manufacturers are investing in developing fast charging technology and networks. The 'Ionity' consortium consisting of BMW, Daimler, Ford, and Volkswagen Group (including Audi and Porsche) have announced a joint venture to construct a network of ultra fast charging stations across Europe, beginning with 400 sites in 2018 (Hall and Lutsey, 2017). Tesla is also committing to fast charging, as they are expanding their fast charging infrastructure to cities: "Many sites will be built further off the highway to allow local Tesla drivers to charge quickly when needed, with the goal of making charging ubiquitous in urban centres" (Tesla, 2017a). Also in the traditional gas station market, interest is sparking. Shell has recently acquired NewMotion, which operates over 50.000 public charge points in Europe.



INTERVIEWS

The increased industry interest is noted by multiple interviewees (Interview 1,2,6,7,8). The focus of the car manufacturers on fast charging is explained by one interviewee by the fact that it resembles refuelling (Interview 12). The scaling effects and influence on the costs sparked by this interest are said to be positive influences (Interview 2,7,8).

6.6 Chapter conclusion

To conclude this chapter, the second sub-question is answered: *What is the profitability and market potential of fast charging compared to normal charging?*. This question is answered by evaluating the factors and active agents in the Feitelson and Salomon (2004) framework that determine the economical feasibility.



CURRENT FEASIBILITY

It can be concluded that both normal and fast charging pass a cost-benefit analysis if concessions are given for 10 to 15 years. The context of subsidised early charging infrastructure has led to a better perceived distribution of benefits and costs for normal charging. An important consideration is that charging should not be more expensive than gasoline on a per kilometre basis, to convince PHEV drivers to drive on electricity. When considering the business model based on electricity sales, fast charging has a higher initial investment, but can generate more revenues when EV adoption increases. The industry interest in normal charging is masked by government subsidies. Both technologies are thus economically feasible, and market parties are entering the market with different interests. Automakers and a number of CPOs are focusing on fast charging, while other CPOs have benefited from the subsidies and start to earn a profit in the coming years.



DEVELOPMENTS IN FEASIBILITY

The developments in the EV context will increase the economic feasibility of both charging solutions. It also means that the societal costs (upgrades of the grid, rental prices of public space), should be re-evaluated. The market will mature increased adoption, higher charge rate and larger batteries all increase the profitability. The usage of fast charging is an uncertain factor in the profitability however. When EV adoption is high, fast charging has a higher potential for market parties than normal charging.



7 Social Feasibility: Consumer Preferences for Charging

The social feasibility of fast charging is determined by consumer preferences. In the changing mobility landscape, consumers have to get used to a new way of 'refuelling' their cars. This chapter describes literature on consumer behaviour and preferences for charging, as well as a focus group carried out to determine future preferences. Current technology and home charging availability make normal charging more attractive in cities. As fast charging resembles the current refuelling experience more, the consumer attitude improves. EV charging behaviour will shift towards 'opportunity charging', where drivers charge when it suits them best. Consensus on a primary mode of charging is not reached during the focus group however.

7.1 Factors in determining the social feasibility

The social feasibility plays a central role in the Feitelson and Salomon framework. Social feasibility is determined as the effectiveness of the suggested innovation in addressing the perceived problems in society (Rienstra et al., 1999). The suggested innovations in this case can be viewed as normal charging and fast charging. The perceived effectiveness is also influenced by experience of the public with similar policies or innovations. Policy entrepreneurs in the form of industry experts or non-business interest groups can try to influence the social feasibility by altering the 'sanctioned discourse'. This is the discourse sanctioned by decision makers as politically feasible. The social feasibility does not directly influence the adoption of an innovation, but works through the political feasibility. The factors and active agents considered in the social feasibility are indicated by the red dotted lines in Figure 27.

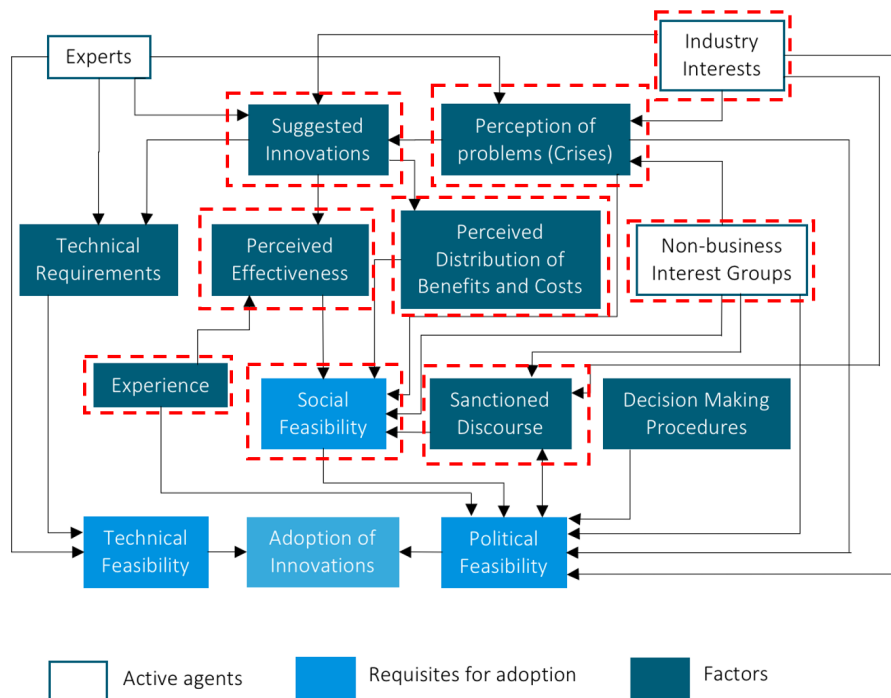


Figure 27: Factors influencing the technical feasibility of fast charging.

First, the perceived effectiveness of fast charging is discussed as an innovation to charge EVs. This is identified in two ways: by identifying charging behaviour and by discussing charging preferences. These are determined from existing research and surveys as well as a focus group held on this topic. But since these studies are dependent on the current (and often past) context, the focus group is based on the context of EVs and EV charging of the coming years. The factors influencing the social feasibility identified from desk research, interviews and focus group are shown in Table 8.

Table 8: Social feasibility factors identified from desk research and interviews.

Factor influencing feasibility	Theoretical category	Desk research sources	Discussed in interview
Charging behaviour of EV drivers	Perceived effectiveness, Perception of problems	Hoekstra and Refa (2017) Hidrue et al. (2011) Bunce et al. (2014) Neubauer et al. (2015)	1,2,3,4,5,6, 7,8,9,10,11
Consumer preferences on normal and fast charging	Perceived effectiveness, distribution of benefits and costs	Hoekstra and Refa (2017) Fastned (2017) Egbue and Long (2012)	1,2,3,4,5, 6,7,8,9,10,11
Consumer preferences in future context	Perceived effectiveness	-	Focus group

7.2 Charging behaviour of EV drivers

The first method that is used to analyse the social feasibility is the analysis of current charging behaviour of EV drivers. By analysing their behaviour, insights can be gained on the usage and preference for charging modes.



DESK RESEARCH

Charging an EV is very different from refuelling a conventional car. Differences include the location of a charging point, a longer 'refuelling' duration and the possibility to 'refuel' when the car is parked. Especially the long recharge time of EVs is different from what people are used to (Boulanger et al., 2011; Hidrue et al., 2011; Tsang et al., 2012).

Another factor concerning charging behaviour is range anxiety. Range anxiety refers to the fear of an EV driver that the battery will be empty before the destination or a suitable charging point is reached (Neubauer et al., 2015). Range anxiety is often a barrier to adoption, as is shown in consumer preference studies (Liao et al., 2017; Tsang et al., 2012). Most trips can be driven on a full battery of current EV models however, and this fear is proven to decrease when consumers actually drive an EV (Egbue and Long, 2012). Range anxiety affects charging behaviour as drivers tend to charge more often than needed. Fast chargers are an important solution to counter range anxiety, proving the importance of a wide network of fast chargers (Liao et al., 2017).

The charging point location concerns the type of location where a vehicle is charged. In literature, three main locations are distinguished: home charging, work charging and public charging. Charging at home has the general preference of EV drivers over other charging points, as availability is guaranteed and it reduces the need for drivers to adapt daily plans to facilitate charging (Neubauer et al., 2015). Charging at work or in public may involve extra costs and charging at public points may require additional planning. Quinn et al. (2010) state that current EV drivers have the capability to charge at home and at work, but the need for charging at public facilities will grow as EV sales and technologies develop. Bunce et al. (2014) states that EV drivers prefer home users preferred to charging at gas stations. The preference matrix for charging locations is shown in Figure 28.

Charging Options Available to User	Home	Work/Destination	Public Charging
Home + Work + Public	1 st	2 nd	3 rd
Only Public	n.a.	2 nd	1 st
Only Work + Public	n.a.	1 st	2 nd
Only Home + Public	1 st	n.a.	2 nd

Figure 28: Location preferences for charging for EV drivers (Bunce et al., 2014)

One way of determining the social feasibility, is analysing the current use of public normal and fast charging. Current charging use is focused on normal charging, but increasing range and charge speed show growing use of fast charging. In a consumer survey conducted by fast charge CPO Fastned, 800 respondents were asked their charging behaviour (Fastned, 2017). Although a bias is introduced in this survey as they at least used fast charging once, it gives insight in their preferences. In Figure 29 their usage of normal and fast charging is shown.

As can be seen, the majority of early adopters uses normal charging on a regular or even daily basis. This seems logical, as home charging is the preferred location to charge. As indicated however, in the future not all EV users can use home charging as 75 % of Dutch households does not have a private driveway (CBS, 2016). When comparing public charging, the usage of Fastned stations and normal public chargers are not that different.

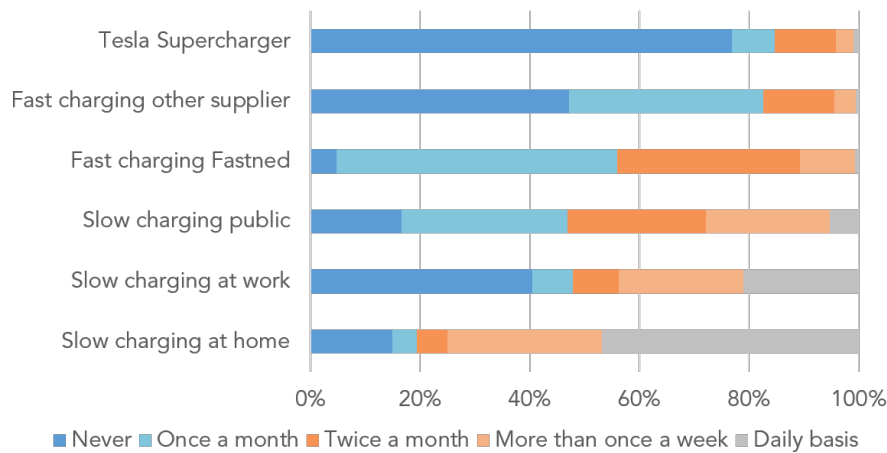


Figure 29: Fast and normal charging behaviour of 800 EV drivers (Fastned, 2017).

Another recent study on Dutch driver characteristics by Hoekstra and Refa (2017) surveyed 286 Dutch EV drivers with 3 years of driving experience. This study provides insight in the current charging behaviour. However, almost all EV drivers participating in the survey can charge at home. The usage of fast charging for Nissan Leaf drivers and Tesla Model S drivers is shown in Figure 30. As can be seen, Tesla Model S drivers use fast charging more than Nissan Leaf drivers.

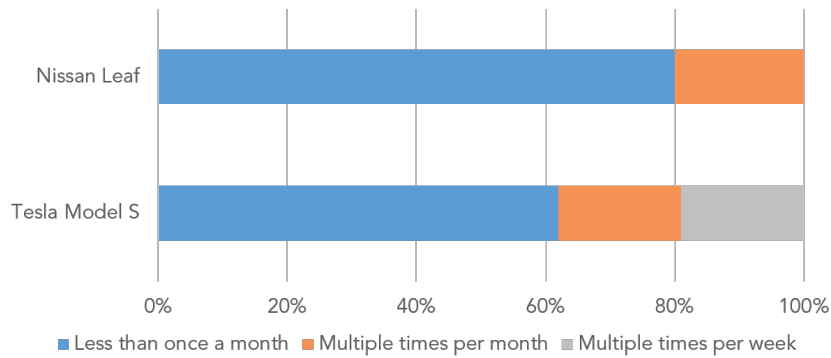


Figure 30: Fast charging use for Nissan Leaf and Tesla Model S drivers (Hoekstra and Refa, 2017)

The study also showed that an increase in EV range will change the charging behaviour and frequency. 80 % of the Nissan Leaf drivers (24 kWh battery) indicated they charged 4 to 6 times per week, while only 38 % of Tesla Model S drivers (60 kWh battery) charged that often (Hoekstra and Refa, 2017). This makes sense, as a larger battery depletes more slowly. This means the number of kWhs per charge will increase: a larger battery charges less often, but a larger amount of kWh. Concluding, current drivers charge primarily at home, but increased EV adoption and growing battery size will increase the usage of fast charging most likely.

🗨️ INTERVIEWS

The conclusions from desk research are largely confirmed during the interviews. Many of the interviewees mentioned that range anxiety is decreasing and mainly experienced by drivers which do not own an EV yet (Interview 1,2,3,4,8). The growing uptake of fast charging for larger batteries is also acknowledged (Interview 1-4, 6-8). One interviewee said that current PHEV users charge on average 12 kW, while Tesla Model S drivers charge 38 kW: more than 3 times as much (Interview 8). It is also interesting to note that as batteries will grow, home charging will be too slow to completely recharge a battery (Interview 2,3). Investing in a heavier grid connections was considered too expensive by the interviewees (Interview 3,4,5).

Another way of looking at social feasibility is investigating the preferences of EV drivers, as is done in the next section.

7.3 Consumer preferences on fast and normal charging

The current charging behaviour is linked to the current charging infrastructure availability. As home charging is available to most EV drivers and fast chargers only along the highways, this provides a skewed image. It is therefore interesting to investigate the preferences of EV drivers.



The survey by Hoekstra and Refa (2017) indicated that fast charger availability is important to EV drivers. From the survey results it is derived that more than 90 % of EV drivers considers fast chargers a good way to increase range and more than 70 % even consider them essential for an EV. Next to that, the preferred mode of charging is investigated. 35 % of EV drivers consider a few public fast chargers a good replacement for many normal public charge points. 60 % of drivers states that the fast chargers along the highway are essential for them to use their EV, and 84 % agrees that fast charging is a good way to increase the range of an EV. 69 % of drivers believe that when chargers are available everywhere, fast chargers are only needed on long trips. This last question is however biased, as this assumes a public charging infrastructure focused on normal charging. In focus groups accompanying this study EV drivers expressed the opinion that fast chargers are one of the best and least expensive ways to increase EV adoption. The results are shown in Figure 31.

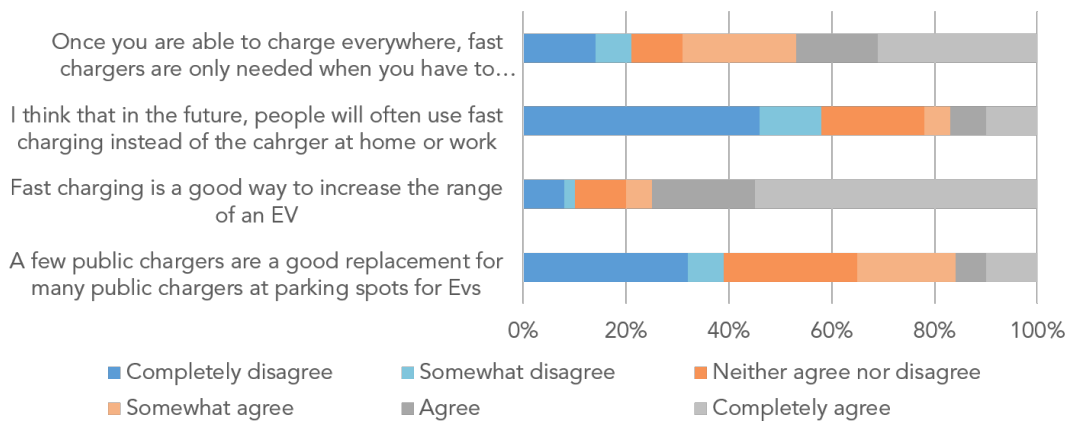


Figure 31: Consumer opinions on fast versus normal charging (Hoekstra and Refa, 2017).

When identifying consumer preferences, the different aspects of the fast charging experience need to be investigated as well. Egbue and Long (2012) showed in a 2012 internet survey among 481 EV consumers that fast charging should preferably take less than 10 minutes. This would be possible when the charge rate goes up to 350 kW in the future. The current fast chargers are experienced as simple to use, but most drivers indicate a lack of facilities and would like lower prices. The results from the survey by Hoekstra and Refa (2017) is shown in Figure 32.

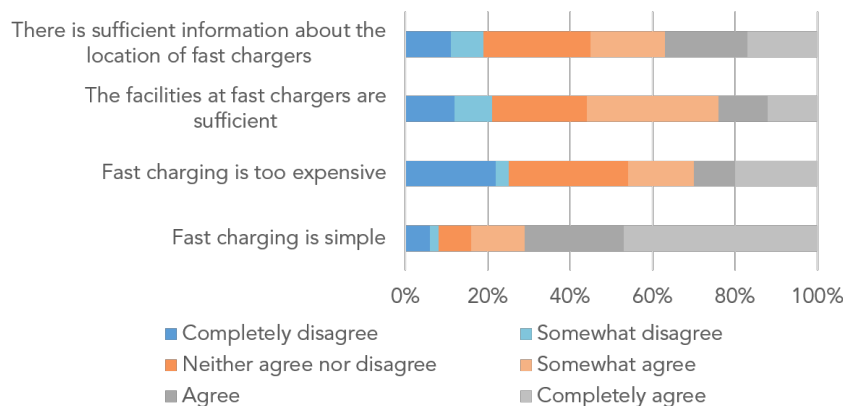


Figure 32: Consumer opinions on fast charging (Hoekstra and Refa, 2017).

Fastned users indicate that they primarily have a need for more highway locations (78 %), faster charging (48 %) but also more city stations (44 %) (Fastned, 2017). This indicates that fast charging is not only preferred along highways, but also in the cities. Their wishes are shown in Figure 33

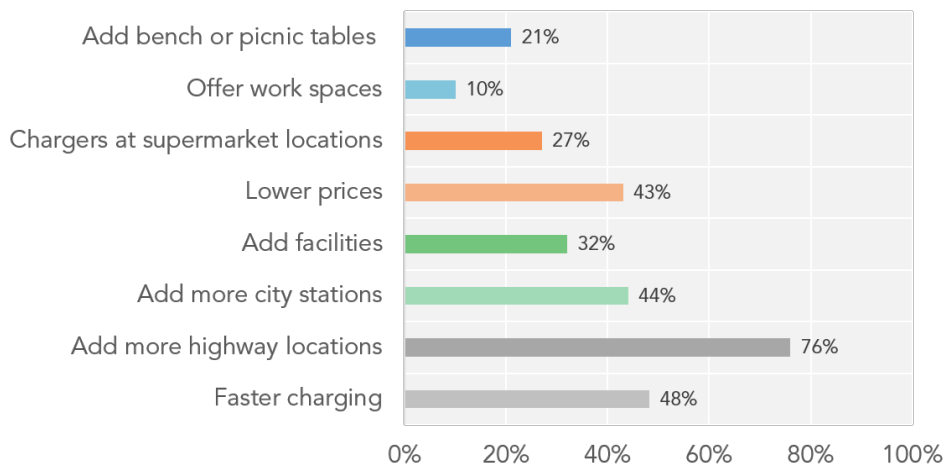


Figure 33: Consumer preferences according to Fastned (2017) survey.

Concluding, fast charging is seen by current EV drivers as an important mode of charging. They see normal charging as the primary mode, but do consider fast charging necessary in their daily use of EVs. Consumers indicate the need for more city locations and better facilities.

INTERVIEWS

A key factor that appeared during the interviews is the 'parking' aspect of charging. An important difference with refuelling is that EVs can charge when the car is parked anyway. An important difference between normal charging and fast charging, is that during normal charging the car is parked. People do not have to wait while charging.

"Peoples behaviour will change with respect to refuelling: people will want to charge when you are parked anyway" (Municipality, Interview 4)

Two factors that determine the perceived effectiveness were mentioned by all interviewees: the ease of use and the price of charging (Interview 1-10). The ease of use is dependent on the availability of charging options. The ease of use can comprise of many different factors. One interviewee mentioned the hassle of carrying around the dirty connection cable for normal chargers (Interview 1), and others stated that the assurance that a charging spot was available was important in their charging decisions (Interview 1,8). When there is no guaranteed availability of a normal charger close to home, some interviewees mentioned that they would consider fast charging instead (Interview 1,2). Others said that they expected normal chargers to be widely available and preferred that to fast charging (Interview 4,8,9).

Since fast charging is more expensive than normal charging, this also plays a role. The price of charging plays an important role when people use their car for private use; but less much so for business use (Interview 1-4,7).

Concluding, users in this early stage of EV adoption prefer home charging, but when they have to use public charging they use normal and fast charging complementary. The price, compared to normal or home charging, is considered high and facilities are not yet sufficient. However, increased usage of fast charging can be expected with increased adoption and growing EV range.

7.4 Developments in charging preferences

Both charging usage and customer preferences are connected to the current context: limited public charging needs, low fast charging rate and small EV batteries. As explained in Chapter 5 however, these factors are all changing rapidly. Therefore a focus group is held on charging preferences with current EV drivers. For this focus group, their preferences are asked on the preferred way of charging in the technological context of the coming years. The focus group showed a more positive attitude towards fast charging, but no consensus on a preferred way of charging.

FOCUS GROUP

As explained in Chapter 3, a focus group was held with 9 EV drivers on their preferences for charging. The questions and context sketched during the discussion are shown in Figure 34. The context is a reflection of the battery size, charging speeds and driving distances expected in the coming years. Only public charging is discussed, as this is the focus of this research. During the focus group several insights have been gained, which are discussed here.

Focus group topics:

1. In what way would you preferably charge your EV when using it privately?
2. In what way would you preferably charge your EV when using it as a lease car?
3. At which locations and which opportunities would you use fast charging?
4. What is your vision of the ideal public charging infrastructure in 2025?

Context:

- 80 kWh battery
- 400 km range
- Normal charging: 11 kW
 - Charge 20-100%: 6h
- Fast charging: 175 kW
 - Charge 20-100%: 20 min
- 250 km per week driving
- Only public charging

Figure 34: Focus group questions and context.

First of all, the focus group attendants expressed an increased preference for fast charging when it resembles gasoline refuelling which they are used to now. Current fast charging was seen as a 'necessity', because the waiting time was long and the facilities were not sufficient. In the context of larger batteries and faster charge rate however, fast charging is perceived much more positively. When fast charging rates are sufficient to allow a full charge in ten to fifteen minutes, participants indicated fast charging would be a good solution for them.

"When 150 kW charging is standard, less chargers are needed at home and charging will go back to how we refuel cars nowadays." (Focus group participant)

Insight 1: When fast charging takes approximately ten minutes, people will experience it much the same as refuelling, and expect the same level of service.

"I have to recharge wherever and whenever I can, otherwise I won't make it home." (Focus group participant)

With the current range and charging availability however (most participants drive a BMW i3 with a range of approximately 160 km), fast charging is only used on long distance trips. The current context means that drivers are continuously aware of their state of charge and will use every possibility to recharge their EV. When the sketched context applies, this will change to 'opportunity charging', in which consumers will charge their EV with

the minimum amount of hassle. If they have access to a public charge point in front of their home, they see this as a good solution. But the same applies to fast charging, especially on longer trips. A 10 to 15 minute charge, to have a cup of coffee and check e-mails, is perceived as a convenient way to recharge an EV.

Insight 2: Charging will change from 'charging wherever and whenever I can' to 'charging where and when it suits me best' when range improves.

The price of charging is of importance for private use of EVs. The participants of the focus group currently used their EV for business purposes, and indicated that price did not matter to them. When using a company car, efficient travel is much more important than the price of charging. Participants did indicate that the price of charging was currently very unclear, and is only shown when you have already decided to charge at that station. For private use, price is a factor of interest. This can be compared to highway or city gasoline recharging, where participants indicated they did not mind to make a small detour to save money.

"For business trips the price per kWh is not an issue, but for private use it is." (Focus group participant)

Insight 3: Price is relevant for private use, but not when using an EV for business purposes.

Overall, when discussing the charging solutions the participants would prefer, there was an interesting discussion. Some participants indicated that when fast charging would be similar to refuelling, they would not need normal chargers at all. Other participants indicated that when they could charge at 11 kW and had access to normal charger in front of their home, they would only use fast charging on longer trips. They stressed the advantage that normal chargers are used when the car is parked anyway, while fast charging required 'waiting' while recharging. The availability of a normal public charger close to home was an important prerequisite for this scenario.

Insight 4: Both the 'fifteen minutes fast charging per week' scenario as the 'one night per week normal charging' scenario have participants who prefer this option.

"The set-up of Aldi is great, a roof full of solar panels and free charging at 50 kW during shopping." (Focus group participant)

Besides the two options suggested at the focus group, the participants indicated a need for an intermediate solution during one-hour stops. Participants indicated that when shopping or at a meeting, charging at approximately 50 kW would be a good solution. Multiple participants mentioned the 50 kW fast chargers at Aldi as an ideal solution to fill up your battery while shopping anyway.

Insight 5: Next to 11 kW normal charging and 150 kW fast charging, there is a need for an intermediate solution during shopping or meetings.

Looking further into the future, and taking other developments into account, the participants saw the charging infrastructure centralising and leaving the city centres. When car sharing and autonomous driving take off, participants thought that the current public infrastructure would disappear. Charging squares or charging garages, where autonomous vehicles would go to by themselves, were seen as the ideal solution. The public space in cities is scarce and the current chargers at parking spots are only needed in a transitional period, participants indicated.

"In the future, I see cars that can be charged autonomously outside of the city at centralised locations." (Focus group participant)

Insight 6: Looking into the future with developments in car sharing and autonomous driving, users predict the charging infrastructure to disappear from the inner cities and concentrate in charging squares or stations.

Concluding, the focus group showed that when range and fast charging rates improve, the experience will resemble current refuelling experiences. Users will charge when it suits them best, and different views exist on the ideal public charging solutions. Price is only relevant for private use, as business drivers only care for the most time efficient way. A summary of quotes and observations made during the focus group can be found in Appendix C.

7.5 Chapter conclusion

In this chapter, the third sub-question is answered: *What are consumer preferences for charging in the current and future context of Dutch cities?*. This question is answered by conducting interviews, interpreting consumer surveys as well as a focus group held on future preferences. The social feasibility is determined mostly by the perceived effectiveness and the perceived distribution of benefits and costs.



CURRENT FEASIBILITY

Currently, the social feasibility of fast charging is mainly high along the highways. In cities, there is a need for more fast chargers as well, but home and normal public charging are the primary modes of charging. The perceived effectiveness is currently lower for fast charging, as fast charging requires waiting while charging. Also the balance of benefits (fast charging, but lack of facilities) and costs (higher price of fast charging) is currently better for normal charging. These factors are changing in the near future however.



DEVELOPMENTS IN FEASIBILITY

It can be concluded that as fast charging resembles the current refuelling experience more, the consumer attitude improves. From charging behaviour an increased uptake of fast charging can be seen for growing EV battery sizes. When EV adoption increases, home charging will become less available changing the focus in cities to public charging. As the focus group results indicated, EV charging behaviour will shift towards 'opportunity charging', where drivers charge when it suits them best. The price of fast charging can form a barrier for private drivers, but business users do not perceive cost as an issue. The dynamics in consumer preferences are difficult to predict however, as some EV drivers prefer normal charging, and others prefer fast charging in future context.

The social feasibility has a strong influence on the political feasibility as well. The factors and actors involved in the political feasibility are discussed in the next chapter.



8 Political Feasibility: Decision Making and Policy

The political feasibility plays an important role in the adoption of an innovation. Since public charging infrastructure is located in the public space, policy and regulations determine the feasibility significantly. This chapter determines the political feasibility of fast charging. Political feasibility is influenced by social feasibility, existing decision making procedures, perceived crises, but also by the lobby of industry and other interest groups. First, national and local policies are explored. Next, the effect of decision making procedures and other stakeholders on policy are determined.

8.1 Factors in determining the political feasibility

As stated in Chapter 7, political feasibility is influenced by social feasibility as politicians take voter preferences into account. Decisions on transport innovations however are usually not topics the public decides their vote on, and are based on routine decision making procedures. Feitelson and Salomon (2004) state that decision makers provide solutions to perceived problems, in a way the support from different groups is maximised and that can be explained with arguments within the currently leading sanctioned discourse. Experience with innovation also plays a role, as well as the decision making procedures in place. The factors and active agents considered in the political feasibility are indicated by the red dotted lines in Figure 35.

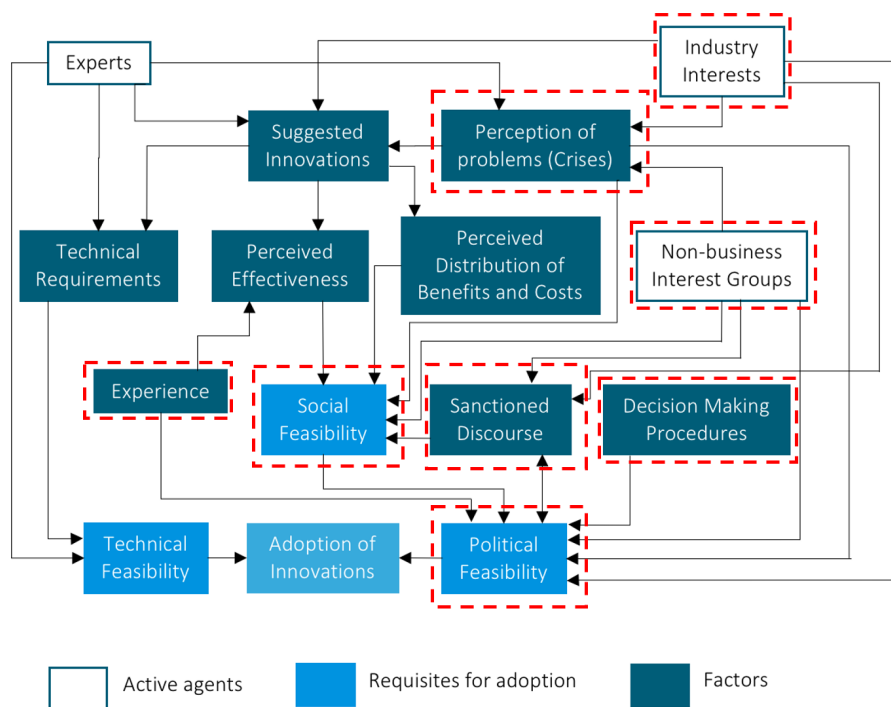


Figure 35: Factors influencing the technical feasibility of fast charging.

The relevant factors for the feasibility of fast charging are identified during desk research and further explored during interviews. Especially municipalities provide valuable information, as they are responsible for installing public charging infrastructure. An overview of discussed factors and sources is shown in Table 9.

Table 9: Political feasibility factors identified from desk research and interviews.

Factor influencing feasibility	Theoretical category	Desk research sources	Discussed in interview
National and local policy on charging installation	Decision making procedures, experience	RVO (2017) RVO (2011) Hall et al. (2017)	1,2,3,4,5,6,10
Comparison with international availability of fast charging	Decision making procedures	Hall et al. (2017) Holtsmark (2014)	3,4,12
Impact on public space of future installation of chargers	Decision making procedures	Ecofys (2016) G4 (2014)	1,2,3,4,5,6,7,8,9,10
Transition of gas station infrastructure to charging station infrastructure	Industry interests, Decision making procedures	Amsterdam (2015)	3,4,5,11

8.2 National and local policies on charging infrastructure

In this section an overview of national and local policies is given, as the sanctioned discourse and decision making procedures affect the political feasibility. First, the goals and policies of the national government are stated. As municipalities are primarily responsible for developing charging infrastructure, these policies are evaluated next.



DESK RESEARCH

Policy documents and publicly accessible policy meetings and are the primary sources of information for the desk research.

8.2.1 National policy programs

The Dutch national government has set ambitious goals for EV adoption. These goals include 75,000 EVs on the road by 2020, and 50 % of new cars sales at EVs by 2025 (RVO, 2015). So called 'Green Deals' have been formulated to achieve these goals, which are deals between the government and multiple other parties. The first Green Deal of 2009 included 65 million euros to make the Netherlands a front-runner in EV adoption (RVO, 2011). The e-Laad foundation, consisting of the DSOs in the Netherlands, installed and maintained much of the 3000 first normal charging points. The Green Deal of 2015 made 5.6 million euros available for municipalities to install public charging points in cities (RVO, 2015). Along the highways, Rijkswaterstaat gave out 250 concessions at strategic locations to install fast chargers in 2011 (RVO, 2011).

Next to that, the national government formed various collaborations with business and non-business organisations to promote knowledge creation. The National Knowledge Platform for Charging Infrastructure (NKL) is one example, with the goal to bring down costs of charging infrastructure. The Formula E-Team is a platform that advises various governments and businesses on how to stimulate the development of charging infrastructure. Finally, the Open Charge Point Interface (OCPI) protocol is developed, which allowed the interoperability of charge points (IEA, 2017). These measures shows the ambition of the government, and the willingness to invest in installing charging infrastructure.

8.2.2 Role of the national government in installing infrastructure

In 2012, the national government coordinated efforts to guide charging infrastructure policy. Two models have been developed: the 'charging tree' in which charging options are prioritised, and the market model in which the central roles and stakeholders are determined.

'Charging tree'

The basic principle of the 'charging tree' is that the installation of new chargers is demand driven ('paal volgt auto' in Dutch). The charging tree specifies the prioritisation of where charging points are installed. Installation of chargers on private property (at home or work) has the first priority. Semi-public charging locations (shopping centres or business premises) are next in priority. Finally, public charging infrastructure meets the remaining need for charging. The demand for public facilities is expected to grow in the coming years, as 75 % of Dutch households do not have access to private parking (CBS, 2016). The governing thought is that private charging can be cheaper at home or work, and the public space in cities is spared as much as possible.

Market model

Next to the prioritisation of charging locations, the government proposed a market model to guide the newly emerging system. In 2012, Innopay developed this model in collaboration with energy companies, mobility providers and interest groups. The market model standardises two matters. First, the interoperability of charging stations in the Netherlands, and secondly the payment systems for the amount of electricity used. The key principles of this model were (Rijksoverheid, 2016):

- Freedom of choice in respect of the relationship with other players (simple to switch providers)
- Competition: dynamic and competitive market with transparent admission criteria
- Convenience: simplicity and uniformity
- Cost effectiveness: optimise such that SMEs can enter the market
- Future-proof: able to respond flexibly to technological changes
- Self-regulating and requiring no amendment of legislation and regulations
- The government will act as facilitator, regulate and help start the process

These principles show the ambition of an open market with cost effective and future proof charging infrastructure. As the costs of charging infrastructure are decreasing, the national government has stated that the installation of charging infrastructure is a task for market parties. Since local governments are responsible for installing new chargers, their role and policy is analysed next.

8.2.3 Local governments and their role

Municipalities play a major role in local EV adoption as they are primarily responsible for the installation of new charging infrastructure. The policies and strategies of municipalities vary however, as do their demographics and need for charging facilities. Municipalities can be divided in roughly two groups: facilitating and actively stimulating EV adoption. The G4 cities (Amsterdam, Rotterdam, Den Haag and Utrecht) of this case study use EV adoption to improve urban air quality and have installed large numbers of normal chargers in the public environment G4 (2014). These cities have paid a large part of the installation costs and gave out concessions to parties to operate the chargers. These parties range from electricity generating companies to construction companies. Large cities have more funding available because of the local air pollution they face (RVO, 2016a).

The approach of the G4 municipalities of Amsterdam, Utrecht, Den Haag and Rotterdam also differ between them. The EV adoption rate in urban areas is usually higher than national averages, and major cities can be leaders in the development and testing of policy (Hall et al., 2017). This is represented by the fact that the 14 cities with the highest EV sales rates in the world account for 32 % of all EV sales in 2015, while only representing 1.5 % of the global population (Hall et al., 2017).

The Dutch cities Utrecht and Amsterdam are ranked 3rd and 7th in the world in EV adoption. Their EV sales figures are 14.7 and 9.7 % respectively, compared to the national 6.4% average (Hall et al., 2017). EV support actions for the cities of Amsterdam and Utrecht regarding charging infrastructure are summarised in Figure 36. These measures include targets, financial incentives in the form of subsidies for installing charging points, direct deployment through contracts with charge point suppliers and demand-based applications for the installation of public charging stations.

AMSTERDAM, NETHERLANDS	UTRECHT, NETHERLANDS
<ul style="list-style-type: none"> • 1,341 total charge points and 36 fast charge points • 4,000 charge points planned by 2018 • Public charging stations are powered by locally generated wind energy • Residents/ employees can submit application for new public charging station • 500 euro subsidy for private charging point • 1000 euro subsidy for semi-private charging point 	<ul style="list-style-type: none"> • 987 total charge points and 46 fast charge points • All charging points will supply only green energy (Utrecht Energy Deal) • 500 euros subsidy for private charging point • 1,500 euros subsidy for semi-public charging points • 160 new charging stations planned in 2017

Figure 36: EV charging infrastructure policies in Amsterdam and Utrecht (Hall et al., 2017).

New installation of charging stations in cities however is mainly geared at normal charging stations. The municipality of Amsterdam plans to have 4000 regular charge points in 2018 in Amsterdam, while only having 36 fast charge locations (Amsterdam, 2015). The Hague is the first large municipality which is opening fast charge locations in a charging station set-up (Fastned, 2016). This focus on normal chargers in national and local policy is also discussed during the interviews with policy makers.

INTERVIEWS

Considering the national policies, the interviewees all mentioned the importance of the historic context. The early e-Laad charging stations were installed to stimulate EV adoption and provided the Netherlands with an important baseline for EV charging. After that, the 2015 Green Deal provided municipalities with funds to install public chargers by themselves. Next to that, the largest cities have access to national funds to increase the air quality in their cities (Interview 3,4,5). These measures made a sharp distinction between the approach along the highways (fast chargers) and the approach in cities (normal chargers). Interviewees agreed this was a logical approach in the early stages of EV adoption.

“Maybe we have said that charging infrastructure is a market activity too early. The business case of charging poles is still not viable”.
(Municipality, Interview 3)

The majority of funds for subsidising chargers is expected to stop around 2018 however (Interview 2,3) and the government wants charging infrastructure to become a market activity. Two interviewees indicated that this transition from government funding to market activity has come too early and a calibration of the market model is necessary (Interview 5,10).

As stated, local policies are dependent on the size of the municipality and its context. Because of these differences, municipalities may take up several roles or positions – reacting, facilitating or incentivising. Examples of roles include (Interview 1,3,4,5):

- A municipality which cooperates with requests made by third parties. In that case, the municipality is merely the authority granting an exemption or licence and issuing a traffic order.

- A municipality which itself takes the initiative to ensure the installation of charging infrastructure. In that case, the municipality is the applicant and also the authority granting party.
- A municipality which acts as an authority granting a concession or contract for the charging infrastructure in public spaces to a third party.

The choice of these approaches depends on financial resources, but also on a number of other aspects (Interview 2,3,4). There are a number of considerations to take into account. When taking a proactive approach, as with granting a concession or installing chargers yourself, you have much more influence on the process. In that case municipalities can influence the pricing of charging and the uniformity in charging solutions. Smaller municipalities usually have less funds available. They comply more easily to air quality norms and have less budget overall. Medium-sized municipalities are usually more reactive: they receive applications for public charging points from citizens. Because of limited resources, they usually depend more on investments from market parties (Interview 5).

The approach between large cities differs based on context. As Amsterdam has a large shortage of public space, they are reluctant to use this for EV charging and especially fast charging (Interview 3). Installing normal chargers is a lower risk, as the usage is more predictable and the contract duration is usually lower (Interview 1,2). The Hague is unique in the fact that it owns all the charging infrastructure as a municipality, having greater control over their placement (Interview 4). The Hague also differs from other municipalities as they build more chargers than the current demand. In that way, they try to stimulate EV adoption and prepare for increasing EV numbers in their city.

“The Hague is unique in the way that it does not only builds charging stations for existing EV drivers, but also for future ones” (Municipality, Interview 4).

Concluding, the national and local policies are primarily focused on normal chargers. The decision making procedures are historically geared towards normal chargers. The approach for installing new chargers differs per municipality, but most goals are geared towards more normal chargers. Next, the policies and fast charging availability in other leading EV countries are investigated.

8.3 Fast charging availability in leading EV countries

It is interesting to see how this focus on normal charging compares to other countries. The fast charger availability in other leading EV cities are compared, and an interview is held with the Norwegian drivers association.



DESK RESEARCH

In Figure 37, the amount of public charge points per million population is shown. The rounds show the percentage of the public charge points which are DC fast chargers. As can be seen, this number for the Netherlands is 2 %, significantly lower than for other leading EV markets. EV leaders such as Norway, the United States and China all have fast charger percentages over 10 % (Hall et al., 2017). This can be partly explained by the fact that these countries are larger, and thus larger distances have to be covered by EVs.

When looking at cities however, a similar trend is visible as is shown in Figure 38. Dutch cities are focused on normal chargers, where a front-runner of Oslo with similar number of charge points has twice as many fast chargers (Hall et al., 2017).

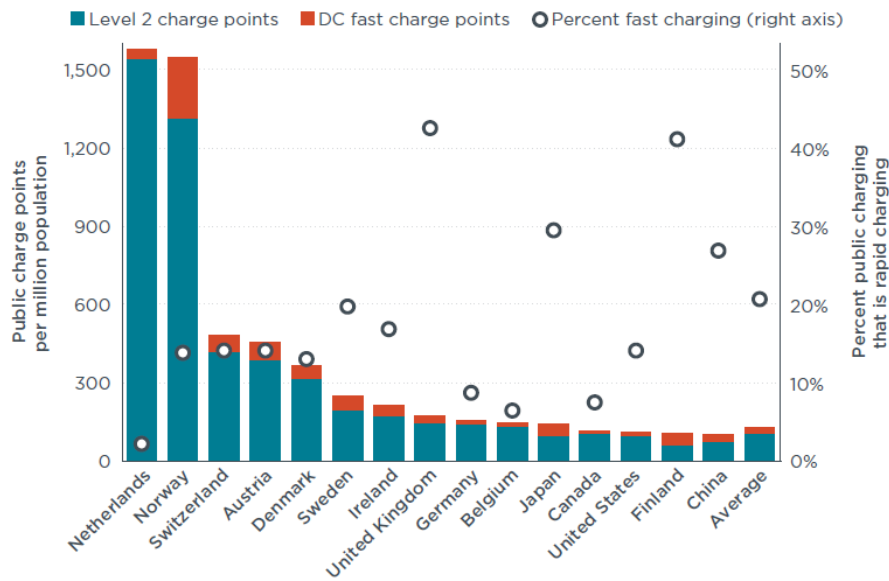


Figure 37: The percentage of fast charge points in countries worldwide (Hall et al., 2017).

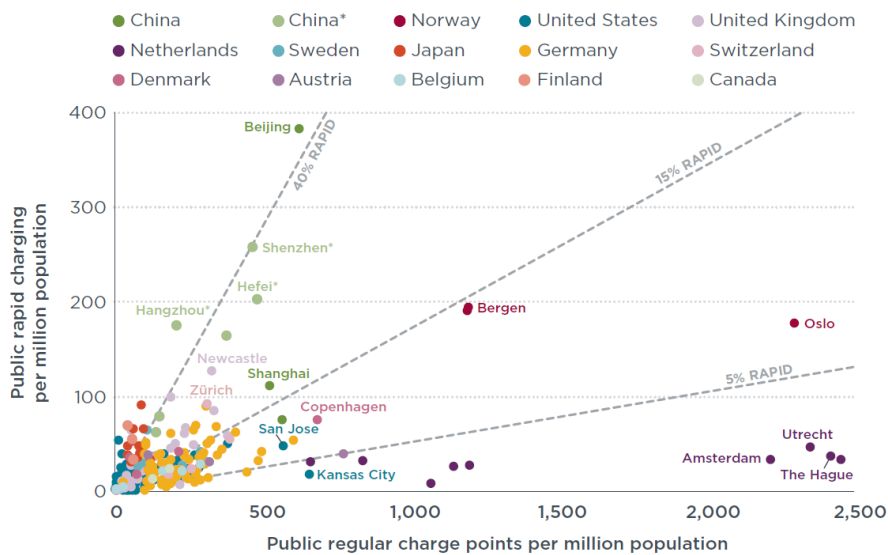


Figure 38: The percentage of fast charge points in cities worldwide (Hall et al., 2017).

 INTERVIEWS

Interviewed municipalities considered Oslo as a similar context as the Dutch G4 cities (Interview 3,4,10). In an interview with the spokesperson of the Norwegian EV drivers association, it was pointed out that Norway installed more fast chargers in and around cities in the first wave of charger installations (Interview 12). Norway also has a higher percentage of BEVs than the Netherlands, suggesting an increased need for fast chargers for larger battery sizes (Interview 12). In Oslo, chargers are concentrated in charging squares, and Tesla provides semi-public chargers near IKEAs. Norway has more private parking in parking garages than the Netherlands, and in those areas 11 to 22 kW chargers are installed (Interview 12).

Concluding, in comparison with other countries, the Netherlands has installed very few fast chargers. This can partly be explained by the shorter driving distances, but still holds for comparable cities such as Oslo. The impact of installing chargers on the public space is discussed next.

8.4 Impact on public space: future installation of public chargers

Public charging infrastructure has a large impact on the living environment. Charging solutions take up public space, and an efficient use is preferable. In this section this effect on the decision making procedures is discussed.



DESK RESEARCH

Fast chargers can service more EVs compared to normal chargers, meaning that there are less fast chargers necessary to meet charging needs. To estimate charging needs, a number of models have been made by research institutes. In a recent study by Ecofys (2016) commissioned by the ministry of Economic Affairs, the number of needed public chargers is estimated. Fast chargers are only positioned along the highways in this model. Over 1 million public charge points are needed in 2035 if only normal chargers are used in this model, as is shown in Figure 39.

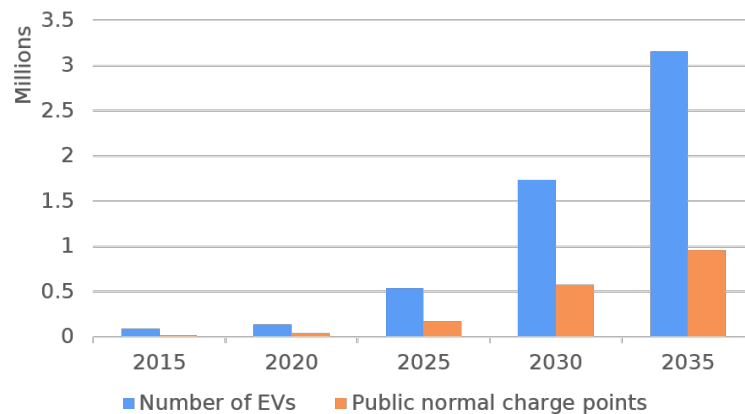
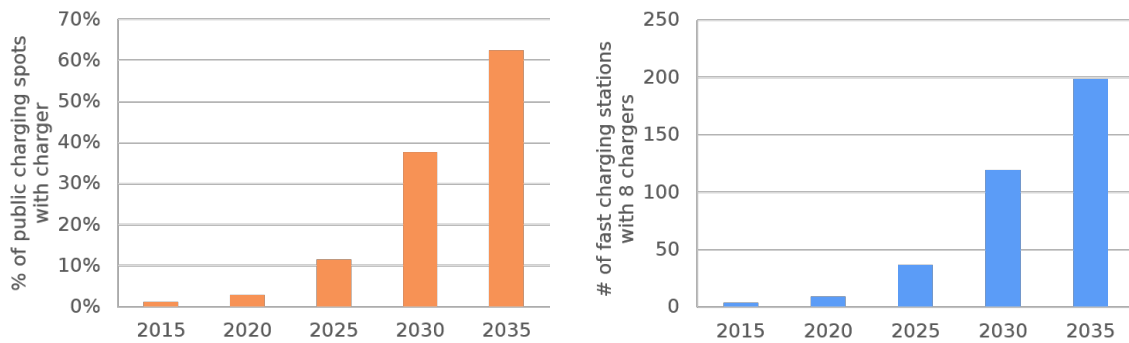


Figure 39: The number of EVs and needed public charge points, according to Ecofys (2016).

When interpolating these numbers to the city of Amsterdam, this means that 60 % of the parking spots need to be equipped with a normal charging pole in 2035 (G4, 2014). This corresponds to approximately 85.000 normal charge points. This would have an enormous impact on the public space, and on the electricity grid as discussed in Chapter 5. To cover the same charging needs, assuming a 50 % occupancy rate and a charge rate of 150 kW, approximately 200 stations with 8 chargers each are needed in the city of Amsterdam (CBS, 2016). With currently 120 gas stations already in Amsterdam, this would have a lower impact on public space (CBS, 2016). If charge speeds go up to 350 kW, the existing gas station infrastructure would even be sufficient. This is visualised in Figure 40.

Concluding, the models currently made by research institutes would have a large impact on public space. Fast chargers can replace a large number of normal chargers in charging capacity. The current gas station infrastructure could even provide the charging needs in 2035 if the charging speed goes up to 350 kW.



(a) Percentage of parking spots needed in only normal (b) Number of 8 charger stations needed in only fast charging scenario.

Figure 40: The effect on public space if only normal or fast chargers are installed.

 INTERVIEWS

When discussing the future installation of chargers and their impact on public space, most policy makers agree that a hybrid mix of charging solutions is needed (Interview 3-5,8,9). The mix can differ per neighbourhood, and predictive models made by consultancies determine the charging needs for each specific case (Interview 6,7). Efficient use of the public space is the goal (Interview 1-5,7-9) and a solution only consisting of normal chargers seems not to be in line with these considerations.

“We want as little charging infrastructure as possible”. (E-lead symposium, Interview 13)

The discrepancy between the models and the remarks by the interviewees could indicate that the focus is slowly shifting towards a more hybrid mix. Existing experience with normal chargers in cities could delay the changing perspective however (Interview 1,2).

As stated, logical locations for fast charger stations are the current gas stations. This is discussed in the next section.

8.5 Transition from gas stations to charging stations

There is an increasing interest of gas station operators to install fast chargers at their locations in cities. As EVs are likely to replace ICEVs in the long run, the transition from gas stations to charging stations plays an important role. This is discussed during the interviews with policy makers.

 INTERVIEWS

The public space in cities is scarce, especially when a station design is needed (Interview 3,4). There are not many locations where there is sufficient space, but the existing gas station locations are situated in strategic locations, along access roads to cities (Interview 3,4,11). Municipalities therefore favour locations in the private space, near shopping centres for example. Municipalities have suggested that gas stations are also important locations for future charging stations (Interview 3,4). For the renewal of concessions, municipalities are considering to force gas station operators to install fast charge points. A gas station operator in Amsterdam indicated however, that it was unclear to him what the requirements for charging infrastructure are in the future. (Interview 11).

Fast charge operators mention that as long as gas station operators make more profit selling gasoline, the fast charging facilities are not their priority (Interview 7,8). It is mentioned that municipalities should formulate adequate policy in relation to future gas station concessions (Interview 3,4,7,8). This includes adequate policy to create equal opportunities for current incumbent parties (oil companies) and current charge point operators.

“Why aren’t their more fast chargers at gas stations in cities? That is a logical option, but there are now operators who make more money selling gasoline”. (Municipality, Interview 3)

Concluding, gas stations provide strategic locations for future charging stations. The existing system of gas station operators have other interests however, and adequate policy is needed to increase the feasibility of fast charging in this respect.

8.6 Chapter conclusion

In this chapter, the third sub-question is answered: *What is the political feasibility of fast charging in the current and future context of Dutch cities?*. This question is answered by conducting interviews with municipalities, interpreting policy documents and comparing Dutch policy with other countries.



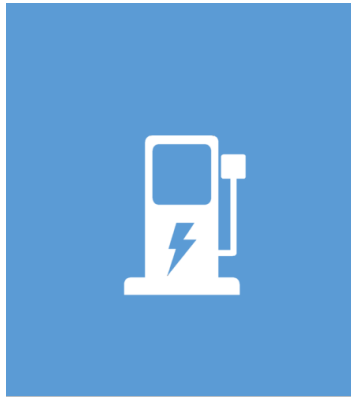
CURRENT FEASIBILITY

Currently, the decision making procedures and experience with normal charging policies favour the installation of normal chargers. National and local governments are leaving the installation of new chargers to the market, but decision making procedures and scarce public space complicate the installation of fast charging stations. Internationally, the Netherlands has a low percentage of fast chargers. When extrapolating existing models to the future, it could mean that up to 60 % of public parking in Amsterdam is needed for normal chargers. Fast charging can act as a solution to alleviate pressure on the public space.



DEVELOPMENTS IN FEASIBILITY

Policy makers agree that a hybrid mix of normal and fast chargers are necessary and are starting to set-up pilots. Industry interest is also intensifying, possibly influencing the political landscape. Logical locations for future public fast charging stations are gas stations. If charging rate goes up to 350 kW, the current gas station infrastructure could provide for the charging needs without normal chargers in 2035. However, adequate policy is needed for the renewal of gas station concessions to increase the political feasibility of gas stations.



9 Results: Feasibility of Fast Charging in Dutch Cities

The feasibility of fast charging in Dutch cities has been evaluated using the Feitelson and Salomon framework. Using desk research, semi-structured interviews and a focus group, the technical, economical, social and political feasibility have been analysed. In this chapter these are combined for the current situation and future developments. The current focus on normal charging in favour of fast charging can be explained when considering the current EVs and charging technology and availability of home charging for early adopters. When taking future developments into account however, a shift in focus towards fast charging provides a more efficient charging infrastructure in cities.

9.1 Explanation of current focus on normal charging

The four streams of feasibility described in Chapter 5 to 8 are combined in this section to explain the current focus on normal charging in Dutch cities. As explained in the introduction, fast charging is currently mainly used along highways to contest range anxiety, and scarcely seen as a solution for public charging in cities. This is also reflected in current policy of national and local governments. In this section the reasons for this focus are explained.



CURRENT FEASIBILITY

Each chapter concluded on the current feasibility concerning the relevant type of feasibility. Relevant factors following the Feitelson and Salomon framework were identified and conclusions drawn. In combining the conclusions from the previous chapters, the fifth research sub-question can be answered:

How can the current focus of the Dutch government on normal charging be explained?

An overview of the factors that explain this focus is provided in Table 10. With the current situation the Dutch charging infrastructure system at the time of this research, fall of 2017, is meant.

A number of factors stand out, when explaining the current focus of the Dutch government on normal charging in cities. From the desk research and interviews it is concluded that the main reasons stem from the technical and social perspectives, with the latter also strongly influencing the political feasibility. Desk research showed that most early EVs on the Dutch roads were PHEVs, which did not have fast charging capabilities. Next to that, most early adopters have access to home charging and thus have limited needs for other charging solutions in the city. Therefore fast charging is mainly seen as a need along the highways to contest range anxiety. Normal charging is also seen by DSOs as an important factor in the 'smart grid' to balance supply and demand. This resulted in much interest and experience with installing normal chargers.

From the political perspective, the positive attitude towards normal charging can be explained by analysing the current policy incentives and interviews with municipalities. First of all, the funds for installing public normal chargers are paid for by subsidies from the national government until now. In this way, municipalities can address the problem without spending local funds. This also attracted industry interest, as profits could be earned when making use of the subsidies. The installation of normal chargers have the added benefit of lower costs per charger (low risk) and a lower need for long term commitment. Next to that, policy makers could deal with the problem in a visible way by providing citizens chargers in front of their home. Finally, normal chargers interfere less with decision making procedures, as no new scarce public space needs to be allocated.

Table 10: Factors that explain the current focus on normal charging.

Feasibility	Factor	Current focus on normal charging in cities
Technical feasibility	<ul style="list-style-type: none"> - Technical requirements - Suggested innovations 	<ul style="list-style-type: none"> - Majority PHEVs without fast charging capability - In alignment with suggested innovations such as smart grids and V2G
Economical feasibility	<ul style="list-style-type: none"> - Perceived effectiveness - Perceived distribution of benefits and costs 	<ul style="list-style-type: none"> - Profitability of fast charging low at low adoption - Subsidies on normal chargers attracted industry interest
Social feasibility	<ul style="list-style-type: none"> - Perception of problems - Perceived effectiveness 	<ul style="list-style-type: none"> - Early adopters have mostly access to home chargers - Perceived effectiveness is better: more convenience (no waiting & close to home) at a low price
Political feasibility	<ul style="list-style-type: none"> - Social feasibility / Perception of problems - Industry interests / Decision making - Decision making - Social feasibility - Experience - Non-business & Industry interests 	<ul style="list-style-type: none"> - Effective solution for perceived problem at minimum costs as these are born by national government - Does not interfere with existing interests of incumbents (gas stations) - Low risk: no new public spaces or long contracts - Deals with the perceived problem in a visible way - Growing experience in public normal charging - No-one is negatively effected and multiple interest groups support it

While the current focus can be explained, the future developments ask for a more hybrid mix of charging solutions in cities. This is explained in Section 9.2.

9.2 Developments affecting the feasibility of fast charging

Sparked by technological developments in EV batteries and fast chargers, the feasibility of fast chargers as a solution for public charging in cities is growing. Next to exploring the current situation, also developments in the technological, economical, social and political areas are researched. These developments are analysed using the Feitelson and Salomon framework to conclude on the future feasibility of fast charging in cities in this section.



DEVELOPMENTS IN FEASIBILITY

Combining the findings of Chapter 5 to 8 concerning the developments in these four categories, the final sub-question can be answered:

How do future developments affect the feasibility of fast charging in Dutch cities?

As stated before, it can generally be concluded that the feasibility of fast charging develop positively. The technological advancements influence economical and social factors, which in its turn influence the political feasibility. The positive developments in the feasibility categories, including the corresponding factor in Feitelson and Salomon, are shown in Table 11.

The increased charging rate up to 150 kW mean that the technical capabilities of fast charging will be more in line with consumer preferences. With increasing adoption, the pressure on the electricity grid will also increase. Considering a Tesla car uses as much energy overnight as five households, it is predicted cables and transformers will overload when large numbers of EVs will charge simultaneously. The interviewees noted that fast charging can alleviate the pressure on the low voltage grid in certain neighbourhoods, as fast chargers are connected to the medium voltage grid. Car sharing and autonomous driving, further increase the need for fast charging, as the up-time of EVs will increase significantly.

Table 11: Positive developments in the feasibility of fast charging.

Feasibility	Factor	Positive developments in feasibility
Technical feasibility	- Technical requirements	- Increasing range and charge rate up to 150 kW mean a higher uptake of fast charging
	- Technical requirements	- Peaks in the low voltage grid in neighbourhoods can be alleviated with centralised fast charging
	- Suggested innovations	- Autonomous driving and car sharing increase fast charging needs because of higher up-time of cars
Economical feasibility	- Perceived distribution of benefits and costs	- Perceived distribution of benefits and costs increases as costs go down and benefits (speed, facilities) go up
	- Industry interests	- Revenue of fast charging increase with EV adoption, range and charge rate
Social feasibility	- Industry interests	- Research and mass production increases learning and scaling effects and drive down cost
	- Perceived effectiveness	- Attitude towards fast charging improves when it resembles refuelling experience
	- Suggested innovations	- 'Opportunity charging' shows need for a variety of charging solutions
Political feasibility	- Perceived effectiveness	- Business drivers, taxi's and car sharing users are expected to use fast charging
	- Perception of problems	- When adoption intensifies, fast chargers alleviate pressure on public space, grid and installation speed
	- Industry interests	- Increasing industry interests can influence political landscape towards fast charging
	- Decision making procedures	- Policy makers agree that a hybrid charging infrastructure is needed
	- Experience	- Willingness to cooperate in pilots increases experience with fast charging

The economical feasibility will increase in multiple ways. The perceived distribution of benefits and costs will improve, as costs are expected to go down with larger scale. Perceived benefits increase as faster charging increasingly resembles the current refuelling experience of consumers. Industry interest is already intensifying, as revenue possibilities increase with a larger range, faster charge speed and increased adoption.

Social feasibility also improves as the focus group results indicated, EV charging behaviour will shift towards 'opportunity charging', where drivers charge when it suits them best. The interviews showed that all stakeholders expect a hybrid charging system, where different kinds of normal and fast charging co-exist. Some interviewees expect that as fast charging approaches 350 kW, fast charging will become the dominant way of charging.

From the political perspective, interviews and desk research indicate that fast charging has a lower impact on public space as it has a larger EV capacity. Fast chargers can replace a large number of normal chargers. Increasing industry interest can also influence the sanctioned discourse regarding charging solutions. From the interviews it is concluded that policy makers agree that a hybrid solution of normal and fast chargers is needed. Most policy makers are willing to cooperate in pilots. Next to these positive developments in the feasibility, also a number of uncertain and negative factors have been identified. These are discussed next.

Table 12: Uncertain and negative developments in the feasibility of fast charging.

Feasibility	?/-	Factor	Uncertain/negative development in feasibility
Technical feasibility	?	- Technical requirements	- Introduction of 350 kW charging can take a long time due to model availability
	?	- Suggested innovations	- Approach for electrification (renewables, heating) can influence EV charging layout in cities
	?	- Suggested innovations	- Uptake of autonomous driving is uncertain
Economical feasibility	?	- Industry interests	- Industry interest for fast charging in cities is uncertain due to uncertain uptake of fast charging
Social feasibility	-	- Perceived effectiveness	- 'Waiting' while charging is not preferred
	?	- Perceived effectiveness	- No consensus on preferred mode of charging yet
	?	- Perceived distribution of benefits and costs	- Higher price of fast charging can form a barrier for private users
Political feasibility	-	- Experience	- Experience and interests for normal charging
	-	- Industry interests	- Current gas station infrastructure can slow down introduction of fast charging
	?	- Decision making procedures	- New public space or new policies for gas stations are needed in crowded cities

9.2.1 Uncertain and negative developments in future feasibility

Although the overall developments in fast charging positively influence the feasibility of fast charging in cities, also a number of uncertain and negative developments can be identified. These factors are mainly concerned with the social and political perspective. Consumer attitudes and willingness to wait while charging and pay a premium for high charge rates are uncertain. Political uncertainties are mainly concerned with vested interests in the normal charging and existing gas station systems. The factors are shown in Table 12, including the corresponding factor from Feitelson and Salomon and if this is an uncertain (?) or negative (-) factor.

From the desk research and interviews it can be concluded that although 350 kW charging is in development, battery pack configurations as well as cooling challenges for cabling mean that the wide-scale introduction will not occur before 2023. Most EV models on the market will be capable of charging at 100 to 150 kW. This means that charging will still take longer than refuelling in the coming years. Two co-evolving technological developments present further uncertainties. The approach that will be taken on a national and local level concerning the further electrification of consumer energy (heating, renewable energy) can influence charging as well. Stakeholders can try and sell contracts for multiple services, convincing customers to use normal charging. Also developments in car sharing and autonomous driving remain uncertain. Although these transitions have a long time horizon of ten to fifteen years, they can influence the design of the charging infrastructure considerably. If breakthroughs in V2G technology or smart charging occur, EVs could play an important role in the energy transition which would favour normal charging. An accelerated introduction of car sharing or autonomous driving however, would positively influence fast charging.

The social perspective shows an important uncertainty, as the focus group showed that the preferences of EV drivers are difficult to predict. If public normal chargers will become widely accessible and drivers prefer this to fast charging, the feasibility and profitability of fast charging will decrease. Other drivers indicated that as fast charging resembles refuelling, this would become their preferred way of charging. From the focus group no consensus was reached on a preferred mode of charging. The price of fast charging can form a barrier for private drivers, but business users do not perceive cost as an issue. The percentage of EV drivers that will use fast charging as their preferred way of charging is still difficult to determine from consumer surveys and the focus group results.

From interviews it is concluded that the current political landscape negatively influences the feasibility of fast charging. The experience with and current focus on normal chargers can hamper the introduction of fast chargers. And as fast charging stations need either new public space or have to be developed at existing gas stations, this introduces challenges in creating new decision making procedures. Finally, an important political aspect is the way in which municipalities handle gas station concessions in the future. As gas stations are located in strategic locations in cities, and public space is scarce, these locations are likely to transform into charging stations in the future. Vested interests and higher revenues of gasoline sales in the coming years could hamper the introduction of fast charging in these locations.

Concluding, the feasibility of fast charging in cities will develop positively in the coming years. Sparked by technological advancements, social, economical and political feasibility increases. However some uncertain and negative developments could prevent fast charging from adoption in cities. Consumer preferences and existing procedures and interests are the most important factors.

Following these results, a number of concrete recommendations are formulated for future policy as well as for businesses strategies. These are stated in the next sections.

9.3 Policy recommendations on public charging in cities

Based on the changing EV landscape and the conducted interviews and focus group, recommendations for national and local governments on public charging infrastructure are presented in this section. Policy recommendations based on the four feasibility categories are shown in Table 13.

Table 13: Policy recommendations regarding public charging infrastructure in cities

Feasibility	Policy recommendations
Technical feasibility	- Monitor and stimulate developments in charging, electrification and autonomous driving and car sharing
Economical feasibility	- Assure fair prices for charging when concessions are given out to third parties
Social feasibility	- Monitor consumer preferences for charging, especially when adoption intensifies and home charging will not be the primary mode in cities
Political feasibility	- Stimulate EV adoption by creating opportunities for normal and fast charging possibilities in cities
	- Pro-active installation of chargers and efficient use of public space are needed when adoption increases
	- Develop policy for the transition of gas stations to charging stations
	- Determine grid limits in neighbourhoods and take upgrade costs into account when determining new charging infrastructure installation

Technological development is not the task of policy makers, but active monitoring and stimulation of these developments is recommended. Pilots with new technologies, as well as car sharing and autonomous driving should be carried out. Car sharing, autonomous driving, and car-free city centres affect the charging infrastructure landscape in cities. When long-term concessions are awarded (which are necessary to ensure profitability), these effects should be incorporated in the decision making procedures. From the economical perspective, an active monitoring of the price of charging is desirable. If one party gets (almost) a monopoly on charging solutions in a city, this could result in too high prices for consumers. If these are higher than the price of gasoline, this will decrease EV adoption.

Consumer preferences have a strong impact on policy in cities, and therefore should be closely monitored. A major shift in consumer wishes can be expected, since most current EV drivers primarily charge at home. Since this is not possible when EV adoption increases, charging behaviour will change significantly.

Also a number of recommendations from the political perspective are given. First of all, the acceleration in EV adoption expected in the coming decade, asks for a more pro-active approach in installing chargers. The current demand-driven approach cannot keep up with the charging needs when EV adoption exponentially increases the coming years. Pro-active installation of normal and fast chargers is necessary for efficient use of the public space. To achieve this, a hybrid mix of normal and fast chargers is needed. Policy makers should be aware that existing experience and granted subsidies favour normal chargers, and base future policy on efficient use of the public space. The limits of the public space and the electricity grid should be taken into account. To prevent unnecessary delays, DSOs should be given permission to upgrade specific sections of the grid pro-actively.

Considering the locations of public chargers in a city, curbside chargers as well as gas stations provide logical charging possibilities. To guarantee a smooth transition from gas stations to charging stations, policy should be adapted such that fast charging can be incorporated at these locations. New market parties should get equal opportunities to install chargers at these locations to stimulate market formation.

9.4 Business recommendations for fast charging CPOs

To accelerate the adoption of fast charging and create a profitable business, a number of recommendations for fast charge point operators are given. These are categorised per feasibility type in Table 14.

Table 14: Recommendations for fast charge CPOs to increase adoption of fast charging in cities

Feasibility	Fast charging CPO recommendations
Technical feasibility	<ul style="list-style-type: none"> - Offer a range of charging solutions (50 - 150 kW) at different locations - Monitor and participate in developments in autonomous driving
Economical feasibility	<ul style="list-style-type: none"> - Assure that kWh price stays competitive with diesel/gasoline prices - Explore other business models to earn additional revenue besides selling electricity - As additional infrastructure in station set-up is expensive, existing infrastructure could be used
Social feasibility	<ul style="list-style-type: none"> - Focus on groups that use fast charging regularly, such as business drivers, taxi's and car sharers - Combine semi-fast charging (30-100 kW) with activities such as shopping, eating, meetings - Provide adequate facilities when users have to wait while charging
Political feasibility	<ul style="list-style-type: none"> - Actively participate in developing new policy for the transition from gas stations to charging stations - Discuss the advantages/disadvantages of 'smart grids' with national and local governments and DSOs

First of all, it is recommended to offer a range of fast charging solutions based on target group preferences and different charging situations. From the focus group it is concluded that 50 kW chargers can be a good solution at shopping centres at meeting points, while 150 kW fast charging can be used for quick top-ups. Next to that, it is advised that the developments in car sharing, taxi usage and autonomous driving are closely monitored. These groups have an increased need for fast charging, and providing them appropriate solutions can increase revenues. As these groups communicate their needs clearly, the perceived effectiveness of fast charging as a solution is high in these cases.

Economically, it is interesting to explore different business models to earn additional revenues. Partnerships with restaurants or hotels can be interesting, located in the public and private space. As the limited public space in cities is a delaying factor, other locations might provide faster access to new locations.

Positive consumer attitudes are important to attract new customers and convince them of the utility of fast charging. Business drivers are a likely group to switch to EVs first, and as they drive long distances have increased fast charging needs. It is also recommended to offer a range of charging speeds (and corresponding prices) that suit the charging opportunity. At shops, restaurants and hotels cheaper 30-50 kW chargers can be installed, while at gas stations the highest possible speed would be desirable. When the element of waiting is involved when charging, facilities (coffee, internet etc.) are important for consumers.

Next, it is recommended to develop new policy and decision making procedures with municipalities and national government. The transition from gas stations to charging stations is an important topic, as these provide strategic locations in cities. Finally, strategic considerations are developed based on a fast or slow EV adoption and autonomous driving transition. These provide four scenarios with a large impact on cities, as shown in Figure 41.

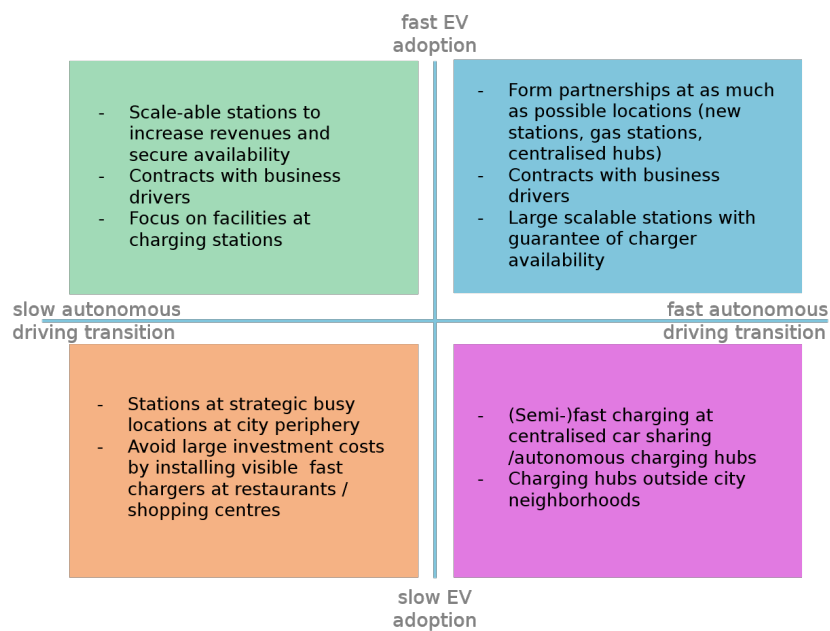


Figure 41: Business strategies based on four scenarios.

The first scenario represents a fast EV adoption, but a slow transition in autonomous driving. It is advised that the focus is on scalable stations to increase revenues efficiently while guaranteeing charger availability for consumers. Contracts with business drivers provide a constant flow of income, and consumer experience is key. If both transitions happen quickly, it is expected that fast charging will grow exponentially. New locations should be acquired at both public and private locations in cities.

If on the other hand both transitions will develop slowly, strategic locations along busy routes in and out of cities should be acquired. If possible, existing infrastructure (gas stations) could be used to avoid expensive installation costs. In this case it is important however to maintain good visibility and customer experience. In the unlikely case that EV adoption will lag behind autonomous driving, the focus should be on charging hubs. When autonomous driving takes off, charging will most likely occur centralised, and this is also profitable. At the peripheries of neighbourhoods and at centralised charging hubs large charging stations should be installed.

The technological, economical, social and political results have been combined, and recommendations have been formulated in this chapter. Next, the main findings are presented and the results are discussed in Chapter 10.



10 Conclusion & Discussion

In this chapter the research is concluded and discussed. Fast charging is concluded to be increasingly feasible as a public charging solution in Dutch cities. The developments sparked by increasing EV adoption and fast charging technology increase the feasibility of fast charging. Increasing industry interest, consumer attitudes and high capacity of fast chargers make it an important solution in the hybrid mix of charging solutions. Uncertainties in adoption include consumer attitude, experience with normal charging and policy regarding gas stations. The main findings of the current situation and future developments are presented by answering the research question. These are discussed, and the scientific and practical contributions of this research are stated. Finally, the limitations of the research and recommendations for future research are given.

10.1 Main findings

To conclude this research, the main research question is answered. The research question is:

To what extent is public fast charging feasible from a technical, economical, social and political perspective in the current and future context of Dutch cities?

It is concluded that fast charging is increasingly feasible as a charging solution in Dutch cities. The current focus on normal charging in cities is caused by the current EVs capabilities and charging technology. Larger batteries and faster charge rates however increase the feasibility of fast charging. The acceleration of EV adoption asks for a hybrid mix of normal and fast charging solutions in crowded Dutch cities to accommodate the charging needs. The increasing industry interest, consumer attitude and high charging capacity make fast charging an important factor in the future public charging infrastructure.

The current focus on normal charging in favour of normal charging can be explained by a number of factors. From the technical perspective, the focus is explained by the fact that the majority of EVs on the Dutch roads nowadays are PHEVs without fast charging capability. Economically, the profitability of fast chargers at low adoption rates is difficult, resulting in low industry interest. Social feasibility is mostly high along the highways, as most early adopters have access to home charging and use fast charging only as a range extender. Politically, a number of factors play a role. Installing normal chargers is a lower risk for municipalities. And as most normal chargers are installed with national subsidies, municipalities solve the problem of charging needs at minimal costs. The growing experience with normal chargers and low impact on decision making procedures increase this focus.

In the coming decade EV adoption will accelerate and public fast charging in cities becomes increasingly feasible. This is primarily because of four factors. First, the faster charge rate will increase the consumer attitude as well as the profitability for market parties. Second, industry interest in fast charging will intensify, bringing down costs, influencing the consumer perception as well as the political feasibility. Third, when EV numbers increase exponentially in cities, fast charging can alleviate pressure on the public space (as it can replace a large number of normal chargers), the grid (as it does not contribute to low voltage grid peaks) and capacity problems (as grid upgrades and installation of chargers are time intensive). Finally, trends in autonomous driving and car sharing increase the demand for quick recharging of EV batteries.

Finally, three factors are determined that could hinder or delay the adoption of fast charging. The existing decision making procedures hinder new installation of fast chargers, since new public space is sparsely allocated and the transition of existing gas stations is difficult due to interests of oil companies. Secondly, the existing (financial) interests and experience with normal charging could affect the sanctioned discourse in such a way that fast charging is not perceived as an effective solution. Third, the consumer preferences are still uncertain in their development. The focus group results indicate a positive development in the attitude towards fast charging, but it is still unclear what the preferred mode of charging will become.

Next, the findings are discussed in more detail.

10.2 Discussion

The main findings are interpreted and discussed in this section and linked to the research field. The current situation is discussed first, and the developments in the feasibility of fast charging after.

10.2.1 Current focus on normal charging

The current focus of Dutch local and national governments on normal charging in cities can be clearly explained by the results. Following the Feitelson and Salomon framework, the main explanatory factors stem from the technical and social perspective, influencing the political feasibility. Fast charging is not an often suggested innovation in cities, and seen mainly as necessary innovation along the highways.

From the technological perspective, the focus is explained by the fact that the majority of EVs on the Dutch roads nowadays are PHEVs without fast charging capability. Next to that, the interviews showed that normal charging is in alignment with suggested innovations by grid operators such as smart grids and vehicle-to-grid technology. There is a relatively strong influence of DSOs in the Netherlands which were heavily involved in the early installation of chargers. The need for fast chargers, and thus the social feasibility, was lower in cities as most early adopters had access to home charging. The profitability of fast chargers at low adoption rates is also difficult, resulting in low industry interest for installing fast chargers in cities up until now.

This resulted in a limited political focus on fast charging in cities, caused by a number of factors identified from desk research and interviews. First of all, installing normal chargers is a lower risk for municipalities. It solves the problem (citizens need public charging facilities) in a visible way. And since most early normal chargers are installed with national subsidies, municipalities solve the problem at minimal costs. Multiple interest groups support it, as environmentalists are aligned with industry interests and incumbent gasoline selling parties are not negatively affected. The growing experience with installing normal chargers might also reinforce the focus on normal chargers in policy. Finally, installing normal charging does not interfere with current decision making procedures. Fast chargers on the other hand, often require a new development plan for scarce public space in cities.

It can be said that the factors identified using the Feitelson and Salomon framework can explain the current focus. The explanatory value of using the framework lies in the combination of the different perspectives. Although some explanatory factors are evident (PHEVs on the road, low industry interest, home charging availability), two findings were unexpected. Firstly, the large role of DSOs in the early charger installations could have influenced the focus on normal charging. Especially when comparing this internationally, the Netherlands has a very low percentage of fast chargers. The second finding is the way chargers have been financed for the past years. As national subsidies for normal chargers were available to municipalities, they could serve EV drivers in a visible way without spending local funds. It can be argued that normal charging is favoured by the government in this way. Taken the other perspectives into account however, government support was necessary to stimulate EV adoption. Normal chargers were the most logical option for this, considering the EV availability.

Interesting to note is that most of the factors that prevented the adoption of fast charging in cities however, are rapidly developing in a positive way. The results concerning these developments are discussed next.

10.2.2 Developments in the feasibility of fast charging

The results show that the feasibility of fast charging in cities is increasing, sparked by developments in EV batteries and fast charger technology. These development influence the social and economical feasibility positively, which in turn increase the political feasibility. Interesting to note is that the identified factors that explain the current focus on normal chargers are all changing rapidly.

The increased range of EVs and the fast charging rate of 150 kW mean that the technical capabilities of fast charging will be more in line with consumer preferences. Car sharing and autonomous driving further increase the need for fast charging in the future. This also affects Economical feasibility as increased adoption, charge rate and industry interest increase revenues and bring down costs. Social feasibility increases, as fast charging increasingly resembles the current refuelling experience of consumers. As the focus group results indicated, EV charging behaviour will shift towards 'opportunity charging', where drivers charge when it suits them best. Business drivers will most likely change to EVs first, and this groups has increased fast charging needs because of long trips.

From the political perspective, interviews and desk research indicate that fast charging can alleviate pressure on the public space and the low voltage electricity grid in specific neighbourhoods. As adoption increases, charging needs increase as well and will have a significant impact on the public space in cities. As fast chargers can replace a large number of normal chargers, they provide an efficient way of increasing charging capacity. From the interviews it is concluded that policy makers agree that a hybrid solution of normal and fast chargers is needed.

The results thus indicate a positive shift in feasibility of fast charging in cities, but a number of uncertain and negative factors are identified as well. These stem mainly from the social and political perspective. The focus group results showed that the preferences of EV drivers are very difficult to predict. If public normal chargers will become widely accessible, some EV drivers prefer this to fast charging. Other EV drivers indicated that as fast charging will resemble refuelling, this would become their preferred way of charging. As social feasibility plays a crucial role in the Feitelson and Salomon framework, this is an interesting finding. This extends existing research, as most consumer preference studies are strongly connected to the existing context (charge rate, EV capabilities).

Another possible negative factor and interesting finding is that the current political landscape negatively influences the adoption of fast charging in cities. The experience with normal chargers and existing decision making procedures can hamper the introduction of fast charging. As fast chargers need either new public space or have to be developed at existing gas stations, this requires new policy and procedures. An important political aspect is the way in which municipalities handle gas station concessions in the future. As gas stations are located in strategic locations in cities, and public space is scarce, these locations are likely to transform into charging stations in the future. Vested interests and higher revenues of gasoline sales in the coming years could hamper the introduction of fast charging in these locations.

The results indicate that developments increase the feasibility of fast charging positively. Since EV adoption will increase exponentially in the coming decade, the charging needs will increase exponentially as well. The results indicate that in order to facilitate this in the context of crowded Dutch cities, a hybrid mix of fast and normal chargers is necessary. Interesting to note is that although most policy makers agree on this, the current political feasibility in cities is low. This is in contrast with other leading EV cities and countries. Municipalities should adapt their decision making procedures if they want to facilitate fast charging in their cities, which is shown to positively affect EV adoption.

After discussing the results of this research extensively in this section, the scientific and practical contributions are discussed next.

10.3 Contributions of the research

In this section, the scientific, managerial and societal contributions of the study are discussed. The findings are related to the broader problem statement raised in the introduction, as well as compared to previous scientific studies.

10.3.1 Scientific contributions

This research contributes to the scientific body of knowledge in a number of ways. The combination of perspectives to analyse the feasibility of fast charging provides new insights, as well as the focus on cities as location. Next to that, new insights in using the Feitelson and Salomon framework are provided and possible enhancements are given in this section.

Firstly, the research combines the technological, economical, social and political perspectives to determine the feasibility of fast charging. As previous studies focused mainly on one perspective, the findings of this study add to the body of knowledge. Also the choice for the case study of Dutch cities is new for research on fast charging. As in the early stages of EV adoption fast charging is seen as a solution along the highways, this study adds to these studies. The focus group results especially provide crucial new information, since most consumer studies are focused on outdated context (small batteries, no fast charging capability). The lack of consensus between EV drivers on their preferred mode of charging in cities provides an interesting new research topic.

Generalisability of results

Since the research conducted is a case of the large Dutch cities (Amsterdam, Rotterdam, The Hague and Utrecht), it is interesting to discuss the generalisability of the results. This is done in two ways: for smaller cities in the Netherlands, and for other cities in other countries.

Firstly, the context in smaller cities is different in a number of ways. As in smaller cities more people have access to private parking, the needs for public charging are lower. Next to that, public space is less scarce, decreasing the political difficulties in allocating space for fast charging stations. Smaller cities also usually work with permits instead of concessions, which makes it easier for market parties to install chargers. This means that the political and economical feasibility in these areas is higher, but that the needs for public charging may lag behind the bigger cities. The results can be generalised however by concluding that a hybrid mix of charging solutions is needed in cities to effectively stimulate EV adoption.

When looking at other countries, the context also differs from country to country. As most countries already have a higher percentage of fast chargers, it could be said that the feasibility there is higher. This can partly be explained by the larger travel distances in other leading EV countries such as Norway and the United States. The possibilities for installing chargers also depend on the electricity grid available in that country. In particular the technical, economical and social factors identified are likely to be valid in other countries as well. The local context and political landscape should always be taken into account however.

Enhancements to the Feitelson and Salomon framework

Next to that, a number of possible enhancements of the Feitelson and Salomon framework are determined. The framework is generally found to be effective in mapping the factors and agents that determine the adoption of an innovation. Some factors have been identified however that do not fit the framework.

First, co-evolving innovations are difficult to map using the framework. Autonomous driving, car sharing and the renewable energy transition all affect the adoption of fast charging indirectly. They can have significant effects on the design of public space in cities. This factor is not incorporated in the current framework, but could be modelled as an effect influencing the suggested innovations. Secondly, the resistance of the existing regime towards new innovations is difficult to map with the framework. Incumbent firms (selling gasoline in this case) resisting new market developments are a well-known influence in socio-technical transition literature. In the Feitelson and Salomon framework this could be termed as 'industry interests', but more emphasis on the existing regime could enhance the framework. The existing regime can be said to influence the perception of problems, the decision making procedures, and the political feasibility.

Secondly, since the framework is a time static snapshot of the situation, a more dynamic approach would help in analysing the dynamic process of innovation adoption. The time static analysis is supplemented in this research by evaluating the developments affecting the feasibility and by identifying the uncertainties in development. Reflecting on the theory on socio-technical transitions, the dynamics effects in the adoption of innovations could be modelled in a number of ways.

The Hekkert et al. (2007) framework addresses this by identifying functions of innovation systems and motors of change, processes that accelerate technological transitions. Similar relations that accelerate the adoption of an innovation between the factors in the Feitelson and Salomon framework could possibly enhance the framework. In their study, Feitelson and Salomon state that 'policy entrepreneurs' can put an innovation on the agenda when a window of opportunity occurs. Two other 'active agents' are stated here that could have such an effect in the charging infrastructure system.

First of all, the effect of increased EV range and fast charging rate by experts can create a snowball effect in the Feitelson and Salomon framework. Increased expert attitudes mean that fast charging can become a suggested innovation as charging solution in cities. The perceived effectiveness is increased, as fast charging resembles the refuelling experience more. This in turn creates a more positive attitude from consumers, and this increased social feasibility influence the political feasibility and decision making procedures.

Second, the industry interest by large car manufacturers (BMW, Audi, Porsche) and fuel companies (e.g. Shell) can result in a dynamic acceleration in the adoption of fast charging. First, learning and scaling effects can drive down the costs of production and increase performance. It can also influence the perception of the public positively, as industry interests can influence the perceived effectiveness of an innovation. Thirdly, this might accelerate the political feasibility by influencing decision making procedures by lobbying. These two actors are indicated in the framework in Figure 42.

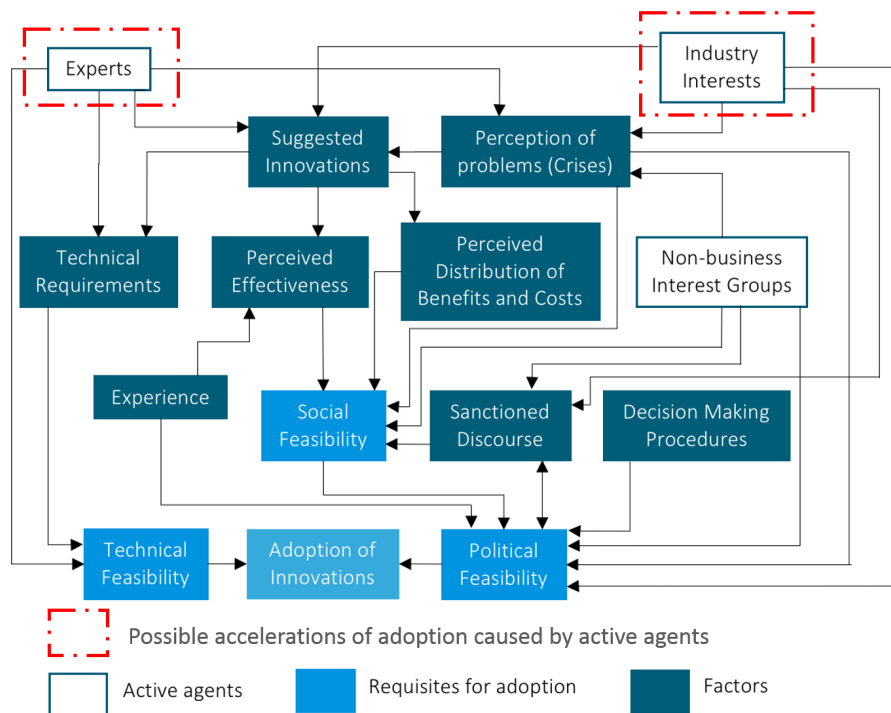


Figure 42: Possible enhancements of the Feitelson and Salomon framework

Now the scientific contributions of this study are discussed, the contributions in terms of managerial and societal contributions are discussed.

10.3.2 Managerial contributions

The managerial contributions of this research can first of all be found in the factors that influence the adoption of fast charging in cities. Policy makers can use these insights in developing future policies concerning charging infrastructure. Investments by local and national governments in public charging infrastructure could be done more efficiently. The factors that change over time can also be identified from this research when adaptive policies are implemented. As the findings indicate that a hybrid mix of normal and fast chargers is necessary, decision making procedures could be formed accordingly.

For businesses, the managerial contribution is fourfold. First, the arguments from this thesis could be used by fast charging operators when discussing the placement of fast chargers with local governments. Secondly, the insights from the focus group could be used to alter the locations, types of chargers or payment plans for their services. New business models could be developed based on the consumer preferences. The third contribution for businesses is the identification of the factors that prevent the adoption of fast charging. These hampering factors are positioned in the political context, and actors in the fast charging business could try and influence these factors. This can be done by lobbying at the local and national level to adapt the decision making procedures. Finally, a number of concrete recommendations have been formulated. Also a rough sketch of strategies is provided based on fast or slow transitions in EV adoption and autonomous driving, and this could aid businesses in developing their strategies in the coming years.

10.3.3 Societal contributions

The societal relevance can be found in the fact that a more efficient and effective charging infrastructure stimulates EV adoption. This helps to meet environmental goals to reduce GHG emissions, fossil fuel depletion and urban air pollution. Fast charging availability is determined to stimulate EV adoption, and the findings from this study show the relevant factors involved.

Next to that, charging infrastructure will have a significant impact on public space in cities in the coming decade. Infrastructure that suits the needs of EV drivers and creates a good living environment is therefore desirable. Finally, an unbalanced charging infrastructure can result in higher risks for the stability of the electricity grid and high societal costs involved in upgraded electricity grids.

Following the contributions of the study, topics for future research and new research areas are discussed next.

10.4 Limitations & recommendations for future research

As EV charging infrastructure, and especially fast charging, is a relatively new research field, numerous interesting topics for future research can be identified.

First of all, as cooperation between stakeholders is necessary in large-scale transitions, a more elaborate analysis on the interests and strategies in the charging infrastructure system could provide new insights. An example could be the potential conflicts between oil companies and current charge point operators. The higher profitability of selling gasoline could hamper the introduction of charging stations, and the interests in this field could provide new insights in the feasibility of fast charging.

Second, the current scope of the research is limited to Dutch cities. As the percentage of fast chargers in cities is relatively low in the Netherlands compared to other leading EV markets, an international comparison might explain these differences in more detail. An international comparison of policies regarding fast charging in cities and the context of these countries could provide valuable lessons for the Dutch context.

Third, the presented enhancements for the Feitelson and Salomon framework are solely based on the case study presented in this research. Therefore their generalisability can be limited. Although the enhancements are expected to be valid for most transport innovations, multiple case studies should be performed to validate these factors.

Fourth, some perspectives are still limited in scientific research on fast charging. Large scale surveys on charging preferences among Dutch EV drivers concerning fast charging and research into the political aspects of the transition of gas stations to fast charging stations are analyses that would add to the body of knowledge.

And finally, the effect of car sharing and autonomous driving on charging infrastructure provides an interesting dynamic between different socio-technical systems. Almost all interviewees agreed that these transitions would have an effect on EV charging, but when and how these trends would develop was uncertain. Since the effect of an autonomous car fleet would have significant consequences on the way EVs charge, this provides an interesting research topic.

Concluding, the rapidly developing EV and charging infrastructure system provides numerous interesting topics for further investigation. As this topic combines so many perspectives and developments, new insights are needed in this constantly changing environment.

Epilogue

In this epilogue I present my view of the public charging infrastructure of the future in the Netherlands. During the past six months I have spoken to many people in the sector in interviews and during symposiums. Next to that, I have identified bottlenecks that require the attention of policy makers in municipalities. These will also be presented in a 5-pager which can be shared with municipalities in the Netherlands.

Transitional period: 2018 - 2025

The coming years of electric mobility in the Netherlands will be one of transition. Diesel and gasoline cars will be replaced by EVs, and cities will use more and more green and renewable energy. Car sharing will grow and autonomous driving will make its introduction. All these developments take place in a world where more people will live in cities. These developments ask for a different way of living and organising our transport in cities.

Efficient use of our public space will be necessary, and a new way of mobility will make its introduction. EVs not only provide a green alternative to ICEVs, they also alter our cities in terms of where and how cars are parked, charged and used. These developments take place however in an existing system of ICEVs and gas stations. When large scale transitions occur, the existing system both actively and passively resists these changes. Existing decision making procedures and experience, interests of car manufacturers and oil companies, and bounded rationality of consumers can all delay the transition.

Combining these effects, I believe the charging infrastructure will consist of a hybrid mix of solutions. The majority of cars charge using normal chargers. Then, 50 kW chargers are available at shops, restaurants, meeting centres and other locations where consumers stop for approximately one or two hours. Next to that, fast charging stations are build at the periphery of cities. The charging solutions are visualised in Figure 43.



Figure 43: The cityscape and charging solutions during the transition period.

New mobility landscape in cities: 2025 - 2035

From 2025 onward, EVs will become the dominant technology. Combinations with renewable energy and car sharing create synergistic systems where energy is produced locally and cars are used efficiently. Because of growing urbanisation, vehicles will be more scarce in city centres. Larger loading hubs are set-up on the periphery of the city, where centralised and efficient charging will take place. Depending on the duration of parking, the charging speed is selected.

As the car fleet will shrink, and the utilisation rate of EVs will increase, faster charging solutions are needed. Fast charging will take an important role in this new mobility landscape, and the normal chargers will slowly disappear from city centres. Impressions of charging hubs, autonomous driving experiences and the green, car-free city centres is given in Figure 44.



Figure 44: The city centres and charging solutions in the new mobility landscape.

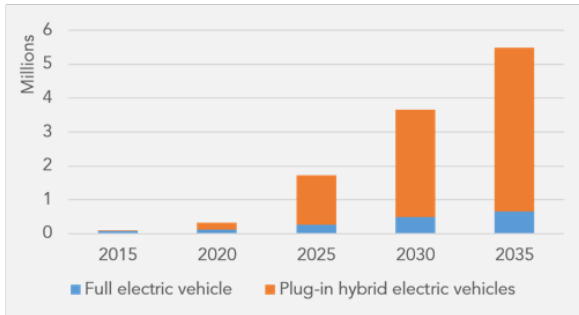
This dynamic and large discrepancy between the new mobility landscape and the current situation has implications for the decade to come. As it is likely that the charging infrastructure on the long term will disappear from city centres, new installation of chargers at these locations should be done with care. A number of bottlenecks have been identified for the installation of public chargers in cities. These are presented next.

Bottlenecks for a future-proof charging infrastructure

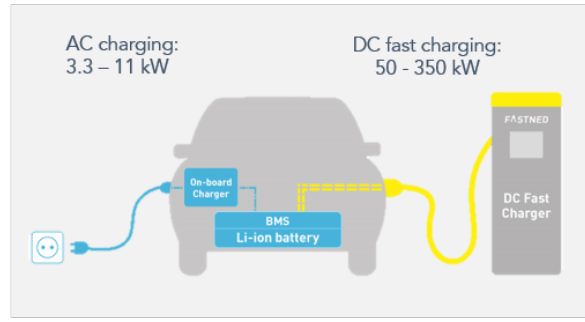
As municipalities prepare for the EV boom, a number of things have to be taken into account. The current approach of installing normal chargers is logical given the current context. This context is changing rapidly however, and the current approach is not scalable to the future. There are a number of steps that need to be taken now, in order to be prepared for the EV acceleration. These are shown visually below.

PUBLIC EV CHARGING FACTS & BOTTLENECKS

Many challenges exist in the installation of EV charging infrastructure, including the technology, the charging locations and the impact on the electricity grid. An overview of developments and key figures and bottlenecks is presented.



“ In order to meet charging needs, normal and fast charging will be needed at parking spots, restaurants, shopping centres and charging stations. ”



ELECTRICITY GRID

- One Tesla uses as much energy as 5 households
- Fast charging alleviates pressure on the low voltage grid of EV charging
- Electrification of heating and energy generation should also be considered

CAR SHARING & AUTONOMOUS DRIVING

- Car sharing and autonomous driving will shift car traffic from the city centre to the periphery
- At these locations, (semi-)fast charging is ideal at charging hubs
- Depreciation of chargers installed from 2020 onwards should be taken into account

GAS / CHARGING STATIONS

- Gas stations provide logical locations for charging stations
- EV charging has less safety restrictions
- New concessions for gas stations should incorporate EV charging and provide opportunities for EV parties

PUBLIC SPACE

- Almost all parking spaces in cities would be needed to charge EVs if only normal charging is used
- This is not possible: a hybrid mix of charging solutions is needed
- Centralised charging is more efficient and future-proof

“I want as little as possible chargers in my city”

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A Appendix: Interview Protocol

In this appendix the interview protocol is presented. Since most interviewees were interviewed in Dutch, the questions are stated in Dutch.

Naam:

Functie:

Organisatie:

Datum en tijd:

Introductie

- Wederzijdse kennismaking: Voorstellen en achtergrond introduceren
- Tijd van het interview: Het interview zal ongeveer 45 minuten duren
- Opname van het interview en goedkeuring: Vindt u het goed als ik het interview opneem om het later terug te kunnen luisteren en te gebruiken in mijn onderzoek?
- Introductie van het onderzoek: Master scriptie Technische Bestuurskunde aan de TU Delft naar de afweging van verschillende manieren van laden (normale laadpalen, laadpleinen, snelladen) in de publieke omgeving in steden.
- Opzet interview: Eerst wat algemene vragen over relatie geïnterviewde met het thema, daarna vragen vanuit vier 'feasibility's': technische, economische, sociale en politieke factoren.

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
Probe: Wat is/was uw rol bij [...]? Welke projecten/onderzoeken heeft u aan meegewerkt?
2. Wat is het doel van de gemeente bij het installeren van laadinfrastructuur voor elektrische auto's?
Probe: Doelstellingen voor luchtkwaliteit, EV gebruik stimuleren, werkgelegenheid, effect op openbare ruimte?
3. Wat zijn de belangrijkste factoren die de afweging tussen normaal laden en snelladen in de stedelijke omgeving bepalen voor gemeentes volgens u?
Probe: Investeringskosten? Subsidie?
4. Hoe komt het denkt u dat gemeentes nu vooral gericht zijn op langzaamladen in de publieke ruimte?
Probe: Klantvoorkeuren? Vragen van burgers? Subsidie van nationale overheid?

Technische haalbaarheid

5. Denkt u dat de toename van actieradius betekent dat er meer of minder gebruik wordt gemaakt van snelladen? En waarom?
6. Denkt u dat de ontwikkeling van snellaadtechniek tot 350 kW er voor zal zorgen dat er meer gebruikt wordt gemaakt van snelladen? En op welke termijn denkt u dat?
7. De adoptie van EV vertoont verschillende synergieën met bijvoorbeeld shared vehicles en autonomous driving. Denkt u dat deze trends een effect gaan hebben op de manier waarop EVs geladen worden? En zo ja, op welke manier?

8. Een belangrijke technische factor is de impact van EVs op het elektriciteitsnet en de rol hiervan in de energietransitie. Er zijn investeringen in het net nodig om de groei van EVs aan te kunnen. Heeft u een beeld hoeveel EVs er in een wijk bijgeplaatst kunnen worden zonder verdere investeringen?
9. Welke rol speelt smart charging in het tegengaan van nodige investeringen? En op welke termijn is dat haalbaar denkt u?
10. Hoe ziet u de afweging tussen snelladen en normaal laden in deze context?
Probe: laagspannings- / middenspanningsnet. Minder buffer voor duurzame energie
11. Als een van de voordelen van normaal laden wordt vaak genoemd dat EVs kunnen terugleveren aan het net (V2G, V2X). Hoe kijkt u tegen de haalbaarheid van deze opties aan? Ook qua verdienmodel? En op welke termijn?

Economische haalbaarheid

12. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
13. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?

Sociale haalbaarheid

14. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?

Politieke haalbaarheid

15. Hoe denkt u dat gemeenten de afweging maken tussen 'normaal laden' en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?
16. Welke factoren zijn volgens u van belang bij de afweging van de maatschappelijke kosten en baten van beide laadoplossingen?
Probe: impact op publieke ruimte, investering in het net, kosten van totale laadinfrastructuur
17. Het doel is om uiteindelijk met beleidsaanbevelingen te komen voor grote gemeentes. Heeft u hier ideeën over? Hoe zouden gemeentes zich goed kunnen voorbereiden op de snelle groei van EVs in de komende jaren?
18. Een uitdaging bij snelladen is de huidige infrastructuur van benzinstations. Heeft u ideeën hoe gemeentes om moeten gaan met de transitie van fossiele brandstoffen naar EVs bij pompstations?

B Appendix: Interview Summaries

In this appendix summaries of the interviews are documented. Since all interviews (except Interview 8) are conducted in Dutch, the answers are also summarised in Dutch. As already stated in section 3, some types of feasibility are discussed more with experts than others. The organisations interviews and the type of feasibility discussed are shown in Table 15. Therefore not all questions are asked to all interviewees.

Table 15: Interview list and focus during interviews.

Segment	Organisation	Technical	Economical	Social	Political
Government	Municipality Amsterdam, The Hague, Dordrecht		✓	✓	✓
Charge point operator	Fastned, Allego	✓	✓	✓	
Research institutes	E-laadNL, TU Eindhoven	✓	✓	✓	✓
Drivers organisation	Elbil (Norway)			✓	✓
Grid operators	Stedin	✓			✓
Consultants	OverMorgen, EVConsult, APPM	✓	✓	✓	✓
Gas station owners	BP Slagboom		✓		✓

Interview 1: TU Eindhoven

Naam: Auke Hoekstra

Functie: Auke Hoekstra, senior advisor mobility at TU/e, ElaadNL, Alliander

Organisatie: TU Eindhoven

Datum en tijd: 30 Oktober 2017 16:00 – 17:00

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?

Heb mij op ontwikkeling in duurzame energie gericht. Voorspellen van toekomst is ingewikkeld, met agent based modelling kan je realistisch modelleren en meerdere trends en feedback loops meenemen. Momenteel voor de TU Eindhoven. Interessant om snelladen mee te nemen in scenario's en aannames in het Spark City model.

2. Wat zijn de belangrijkste factoren die de afweging tussen normaal laden en snelladen in de stedelijke omgeving bepalen voor gemeentes volgens u?

- Er is een bredere context van duurzame energie-opwekkers en netbeheerders die ook betrokken raken bij dit vraagstuk, neem dit ook mee.

- Prijs is belangrijk. Ook gemak, dat uit zich in het wachten bij een snellader, of de beschikbaarheid van reguliere laadpalen in de straat.

- Belangrijk is ook de prijs van een extra kW laadvermogen. Als deze laag wordt, wordt het interessant om 20 kW AC laders in de auto te verwerken. Als dat duur blijft, kan er alleen een 'noodlader' van 3.7 kW in de auto en de hoge vermogens in de snellader.

3. Hoe komt het denkt u dat gemeentes nu vooral gericht zijn op langzaam laden in de publieke ruimte?
Snelladen zit nog niet in beleid omdat het nog te nieuw is; en vraag is of snelladen wel het probleem oplost: willen burgers dit wel?

Technische haalbaarheid

4. Denkt u dat de toename van actieradius betekent dat er meer of minder gebruik wordt gemaakt van snelladen? En waarom?
Grotere batterij zorgt voor minder vaak laden.
5. Denkt u dat de ontwikkeling van snellaadtechniek tot 350 kW er voor zal zorgen dat er meer gebruikt wordt gemaakt van snelladen? En op welke termijn denkt u dat?
Belangrijke ontwikkeling hierin wordt de prijs per kW extra laadvermogen. Als snelladers goedkoper worden, is dat interessant voor de business case; tegelijkertijd wordt het dan ook goedkoper om aan boord een 20 kW lader te nemen.
6. De adoptie van EV vertoont verschillende synergieën met bijvoorbeeld shared vehicles en autonomous driving. Denkt u dat deze trends een effect gaan hebben op de manier waarop EVs geladen worden? En zo ja, op welke manier?
*- Omslag in mobiliteit is een driepoot: het wordt elektrisch, het wordt delen en het wordt autonoom. Delen wordt pas interessant als het autonoom kan. Dit kan in het voordeel van snelladen werken, hoger gebruik van auto's.
- Heel lastig om te voorspellen. Duurt een jaar of 5 of 10 voordat zelf-rijdende auto's geïntroduceerd worden. Zal vooral een politieke afweging worden.*
7. Een belangrijke technische factor is de impact van EVs op het elektriciteitsnet en de rol hiervan in de energie transitie. Welke rol speelt smart charging in het tegengaan van nodige investeringen? En op welke termijn is dat haalbaar denkt u?
Er is zeker potentie in het reduceren van kosten, maar niet een doorslaggevende reden. Grootste efficiëntieslag zit in energie efficiëntie van elektrische auto's. Daarna grote klap bij het slim wegzetten van duurzame energie. Dan de volgende klap bij power quality, dat het voltage niet te laag wordt en de frequentie goed blijft. En als laatste dat de netten er niet uit klappen. Cumulatief is er daar veel te halen, de kosten zijn puur ICT-gerelateerd.
8. Hoe ziet u de afweging tussen snelladen en normaal laden in deze context?
Bij fast charging heb je geen potentie voor smart charging, maar je hebt ook geen last ervan. Als je in de buurt zit van middenspanningpunten zit, heb je relatief weinig last van fast charging. Maar voor het slim gebruiken van zon- en windenergie heb je er minder aan.

Economische haalbaarheid

9. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
*- Hoe sneller ze gaan laden, hoe meer EVs en hoe groter de batterij, hoe beter voor de snellader business cases. Zeker met 350 kW gaat dat veel effect hebben.
- Voor de laders thuis, de grotere batterij die het meest effect heeft. De auto's blijven vaak minimaal 12 uur staan, dus als de batterij groter wordt kan je meer kWh verkopen.*
10. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?

Sociale haalbaarheid

11. Op welke manier denkt u dat de klant voorkeuren gaan veranderen in de toekomst voor het opladen van EVs?
- *Survey gehouden, zal ik je toesturen over klant voorkeuren. Zit ook een deel over snelladen in. Momenteel willen mensen het meer als range extender, niet als hoofdlader. Maar dat kan veranderen in de toekomst.*
 - *Een van de dingen die ook meespeelt is het snoer van de lader. Het is prettiger als het snoer aan de lader zit, geen gedoe. Hetzelfde met de standaarden, dat zal over een jaar of vijf wel gestandaardiseerd zijn.*
 - *Persoonlijk vervelend als er onzekerheid is over de locatie van de snellader, je moet net van je route af. Zou veranderen als de routeplanner dat voor jou bepaalt.*
 - *Mensen die een Tesla hebben kijken nu al heel anders aan tegen laden dan mensen die bijv. een Leaf hebben. Tesla-rijders geven een beter beeld; je moet kijken hoe Tesla rijders in de toekomst 200 kW laders gaan gebruiken?*

Politieke haalbaarheid

12. Hoe denkt u dat gemeenten de afweging maken tussen 'normaal laden' en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?
- *Minder palen is beter. Goed om plekken van te voren te reserveren op strategische plekken, en als ze nodig zijn kan je snel extra punten installeren.*
 - *Parkeerdruk en effect op openbare ruimte spelen mee in afweging bij gemeentes. Gijs van der Poel heeft 3 modellen over het beleid van gemeentes: Pro-actief, paal volgt auto en governance. We gaan steeds meer naar governance model toe.*
 - *Voor parkeerdruk kan je ook denken aan incentives als hogere prijs voor parkeren voor niet EVs.*
13. Welke factoren zijn volgens u van belang bij de afweging van de maatschappelijke kosten en baten van beide laadoplossingen?
- *Het wordt hoe dan ook een hybride oplossing; beide opties zullen er zijn. En het is een no-regret optie om normale laadpunten neer te zetten, deze gaan toch nodig zijn.*
 - *Er is ook een hoge no-regret optie voor snelladers: daar kan je normale laadpunten mee uitsparen, en die worden echt wel gebruikt.*
 - *Laadpleinen zijn ook een interessante optie; garantie dat er plek is, maar je moet vaak wat verder lopen.*
 - *Smart charging is voornamelijk belangrijk voor thuis- en werkladen, heeft minder potentieel voor publieke punten.*
14. Het doel is om uiteindelijk met beleidsaanbevelingen te komen voor grote gemeentes. Heeft u hier ideeën over? Hoe zouden gemeentes zich goed kunnen voorbereiden op de snelle groei van EVs in de komende jaren?
- *Je kan voorlopig zonder zorgen veel snelladers en langzame laders installeren, want EVs gaan hard groeien de komende tijd.*
 - *Reken dit eens door voor gemeentes: Stel dat 80% van de kilometers in de stad met publiek laden gaat, kan je per wijk al gauw een X aantal snelladers gebruiken.*
15. Een uitdaging bij snelladen is de huidige infrastructuur van benzinstations. Heeft u ideeën hoe gemeentes om moeten gaan met de transitie van fossiele brandstoffen naar EVs bij pompstations?
- Zeker als er een tankstation staat dat steeds minder gebruikt wordt, is het nuttig om daar een snellaadstation van te maken.*

Interview 2: Distribution System Operator

Naam: Paul Broos

Functie: Projectleider elektrisch vervoer ElaadNL

Organisatie: Stichting ElaadNL

Datum en tijd: 3 november 2017, 11:00 – 11:45

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
Al 8 jaar met EV ontwikkeling bezig. Eerst bij Eneco, later bij Stedin en ElaadNL
2. Wat is het doel van de gemeente bij het installeren van laadinfrastructuur voor elektrische auto's?
- Vanuit overheid: efficiënt gebruik van de openbare ruimte. Wil je elke straat vol zetten met laadpalen, of dat concentreren bij laadpleinen bijvoorbeeld?
- Hoe past het in mijn openbare ruimte, hoe heb ik er zo min mogelijk last van, hoe kost het mij zo min mogelijk. Business case vanuit markt het liefst.
3. Wat zijn de belangrijkste factoren die de afweging tussen normaal laden en snelladen in de stedelijke omgeving bepalen voor gemeentes volgens u?
Speelt veel psychologie en mindset bij de EV rijder. Als ik 's nachts plotseling naar de dokter moet, moet er voldoende energie in de batterij zitten. Als de auto voor de deur staat kan ik altijd weg, als de auto drie straten verder aan een laadpaal zit, heb je er geen zicht op.
4. Hoe komt het denkt u dat gemeentes nu vooral gericht zijn op langzaamladen in de publieke ruimte?
- Techniek was er nog niet klaar voor, en de vraag was niet zo dringend.
- 90% van elektrische auto's was PHEV, kan toch alleen maar 3.7 kW laden. De huidige 15.000 BEV rijders kunnen grotendeels thuis laden.
- Nu gaan de PHEV verdwijnen, er komen 60-100 kWh BEVs. Dan ga je niet meer allen thuis met 3.7 kW opladen, dan duurt het anderhalve dag.
- Ga je dan thuis je netaansluiting verzwaren, en wat heb je daar voor over? Of ga je publiek laden? Ligt er maar net aan wat die publieke palen kunnen ook.

Technische haalbaarheid

5. Denkt u dat de ontwikkeling van snellaadtechniek tot 350 kW er voor zal zorgen dat er meer gebruikt wordt gemaakt van snelladen? En op welke termijn denkt u dat?
- Ja, als ik met 400 kW kan laden bij de Albert Heijn en daarmee voldoende energie heb voor de hele week, lijkt mij dat als klant heel aantrekkelijk. Kost geen extra tijd, geen extra moeite.
- Maar auto's die dit kunnen zijn er nog lang niet. Tesla kan met ong. 100 kW laden, dan houdt het op. Over 5 of 10 jaar is het echter zeker zo ver.
- Belangrijk wordt ook wat er gebeurt met de accu als je elke week met 800V gaat laden. Er moet een bepaald aantal laadcycli gehaald worden.

6. De adoptie van EV vertoont verschillende synergieën met bijvoorbeeld shared vehicles en autonomous driving. Denkt u dat deze trends een effect gaan hebben op de manier waarop EVs geladen worden? En zo ja, op welke manier?
- Als dat realiteit wordt, gaan we van 8 miljoen naar 2 miljoen auto's. Dan gaan EVs wellicht uit het zicht opladen op een bedrijventerrein.
 - Er is een mogelijkheid dat je alle paaltjes die we nu plaatsen over 15 jaar niet meer nodig hebben.
 - Niemand weet hoe snel dat gaat. Autonoom rijden op level 4/level 5 komt eraan, maar in stad is dat nog een ander verhaal met veel fietsers etc.
 - Marktpartijen als PON geloven erin, te zien aan het opkopen van GreenWheels.
7. Een belangrijke technische factor is de impact van EVs op het elektriciteitsnet en de rol hiervan in de energietransitie. Er zijn investeringen in het net nodig om de groei van EVs aan te kunnen. Heeft u een beeld hoeveel EVs er in een wijk bijgeplaatst kunnen worden zonder verdere investeringen?
- Hangt er helemaal vanaf wat er al op de kabel zit op een locatie. Er zijn stukken net die zwakker zijn. Overbelasting kan je gedeeltelijk voorkomen met slim laden.
 - Een argument is dat veel mensen toch al zon op de daken gaan leggen, dus het net moet toch al verzaagd worden. Dan zijn laadpalen niet zo'n issue.
 - Als er op 3 kW geladen wordt, gaat het vaak nog wel op 3x25A aansluiting, ongeveer 17 kW per aansluiting. Gelijktijdigheidsfactor is vaak laag. Kabels zijn gedimensioneerd op 4 kW per huis.
 - In oude wijken (bijv. in Amsterdam) was de rekenwaarde 2 kW, dan kom je veel sneller in de problemen. Als je daar tien auto's hebt die tegelijk gaan laden kom je in de problemen; iedere netbeheerder kan precies aanwijzen waar dit speelt.
 - Je moet dit slim monitoren: worden kabels warm, wat zijn voltages aan het einde van de kabel, wat doet de invoering van die zonnepanelen.
 - 7 miljoen meters, slimme meters, mogen niet gebruiken door privacy. Dus in ieder geval sensoren op distributiestations.
8. Welke rol speelt smart charging in het tegengaan van nodige investeringen? En op welke termijn is dat haalbaar denkt u?
- Er komen perverse prikkels, verdienmodellen waar het het beste is als de EV zo lang mogelijk aan de laadpaal staat.
 - Er zit potentieel ongeveer 150 euro per jaar voordeel in, gedeeld met de gebruiker. Zelfde voor V2G, moet zo lang mogelijk aan de lader hangen.
 - Je moet iets balanceren als je straks hele Noordzee en Drenthe vol hebt staan met windmolens. Dus als je dan 8 miljoen EVs hebt heb je je buffer: Elaad ziet dit als een reeel toekomstbeeld. Dan moeten er veel palen zijn: op werk, bij mensen thuis, op de straat.
 - Er zijn al verschillende proeven met smart charging: Liander doet een pilot in Amsterdam met Tesla chauffers.
 - Landelijk echter nog ingewikkeld hoe je dat doet met tarivering? In pilots kan dat makkelijk met bijv. een cadeaubon. Probleem is dat een kleinverbruiksaansluiting een vast capaciteitstarief heeft, er is geen prijsinstrument voor de netbeheerder om mensen te belonen voor minder afname op een bepaald moment.
 - Energieleverancier heeft tegengestelde belangen: die verdient geld met centrales die bij kunnen stoken op piekmomenten.
 - De waarde van programmaverantwoordelijkheid en energieproductie is hoger dan wat de netbeheerder kan bieden aan flexibiliteit, dus er is weinig marktpotentie voor smart charging.
 - Zit ook een politiek aspect aan: vast capaciteitstarief is ooit vastgesteld omdat we dan kosten kunnen socialiseren en als je zegt ik ga het variabel maken of er een aparte categorie van maken, dan moeten lage SES bijbetalen aan de EVs van mensen met een hoge SES.

9. Hoe ziet u de afweging tussen snelladen en normaal laden in deze context?

- Middenspanningsnet is veel robuuster, meer capaciteit. Dan is het meer een issue hoeveel kabels je moet trekken. Fastned moet soms kilometers kabel trekken, maar in de stad is dat minder ver meestal.

- Onderzoek over de integrale maatschappelijke kosten van beide opties geopperd door ElaadNL, opgepakt door Ministerie IW. Kosten voor de laadpaalexploitant, als ook de kosten voor de overheid worden meegenomen.

- Nu zie je dat het subsidiegeld naar langzaamladen gaan, en is dat dan eerlijk? Als snelladers maatschappelijker goedkoper zijn, moet je daar wellicht meer op richten in beleid.

10. Als een van de voordelen van normaal laden wordt vaak genoemd dat EVs kunnen terugleveren aan het net (V2G, V2X). Hoe kijkt u tegen de haalbaarheid van deze opties aan? Ook qua verdienmodel? En op welke termijn?

- Verdienmodel van V2G is denk ik pas haalbaar over jaar of 10. Zeker niet met de accu's van nu.

- Je moet een keer met een batterijexpert praten, wanneer dat dichterbij komt. Op het moment dat er probleemloos 20.000 of 30.000 cycli in de accu zitten, is het prima dat er terug wordt geleverd. Zolang dat nog niet het geval is, is het minder haalbaar.

- Er is wel een pilot met Stedin en Utrecht in Lombok met 150 auto's, maar gaat nog niet mainstream gebeuren. Accu's zijn niet te garanderen voor laadcycli.

- Ontwikkelingen op dit vlak komen later dan de EV boost.

- Autobedrijven sorteren wel voor, Renault heeft energieservicebedrijf opgericht, en aandeel in Jedlix genomen (smart charging). Ze hebben wel plannen om energieprovider te worden.

- Als accus goed genoeg zijn gaat dit wel een rol spelen. Tesla heeft ook altijd geroepen, wij zijn geen autofabrikant maar een energieprovider. Daarom leveren wij Powerwalls voor thuis, zonnepanelen, en auto's zijn ook een onderdeel van die keten.

Economische haalbaarheid

11. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?

Laatste aanbesteding in Brabant van Nuon/Heijmans was zonder subsidie. TCO van langzaam-laadpaal over 8 jaar is ongeveer 8000 euro.

12. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?

De vraag is of je exploitanten kan vinden die willen investeren om die plek veilig te stellen voor de toekomst. Partijen als Allego en Fastned willen dat wel. Die nemen het verlies nu voor lief met de vooruitzichten voor de toekomst.

Sociale haalbaarheid

13. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?

Politieke haalbaarheid

14. Hoe denkt u dat gemeenten de afweging maken tussen 'normaal laden' en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?

- Paar gemeentes zijn hiermee bezig, bijvoorbeeld Rotterdam, heeft er een consultant op gezet van APPM.

- Den Haag heeft twee Fastned stations in de stad, focust op de grote toegangswegen.

- In Amsterdam nog geen duidelijk beleid, vaak bij enkele benzinestations snelladers geïnstalleerd.

15. Welke factoren zijn volgens u van belang bij de afweging van de maatschappelijke kosten en baten van beide laadoplossingen?
- Of ze ook bereikbaar zijn voor bezoekers, op weg naar huis voor woon-werkverkeer. Past in de gewoonte om op weg naar huis even te tanken.
 - Bepaling van locaties in de binnenstad: zou op de hoek van de straat op een laadpleintje kunnen, of bij de supermarkt.
 - En hoe doe je dat in vinexwijken waar veel te weinig parkeerruimte is?
16. Een uitdaging bij snelladen is de huidige infrastructuur van benzinstations. Heeft u ideeën hoe gemeentes om moeten gaan met de transitie van fossiele brandstoffen naar EVs bij pompstations?
- De benzinepomp op de hoek kan gewoon bij de netbeheerder een aansluiting aanvragen, en een snellader neerzetten. Van niemand toestemming voor nodig. Dat kan gemeente niet tegenhouden.

Interview 3: Gemeente Amsterdam

Naam: Bart Vertelman and Doede Bardok
Functie: Projectmanager en -leider EV, Gemeente Amsterdam
Organisatie: Gemeente Amsterdam
Datum en tijd: 23 november 2017 10:00

Algemene vragen en politieke context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
Projectleider openbare oplaadinfrastructuur. Vershuift ook naar naast de openbare ruimte, hoe kunnen we ook in garages, bij VvE ook geladen kan worden.
2. Wat is het doel van de gemeente bij het installeren van laadinfrastructuur voor elektrische auto's?
 - Begonnen vanuit luchtkwaliteit in 2008/2009 omdat EU normen niet gehaald dreigden te worden. Inmiddels nog maar 5 stadsdelen waar normen niet worden gehaald.
 - Huidige college gaat voor gezondheid: bijv. brommers worden nu meegenomen.
 - Langzaam gaat dat richting uitstootvrij: ambitie om dat in 2025 te behalen. Komende verkiezingen verwachting dat ambities verder worden opgeschroefd.
 - Hoe meer mogelijkheden er zijn om te laden, hoe beter. En bij voorkeur buiten de openbare ruimte.
 - Zijn een aantal perspectieven: Stedenbouw: elk object in de openbare ruimte is teveel; Niet stimuleren van autobezit in Amsterdam: auto's van vergunninghouders naar parkeergarages brengen. Infrastructuur in garages. Zou fijn zijn als er minder behoefte is op straat.

3. Wat zijn de belangrijkste factoren die de afweging tussen normaal laden en snelladen in de stedelijke omgeving bepalen voor gemeentes volgens u?
- *Elektrisch rijden is nog niet normaal, nog veel barrières. Dat doet de gemeente met drie sporen: stimuleren met aanschafsubsidies, om over de eerste drempel te halen. Faciliteren met oplaad infrastructuur, is ook voor een groot deel psychisch (het gevoel dat je niet strand). Laatste is een stok achter de deur met de milieuzones, uiteindelijk gaat het gewoon gebeuren. Bijv. met taxi's in Amsterdam.*
 - *Het maakt Amsterdam niet uit welke techniek het wordt. Het doel is uitstootvrij, laadinfrastructuur is daaraan ondergeschikt. Wat we tot nu toe zien is dat snelladers aanvankelijk weinig werden gebruikt, nu wel meer maar vooral voor taxi's. Nu ook nieuwe aanbesteding.*
 - *Specifieke groepen hebben nu behoefte: eerst taxi's, volgende groep bestel/transportverkeer die tijdens een shift bijladen. Zit een beweging in, gemeente is ook benieuwd waar dat naartoe gaat.*
 - *Wat nodig is moeten we doen. Snellaadnetwerk kan ook als back-up dienen voor mensen die geen oplaadpunt kunnen vinden. Tesla's hebben grote actieradius, dat laadgedrag is anders, die laden nog maar 2x in de week. Meer auto's kunnen faciliteren met het gewone netwerk. Toekomst van laadgedrag.*
 - *Snelladers hebben meer impact op openbare ruimte, je moet goed kijken naar de doelgroepen die er gebruik van maken. Moet in bestemmingsplan, vergunningstraject als je een station wilt plaatsen. Anders is er een gewoon verkeersbesluit, wel maximaal 30 minuten.*
4. Hoe komt het denkt u dat gemeentes nu vooral gericht zijn op langzaamladen in de publieke ruimte?
- *Snellaadstations vragen veel openbare ruimte. "Waarom zet je geen snelladers bij de benzines-tations? Dat is op zich logisch, maar daar zitten nu nog de traditionele partijen en die willen olie verkopen. Alhoewel die partijen ook steeds meer geïnteresseerd beginnen te raken."*
 - *We zijn wel aan het kijken, als je zo'n concessie verlengt of opnieuw uitgeeft, dat je dan verplicht dat ze minimaal ook snelladen aanbieden.*
 - *Zijn niet veel plekken in Amsterdam waar je zomaar een snellaadstation in de openbare ruimte kan bouwen. Dus als partijen dat buiten de openbare ruimte willen doen, vooral doen ,graag zelfs. Wij vullen de gaten op als dat niet voldoende is. En die geven we dan uit in een concessie.*
 - *Wij kiezen plekken die de doelgroepen nu ondersteunen. Er zijn een aantal plekken in Amsterdam waar een commerciële partij geen station zich voorstelt, maar waar via input vanuit de taxibranche wel een locatie gevraagd wordt.*
 - *Nu is er een behoefte die wij moeten invullen, zeker voor de taxibranche. Als die snel moeten verschonen, moeten wij zorgen voor laadinfrastructuur, dan gaan we niet wachten op de markt. Bij benzinestations heb je iets meer geduld, maar wil je met verlengen van vergunningen daar wel op sturen, en bij nieuwe plekken en verzoeken voor snellaadlocaties kunnen via de normale weg behandeld worden.*

5. Hoe bereid Amsterdam zich voor op de versnelling in EV adoptie? - *Je kan straks al plekken reserveren voor toekomstige laadpunten, al die vakken kan je individueel reserveren voor werkzaamheden. Portefeuille voor geschikte plekken en toestemmingen met stadsdelen al geregeld: strategisch plaatsen.*
- *Er is veel data beschikbaar: sommige wijken is de druk hoog op de dalen. Dan kan je gaan bijplaatsen. Ga je dat in een hub oplossen, waar veel deelauto's aan de rand van de wijk opladen? Wat is er nodig, en wat wordt dan ook efficiënt gebruikt?*
 - *IDO-laad veel data. Stel dat 4000 taxi's in een keer overgaan op elektrisch, wat wordt er dan gevraagd voor infrastructuur? Nu ook data van snelladers beschikbaar, dus dan kan je pasnummers goed volgen.*
 - *De G4 data zit inmiddels ook in de IDO-laad database, kan je ook interstedelijk vervoer monitoren.*
 - *Buitenlandse input, op specifieke onderwerpen:*
 - i. *Als je straks de bevoorrading van je stad, wil je al die auto's en vrachtauto's nog in je stad, of ga je hubs creëren, en horen daar enorme laadhubs bij. Met de Duitse auto-industrie die zit op het supersnel laden.*
 - ii. *In Noorwegen hebben ze heel veel EVs, in Oslo lopen ze achter met gewone laadpunten, maar hebben ze wel een aantal locaties waar veel snelladers bij elkaar zijn gezet. Interessant om te kijken hoe dat gebruikt wordt. Gaan mensen ook allemaal naar die snellaadhubs?*

Technische haalbaarheid

6. Een belangrijke technische factor is de impact van EVs op het elektriciteitsnet en de rol hiervan in de energie-transitie. Er zijn investeringen in het net nodig om de groei van EVs aan te kunnen. Heeft u een beeld hoeveel EVs er in een wijk bijgeplaatst kunnen worden zonder verdere investeringen?
- *Op den duur gaat het mis. Het net is nog vrij 'dom', in een straat 5 Tesla's bijplaatsen wordt al snel een probleem. We kijken ook met de netbeheerders, data van de auto's en data's van het net zodat je op voorhand kan zeggen op welke kabels je kan zetten.*
 - *Straks ook data van de duurzame energie opwekking, en hoe kunnen we dat in de auto's krijgen die duurzame energie. Proeven samen met de netbeheerders om dit slim te regelen. Technisch kan het allemaal al, maar lastig om het samen te laten werken.*
 - *We willen voorkomen dat alle straten open hoeven, dat de netbeheerder grote investeringen moet doen en elektrisch rijder wel gestimuleerd kan worden en de business case wel interessant blijft voor partijen als Nuon.*
7. Welke rol speelt smart charging in het tegengaan van nodige investeringen? En op welke termijn is dat haalbaar denkt u?
- Je kan er wel mee sturen, wanneer zijn de pieken. Dat hoeft niet allemaal om 6 uur 's avonds, laden kan later. Kan je ook tariefverschillen voor verzinnen, de keuze is voor de gebruiker.*

Economische haalbaarheid

8. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
- *Subsidies? De laatste concessie was voor 2016 is die gestart voor 7 jaar, daar moest nog wel wat geld bij. Getallen kunnen we niet geven, marktgevoelige informatie. Is een factor 5 afgenomen met de aanbesteding in 2011.*
 - *Meest recente aanbestedingen gaan bijna richting nul, en dat zal misschien wel richting benzinstation-constructies gaan: partijen betalen voor de ruimte, en dragen af per geladen kWh.*

9. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?
- Amsterdam zet ook grenzen aan hoe duur het laden mag zijn, om het concurrerend te houden met brandstofauto's. Laden mag niet duurder zijn dan 28 cent / kWh daarom.
 - Marktpartijen zijn ook geswitcht, eerst geen interesse in de stad, daarna wel.
 - Interessant hoe marktpartijen daar naar kijken, voor ons een signaal welke kant het op gaat.
 - "Wij proberen dat zo goed mogelijk te faciliteren. Wel partijen ook zo goed mogelijk gelijke kansen te geven, dus als we dan zo'n plek hebben in de openbare ruimte, dan besteden we dat aan. Daar mag iedereen op inschrijven."
 - Zal een mix blijven met traditionele partijen, want ook die blijven nog nodig de komende tijd.
 - Ook ander business model, sommige partijen willen stroom verkopen, andere partijen willen broodjes en andere zaken verkopen.
 - Iedereen mag inschrijven voor een aanbesteding, en iedereen kan hier laden.
 - Verschil in laadmodellen: als je vergunningen uitgeeft gaan partijen niet plaatsen op oninteressante plekken. Bij concessies heb je plaatsingsplicht, dan betalen wij iets meer.
 - Bij supermarkten laadpunten plaatsen: graag! In de stad is de grond vaak niet van de supermarkten. Maar bij Arena zou bijvoorbeeld een goede locatie zijn.

Sociale haalbaarheid

10. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?
- Het gedrag is heel anders. Je rijdt naar je bestemming, je plugt in, dat is fijner dan dat je van de weg af moet om 15 minuten te laden.
 - Je ziet in landen waar Tesla nu opkomt, die promoten dat er ook wel een normaal laadnetwerk moet zijn naast de Superchargers. Tesla zegt zelf, 10% vs 90% en dat mensen vooral snelladen onderweg.
 - Tesla promoot de Amsterdamse aanpak.

Politieke haalbaarheid

11. Een uitdaging bij snelladen is de huidige infrastructuur van benzinstations. Heeft u ideeën hoe gemeentes om moeten gaan met de transitie van fossiele brandstoffen naar EVs bij pompstations?
- Contractduur verschilt per locatie. Juridisch gezien kan je pas sturen als je een concessie opnieuw uitgeeft. Dan wil je gaan bijsturen naar schoon.
 - Nieuwe concessie is open voor alle partijen. Maar het zijn nog 2 smaken, Fastned gaat geen olie verkopen, Shell wel allebei.
 - Enige wat je kan doen, je moet op z'n minst ook schoon aanbieden.
 - Daarnaast via concessies voor snellaadlocaties en buiten de openbare ruimte op te bouwen.
 - Het is een beetje zoeken, bestaande structuur en lopende contracten. Nieuwe partijen willen locaties bemachtigen.

Interview 4: Gemeente Den Haag

Naam: Floris van Elzaker
Functie: Projectleider Elektrisch Vervoer
Organisatie: Gemeente Den Haag
Datum en tijd: 15 december 2017 10:00

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
 - *Projectleider EV bij gemeente Den Haag. Verantwoordelijk voor de uitrol van de Haagse laadinfrastructuur; vooral de praktische kant ervan. Ook advies aan het college, maar niet ons besluit welke kant het op gaat.*
 - *800 laadpalen, 5000 unieke gebruikers per maand die samen 1.5 miljoen kilometer op maandbasis rijden.*
 - *Den Haag is uniek in de binnenstedelijk snellaadstations.*
2. Wat is het doel van de gemeente bij het installeren van laadinfrastructuur voor elektrische auto's?
 - *Meerdere belangen, maar het project wordt betaald vanuit luchtkwaliteit. Ook onderdeel van energie-transitie en mobiliteits-transitie. Maar het project wordt beoordeeld vanuit luchtkwaliteit.*
 - *Geld vanuit rijk loopt door tot 2017-2018, daarna de vraag hoe het betaald wordt. Daarna is de vraag welke rol ga je als overheid innemen?*
 - *We zijn als Den Haag nu zelf een netwerk aan het bouwen. Ga je daarin terug en laat je de markt het overnemen? Of blijven we het zelf doen met alle voordelen die dat heeft, maar dan heb je meer capaciteit nodig.*
 - *We bouwen een vraaggestuurd netwerk, maar ook voor mensen die een EV gaan kopen. Je hebt een hybride netwerk nodig: alle vormen van laden zijn nodig voor een goed dekkend netwerk om alle huidige en toekomstige rijders te overtuigen dat het kan.*
 - *Wij kijken af van rest van NL, we bouwen pro-actief. 70% is concreet naar aanleiding van aanvraag, 30% op basis van inzichten die wij als team hebben.*
3. Wat zijn de belangrijkste factoren die de afweging tussen normaal laden en snelladen in de stedelijke omgeving bepalen voor gemeentes volgens u?
 - *Een groot deel eigen ervaring. Maar we gebruiken ook modellen van Over Morgen.*
 - *Alle locaties brengen we in beeld, als er een verzoek komt hoeven we geen locatiebepaling meer te doen.*
 - *We bouwen ook al een minimale dekkingsgraad zodat in de hotspot gebieden er net wat meer rek in zit dan op basis van natuurlijke groei zou zijn.*
 - *Laadpaal heeft 2 stekkers, DH kruist de vakken een voor een af. Hoef je alleen de verfwagen op pad te sturen en zit er wat meer rek in het Haagse netwerk. Om niet teveel weerstand te krijgen in de stad.*
 - *Eisen voor een nieuwe paal: <200m loopafstand, voorkeur niet in het groen, niet voor iemands huis, binnen 25m van het stroomnet. Parkeerdruk heeft geen invloed. Maar uiteindelijk beslissen wij als gemeente, er is veel interpretatie van de experts mogelijk.*
 - *Basis is reguliere laadnetwerk 3x25A. De gemeente DH heeft geen standpunt wat het wordt qua techniek. Snelladen wordt nu ingezet als zekerheid dat je kan laden momenteel. Snellader trekt 2 a 3000 kWh in de maand. Reguliere laadpalen trekken 1500 kWh op maandbasis. Doordat ze er zijn durven mensen elektrisch te laden.*

4. Wat bepaald of gemeentes zelf laadpalen plaatsen of vergunningen verstrekken?

Het heeft vooral met eigen geld te maken. Gemeentes die eigen geld hebben bouwen zelf, en die dat niet hebben laten het aan de markt over.

- DH zit in die afweging. De markt kan het al best wel redelijk. Er zijn ontwikkelingen die gaan spelen die we nog niet kunnen inschatten. Als je dan aan de markt geeft, heb je je invloed uit handen gegeven. Bijvoorbeeld over de rol van laden op de disbalans op het elektriciteitsnet.

- "We weten niet wat we niet weten, en dan is het heel prettig dat we het in eigen hand hebben."

Technische haalbaarheid

5. Denkt u dat de ontwikkeling van snellaadtechniek tot 350 kW er voor zal zorgen dat er meer gebruikt wordt gemaakt van snelladen? En op welke termijn denkt u dat?

- Ja, maar de vraag is of 350 kW laden echt nodig blijkt te zijn. Met 150 kW kan je al 250 km laden in 20 minuten. Hoeveel meerprijs zijn we bereid te betalen en hoeveel energieverlies zijn we bereid te nemen voor sneller laden?

- Met 150 kW kom je al een heel eind. Met 100 kW accu op vakantie, heb ik om de drie uur een half uur rust, dat klinkt wel redelijk.

6. De adoptie van EV vertoont verschillende synergieën met bijvoorbeeld shared vehicles en autonomous driving. Denkt u dat deze trends een effect gaan hebben op de manier waarop EVs geladen worden? En zo ja, op welke manier?

- In gemeente Den Haag wordt hieraan gewerkt, maar bij het Elektrisch Vervoer niet mee bezig. Autonomous driving hoeft ook niet per se elektrisch te zijn.

- We bouwen het huidige laadinfrastructuur voor de huidige auto's. Beiden hebben ongeveer 10 jaar levensduur, tegen die tijd kunnen we ook de huidige palen de grond uit halen. Zelfs als autonomous driving over 5 jaar al helemaal loskomt, hebben de huidige EV rijders hun auto nog niet verkocht.

7. Een belangrijke technische factor is de impact van EVs op het elektriciteitsnet en de rol hiervan in de energietransitie. Er zijn investeringen in het net nodig om de groei van EVs aan te kunnen. Heeft u een beeld hoeveel EVs er in een wijk bijgeplaatst kunnen worden zonder verdere investeringen?

- Elektrisch rijden kost heel veel stroom. Een nacht aan de lader kost evenveel als een gemiddeld huishouden in 5 dagen gebruikt.

- Huidige net gedimensioneerd op 5 a 10 procent rek, dus het huidige net voldoet niet op de lange termijn.

- Dan is de vraag hoe erg een laadpaal het net uit balans gaat brengen. En dan wordt het vraagstuk thema-overstijgend. Hoe gaat de energietransitie plaatsvinden? En hoe hebben we het huidige energievoorzieningssysteem wetmatig vastgelegd?

- De netbeheerder mag alleen investeren obv concrete aanvragen. M.a.w., zij mogen pas investeren als er een probleem is, en niet vooruit plaatsen. Doorlooptijd van een grondstation is 5 jaar, dan ga je wetmatig je energietransitie afremmen.

8. Welke rol speelt smart charging in het tegengaan van nodige investeringen? En op welke termijn is dat haalbaar denkt u?

- We gaan nu wel 'dom' slimladen met standaardprofielen: tussen 5 en 8 de laadsnelheid omhoog. De winst is minimaal, en een marktpartij heeft geen belang bij het balanceren van het net.

- Als ik op de stroommarkt kan gaan handelen, wordt het relevant met de wisselende tarieven. Maar hoe groot is het potentieel? Bij ons is het nou ongeveer 10 euro per dag voor 800 palen. Hoeveel moeite willen wij doen voor 3500 euro per jaar? Dat gaan we niet doen. Nog buiten de softwareontwikkelkosten.

- Alle partijen zijn daar heel erg in aan het zoeken. Als die ontwikkelkosten weer investeringen in het net uitsparen, kan het wel weer interessant zijn.

- Proactief investeren van de netbeheerder kan in ieder geval, daar kunnen we naar handelen.

Economische haalbaarheid

9. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
- *Bouwen en exploiteren hoort bij de markt. De stedelijke inpassing hoort bij de gemeente.*
 - *Voor snelladen verwacht ik op de lange termijn dat tankstations eruit gaan en dat het laadstations worden. Vergelijkbaar concessiemodel als bij tankstations.*
10. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?

Sociale haalbaarheid

11. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?
- *Uitgaande van 100 kWh accu, hoe vaak wil jij van 0 - 100 % laden in een nacht? 80 kWh in een nacht. Als je u 8x11 kWh laadt, heb je aan de huidige laadinfra altijd voldoende. Tot en met 100 kWh accu's is dat echt voldoende.*
 - *Er zijn altijd uitzonderingen dat je niet 8 uur de tijd hebt, en dan heb je snelladen nodig. Ik schat de verhouding 90 - 10% in.*
 - *Snelladen moet er echt zijn, maar het gedrag van mensen gaat veranderen. Mensen willen laden als je toch geparkeerd staat.*
 - *Mensen gaan opportunity chargen, als het ze uitkomt. Als markt ga je dan proberen de EV rijder te verleiden op de plekken waar jij je grootste marge kan pakken. Oftewel voor zo min mogelijk kosten inkopen als voor zoveel mogelijk verkopen. Een van die terreinen die heel geschikt is is P+R terrein zwarte pad in Scheveningen. Lage inkoop, hoge verkoop.*

Politieke haalbaarheid

12. Hoe denkt u dat gemeenten de afweging maken tussen 'normaal laden' en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?
- *Alle laadinfrastructuur is momenteel van de gemeente Den Haag.*
 - *Gemeente bouwt stations beter dan marktpartij. Doorlooptijd 2 jaar ipv 3 a 4 jaar. Omdat wij net wat meer risico kunnen en durven nemen. Wij vragen de netaansluiting eerder aan, en nemen dat risico.*
 - *Ik weet pas zeker dat ergens een snellader komt als hij er staat. Een marktpartij moet wel doen wat ze beloven, dat is een risico.*
 - *Doordat ik ze kan bouwen is het sneller, en voldoet het aan mijn randvoorwaarden. Als ik 'm bouw maak ik een kleine gebiedsontwikkeling eromheen. Een marktpartij zal sneller ophouden dan dat ik dat doe als de risico's te groot worden.*

Interview 5: Gemeente Dordrecht

Naam: Roosmarijn Sweers
Functie: Beleidsmedewerker Energie
Organisatie: Gemeente Dordrecht
Datum en tijd: 7 november 2017, 8:30

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
 - *Beleidsmedewerker Energie bij gemeente Dordrecht, hele plaatje vanuit de energie-transitie, elektrisch rijden is daar een onderdeel van.*
 - *Stuk geschiedenis van laadpalen: in eerste instantie vanuit de netbeheerders vanuit Elaad gezamenlijk palen geïnstalleerd. Daarna abrupt overgelaten aan de markt, maar die was daar nog niet klaar voor. Daarna zijn de grote gemeentes en Brabant gaan aanbesteden, dat was eerst heel duur: 10.000 per paal. Veel gemeentes wilden dat niet aanbesteden en wilden niet zoveel bijleggen per paal. Hoe zorgen we dat er wel palen komen?*
 - *Beleed gemaakt om vergunningen te verlenen. Intussen gevolgd door meer dan 100 gemeentes. Betekent dat je een heel andere verhouding hebt in de markt; als je aanbesteed ga je via privaatrecht, opdracht verstrekken. Bij vergunningen heb je een meer open marktwerking. Dordrecht heeft voor de G32 geholpen met definiëren van beleid hiervoor. Dordrecht heeft een vertegenwoordigende rol gekregen, en vanuit daar afgevaardigd naar het NKL. Drempel voor marktpartijen verlagen, zo min mogelijk eisen stellen aan marktpartijen.*
2. Wat is het doel van de gemeente bij het installeren van laadinfrastructuur voor elektrische auto's?
 - *Vanuit gemeente wil je vanuit energie en luchtkwaliteit dat er laadinfrastructuur is, en zo min mogelijk effect op de parkeerdruk.*
 - *Zo min mogelijk impact op de openbare ruimte.*
3. Wat zijn de belangrijkste factoren die de afweging tussen normaal laden en snelladen in de stedelijke omgeving bepalen voor gemeentes volgens u?
 - *Wordt momenteel geen onderscheid in gemaakt. Verzoek voor snellaadpunt wordt hetzelfde behandeld, als de markt hiervoor mogelijkheid ziet, is dat prima.*
 - *We vragen wel om de behoefte voor de laadpaal te onderbouwen.*
 - *Het is wat ingewikkelder bij snelladen; geen eigen visie op plekken. Als de marktpartij een business case ziet, zal dat wel OK zijn. Als ze in een keer 10 plekken willen aanleggen, en wij hebben het idee dat dat niet in balans is met de behoefte, dan zouden we op dat criterium even doorbrengen.*
 - *We zitten nu nog in de prille marktwerking. Op enig moment zullen er meer partijen komen in de markt, daar moeten we dan een antwoord op hebben. Dan kan je snellaadpunten gaan aanbesteden. Ik kijk daarnaar vanuit transitieoogpunt. Als er volwassen marktwerking komt, dan kan je beleidsregels snel aanpassen.*
 - *Vergunning nu voor onbepaalde tijd. Wij denken dat marktpartijen daar een paal neerzetten omdat ze daar geld aan kunnen verdienen.*

Technische haalbaarheid

4. Een belangrijke technische factor is de impact van EVs op het elektriciteitsnet en de rol hiervan in de energie-transitie. Er zijn investeringen in het net nodig om de groei van EVs aan te kunnen. Heeft u een beeld hoeveel EVs er in een wijk bijgeplaatst kunnen worden zonder verdere investeringen?
 - *Dat gaat gebeuren. Wordt vanuit een breder perspectief bekeken, Drechtsteden integraal aanvliegen, samen met partij een afweging maken.*
 - *Aan de analysekant: effecten van elektrisch rijden meenemen. Ik ga ervanuit dat smart charging gaat gebeuren. Meewegen bij afweging of er in bepaalde wijken wordt gekozen voor warmtenet of all electric. Warmtenet of verzwaring. Drechtsteden is daar ver in, eerste verkenning volgend jaar, verdieping daarna.*

Economische haalbaarheid

5. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
 - Partijen moeten vanuit hun eigen kracht en bevoegdheden werken. "Schoenmaker blijf je leest."*

Politieke haalbaarheid

6. Hoe denkt u dat gemeenten de afweging maken tussen 'normaal laden' en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?
 - *Nieuwe akte in het toneelstuk. Paal volgt auto. Volgende stap wordt: op basis van data inschatting van laadbehoefte. Inschatting maken waar laadbehoefte gaat ontstaan. Dit ga je doen als je een minimale dichtheid hebt van palen. Niet volgens jaar, maar vrij snel daarna wel.*
 - *Drie verschillende rollen: eigenaar/exploitant, energieleverancier, dienstverlener. Op dit moment zijn de 3 rollen in een package deal afgesproken. Zijn heel verschillende rollen. Als gemeente wil je alleen een relatie met de eigenaar/exploitant. We hebben in NL ervoor gekozen dat mensen hun eigen energieleverancier kunnen kiezen. Ook geen relatie met dienstverlener, die relatie heeft de EV-rijder.*
7. Een uitdaging bij snelladen is de huidige infrastructuur van benzinstations. Heeft u ideeën hoe gemeentes om moeten gaan met de transitie van fossiele brandstoffen naar EVs bij pompstations?
 - *Dat klinkt logisch. Nog niet afgestemd met collega's. Ni eerste instantie kijken naar P+R locaties en benzinstations. We hebben een beeld gevormd hoe een energie-neutrale regio eruitziet. Dus ook benzinepompen naar elektrisch. Kijk ook op drechtsteden.nl/energiestrategie.*
 - *Afweging integrale aanpak energietransitie & marktpartijen zo veel mogelijk hun werk laten doen. Expertise zit in de markt, dus wij gaan daar niet op sturen.*

Interview 6: Fast and normal CPO

Naam: Frank Verhulst
Functie: Manager Urban Mobility
Organisatie: Allego
Datum en tijd: 8 december 2017, 12:30

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
Manager urban mobility bij Allego, bezig met alle commerciële vormen van transport, dus alle stromen zoals bussen, auto's, vrachtwagens.
2. Wat is het doel van de gemeente bij het installeren van laadinfrastructuur voor elektrische auto's?
*- Iedere stad spreekt met zes tongen.
- Vanuit elektrische infrastructuur, maar ook vanuit luchtkwaliteit, allerlei belangen die spelen.
- Steden gaan ook groeien, dus er moeten beslissingen gemaakt worden over het binnenstedelijk vervoer. Over 10 jaar zijn de grote steden metropolen waar het vervoer aan de buitenkant wordt tegengehouden.*
3. Wat zijn de belangrijkste factoren die de afweging tussen normaal laden en snelladen in de stedelijke omgeving bepalen voor gemeentes volgens u?
*- Je kan tenders uitschrijven of een open markt model voeren. Wordt nu beide gehanteerd.
- Iedereen probeert het wiel opnieuw uit te vinden, maar er is een relatieve grote 'no-regret' strategie door gewoon te gaan bouwen.
- Overall zal het openbare laden af gaan nemen. Thuis/werk zal men langzaam gaan laden op 11 of 22 kW, onderweg zal het snelladen blijven.*
4. Hoe komt het denkt u dat gemeentes nu vooral gericht zijn op langzaamladen in de publieke ruimte?
Vloot van vandaag zijn PHEVs, die kunnen niet snelladen. Belangrijk dat we geen evolutiestappen overslaan.

Technische haalbaarheid

5. Denkt u dat de toename van actieradius betekent dat er meer of minder gebruik wordt gemaakt van snelladen? En waarom?
Dat zal een positief effect hebben. Je ziet ook dat de OEMs allemaal inzetten op het ontwikkelen van een snellaadnetwerk.
6. Denkt u dat de ontwikkeling van snellaadtechniek tot 350 kW er voor zal zorgen dat er meer gebruikt wordt gemaakt van snelladen? En op welke termijn denkt u dat?
Ja, maar 350 kW laden laat nog wel even op zich wachten. Waarschijnlijker dat er in de nabije toekomst op 150 kW wordt geladen.

Economische haalbaarheid

7. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
*- De vraag is of de business case ooit zwarte cijfers krijgt voor normaal laden.
- Wie gaat deze palen neerzetten in de toekomst?*

8. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?
- *De langetermijnvisie van de industrie lijkt gericht op snelladen. 500 of 600 km binnen een kwartier laden verandert de markt.*

Sociale haalbaarheid

9. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?
- *Er gaat zeker een verschuiving richting snelladen komen. Maar de mindset van mensen is moeilijk te veranderen. Niemand zit erop te wachten om hun gedrag aan te passen, maar er is geen keuze.*
 - *Prijs zal voor de normale rijders een rol spelen, voor zakelijke gebruikers veel minder.*

Politieke haalbaarheid

10. Hoe denkt u dat gemeenten de afweging maken tussen 'normaal laden' en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?
11. Welke factoren zijn volgens u van belang bij de afweging van de maatschappelijke kosten en baten van beide laadoplossingen?
- *De inrichting van de publieke ruimte speelt een belangrijke rol. De huidige vloot tot 50 kW kan voor een deel in de behoefte voorzien.*
 - *Daar zal een tweede ring bijkomen met een aantal P+R locaties waar er op laag vermogen wordt geladen. Daarnaast voor passanten op 350 kW laden.*
12. Het doel is om uiteindelijk met beleidsaanbevelingen te komen voor grote gemeentes. Heeft u hier ideeën over? Hoe zouden gemeentes zich goed kunnen voorbereiden op de snelle groei van EVs in de komende jaren?
- *Er zijn een aantal evolutiestappen. Eerst AC laden, dan laadpleinen, dan een combinatie van 50 en 350 kW laders en uiteindelijk het weren van auto's uit het stadscentrum.*
 - *De sleutel ligt bij de steden. Door de grote groei gaan steden uiteindelijk dichtslippen, dus die zullen auto's gaan weren. Dat heeft effect op de laadinfrastructuur.*

Interview 7: Fast charging CPO

Naam: Pepijn Vloemans
Functie: Public Affairs and Communication
Organisatie: Fastned
Datum en tijd: 3 oktober 2017, 15:30

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
Communicatie, marketing en public affairs bij Fastned. En ook actief bij Formula E team, grote club van actoren in het laadsysteem. Ook veel contact met politici, netbeheerders. Ook geeft Fastned colleges om informatie te verlenen over snelladen.
2. Hoe komt het denkt u dat gemeentes nu vooral gericht zijn op langzaamladen in de publieke ruimte?
*- Ze zijn eraan gewend, dat is het taalgebruik wat gebruikt wordt. Snelladen wordt momenteel nog niet meegenomen als een optie.
- Ook door de markt met belanghebbenden die ontstaan is, zijn er allemaal partijen die belang hebben in de laadmarkt.*

Technische haalbaarheid

3. Denkt u dat de toename van actieradius betekent dat er meer of minder gebruik wordt gemaakt van snelladen? En waarom?
*- Ja. Nu is een paaltje bij je huis noodzakelijk, je gaat niet op pad met een half lege accu van 20 kWh. Dat is anders als je kan snelladen, en je accu kan weer 300 of 400 km mee.
- Met huidige actieradius zijn die laadpalen wel logisch.*
4. Denkt u dat de ontwikkeling van snellaadtechniek tot 350 kW er voor zal zorgen dat er meer gebruikt wordt gemaakt van snelladen? En op welke termijn denkt u dat?
- Doorbraak naar 150 kW gaat de perceptie van mensen veranderen. Als je 1x per week even moet laden, is dat veel haalbaarder.
5. De adoptie van EV vertoont verschillende synergieën met bijvoorbeeld shared vehicles en autonomous driving. Denkt u dat deze trends een effect gaan hebben op de manier waarop EVs geladen worden? En zo ja, op welke manier?
- Steden beginnen met deze revoluties als elektrische taxi's, deelauto's en autonome auto's. Dat vraagt allemaal om meer snelladen.
6. Een belangrijke technische factor is de impact van EVs op het elektriciteitsnet en de rol hiervan in de energietransitie. Er zijn investeringen in het net nodig om de groei van EVs aan te kunnen. Hoe ziet u de afweging tussen snelladen en normaal laden in deze context?
*Het gesprek hierover verplaatsen naar een hoger niveau. Smart charging moet op het hele grid plaatsvinden, op LV en MV spanning. Het laagspanningsnet wordt ontzien door snelladen.
- Snelladen kan bijdragen aan de stabiliteit van het net.*

Economische haalbaarheid

7. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
*- Alles wat met schaalgrootte te maken heeft is in het voordeel van snelladen.
- NKL doet hier veel berekeningen voor, kostenreductie van laadpalen.*

8. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?
- Geef in ieder geval meerdere type oplossingen een kans in een jonge markt.

Sociale haalbaarheid

9. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?
- Dat gaat positief veranderen. Zowel grotere accu's als laadvermogen als EV adoptie gaat ervoor zorgen dat het steeds meer op tanken gaat lijken. Vooral de hogere laadsnelheid zal de klantvoorkeur positief veranderen.

Politieke haalbaarheid

10. Hoe denkt u dat gemeenten de afweging maken tussen 'normaal laden' en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?
- Ze zullen zich veel meer moeten gaan voorbereiden op de hockeystick curve. Er is nu misschien nog weinig vraag, maar als we voorbereid willen zijn moeten we nu al nadenken over de laadinfrastructuur van de toekomst. - Het aantal aanvragen wat binnenkomt gaat te groot worden, daar kan een gemeente op een gegeven niet meer tegenop bouwen.
11. Welke factoren zijn volgens u van belang bij de afweging van de maatschappelijke kosten en baten van beide laadoplossingen?
- Publieke ruimte, parkeermarkt, kosten van laadinfrastructuur, gemak van de gebruiker.
12. Het doel is om uiteindelijk met beleidsaanbevelingen te komen voor grote gemeentes. Heeft u hier ideeën over? Hoe zouden gemeentes zich goed kunnen voorbereiden op de snelle groei van EVs in de komende jaren?
- Bezwaar tegen dat de voordelen in de vorm van subsidies alleen naar normaal laden gaan, en niet naar andere laad technologieën.
- Huidige markt is niet op te schalen met laadpalen als er echt veel EVs komen.
- Het wordt veel te duur, laadinfrastructuur moet vervroegd worden afgeschreven als auto's alleen nog maar kunnen snelladen.
- Publieke ruimte wordt dan ook ontsierd, er ontstaan rare taferelen op de parkeermarkt.
- Concluderend, het is niet schaalbaar naar de toekomst.
13. Een uitdaging bij snelladen is de huidige infrastructuur van benzinstations. Heeft u ideeën hoe gemeentes om moeten gaan met de transitie van fossiele brandstoffen naar EVs bij pompstations?
- Je hebt beperkte groeikans bij een benzinstations, maar 2 of 4 snelladers bij kunnen plaatsen.
- Je laat geen nieuwe start-ups toe, bestaande partijen blijven dat dan doen met wellicht andere belangen.
- Op plekken waar de druk op de grond hoog is (langs de grachten), moet je geen stations bouwen. Maar langs uitvalswegen is een goede optie.

Interview 8: Consultancy

Naam: Harm Welleweerd
Functie: Business Developer Duurzame Mobiliteit
Organisatie: Over Morgen
Datum en tijd: 7 november 2017, 11:00

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
Projectleider duurzame mobiliteit bij Over Morgen. Doen veel projecten in de energietransitie, dus ook breder dan EV.
2. Wat zijn de belangrijkste factoren die de afweging tussen normaal laden en snelladen in de stedelijke omgeving bepalen voor gemeentes volgens u?
 - Bij weinig gemeentes staat snelladen al op het vizier, wij raden het wel altijd aan.
 - De gebruiker staat centraal, de wens en het gemak van de gebruiker zijn het belangrijkste.
 - Ook het ruimtebeslag, en het functioneren van de openbare ruimte.
 - Business case is geen grote afweging voor meeste gemeentes. Behalve voor Den Haag, die exploiteren palen zelf.
3. Hoe komt het denkt u dat gemeentes nu vooral gericht zijn op langzaamladen in de publieke ruimte?
Het is nog te nieuw, het staat nog helemaal niet op de radar. Of gemeentes kennen het verschil nog niet precies.

Technische haalbaarheid

4. Denkt u dat de toename van actieradius betekent dat er meer of minder gebruik wordt gemaakt van snelladen? En waarom?
 - Een EV heeft nu 20-40 kW, die laden zo vaak mogelijk, ongeveer 5x per week.
 - Met grotere accu's, 1.3x per week. Als deze snelladen, pakken ze in een keer veel meer energie. Dus groot verschil in laadgedrag.
 - Transactiegrootte ongeveer 12 kWh bij kleine accu's en 38 kWh bij grotere auto's.
5. De adoptie van EV vertoont verschillende synergieën met bijvoorbeeld shared vehicles en autonomous driving. Denkt u dat deze trends een effect gaan hebben op de manier waarop EVs geladen worden? En zo ja, op welke manier?
 - Ja, dit zijn game changers. Car sharing valt nog wel mee, autonomous zeker.
 - Gebied na 2020, en daarom heel erg vaag. Meer deelauto's, laadgedrag is moeilijk te voorspellen. Weinig kleine transacties.
 - Conclusie: je hebt snelladen nodig, maar het overgrote deel gaat op de publieke laadpalen van de stad.
 - Voor autonoom rijden gaat alles op z'n kop, maar dat duurt nog veel langer. De auto kan naar de lader komen in dat geval. Waar wil je dat auto's gaan parkeren? Daar ga je laden.

Economische haalbaarheid

6. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
 - Ja, die business case gaat zeker omhoog, zeker op goede plekken.
 - Als dit gaat ontploffen, dan denk ik wel dat het terugverdiend gaat worden.
 - Rond 7 of 8 jaar kan een normale paal terugverdiend worden. Grosso modo 3000 euro investeringen, en een rustig stijgend aantal kWh, verdient je hem in 7 a 8 jaar terug.
7. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?
 - Er zal voor verschillende laadmogelijkheden (11, 22, 50, 150 kW) een markt ontstaan.
 - 350 kW laden zie ik nog niet zo snel ontstaan, dat is de meerprijs in de keten misschien niet waard.
 - Snelladen gecentreerd kan goedkoper worden dan normale paaltjes, maar laadpleinen met normale laders zijn dan nog weer gunstiger.

Sociale haalbaarheid

8. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?
 - Samen met IDO-laad onderzoek naar laadgedrag van huidige EV-rijders.
 - Zo gemakkelijk mogen laden is heel belangrijk, over alle ritten die je maak.
 - Als je naar 2025 kijkt, zal het een soort luxe-keuze komen. Dat noemen wij 'opportunity charging', op het werk, thuis, langs de weg. De snelheid is anders voor al die opties.
 - Bij opportunity geldt prijs, beschikbaarheid/zekerheid en gemak voor de gebruiker.
 - Voor grote groepen zal 150 kW snelladen niet zo vaak noodzakelijk zijn, maar normaal of 50 kW laden als je ergens toch bent is dan logischer.

Politieke haalbaarheid

9. Hoe denkt u dat gemeenten de afweging maken tussen 'normaal laden' en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?
 - Laadinfrastructuur centraliseren. Voordelen: kans dat je kan laden neemt toe. Het is goedkoper, en het is beter te doen met smart charging. En voor slim gebruik van de openbare ruimte heeft het ook voordelen.
 - Wij maken modellen om dit slim in te schatten, is te vinden op onze website.
 - Onhaalbaar om met alleen publieke normale palen 1 miljoen EVs op te laden, want dat verdraagt de publieke ruimte niet. We hebben ook werkladen nodig, en ook snelladen.
10. Welke factoren zijn volgens u van belang bij de afweging van de maatschappelijke kosten en baten van beide laadoplossingen?
 - Ruimtelijke inpassing wordt heel belangrijk. Laadpalen zijn niet mooi, mensen zijn er niet blij mee. Dat zijn dingen die later een grotere invloed hebben.
 - Wij kijken wat verdraagt de ruimte, wat kan langdurig in de openbare ruimte bestaan.

11. Het doel is om uiteindelijk met beleidsaanbevelingen te komen voor grote gemeentes. Heeft u hier ideeën over? Hoe zouden gemeentes zich goed kunnen voorbereiden op de snelle groei van EVs in de komende jaren?
- *Combineer de verschillende laadopties. De notie dat alle EVs opgeladen kunnen worden met normale laders is niet haalbaar.*
 - *Faciliterend beleid is niet het meest efficiënt. Dat leidt niet tot een versnelling van energietransitie. Maar dat gaat wel hard.*
 - *Vanuit de overheid is het geen taak om laadpunten te exploiteren. Het is wel hun taak om de kaders te stellen.*
12. Een uitdaging bij snelladen is de huidige infrastructuur van benzinstations. Heeft u ideeën hoe gemeentes om moeten gaan met de transitie van fossiele brandstoffen naar EVs bij pompstations?
- *Er zijn op meer plekken geschikte locaties voor snellaadstations dan voor tankstations. Dus een gemeente heeft veel meer plekken om snellaadstations te bouwen dan alleen de huidige tankstations.*

Interview 9: Consultancy

Naam: Roland Steinmetz
Functie: Directeur EVConsult Nederland
Organisatie: EVConsult
Datum en tijd: 3 november 2017, 16:00

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
Directeur van EVConsult, een van de weinige bureaus die volledig gericht zijn op EV. Door heel Europa project op gebied van EV, maar focus is op Nederland.
2. Wat zijn de belangrijkste factoren die de afweging tussen normaal laden en snelladen in de stedelijke omgeving bepalen voor gemeentes volgens u?
 - *Amsterdam zet op allebei in: publiek laden, privé laden en snelladen. Maar nog minder op snelladen, vooral nog omdat er weinig vraag naar is (hybrids, 50 kW). Alle soorten laden op alle soorten plekken.*
 - *Veel gemeentes hebben niet het gevoel dat ze er iets mee moeten, en hebben een vergunningmodel.*
 - *En nog een tussengroep die interesse beginnen te krijgen.*
 - *Steeds meer provincies beginnen nu wel naar snelladen te kijken.*
3. Hoe komt het denkt u dat gemeentes nu vooral gericht zijn op langzaamladen in de publieke ruimte?
Er was al snel een beeld dat er voor normaal laden subsidie nodig was, en oprichting van NKL en allerlei clubs. En voor snelladen zou er al heel snel een business case ontstaan. Zo'n beeld is er op een gegeven moment ontstaan.

Technische haalbaarheid

4. Denkt u dat de toename van actieradius betekent dat er meer of minder gebruik wordt gemaakt van snelladen? En waarom?
 - *Gereden afstand neemt niet toe, de accu neemt wel toe, gemiddeld 80 kWh waarschijnlijk.*
 - *Waarschijnlijk iets meer snelladen, het gemak wordt hoger en de prijs iets lager.*

5. Denkt u dat de ontwikkeling van snellaadtechniek tot 350 kW er voor zal zorgen dat er meer gebruikt wordt gemaakt van snelladen? En op welke termijn denkt u dat?
- Ja, de snelheid gaat omhoog. Grotere capaciteit, en het gebruiksgemak neemt toe. Dit zal een positief effect hebben op snelladen.
6. De adoptie van EV vertoont verschillende synergieën met bijvoorbeeld shared vehicles en autonomous driving. Denkt u dat deze trends een effect gaan hebben op de manier waarop EVs geladen worden? En zo ja, op welke manier?
Jazeker, dat gaat een groot effect hebben ten voordele van snelladen. Maar de grote vraag is op welke termijn dit gaat gebeuren. Ik zie dit de komende 10 jaar nog niet zo snel gebeuren.
7. Een belangrijke technische factor is de impact van EVs op het elektriciteitsnet en de rol hiervan in de energietransitie. Er zijn investeringen in het net nodig om de groei van EVs aan te kunnen. Heeft u een beeld hoeveel EVs er in een wijk bijgeplaatst kunnen worden zonder verdere investeringen?
- Ja hier doen wij wel studies over voor gemeentes en provincies. Maar je moet het ook zien in de potentie die het heeft op de markt uiteindelijk.
8. Welke rol speelt smart charging in het tegengaan van nodige investeringen? En op welke termijn is dat haalbaar denkt u?
- Als je 50.000 palen beheert en als je dat bundelt, zit er nog best wel wat waarde in.
9. Hoe ziet u de afweging tussen snelladen en normaal laden in deze context?
- Gevoeligheid op het MV net liggen laag, maar de kosten voor de aansluiting kunnen wel erg hoog zijn voor snelladen.

Economische haalbaarheid

10. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
*- Maken wij veel, een aantal scenario's en hoeveel geld er bij de business case moet. Voor zowel normaal laden en snelladen.
 - Bij de huidige sommen van snelladen kom je niet uit. Over 15 jaar, met EV adoptie ziet het er gezond uit. Maar over 7 jaar is dat niet mogelijk.
 - De business case van normaal laden in de stad gaat niet zomaar ontstaan.*
11. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?
*- Beiden blijven nodig. Als er 1 miljoen voertuigen komen, zal er aan beide opties wel verdiend kunnen worden.
 - Er worden bredere vraagstukken en andere aspecten meegenomen waardoor partijen toch interesse hebben zonder subsidie te installeren.
 - Ioniq consortium ziet snelladen op 350 kW nog wel voornamelijk als range extender.*

Sociale haalbaarheid

12. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?
*- Ik zie het gebruik toenemen, dat wordt essentieel.
 - Nu is de prijs nog hoog, maar het gebruik van snelladen gaat toeneemt.
 - Prijs gaat ook omlaag, en de bezettingsgraad gaat ook toenemen.
 - Nissan Leaf en Tesla rijders zullen nu heel wat anders zeggen.
 - Zelfrijdend zal een grote impact hebben. Groot vraagteken hoe snel dit gaat echter.
 - Basisladen zal nog wel lang bij normaal laden blijven denken wij.*

Politieke haalbaarheid

13. Hoe denkt u dat gemeenten de afweging maken tussen normaal laden en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?
 - Ze willen geen publieke ruimte opgeven als dat de komende jaren nog niet gebruikt wordt, dat is zonde.
 - Zal ook grote transitie richting parkeergarages etc. komen. Nu is zichtbaarheid heel goed voor publieke punten, maar dat zal niet op dezelfde snelheid door blijven gaan.
14. Het doel is om uiteindelijk met beleidsaanbevelingen te komen voor grote gemeentes. Heeft u hier ideeën over? Hoe zouden gemeentes zich goed kunnen voorbereiden op de snelle groei van EVs in de komende jaren?
 - Alle infrastructuur die er gebouwd gaat worden, is goed. In een groeicurve is er altijd ruimte voor nog meer laadinfrastructuur.
 - Het brede pallet met normaal laden zeker neerzetten. Maar ook locaties voor snelladen zullen nodig zijn, voornamelijk aan de randen van de stad.
 - Ook voor elektrische trucs, dicht bij uitvalswegen in de steden.
15. Een uitdaging bij snelladen is de huidige infrastructuur van benzinstations. Heeft u ideeën hoe gemeentes om moeten gaan met de transitie van fossiele brandstoffen naar EVs bij pompstations?
 - Kan op heel veel manieren. Total verplichten bij te plaatsen, nieuwe plekken vrij maken, bij supermarkten.
 - Het is best charmant om nieuwe plekken uit te geven, om ook nieuwe partijen een kans te geven.
 - Je kan ook zeggen bij elke vernieuwing van de concessie moet er X snelladers bij komen.

Interview 10: Consultancy

Naam: Frank ten Wolde
Functie: Projectleider Energie en Elektrisch Vervoer
Organisatie: APPM Management Consultants
Datum en tijd: 3 november 2017, 11:00

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
 - Sinds 2010 bij Rijkswaterstaat verantwoordelijk voor elektrisch vervoer. Onder andere de vergunningen langs de snelwegen kwamen daaruit voort.
 - Liason tussen IW en EZ op het gebied van elektrisch vervoer. EZ was verantwoordelijk voor EV, IW voor andere mobiliteit. Dat botste af en toe.
 - Sinds kort werkzaam bij APPM als EV expert. Sinds september bij gemeente Rotterdam voor herschrijven van visie voor elektrisch vervoer.
 - Ook een kleine opdracht voor I&M over de maatschappelijke kosten en baten van verschillende laadoplossingen met verschillende vermogens. Kijken vanuit overheid, netbeheerder en de markt. Alle partijen zeggen dat een hybride mix de oplossing is.

2. Wat is het doel van de gemeente bij het installeren van laadinfrastructuur voor elektrische auto's?
- Voor de grote gemeentes is dat luchtkwaliteit. De G4 hebben van IW een grote zak geld gekregen voor luchtkwaliteit. Veel gemeentes kiezen dan voor laadinfrastructuur, mobiliteit is voor 30% veroorzaker van luchtvervuiling.
 - In de grote steden komt ook langzaam de vraag op gang. En nee verkopen is niet leuk, dus komt er beleid over laadinfrastructuur.
 - Amsterdam en Den Haag hebben bijvoorbeeld best een andere insteek. Ze willen allebei de EV rijder faciliteren, maar doen dat op een andere manier.
 - In Nederland hebben we de 'ladder van laden' en 'paal volgt auto'. Gemeentes hebben in het begin proactief palen neergezet; nu komt er al een wat reactievere houding.
 - In de grote steden, is er een marktmodel aan het ontstaan. Marktpartijen hebben gebruikers nodig om een goede business case op een paal te maken. Misschien wel te snel geroepen dat het een marktactiviteit is. Terwijl er de komende jaren nog veel geld bij moet om het rendabel te maken. Een a twee gebruikers is eigenlijk te weinig, en je kan er eigenlijk moeilijk meer krijgen omdat je langzaam laadt.

Technische haalbaarheid

3. Denkt u dat de ontwikkeling van snellaadtechniek tot 350 kW er voor zal zorgen dat er meer gebruikt wordt gemaakt van snelladen? En op welke termijn denkt u dat?
- Er is een soort 'ratrace' naar hogere vermogens ontstaan, die niet per se gelinkt lijkt te zijn naar de vraag.*
4. De adoptie van EV vertoont verschillende synergieën met bijvoorbeeld shared vehicles en autonomous driving. Denkt u dat deze trends een effect gaan hebben op de manier waarop EVs geladen worden? En zo ja, op welke manier?
- Dat is nog lang niet zo omarmd als we allemaal dachten. En daar moet je positief over zijn, en die 60.000 uit de Green Deal wordt nog lang niet gehaald.
 - Alle drie de generaties zijn gewend om zo in de auto te stappen. Dat gaat wel veranderen, maar het duurt wel even.
 - Wij zien het hebben van een auto als luxe, en die geef je niet zomaar op.
5. Een belangrijke technische factor is de impact van EVs op het elektriciteitsnet en de rol hiervan in de energietransitie. Er zijn investeringen in het net nodig om de groei van EVs aan te kunnen. Heeft u een beeld hoeveel EVs er in een wijk bijgeplaatst kunnen worden zonder verdere investeringen?
- Het net kan heel veel aan, maar er zijn wel een aantal kritische punten aanwijzen.
 - Als iedereen een vermogen zoals een Tesla krijgt, en gaat thuisladen, dan zeggen de netbeheerders we moeten van een kabel van 40 huizen terug naar 20 huizen.
 - Je moet dat in het grotere geheel zien, als we van het gas afgaan heeft dat een veel grotere impact. Dat is de totaalopgave, dan heb je het over de energietransitie.
 - Je gaat kijken hoe je het net kan optimaliseren, op stads- of wijkniveau. Een stukje met zonne-energie, een ander stukje nog best lang met biogas. En smart charging met een statische accu in je meterkast geloof ik er wel in.
 - Het net in huis wordt veel belangrijker. Als we lokaal gaan opwekken, wordt je huis je energiesysteem, dan gaan we grid-loos. Dat beseft niemand zich, en dan gaan er belangen zitten.
6. Welke rol speelt smart charging in het tegengaan van nodige investeringen? En op welke termijn is dat haalbaar denkt u?
- Nu wordt geroepen dat smart charging alle piekbelasting wordt weggehaald. Dat vind ik nog maar de vraag.
 - De piek is niet als alle auto's aan de laadpaal hangen. Als particuliere EV rijder is het leuk om daarmee te spelen, zeker als de dubbele belasting eraf gaat.
 - Als je kijkt binnen het systeem, of je het daarmee op gaat lossen.

7. Hoe ziet u de afweging tussen snelladen en normaal laden in deze context?

Netbeheerders zijn in principe publiek, maar hebben ook hun eigen belang en redeneren af en toe uit die positie. Om te kijken wat is de maatschappelijk beste investering, kijken zij heel erg naar het net, maar dat hoeft niet per se de beste investering te zijn.

Economische haalbaarheid

8. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?

- *We kunnen blijven rekenen, maar de case blijft heel lastig.*
- *Wat heel belangrijk is, elektrisch rijden moet goedkoper blijven dan een benzine auto. Gemeentes zetten een maximum prijs per kWh, om de energietransitie mogelijk te maken.*
- *Als je bijvoorbeeld kijkt naar Allego, zij bieden gratis palen, maar wel voor een euro per kWh, terwijl het bij de gemeente 34 cent is. Bij gemeentes met een vergunningenmodel, komen er dus palen van een euro en van 34 cent. Dat is een raar signaal naar de EV rijder toe, en dan wordt maar een categorie laadpalen gebruikt.*
- *Daardoor krijg je scheefgroei van de markt, en als er in bepaalde gemeentes maar een exploitant is, als je dan gaat rekenen dan is je conventionele auto veel goedkoper.*

Sociale haalbaarheid

9. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?

- *Dat soort ontwikkelingen zouden we ook eens tegen EV aan moeten houden. Veel te maken met gedragsverandering; dat is belangrijker dan dat die auto elektrisch is.*
- *Als we maar hetzelfde kunnen blijven doen; voor de deur blijven staan en ver kunnen rijden.*

Politieke haalbaarheid

10. Hoe denkt u dat gemeenten de afweging maken tussen 'normaal laden' en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?

- *In het begin hebben we op AC laden ingezet. Als je nu nieuwe oplossingen gaat bieden, bijv. een laadplein met snelladen, raakt de marktpartij van de eerste ronde zijn gebruikers kwijt.*
- *Eerst hebben we als NL goed gedaan, zijn eerst met alle partijen een marktmodel gaan schetsen. Dat heeft InnoPay gedaan, gedreven vanuit de markt. We hebben niet, toen het veranderde, eens teruggedaan naar de tekentafel.*
- *Beleid is 90% gericht op AC laden, je ziet nu wel dat er iets meer gekeken wordt naar snelladen. Ik denk dat snelladen niet meer dan 15-20% wordt, zeker niet gezien de voertuigen die op de markt komen de komende jaren. - Duitse OEMs investeren nu heel veel in het DC netwerk, dus die roepen dat het DC wordt. - DC haalt het voordeel van de EV weg, dat je auto iets nuttigs doet als ie stilstaat. De rol van de werkgevers mist hier vaak in, want daar staan auto's vaak stil.*

11. Welke factoren zijn volgens u van belang bij de afweging van de maatschappelijke kosten en baten van beide laadoplossingen?

- *Goed omgaan met de openbare ruimte, er is een krapte aan openbare ruimte.*
- *Dat wil je op een goede manier aan de markt geven. En alle partijen een eerlijke kans geven.*
- *Gemeentes hebben door dat de locaties van benzinestations niet zo raar zijn gekozen. Een verschuiving in de dienstverlening is logisch. In de steden zijn de veilingopbrengsten ook op te brengen voor EV exploitanten.*
- *We zijn nog aan het leren wat er in wijken gaat gebeuren. Auto's misschien wel opvangen aan het rand van de wijk. Dat zou op termijn een interessante energievraag zijn.*

12. Het doel is om uiteindelijk met beleidsaanbevelingen te komen voor grote gemeentes. Heeft u hier ideeën over? Hoe zouden gemeentes zich goed kunnen voorbereiden op de snelle groei van EVs in de komende jaren?
- *Je hebt nu nog 3 a 4 jaar de tijd daar een passen netwerk bij te ontwikkelen.*
 - *Locatie kan veranderen, als je 3-fase gaat laden kan alleen laden bij de werkgever alleen al voldoende zou kunnen zijn.*
 - *Je gaat als gemeente een tijdje AC faciliteren, en je fall back optie wordt iets met snelladen.*
 - *Op de korte termijn niet zo heel veel ontwikkelingen met laadpleinen, als er schaarste komt. Dan worden dat soort opties interessant.*
 - *Als gemeente moet je adaptief beleid voeren: kijk hoe het zich ontwikkelt en pas het daar op aan. Houd je ogen en oren open welke vraag er ontstaat bij de gebruikers.*
 - *EV rijders worden vaak vergeten, te vaak een discussie van netbeheerders, marktpartijen en de overheid.*

Interview 11: Gas station owner

Naam: Dick Slagboom

Functie: Eigenaar

Organisatie: BP Gooiseweg Amsterdam

Datum en tijd: 16 december 2017, 16:00

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
Eigenaar van BP Slagboom aan de Gooiseweg Amsterdam.
2. Wat is het doel van de gemeente bij het installeren van laadinfrastructuur voor elektrische auto's?
Amsterdam stelt hoge eisen, maar is nog niet heel duidelijk hoe benzinestations daar in passen. Zal in gesprek moeten gaan waar beide partijen elkaar in kunnen vinden.
 - *Als concessies aflopen, zal er toch een nieuw plan moeten komen.*
 - *Alle vastgoed is gecentraliseerd in Amsterdam nu, dat geeft ook een nieuwe aanpak.*

Economische haalbaarheid

3. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
- Commercieel gezien is het nog niet heel interessant. Investering valt nog wel mee, maar de vraag is of mensen een uur willen wachten op een station.
- Er moet ook verdiend worden aan activiteiten eromheen, zoals autowassen, restaurants etcetera.
4. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?
- Ik ben zelf een dodo: dealer owned, dealer operated. Ik kan dus zelf kiezen met welke partijen ik in zee ga. Alle risico's zijn dus ook voor mij zelf.
- Combinaties met derde partijen zou ik wel voor open staan.
- Commercieel gezien gaat het tankstation van de toekomst er anders uitzien.

Sociale haalbaarheid

5. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?

Mensen hebben nu nog niet zo'n zin om zo lang te wachten op laden bij een tankstation. Als dat in de toekomst verandert, sta ik daar uiteraard voor over.

Politieke haalbaarheid

6. Hoe denkt u dat gemeenten de afweging maken tussen 'normaal laden' en snelladen in de publieke ruimte zullen gaan maken in de toekomst? En zo ja, op welke manier?

- Er zullen ook andere voorwaardes aan de vergunningen komen, veranderingen voor de toekomstige pompstations.

- Toekomst voor een benzinstation is moeilijk te overzien. Gemeente Amsterdam is een voortrekker van elektrische energie. Toekomstperspectief voor een benzinstation is wel een issue. Interessant om dat eens te gaan vormgeven.

7. Welke factoren zijn volgens u van belang bij de afweging van de maatschappelijke kosten en baten van beide laadoplossingen?

- Bepaalt ook wat de gemeente hierin wil. Als het stadscentrum verkeersluw wordt, komen er aan de rand van de stad een soort transferium. Openbaar vervoer of fietsend dan de stad in, en wordt er geladen aan de rand van de stad.

8. Een uitdaging bij snelladen is de huidige infrastructuur van benzinstations. Heeft u ideeën hoe gemeentes om moeten gaan met de transitie van fossiele brandstoffen naar EVs bij pompstations?

- Ja, als het commercieel interessant wordt, zal ik dat zeker gaan installeren. Zonnepanelen op het dak en een aantal pompeilanden omvormen naar laadstations. Doe ik nu al voor een punt met aardgas.

Interview 12: Norwegian Drivers Association

Naam: Petter Haugneland
Functie: Communication Manager
Organisatie: Norsk elbilforening
Datum en tijd: 7 december 2017, 11:00

Algemene vragen en context

1. Kunt u iets meer over uzelf en uw rol bij uw organisatie vertellen?
Communication manager for the Norwegian drivers association. We advice numerous organisation on the driver preferences and needs. For instance, the chargers are not yet very user friendly, a lot of different cards are needed to charge your EV.
2. Wat is het doel van de gemeente bij het installeren van laadinfrastructuur voor elektrische auto's?
 - *For fast charging stations there are grants for parties who want to install chargers, 50 km in between.*
 - *In cities there already is a high enough EV density to install them without support.*
 - *New grant where there are no fast charger stations in smaller municipalities.*
 - *We try to influence CPO's to install chargers in front of the market to stimulate EV adoption.*
3. Wat zijn de belangrijkste factoren die de afweging tussen normaal laden en snelladen in de stedelijke omgeving bepalen voor gemeentes volgens u?
 - *First of all, there should be a system for parking garages, offices and apartment buildings. People charge mostly at home or work, also cheapest to build indoor.*
 - *For street parking, put them op by demand. 22 kW stations are future proof for coming batteries, if you charge one night per week you are set for a week.*
 - *Fast chargers are also necessary, for commercial vehicles mostly (taxi's, delivery vans). Ratio is something we should test out.*
4. Is er in Noorwegen veel meer toegang tot parkeerplaatsen?
Yes, there are a lot of parking garages or at least possibilities to get the cars out of the street level. Only in city centres public spaces are needed for parking.

Technische haalbaarheid

5. De adoptie van EV vertoont verschillende synergieën met bijvoorbeeld shared vehicles en autonomous driving. Denkt u dat deze trends een effect gaan hebben op de manier waarop EVs geladen worden? En zo ja, op welke manier?
Yes, but not yet considered in policies. We are already lagging behind in terms of charging infrastructure. The investments done today will not be lost, if car sharing takes off.
6. Een belangrijke technische factor is de impact van EVs op het elektriciteitsnet en de rol hiervan in de energietransitie. Er zijn investeringen in het net nodig om de groei van EVs aan te kunnen. Heeft u een beeld hoeveel EVs er in een wijk bijgeplaatst kunnen worden zonder verdere investeringen?
 - *There have been some reports on upgrading the grid. The national grid owners say it is not a big problem.*
 - *People use more electricity for everything anyway, so you need to upgrade anyway. EVs will probably more a resource to help with the grid, than a problem.*

7. Welke rol speelt smart charging in het tegengaan van nodige investeringen? En op welke termijn is dat haalbaar denkt u?
- *Preferably, slow charging at home or work, can deal with the peaks efficiently. We need both solutions.*

Economische haalbaarheid

8. Hoe kijkt u tegen de business case van normaal laden en snelladen aan? En ziet u de business case van beide opties in de toekomst veranderen?
- *Some municipalities and organisations support it in public spaces in cooperation with energy companies.*
 - *There is not the best business case for normal chargers.*
9. Hoe denkt u dat de markt zich gaat ontwikkelen? Zullen commerciële partijen zich uiteindelijk meer op snelladen of langzaamladen gaan richten?
- *Tesla is installing fast chargers at IKEA stores.*
 - *Also at gas stations, but there is not too much space to install many chargers.*
 - *It will be combined with other activities, such as shops, restaurants etcetera.*
 - *Car manufacturers focus on fast charging, is is similar to gas stations that are up now.*

Sociale haalbaarheid

10. Op welke manier denkt u dat de klantvoorkeuren gaan veranderen in de toekomst voor het opladen van EVs?
- *It's very abstract for people to grasp. People charge at home people, but they like fast charging stations when they need to fill up quickly.*
 - *It also depends on the price, professional users will be willing to pay this extra price. Time is money.*
 - *Best would be that you have different options, at a shopping centre you want to fill up in 2 hours for example.*

Politieke haalbaarheid

11. Wat kunnen Nederland en Noorwegen van elkaar leren?
- In the Netherlands there is a lot of industry and new innovations and technology. The Netherlands is creating an industry, Norway is more invested in oil still.*
- *In Norway we never had a big plan, we just started building. And we learned while doing. We started with making the EVs affordable. To get a better infrastructure, you need more cars. That is not a long-term policy.*

C Appendix: Focus Group Summary

This appendix provides a summary of the focus group. Key points and findings, as well as notable quotes and observations made by the second observer. The findings are summarised per question asked during the focus group.

Deelnemers: 9 EV rijders met ervaring in een BMW i3

Organisatie: Royal Haskoning DHV office

Datum en tijd: 17 januari 2018, 12:30 - 13:45

Question 1: Charging preferences private use

Start time: 12:37

End time: 12:51

Key points and findings

- Snelladen is eigenlijk hetzelfde als tanken met benzine/diesel. Als er 150 kW laders zijn is dit een goede manier.
- 20 minuten voor snelladen is nog wel wat te lang om niets te doen, dus het zou een mogelijkheid zijn dit te combineren met bijv. het doen van de dagelijkse boodschappen.
- Laden zou men graag willen combineren met parkeren. Parkeren moet je toch!
- Gebruikers laden overal waar dat kan, om zoveel mogelijk een volle tank te hebben. Dit geeft zekerheid, gezien de relatief kleine actieradius van de auto, de beperkte beschikbaarheid van laadinfrastructuur, en de lange tijd die het laden nodig heeft.
- Een snelle laadpaal in de buurt kan een alternatief zijn voor thuis laden.
- Normaal laden (11kW) maakt het niet de moeite waard om op te laden voor korte stops van bijv. 30 minuten.

Quotes

- "Als 150 kW laden de standaard is, zullen er minder thuisladers nodig zijn en zal het meer gaan lijken op hoe we nu tanken."
- "Ik overweeg soms de trein te pakken, omdat het laadnetwerk ontoereikend is."
- "Ik heb wel eens drie keer op één dag moeten opladen."
- "Publieke palen in de buurt zijn vaak bezet, het is voor mij soms een grote puzzel om mijn auto te laden."
- "Ik ken inmiddels alle elektrische rijders in de buurt."
- "Ik kijk eigenlijk continue naar mijn meter hoeveel bereik ik momenteel heb."

Observations

- Stel, een bestuurder met een accu tot 80% opgeladen komt naar een woonwijk, en plukt de auto aan een stekker. Even later komt een bestuurder met een bijna lege accu aanrijden, maar de laadpaal is al bezet. Is dit eerlijk? Hoe maak je hier, indien er minder laadpalen zijn dan auto's "eerlijk" gebruik van? Of lost dit zichzelf op?

- Op dit moment zorgt de combinatie van een relatief kleine actieradius van de BMW i3, de beperkte beschikbaarheid van laadpalen, en de relatief lange laadtijd bij Fastned ervoor dat rijders continue bewust bezig zijn met de afstand die ze nog kunnen afleggen. Sommige rijders accepteren dit, en vinden dat het erbij hoort als je naar Groningen gaat dat je dan 3 keer moet tanken, anderen vermijden daardoor liever de auto voor lange afstanden en pakken de trein.

Question 2: Charging preferences business use

Start time: 12:51

End time: 13:04

Key points and findings

- Als er geen plek meer beschikbaar is om te laden bij mijn huis, zou ik Fastned gebruiken.
- Naarmate het bereik van de auto's toeneemt, zal er minder snelladen plaatsvinden, omdat men aan huis meer dan genoeg accu kan opladen voor een rit.
- Zodra het 175 kW laden doorbreekt, is er minder laadinfrastructuur thuis nodig en tanken we alleen maar zoals we nu de brandstof auto's tanken.
- De twee systemen kunnen/zullen parallel aan elkaar blijven bestaan.
- Smart-grids kunnen gebruikt worden om slim in te spelen op vraag en aanbod van laadcapaciteit.
- De toekomst is nog wel onzeker, wie weet kunnen we allemaal op waterstofgas rijden in 2025, in plaats van elektrisch?
- Voor de zakelijke rijder spelen de kosten per kWh laden geen rol, voor consumenten wel. Zakelijke rijders zullen dus minder kijken naar de prijs voor het laden.
- Fastned biedt nu het elektrisch laden aan, tegen dezelfde prijs per km als de brandstofkosten.

Quotes

- "Voor zakelijk gebruik is de kWh prijs geen probleem, dan gaat het echt alleen maar om de efficiëntste manier van laden."
- "Ik moet op elk beschikbaar moment laden, anders kom ik niet thuis."
- "De stroomprijzen voor het elektrisch rijden zijn ondoorzichtig."
- "Als ik met 11 kW thuis kan laden, zal ik nooit met Fastned gaan laden!"
- "Ik gebruik Fastned alleen om thuis mee te komen, het is puur een escape."

Observations

- Het lijkt alsof er twee "kampen" zijn:
- Snelladen krijgt de overhand: accu's kunnen dermate snel geladen worden, zodat het in een tijdsbestek van 5 à 10 minuten klaar is. Dan kan je in de tussentijd lekker een kopje koffie drinken. Het bereik speelt dan ook minder een rol, omdat je na 200/250 km, "slechts" 10 minuten kwijt bent voor een volle tank.

- Normaal laden krijgt de overhand: de capaciteit van de accu's is dermate groot dat er in de praktijk zelden onderweg geladen hoeft te worden. Aan het einde van de dag kunnen alle auto's thuis aan de lader, zodat ze de volgende dag met een volle accu kunnen vertrekken. Hierbij speelt de laadsnelheid een mindere rol, zolang er maar binnen 8 uur (één nacht) een volle accu geladen kan worden.
- Uiteraard zal er in gevallen dat iemand méér dan 300/400 km per dag rijdt, nog steeds een snellader moeten zijn langs de snelweg. Dit is het geval voor bijv. mensen in de sales of op vakantie (zware auto met aanhanger).

Question 3: Locations for fast charging

Start time: 13:10

End time: 13:15

Key points and findings

- Als je auto aan een snellader hangt, moet je erbij blijven om plek vrij te maken zodra de auto is opgeladen.
- Het zou slim zijn als parkeergarages laadplekken gaan voorzien.
- Voor shoppen zou semi-snelladen geschikt zijn, omdat je langer op één plek stilstaat.
- In Duitsland doet Aldi dit op parkeerplekken, dat zou een ideale combinatie van activiteiten zijn.
- Het moet passen bij je activiteit, 'opportunity charging'. Het moet geen extra gedoe vormen om te laden. Als het thuis, op het werk, bij een winkel of als even tanken kan, is dat allemaal prima.

Quotes

- "De set-up van Aldi is geweldig, een dak vol zonnepanelen en gratis 50 kW laden tijdens het shoppen."
- "De niet inspirerende omgeving van Fastned laadstations nodigen niet uit om te laden als het niet strikt noodzakelijk is."
- "Laden met 50 kW tijdens meetings of shoppen lijkt mij een goede oplossing, sneller hoeft niet op die locaties."

Observations

- De deelnemers hebben geen hele duidelijke voorkeur voor locaties. Het is belangrijker dat de laadoplossing past bij de activiteit die ze uit aan het voeren zijn.
- Voordelen zoals gratis laden bij het shoppen of goede faciliteiten lijken een grote invloed te hebben op de perceptie van het laden. Dit is dus belangrijk om goed op orde te hebben.

Question 4: Vision for future charging

Start time: 13:15

End time: 13:30

Key points and findings

- Inductief laden voor autonome auto's kan een grote rol gaan spelen.
- Autonome deelauto's kunnen buiten de stad opgeladen worden, om op afroep volgeladen naar gebruikers binnen de stad gereden te worden.
- Het huidige laadnetwerk zal grotendeels verdwijnen, dit wordt echt als een tussenperiode gezien. Als snelladen en autonome auto's doorbreken, zal de grote hoeveelheid laders in de wijken snel afnemen.
- Centraliseren van laden is een slim idee. Dat is fijn voor bedrijven, en dan heb je er ook geen last van in de woonwijk.

Quotes

- "In de toekomst (2025) hebben we weer het normale laad/tankgedrag zoals we dat nu ook kennen."
- "Wie weet heeft niemand meer een eigen auto, en worden alle auto's gedeeld?"
- "De ontwikkelingen van het autodelen zit met name in het hoofd, mensen vinden een auto een stukje persoonlijke ruimte, en delen die niet graag met onbekenden."
- "In de toekomst zie ik het opladen automatisch gebeuren buiten de steden en woonwijken op centrale plekken."

Observations

- De argumenten die de voorkeuren bepalen in de huidige context of nabije toekomst worden grotendeels losgelaten als er over de verre toekomst wordt nagedacht. Dan ziet men een autonome vloot voor zich die 'zichzelf oplaadt'
- Men lijkt het erover eens dat de komende 10 jaar een transitieperiode is, maar geen ideale oplossing. Opvallend is dat het huidige laadnetwerk dat zou verdwijnen, met hoge kosten tot gevolg.

