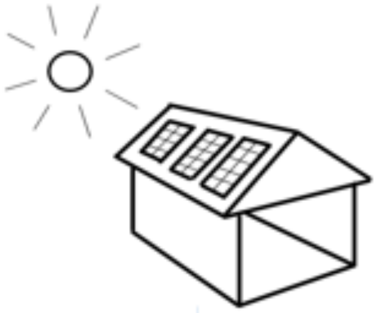
Electric vehicle integration

Stakeholder engagement in the innovation process of electric vehicle integration



smart smart grid solutions

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“The problem is that at a lot of big companies, process becomes a substitute for thinking. You’re encouraged to behave like a little gear in a complex machine. Frankly, it allows you to keep people who aren’t that smart, who aren’t that creative.”

Elon Musk – CEO of Tesla Motors, SpaceX and chairman of SolarCity.

Preface

This paper concludes the Master Business Administration study I have been following at the University of Twente. The insights in this paper come from a research conducted at Locamation B.V. in Enschede. An innovative company working on smart 'smart grid' solutions. Locamation gave me the opportunity to look into a specific smart 'smart grid' solution in combination with the upcoming innovation of electric vehicles, in short electric vehicle integration. A great (potential) innovation that has the promising ambition to change the energy distribution and automotive industry. Within this technological setting I focused on the engagement of stakeholders in the innovation process.

During the time I devoted to my Master thesis I developed myself socially and professionally. This is firstly because Locamation is a very interesting company to work at and secondly because the studied topic is at the point of disrupting incumbent and very significant industries.

I would like to appoint my gratitude to several people who helped me finish this master thesis. Special thanks goes out to Bas Mooijman. My supervisor at Locamation, who helped me focusing on important red lines throughout my master thesis. Secondly I would like to thank the employees at Locamation who were directly involved in the accomplishment of this Master Thesis by giving insightful information and honest feedback. Lastly I want to thank my supervisors from the University of Twente, Dr. Raymond Loohuis, Dr. Kasia Zalewska-Kurek and Dr. Thomas Hoppe for their support and trust in me. A special thanks goes out to Dr. Raymond Loohuis, for his feedback, support and guidance during the master thesis process.

With kind regards,

Ruben Poppink

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Management summary

It is difficult to indicate the value of innovations especially in emerging technology fields, like transportation and energy production. Yet for the organisations involved in working on innovations, it is crucial to have insight in this future value of innovations. What complicates its emergence are the multiple and uncontrollable factors that have influence on the innovation. To analyse the emerging technology the involvement of all stakeholders needs to be taken in account. Stakeholders play a role in many innovation theories, however the role of stakeholders is not covered in depth.

Since the introduction of electric vehicles, many researchers and organisations looked into the appealing idea to use electric vehicles to support the grid. The integration of the storage capacity, of batteries in electric vehicles, into the power grid could have several benefits. Electric vehicle integration technology is already emerging, for example smart charging and vehicle-to-grid (V2G). This research helps innovating organisations such as Locamation in the strategic decision making process about whether or not to invest or further research the electric vehicle integration technology field through an extensive stakeholder analysis.

What is the value of electric vehicle integration for the various stakeholders that are involved in the Netherlands and how can these stakeholders be mobilised in order to shape the direction of innovation process outcomes?

The most important stakeholders that are involved in the integration of electric vehicles in the power grid are electric vehicle owners, distribution network operators, regulatory organisations and innovating organisations. An important advantage for a company considering to invest in a new technology, is that the innovation is in a complementary technological innovation system (TIS) to the TIS the company is operating in already. Mutual stakeholders and networks, influencing factors and other aspects that are already known to the company in the smart grid TIS, are an advantage when operating in the complementary TIS of the new technology. The overall involvement of the stakeholders with the innovation of electric vehicle integration technology can be labelled as bricolage rather than breakthrough. Because of importance of involving users, collaborative networks and associations and evaluators giving valuable feedback.

The involvement of stakeholders can be increased in several ways. For example by evaluating regulations that hinder the innovation process, such as the net metering regulation. However it is complicated due to regulations being favourable for distributed renewable energy generation with PV-systems. It is of utmost importance to have a clear view of the direction of key regulations and legislation about electric vehicle integration. The road taken by regulatory bodies about net metering regulation is going to determine for the most part if some electric vehicle integration technologies are ever going to see the light in the Netherlands behind the niche they are in today.

Forming or joining industry associations for organisations working on electric vehicle integration is also important. It could improve the involvement of regulatory stakeholder groups and other stakeholder groups with the innovation of electric vehicle integration. Furthermore to improve the engagement of the user stakeholder group (especially electric vehicle owners) with the innovation process of electric vehicle integration, incentives could be used for involving them in test programs, pilot projects and evaluation studies.

The research revealed that distribution network operators (DNO's) in the Netherlands are a very important stakeholder when it comes to electric vehicle integration. DNO's are not only designer/ producer but also user and evaluator (e.g. ElaadNL, funded together by the Dutch DNO's) of technology for electric vehicle integration. Besides, DNO's are an important stakeholder in the technological field of smart grids as well. For innovating organisations like Locamation, already present in the smart grid TIS, it is very wisely to team up with one or more DNO's. Not only in the field of smart grids, but also for the possible future entering of the electric vehicle integration technological innovation system.

The different stakeholders involved with the innovation process of electric vehicle integration, have different value perspectives towards the innovation. Some value perspectives hinder the innovation of electric vehicle integration and some instigate the innovation. By mobilising all important stakeholders in the innovation process and aligning their value perspectives of the innovation the direction and rate of innovation can be influenced.

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1. Introduction

1.1 Situation and complication

Can electric vehicles provide support to the power grid or maybe even help to transform centralised energy generation to sustainable distributed energy production? This question arises out of the uncertainty that surrounds innovations in the transportation and energy industry. Nobody knows exactly what transportation and energy supply will look like in the Netherlands in let's say 50 years. However, many organisations have to make strategic decisions that concern emerging technologies in the present. Because of the many uncertainties arising from new technology such as electric cars, organisations are in need to develop as much insights about the technology and transformation as possible.

For innovating organisations it is important to prepare for possible developments in industries that affect them. However, it is difficult to indicate the value of innovations in emerging technology fields. Yet, for involved organisations it is crucial to have insight in this value to determine a strategy concerning the emerging technology (Markard, Stadelmann, & Truffer, 2009). A possible way to determine the future value of innovations in emerging technologies is to look at the innovation process till this point in time and bundle information that can say something about the direction an innovation is heading. What makes it complicated is the several organisations and factors that have influence on the innovation (Freeman, 1995). To analyse the emerging technology the involvement of all stakeholders needs to be taken in account (Geels, 2012). After all involved stakeholders and affecting factors are mapped out, ultimately the involvement of stakeholders with the innovations process may possibly be influenced and shape the direction of innovation process outcomes (Garud & Karnøe, 2003).

In this paper we argue that the current literature on innovation processes does not illuminate sufficiently the engagement of stakeholders in the innovation process and the alignment of stakeholders' perspectives to create value for these stakeholders including their mobilisation.

However, also the adoption of electric vehicles and the integration into the power grid in the Netherlands is depending on many different stakeholders. Electric vehicle integration technology is part of the multi-sided platform of electric vehicles in which several stakeholders are involved (Giordano & Fulli, 2012). Therefore, it can also be assumed that stakeholders have benefits to pursue, different barriers to overcome and various perspectives towards the adaption and uptake of electric vehicles. For instance, distribution network operators have long considered electric vehicles only as an additional load on the power grid. Through the development towards electric vehicle integration, electric vehicles are besides the additional load more and more considered as a valuable source for grid support services. From the perspective of vehicle owners is it the case that they see electric vehicles as a new technology or solution to an existing problem, namely, the personal transportation over land. Yet, still the social acceptance of this new technological solution is difficult to predict. The same applies to the use of electric vehicles for the support of the power grid. The primary function of the electric vehicle remains mobility, with sufficient range. The range of electric vehicles that are integrated in the power grid has to be sufficient for the electric vehicle owners to meet their mobility requirements. These and many more stakeholders (e.g. electric vehicle manufacturers, electricity producers, and regulatory institutions) are involved with the process of innovation and have influence on the direction and rate of the innovation process. The different perspectives can hinder or instigate that process. These stakeholder perspectives and the involvement of stakeholders in the innovation process can give information about the possible value of electric vehicle integration technology and the innovations that come with it. This can help to formulate a strategy for the involvement of stakeholders with the innovation.

The research is based on theory in the innovation research field. Theory about innovation describes many aspects of the innovation process (Van de Ven, Polley, Garud & Venkataraman, 1999). The key concepts that are used are the multi-level perspective (Geels, 2002; Rip & Kemp, 1998) from the technological transitions approach (Geels, 2002; Kamp, 2010; Kemp, 1994), technological innovation system (Carlsson & Stankiewicz, 1991; Jacobsson & Johnson, 2000) from the innovation systems approach (Freeman, 1998; Lundvall, 1985) and stakeholder engagement theories (Garud & Karnøe, 2003; Markard & Truffer, 2006).

1.2 Research goal and research questions

Research goal

Identify the value of electric vehicle integration for the various stakeholders that are involved in the Netherlands, including their perspective towards the innovation process.

Research question

What is the value of electric vehicle integration for the various stakeholders that are involved in the development of electric vehicle integration technology and how can these stakeholders be mobilised in order to shape the direction of the outcome of the innovation process?

Sub-questions to answer the research question:

- **What is the perceived value of stakeholders with regard to the different socio-technical variations of electric vehicle integration?**

  The innovation of electric vehicle integration can be divided into two main socio-technical variations. Is it possible to gain insight in the stakeholders' benefits and costs of the two socio-technical variations? What is the value perception of the different stakeholders?

- **To what extend can the value perception of stakeholders in the innovation process of electric vehicle integration technology be influenced in order to mobilise these stakeholders?**

  The stakeholders linked to electric vehicle integration show a degree of involvement with the innovation. Is it different among the various stakeholder groups? What insights can the general involvement with the electric vehicle integration innovation give? To what extend can the value perception of the stakeholders be influenced and can it be used to mobilise stakeholders?

1.3 Method and context

This section provides a brief overview of the method that is going to be used for this research and a quick impression of the context of this research. The research design that is going to be used is the case study strategy (Bryman & Bell, 2011; Eisenhardt, 1989; Yin, 1994). The context will be the electric vehicle integration technology field. Since the introduction of electric vehicles many researchers and organisations looked into the appealing idea to use electric vehicles to support the grid. The integration of the storage capacity, of batteries in electric vehicles, into the power grid could have several benefits. Electric vehicle integration technology is already emerging, for example smart charging and vehicle-to-grid. This will be the context in which a case study is conducted. More about the case selection in the method section (Chapter 3). The case study design is chosen because of the ability to observe and analyse a complex case by using detailed and intensive analysis of that case.

For this research it is important to understand what stakeholders are involved in the integration of electric vehicles in the power grid and what their influence is on innovation in terms of constraining and enabling factors. Because the innovation process of electric vehicle integration is surrounded by many stakeholders with different interests. A categorisation needs to be made for these stakeholders, with benefits of electric vehicle integration for them, and hindering factors in the innovation process. Electric vehicle integration cannot be seen without electric vehicles nor the power grid. Electric vehicle integration is part of the multi-sided platform of electric vehicles in which several stakeholders are involved. These stakeholders all have influence on the rate and direction of the innovation of electric vehicle integration. The adoption of electric vehicle integration is depending on different stakeholders with different interests (Giordano & Fulli, 2012, p. 253):

- Customers waiting for less expensive and long-range electric vehicles.
- Auto-makers waiting for a market for electric vehicles.

- Power retailers looking for extra-revenues.
- Distribution System Operators (DSO) interested in "vehicle-to-grid" services but cautious about investments.
- Renewable generation companies interested in synergies with electric vehicles to act as distributed storage system.
- Battery suppliers waiting for a stable market to further increase their research and manufacturing capabilities.

For this research on stakeholder value perceptions on electric vehicle integration it is important to take into account this multi-sided platform aspect of electric vehicle integration. The establishment of this multi-sided platform can be seen as a transition from the old regimes surrounding internal combustion engines and centralised energy generation to integrated electric vehicles and distributed renewable energy generation. Important are the connections of this multi-sided platform with the power grid, and its current transformation to a smart grid. In particular for the innovative organisation most of this research was conducted, connections with the specific smart grid solution of substation automation.

Electric vehicle integration technology comes in many forms, the most widely known are smart charging and vehicle-to-grid. Smart charging means that the rate at which electric vehicles are charged is controlled. Vehicle-to-grid means that besides controlling the charge rate, the electric vehicle is able to discharge energy from the battery in the power grid, also called bi-directional charging.

The choice of using the case study design does not limit data collection methods that could be used (e.g. qualitative and quantitative methods can be used in a case study design). In this research qualitative in-depth interviews are used to collect useful data. The research method can be characterised as an intensive qualitative case study (Shadish, Cook, & Campbell, 2002).

1.4 Report structure

In this last section of the introduction an outline of the thesis is given. In the following chapter the relevant theory on innovation and stakeholder engagement is discussed (Chapter 2). At the end of this chapter a theoretical framework is constructed that is used for this thesis. In the next chapter the method for the research is explained (Chapter 3). This chapter contains an extensive view of the context and background and introduces the different stakeholders that are involved. Also operationalisation and methods for data collection and data analysis can be found here. The subsequent chapter gives the results of the research (Chapter 4). These results will lead to the answering of the main research question and a conclusion (Chapter 5). After that a discussion can be found firstly on the used theory and the contribution this research has, secondly on the used research method and results and thirdly on future needed research (Chapter 6). The thesis will conclude with practical implications for organisations on stakeholder engagement (Chapter 7). In the appendices several additional data can be found, for example about an examined sub-case.

2. Theory

In this section the theoretical framework for the research on innovation of electric vehicle integration technology and the engagement of stakeholders in the innovation trajectory is elaborated. Several relevant theories will be discussed to give an insight in the research field of this study. Innovation and stakeholder involvement being the central themes of the framework used in this thesis, appropriate theories are innovations, transitions, innovation systems and multi-level theories. In sections 2.1-2.5 these theories will be explained. In the last part of this chapter (2.6) the framework will be constructed out of these theories.

An innovation is widely defined as “a new idea, which may be a recombination of old ideas, a scheme that challenges the present order, a formula, or a unique approach which is perceived as new by the individuals involved” (Van de Ven, 1986, p. 591). First of all the occurrence of innovation is looked into. What is innovation, how is it occurring and why is it happening? This will be done by looking at various aspects of innovation. After this broad understanding of innovation, the different theoretical approaches to innovation will be described. It is important however that the end goal of this theory section is to find out what theory is already known about stakeholder engagement and involvement with the innovation process. The end point of this theory section will be the role of stakeholders on different levels in the innovation process.

2.1 Innovation

2.1.1 Aspects of innovation

Van de Ven, Polley, Garud and Venkataraman (1999) developed a framework that can be used to identify the different aspects of innovations. This framework focuses on five concepts to define and get a better understanding of the innovation process. To give more insight in the framework the five concepts are described in Appendix E.

In the literature on innovation the distinction is often made between radical and incremental innovations (Dewar & Dutton, 1986; Ettlie, Bridges & O’Keefe, 1984; Hage, 1980). “The major difference captured by the labels radical and incremental is the degree of novel technological process content embodied in the innovation and hence, the degree of new knowledge embedded in the innovation” (Dewar & Dutton, 1986, p. 1423). Innovations are radical if the changes are fundamental and represent revolutionary changes in technology; Innovations are incremental if the changes are simple adjustments or minor improvements in current technology (Dewar & Dutton, 1986).

How the aforementioned five key concepts together form the innovation process becomes clear when Van de Ven et al. define this process that is called the innovation journey. The innovation process can be seen as “new *ideas* that are developed and implemented to achieve desired *outcomes* by *people* who engage in *transactions* (relationships) with others in changing institutional and organizational *contexts*” (Van de Ven et al., 1999, p. 6-7). It becomes clear that important aspects of innovations are people with ideas, how these people interact or work together and the surroundings that have influence on the whole process and the results. Many scholars have looked into this process of innovation and several theories and concepts have emerged to get a better understanding how it actually works; Technological Transitions approach and the Innovation Systems approach (Markard & Truffer, 2008). The latter is often focused on the creation and diffusion of a specific innovation or technology. Over the years several versions of innovation systems have emerged and are applied to a wide range of innovations (Carlsson & Stankiewicz, 1991; Edquist, 1997). The technological transitions approach takes a somewhat other stance and focusses mainly on the transformation of an established system by a diversity of innovations. Both perspectives have a contribution to the deeper understanding of innovations and transformation processes (Markard & Truffer, 2008) and are useful for the analysis of the innovation of electric vehicle integration technology.

2.2 Innovations approaches differ about stakeholders

2.2.1 Technological transitions approach

Geels (2002, p. 1257) defines technological transitions as "major technological transformations in the way societal functions such as transportation, communication, housing, feeding, are fulfilled." In the transition towards the widespread use of electric vehicles and their integration in the power grid often the focus is on the technical aspects of these innovations. However next to these technical aspects, it is important also to look at the social aspects of these innovations. The social system that develops and implements the new technology together with the technical characteristics determines the success of a new technology (Kamp, 2010). This is in line with the statements done by Sovacool and Hirsh (2008) that besides the many technical barriers of a transition to a vehicle-to-grid system, also barriers relating to customer behaviour with regard to cultural, political, social and economic values. That is why these transitions are often called socio-technical transitions (Geels, 2010).

Multi-level perspective

There are several approaches and frameworks to look at socio-technical transitions. Steinhilber, Wells and Thankappan (2013) state that strategic niche management is a well-developed approach for sustainable innovation with insights of innovation policy practice and focus on the niche part of transitions. Niches being one part of transitions, the other parts are regimes and the landscape. These three parts make up the multi-level framework that is often used to analyse and understand transitions (Geels, 2002; Kemp, 1994).

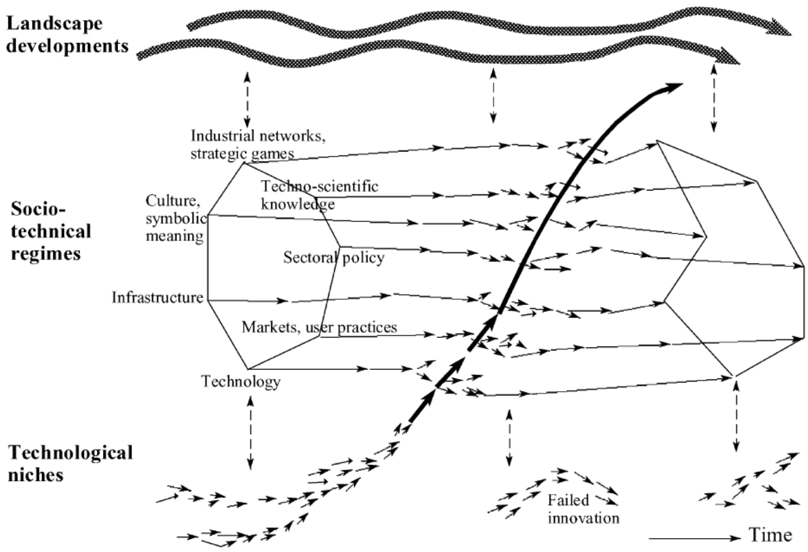

Figure 1 Multi-level perspective on transitions (Geels, 2002)

Geels (2010) describes the multi-level perspective (MLP) as a framework that can be used for the understanding of (sustainability) transitions, providing an overall view of the multi-dimensional complexity of socio-technical systems changes. For the analysis of transitions, the multi-level perspective uses three levels: at the micro-level are the niches where innovations take place, at the meso-level the socio-technical regime embodies the current technologies and at the macro-level the landscape of exogenous factors. The three levels of the MLP, socio-technical landscape, socio-technical regimes and technological niches (Geels, 2002; Rip and Kemp, 1998) are shown in Figure 1. The theoretical framework that is constructed at the end of this chapter contains parts of the multi-level framework and that is why this framework is described in more detail in Appendix F.

2.2.2 Innovation system approach

The second approach that scholars often use for the analysis of fundamental transformation processes is the system innovation approach. Where the technological transitions approach looks mainly at an incumbent system that can be changed by innovations, the innovation system approach is mainly focused on the innovation process itself. Today there are various forms of innovations systems; the first innovation system that was introduced is the national innovation system (Freeman, 1988; Lundvall, 1985). Because of the many forms of innovations systems there is not one definition of the innovation system concept. Freeman (1988) states that an innovation system is a network of institutions in both public and private sectors to initiate, import, modify and diffuse new technologies by activities of these institutions and interaction between them.

After the national innovation system came regional innovation systems and sectoral systems of innovation for innovation systems in certain regions or sections, and also technological systems that focus on a specific technology of product (Markard & Truffer, 2008). Important to understand is that innovation system approach looks at innovation and diffusion of technology as both an individual and a collective act (Edquist, 2001).

Because this thesis is focusing on the development and stakeholder engagement concerning a specific technology (electric vehicle integration technology) and not on all the innovation activities of a nation or region (towards all kinds of technologies) the use of technological systems of innovation is more appropriate than that of territorial innovation systems. Jacobsson and Johnson (2000) indicate that technological systems can be used well for analysing the characteristics of the specific system associated with an emerging technology. That is why the following theory focuses on technological systems.

Technological system

A technological system is a type of innovation system that focusses on a specific technology or technology field. Carlsson and Stankiewicz (1991, p. 111) defined a technological system as a "network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology". Jacobsson and Johnson (2000) define the following elements of technological systems: 1) Actors and their competence, with competence being technical as well as other types of competence. 2) Networks that function as transportation modes for tacit as well as explicit knowledge throughout the innovation system. 3) Institutions, that can be divided in hard institutions, like the capital market, educational system and legislation, and softer institutions like culture.

Several scholars analysed the dynamics of innovation systems and many propose a set of functions of innovation systems (Johnson, 2001; Liu & White, 2001; Lundvall, Johnson, Andersen, & Dalum, 2002). The functions of innovations systems are described in more detail in Appendix E, also more details can be found with regard to understanding the performance and working of (technological) innovation systems.

2.3 Stakeholders in the different innovation approaches

Discussed are both the technological transitions and the innovation system approach for describing innovations and fundamental transformations which are important to fully understand the regime breaking character of electric vehicle innovation and development of infrastructure. The technological transitions approach leads to the use of the multi-level perspective (see section 2.2). From the innovation system approach the technological system is the most suitable, since this thesis is focusing on the development and stakeholder engagement concerning a specific technology (see section 2.2). As described in the previous sections the two innovation approaches take a somewhat different stance towards innovations, however there are also similarities. The involvement of stakeholders in the process of innovations, towards an emerging technological trajectory and adoption, is one of these similarities between the two. In this section the placement of stakeholders in the different innovation theories will be looked into. Also theory on different approaches to engage stakeholders in the innovation process will be described.

2.3.1 Stakeholders in the multi-level perspective

The development process of new technology involves many stakeholders that are interacting, sharing knowledge and working together on problems that arise. Garud and Karnøe (2003, p. 296) state: "The development of technologies entails not just an act of discovery by alert individuals or speculation on the future, but also the creation of a new path through the distributed efforts of many." In the multi-level perspective stakeholders are active in the micro and meso level, the niches and regimes. In the niches are stakeholders developing innovations, in the regimes are incumbent stakeholders in favour of technology that is

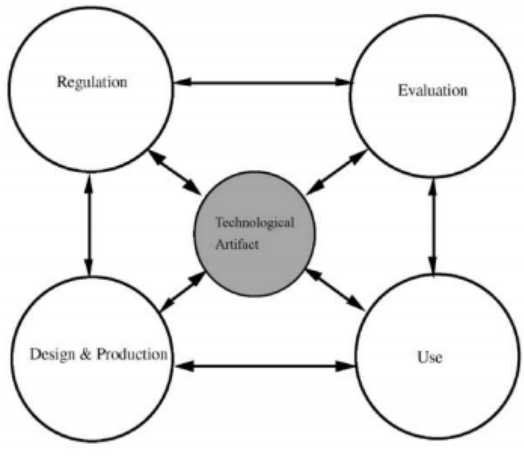

Figure 2 Distributed agents (Garud & Karnøe, 2003)

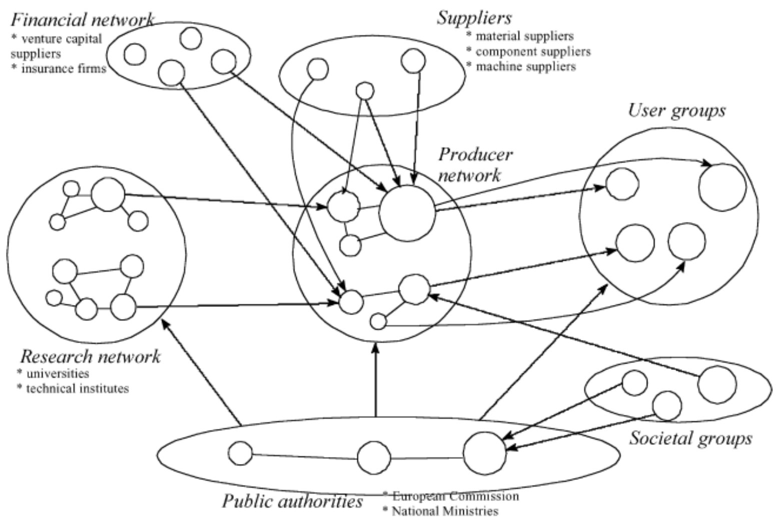

Figure 3 Networks in sociotechnical regimes (Geels, 2002)

already implemented. For the stakeholders at work in the regimes Geels (2002) constructed networks in regimes, see Figure 3. As described at the beginning of this theory chapter Van de Ven and colleagues (1999) pointed out that people and the transactions between them are important in the innovation process. Garud and Karnøe (2003) looked into ways stakeholders are involved in the innovation process. Garud and Karnøe (2003) divide the stakeholders involved in the technology emerging process in several domains, see Figure 2, and for more a more detailed description see Appendix E.

For widespread implementation of a new technology it is important to take into account the input of all the stakeholders that are involved; “technological initiatives that do not build upon the inputs of relevant actors may neither mobilize the required skills and resources nor ensure its acceptance in the wider community” (Garud & Karnøe, 2003, p. 296).

The categorisation of stakeholders in the domains of design/production, use, evaluation and regulation of Garud and Karnøe (2003) has similarities with the multi-actor network described by Geels (2002), as can be seen in Figure 3. Differences are that the evaluation domain does not come forward explicit in the multi-actor network, on the other hand the multi-actor network shows more insight in the surrounding networks, e.g. financial network, suppliers and research networks. The stakeholder categories, “design and production” and “producer network”, “use” and “user groups” and “regulation” and “public authorities” represent to a great extent the same stakeholder groups.

This however can only be stated with regard to the categorisation of stakeholders and explicitly not about the relations between stakeholders and the role they play in the innovation process. The multi-level perspective is less effective when it comes to the role and strategies different stakeholders play in the innovation process, the interaction between them and agency of different stakeholders or stakeholder groups (Markard & Truffer, 2008; Smith, Stirling, & Berkhout, 2005).

2.3.2 Stakeholder perspectives in (technological) innovation systems

Looking at the definition of a technological innovation system it is built up from stakeholders, networks and institutions that work together to generate, diffuse and utilise a technology. So stakeholders are central in the technological system. The focus is however on the transactions and relations between those stakeholders and less on the stakeholders itself. That is also why the stakeholders are not so clearly categorised as in the technological transitions approach and multi-level perspective. Innovation systems can however be used for an stakeholder oriented innovation approach (Markard and Truffer, 2006).

Markard and Truffer (2008) state that to be able to work towards an integrated framework (technological innovation system/multi-level perspective) for the analysis of innovation processes it is needed to restrict the stakeholders, institutions and networks in the innovation system to those that are supportive to the innovation process. This innovation system is called the technological innovation system (TIS).

In comparison with the stakeholders in the technological innovation system, the stakeholders in the regime are those that are against the development and adaption of the innovation in the innovation system. Following these definitions of stakeholders in the meso-level the stakeholders in the regime cannot be in the technological innovation system, and vice versa.

2.4 Lack of stakeholder perspectives in the multi-level perspective

As described above the multi-level perspective has been used in many studies to analyse innovations and fundamental transitions and is perceived useful along the way. However there is also criticism and room for improvement (Genus & Coles, 2008; Markard & Truffer, 2008; Smith et al., 2005). Geels evaluated the multi-level perspective in 2010 and attempts to further develop the approach with insights from scholars that expressed criticism to it. Further down some important criticism to the multi-level perspective.

Smith et al. (2005) say that the multi-level perspective should pay more attention to agency and the role of power in socio-technical transitions. Stakeholders that are involved in a regime and the power relations across the networks of these stakeholders determine the legitimate authority to push change (in the form of an innovation) through (Smith et al., 2005).

Genus and Coles (2008) agree with Smith and colleagues about the lack of attention for agency and power and suggest partial incorporation of the social construction of technology (SCOT) concept and the actor-network theory (ANT). Mainly to consider the contribution and interaction of diverse groups or stakeholders to either socio-technical transformations or stability of the current regime (Genus & Coles, 2008).

Markard and Truffer (2008) looked at both the multi-level perspective and the innovation system approach for the analysis of radical innovation processes and fundamental transformations. Both have strengths and weaknesses and Markard and Truffer suggest the use of an overarching conceptualisation which would build on the complementarities between the two traditions and allows combining their strengths (2008, p. 612).

To understand the stakeholders' perspective and possible mobilisation towards an innovation the roles and strategies, interaction and agency are important (Smith et al., 2005). The multi-level perspective is less powerful when it comes to these important factors (Markard & Truffer, 2008). The technological innovation system approach is inward oriented at the stakeholders in favour of the innovation, not paying much attention to stakeholders hindering the innovation (Markard & Truffer, 2008). More focus is needed on the perspectives stakeholders have towards an innovation, also if the perspective is negative, not only identifying these stakeholders as blocking mechanisms. These stakeholders have much more complex interactions with the innovation process and the mobilisation and engagement with the innovation needs more attention (Smith et al. 2005).

The combining approach is promising, with in mind this thesis' focus on stakeholder perspectives and mobilisation in the innovation process, because it emphasises more on the role of stakeholders power and agency in the multi-level perspective. However there is still need for more focus on the perspectives of stakeholders and their engagement in the innovation process to mobilise them. This is also stated by Garud and Karnøe (2003), to get more insight in the perspectives and engagement of stakeholders they identified two different approaches to it, which are described in the next section.

2.5 Stakeholder engagement, bricolage or breakthrough?

Two approaches in stakeholder engagement with the emerging process of new technology are bricolage and breakthrough (Garud & Karnøe, 2003). In the bricolage approach emergent properties are important. Emergent properties are preserved in the bricolage approach, this means that stakeholders move forward from the inputs that are given and those inputs improve by interaction with other stakeholders (Garud & Karnøe, 2003).

The opposite of the bricolage approach is the breakthrough approach. Where the bricolage approach is roughly a small step development process with the combined input of many relevant stakeholders from the ground up, the breakthrough approach is a big leap development process with some large stakeholders defining what is needed. To clearly explain the difference between breakthrough and bricolage approaches to stakeholder engagement it is useful to look at these different approaches for the several stakeholder groups that are defined in section 2.4.

With the bricolage approach there is a collaborative network between designers, producers and suppliers and several scale-up steps are done with product development in between. The breakthrough approach on the other hand will lack these collaboration networks and the scale-up steps are larger and fewer. The breakthrough approach is characterised by indirect learning input from a few users that are not really incentivised to deliver fault-finding input. The users stakeholder group with the bricolage approach on the other hand gives direct and critical input of many users, partly due incentives to do so. Evaluators in the bricolage approach are co-developing in the innovation process. The evaluators test technological options and give critical input on how to improve the designs. Evaluators in the breakthrough approach only selected the best technological option without giving valuable input on how to improve the designs they evaluated. Also testing standards do not evolve together with the innovation itself, causing accuracy problems with evaluations, because foreseeable future developments are not taken into account. The last stakeholder group described by Garud and Karnøe (2003) are the regulators. In the bricolage approach regulators strategically steer the activities of several stakeholders to combine forces. This could be done by regulations that improve engagement of the stakeholders with the innovation process. In the breakthrough approach regulators also create opportunities for stakeholders to engage in the innovation process, however these opportunities were also closed suddenly again. This causes stakeholders to have no stable future perspectives and forecasts for example investment returns. Breakthrough approach can also be recognised by regulators that do not use regulations to improve the engagement of other stakeholder groups in the innovation process.

2.6 Theoretical framework

In this section the theoretical framework is constructed out of the relevant theory that is described in the sections 2.1-2.5. The theoretical framework consists of a combination of the multi-level perspective, technological (innovation) systems and stakeholder engagement theory. It is based on the combining approach of Markard and Truffer (2008).

Simply put the multi-level perspective consists of a landscape with exogenous factors that influence both the regime of incumbent technologies and niches with innovations. The innovations in the niches can change the regime or overthrow it completely. The technological system is build up from stakeholders, institutions and networks working around an innovation. The technological systems could be seen as surrounding the niches and helping to influence or overthrow the regime(s).

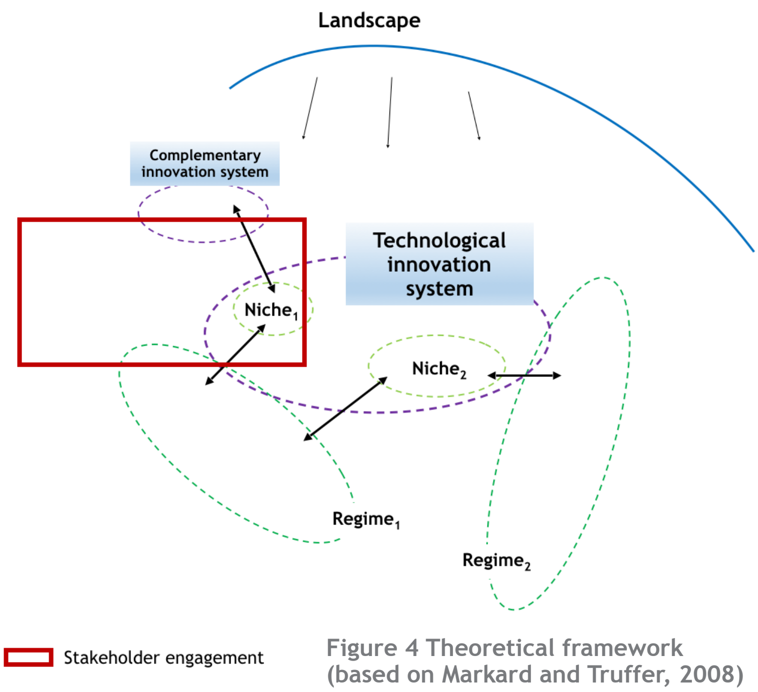

Figure 4 Theoretical framework (based on Markard and Truffer, 2008)

Markard and Truffer (2008) constructed a framework that combines the multi-level perspective with technological (innovation) system. This combined framework consists of four elements: Niches where innovation emerge and develop, the technological innovation system (TIS) where the niches are located, socio-technical regimes with the dominant production structure that is challenging the TIS and a landscape that has influence on the regimes and TIS but is not influenced the other way around. Markard and Truffer state that their framework provides a basis for a stakeholder oriented analysis of innovation processes. The framework does emphasis on stakeholders, however the engagement of stakeholders in the innovation process is not covered with great depth. Neither the role of the stakeholder in the innovation process, the level of engagement or the stakeholder perspectives become completely clear when using the theories of (technological) innovation systems, nor multi-level perspective or the combined approach of Markard and Truffer.

That is why the concept of stakeholder engagement (Garud & Karnøe, 2003) is added to the combining framework of Markard and Truffer. By doing so the framework will emphasise more on the role of stakeholders in the innovation process. That can give valuable insight in the engagement of those stakeholders in the innovation process, ultimately the involvement of stakeholders with the innovations process may possibly be influenced and shape the direction of innovation process outcomes.

Garud and Karnøe (2003) state that to mobilise stakeholders it is important that the regulators stakeholder group use regulations that improve engagement of the stakeholders with the innovation process, because regulators have overarching impact on other stakeholder groups. The mobilisation of stakeholders in the innovation process is dependent on the value perspective these stakeholders have towards the transformation (Smith, Stirling, & Berkhout, 2005). If value perspectives of stakeholders can be influenced it has impact on mobilisation.

The landscape overarches all other components of the framework and its exogenous factors have influence on most of them. The landscape cannot be easily influenced by the other components in the framework. In the centre is the technological innovation system that is the main focus of this thesis, the TIS of electric vehicle integration technology. Within this TIS are several niches forming incubation rooms for innovations to develop and emerge. The niches can be seen as technical variations of the innovation, what these are and how to analyse those can be seen in sections 3.4 and 3.5. The niches and TIS have influence on the existing regimes of dominant production structures and also on complementary innovation systems. As can be seen in Figure 4 the stakeholder engagement concept is placed on part of the niche, technological innovation system, regime and complementary innovation system. Stakeholders are involved in all these parts of the framework and the involvement of stakeholders with the innovation takes place also at these various settings. Functions of innovation systems are found inside the technological innovation system and will be used to analyse the working and performance of the TIS.

3. Method

This chapter can broadly be divided into three parts, the first part gives the context of the research, the second part consists the research design, and the last part is the operationalisation of the research. In the context part the surrounding context of electric vehicles, the power grid and change to smart grid and electric vehicle integration technology is discussed. It is followed by a broad overview of the stakeholders that are involved. The research design gives a description of the empirical approach taken in this thesis and describes the method for data collection and method for data analysis. The last part consists of the operationalisation of research variables. The aim of this chapter is to give a good overview of the research field and the way the research is conducted.

3.1 Context

In this part of the chapter the context of the research is described, starting with the power grid and smart grid, towards electric vehicles and electric vehicle integration. Followed by an introduction to important stakeholders.

3.1.1 Power grid

The power grid is of vital importance to the modern society; without it every day processes, deemed normal today, would not operate. For the power grid to meet the demands on power delivery and quality there are some essential requirements for the power grid to meet. Kundur (1994) says the power grid needs to balance constantly changing demand and supply, operate at minimum costs and stress on the environment, and meet quality standards regarding frequency, voltage and reliability. The power grid in the Netherlands can be divided into four different networks with their own function, from high to low voltage these are the interconnected network, the transportation network, the regional distribution networks and the local distribution networks (Oirsouw & Cobben, 2011). The different networks are connected in substations.

Smart grid

For the power grid to handle changes in demand and the shift from centralised to decentralised power supply the grid has to become smart, hence the term smart grid. The European Regulators Group (ERGEG) (2009, p.18) gives the following definition of a smart grid:

“Smart Grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety.”

3.1.2 Electric vehicles

Electric vehicles are equipped with an electric motor and a battery, which can be charged on the power grid. Habib, Kamran and Rashid (2015, p. 206) mention that additional to the load electric vehicles bring “[electric vehicles] can also act as a distributed storage device. When EVs [electric vehicles] are attached to DN [Distribution Network], battery of vehicle can be used to deliver power to a grid at peak hours of load and thus enhance the reliability of a system”.

There are two modes for electric vehicles to participate in balancing of the energy market, Demand-side Management (DSM) and Vehicle-to-grid (V2G). With the use of demand-side management, charging can be done at a lower rate or even delayed when there is a peak in power demand (Habib et al., 2015). Demand-side management is also known as ‘smart charging’ of electric vehicles. Mobility of the electric vehicle is still priority and the electric vehicle owner can for example set a limit that the electric vehicle is fully charged no later than 7 am (Mal, Chattopadhyay, Yang & Gadh, 2013; Handberg & Owen, 2015).

Vehicle-to-grid

Vehicle-to-grid implies energy can not only flow from the charger to the electric vehicle but also from the electric vehicle to the charger, creating a bi-directional power flow. Kempton and Tomić (2005, p. 269) state that “The basic concept of vehicle-to-grid power is that EDVs [Electric-Drive Vehicles] provide power to the grid while parked. The EDV can be a battery-electric vehicle, fuel cell vehicle, or a plug-in hybrid. Battery EDVs can charge during low demand times and discharge when power is needed”.

3.1.3 Stakeholders

The integration of electric vehicles in the power grid involves various stakeholders in the process. These stakeholders have different interests towards electric vehicles, the charging of electric vehicles, and the impact of electric vehicles on the power grid and the benefits of electric vehicles. To get insight in the different interests they are discussed for the main stakeholders below.

Electric vehicle owners

The main interest of the electric vehicle owner is that his transportation needs are fulfilled. The charging of the electric vehicle needs to supply a battery state of charge that meets the range needed for the mobility requirements of the electric vehicle owner. Within the boundaries of these mobility requirements, electric vehicle owners want to minimise the costs of charging their vehicle. Owners of electric vehicles could be interested in controlled charging or vehicle-to-grid programmes if the financial incentives to participate are high enough and the realisation of the range requirements is not put in danger. With vehicle-to-grid comes the electric vehicle owners' interest with battery degradation. The cost of battery degradation as a result of vehicle-to-grid charging/discharging has to be offset by the financial incentives to participate with a vehicle-to-grid program.

Distribution network operators

The most important interest of the distribution grid operators is the reliability of the distribution grid under their control. The reliability can be disturbed if many electric vehicles are being charged at the same time of the day, causing the distribution grid to be overloaded. Distribution grid operators could be interested in controlled charging of electric vehicles or vehicle-to-grid if investments in the distribution grid can be avoided or delayed. With controlled charging the charge rate could be lowered or the load of charging could be shifted to times with no peak in demand. Additionally with vehicle-to-grid electric vehicles could supply energy to the grid at times of peak demand.

Electricity suppliers

The primary interest of the electricity suppliers is the reliable and efficient production of electricity. Important for reliability and efficiency is the balance between supply and demand on the electricity market. If many electric vehicles are charged at the same time of the day the electricity demand could become higher than the production capacity of the electricity suppliers. Controlled charging of electric vehicles and vehicle-to-grid can provide balancing of supply and demand. If the electricity demand of electric vehicles is balanced, the additional energy consumption of electric vehicles means new revenue for electricity suppliers.

Government

Concerning electric vehicles in general the Dutch government is interested in the lowering of greenhouse gas emissions, the improvement of air quality in cities and the realisation of green economic profit (Bakker, Maat & Van Wee, 2014). To facilitate the adoption of electric vehicles, many governmental measures can be taken and the Dutch government has taken several. For example incentives for electric vehicle owners, funding for charging infrastructure and several activities to bring stakeholders together. If controlled charging and vehicle-to-grid can lower the costs of electric vehicle charging for electric vehicle owners as well for distribution grid operators the adoption of electric vehicles can be increased.

Other stakeholders

Several other stakeholders are involved with the integration of electric vehicles in the power grid. Not all of these stakeholders will be discussed in full length in this research. Some stakeholders for instance play small roles in the innovation process or their role is clear. For example electric vehicle manufacturing companies. As Giordano and Fulli (2012) state auto-makers simply wait for a market for electric vehicles. However electric vehicle makers are interested in better integrated electric vehicles and ancillary benefits, but cautious about battery degradation and lower range.

3.2 Research design

As basic research design the case study (Bryman & Bell, 2011; Eisenhardt, 1989; Yin, 1994) is used. Punch (2005) defines a case study as the basic idea to study one case in detail with the methods that are appropriate. This implies that the research methods used within the case study design are not limited. The case study design is chosen for this research because of the ability to develop an understanding of the case as much as possible, which is also an objective of the case study design stated by Punch (2005). The descriptive and qualitative nature of this research also make the case study a suitable research strategy. An additional reason to use the case study design is that it enables to observe and analyse a complex case by using detailed and intensive analysis of a single case (Bryman & Bell, 2011). The last important reason to use a case study design is related to the focus on stakeholders (engagement) of this research. Shadish et al. (2002) state that case studies are broad in the information they yield and can give stakeholders information about useful and diverse matters. This is important since part of the goal of this research is the information to stakeholders about stakeholder engagement and mobilisation. In line with Shadish et al. (2002) we describe the research design as an intensive qualitative case study. A case study can consist of either a single or multiple cases (Eisenhardt, 1989) and the levels of analysis can differ. In this research a broad level of analysis is used for the main case (electric vehicle integration innovation process in the Netherlands) and a more detailed level of analysis for the sub-case (pilot-project for electric vehicle integration technology). More about case study and the selection of the case after the following paragraph.

This research design applies to the main research, however a preliminary analysis is done before the beginning of the research. This initial analysis was to explore the field of innovation and the field of electric vehicle integration technology. With the information gathered in this early research stage it was possible to look at the fit between theory about innovation and stakeholder engagement and the issue of electric vehicle integration. The information is derived from literature review of innovation theories and information gathered at Locamation (the company active in this niche) about smart grids, electric vehicle charging and electric vehicle integration.

3.2.1 Selection and sampling

Many case studies use the company as the case (Piekkari, Welch & Paavilainen, 2008). Bryman and Bell (2011) state that a case in a case study can be a single organisation, a single location, a person or a single event. A technology field or innovation process is not named here (but is oftentimes considered as event). However Punch (2005) states that almost anything, from simple to complex, can be a case. The case is a phenomenon or some sort of occurring in a bounded context, like an individual, role, small group, organisation, community, nation and also a decision, policy or process and many other possibilities (Punch, 2005). Piekkari et al. agree with Punch that a case can be a whole industry, for example the study of Calori, Melin, Atamer and Gustavsson (2000) about industry differences. The case for this research is the electric vehicle integration innovation process in the Netherlands. Within this case are several units to be analysed and also a sub-case can be analysed that may contribute to the main case. Units to be analysed are mainly the stakeholders in the innovation process, which are specified in the section about stakeholders (see section 3.4.3). A sub-case in the case of electric vehicle integration technology can be a pilot-project for a specific electric vehicle integration technology. For sampling of the units the so called snowball sampling method will be used.

Snowball sampling starts with the initial contact with a small group of people that are (or appear) relevant for gathering information for the research. These initial people are used to getting to know others relevant for the research. So by doing the research the subjects for information gathering are becoming known. Bryman and Bell (2011) state that snowball sampling can be well used within a qualitative research setting.

3.3 Data collection

Data collection starts at the first starting point of the selection and snowball sampling process as shown here and is the result of the preliminary research on the innovation of electric vehicle integration technology. The stakeholders that come out of the snowball sampling will also be stakeholders in the TIS of electric vehicle integration technology.

Data collection is done in the form of qualitative in-depth interviews with these stakeholders. The interviews have an unstructured nature. On forehand the topics that will be addressed are clear, however there is room for the interviewees/interviewer to give direction to the interview by (unconsciously) pointing out important topics. Before the in-depth interviews are conducted an interview protocol is established. As much of the interviews are in person or otherwise by phone and lasted for around an hour each interview. The questions posed to the stakeholders are about their perception about the innovation of electric vehicle integration and their perception of the relationships and interactions with other stakeholders in the field or technological innovation system. More details about the interviewees and the posed questions for the stakeholder groups below.

Distribution network operators

Because electric vehicle integration technology could provide balancing services for the power grid, the technology could be very interesting for distribution network operators. In practice, electric vehicles will act as mobile energy storage units that can absorb excess energy and possible even discharge when needed. Grid operators will get a potential way to release stress on their electricity grid. That makes grid operators important stakeholders and furthermore they could give estimates of the potential value of vehicle-to-grid. In the Netherlands there are eight distribution network operators (Eclareon, 2011). The size of the distribution grid they operate varies substantially. There are three distribution network operators that have a large segment of the market: Liander, Enexis and Stedin. To get a good understanding of the power grid in the Netherlands and the opportunities for vehicle-to-grid all major distribution network operators were interviewed. At Liander Paul Bierman, head of vehicle-to-grid project was interviewed. At Enexis the interview took place with innovator Lennart Verheijen and at Stedin with expert asset manager Henk Fidder. Interviews started with a set of questions about their knowledge about electric vehicle integration and their (organisations) perspective towards this possible innovation. After that the interviewees were asked about the value perception of electric vehicle integration for their organisations through questions about costs, benefits, value creation, advantages and disadvantages. The next set of questions are focused on the stakeholders the organisation worked with on electric vehicle integration and how these stakeholders are mobilised and engaged (including their own organisation). In addition specific questions are asked about the influence of regulation, environmental or organisational changes and smart grids on the value perspective and engagement of their organisation towards electric vehicle integration.

Electric vehicle owners

As potential users of smart charging or a vehicle-to-grid system electric vehicle owners are a key source for benefits and barriers of electric vehicle integration. Difference between the interviews with electric vehicle owners and the other interviews is the fewer prior knowledge about the working of the electricity grid, the need for balance on the grid and therefor the need for electric vehicle integration. In general the interviews were shorter in comparison with the other interviews, also because of the different setting, often at electric vehicle charging sites. The interviews started with questions about their knowledge about electric vehicles and the different ways to charge it. After that the interviewees were asked about their perception of value of electric vehicles and if the integration of electric vehicles (by smart charging and/or vehicle-to-grid) would change that. Interviewees were asked if they already participate in projects for electric vehicle integration and how they could be engaged towards future projects. Specific questions were asked about the benefits electric vehicle integration would need to give them to offset disadvantages or overcome barriers like battery degradation and range anxiety.

Innovating organisation

In addition to the distribution network operators, the organisation working on the innovation itself is important. This is important to explore the links between electric vehicle integration and the current focus of innovating organisations on smart grids and specifically substation automation. The employees of the innovating organisation Locamation who are interviewed are those employees who (have done) work that has the most affinity with electric vehicle integration. For example some employees have worked on the project In4Energy, in which Locamation, among other things, worked on integration of substation automation technology and electric vehicle charging. Two employees at Locamation had a major role in this project and were both interviewed, Harold Kappert, program manager at Locamation and marketing manager Bas Mooijman. Also the manager product development at Locamation, Omar Mansour was interviewed. The interviews started with a set of questions about their knowledge about electric vehicle integration and their (companies) perspective towards this possible innovation. Continuing with a set of questions about projects already done in the field of electric vehicle integration and possible synergies with the field of work the organisation's focus is on at the moment. The next set of questions are focused on the stakeholders the organisation collaborates with when new products are developed, how they are engaged and mobilised. Specific questions are asked about the IN4Energy project and influence of the outcomes of that project on the perspective towards electric vehicle integration.

3.4 Data analysis

To analyse the data from the qualitative in-dept interviews with the different stakeholders analysis is done in four parts. The main analysis consists of the firstly the variation analysis to analyse value perception of stakeholders towards the innovation variants and secondly the stakeholder engagement analysis to analyse mobilisation of stakeholders (see Figure 5). Preliminary to the main analysis are the other two parts of the analysis, the basic analysis to analysis the technological innovation system and context analysis for breaking down important surrounding factors. Central in to the data analysis is the technological innovations system of electric vehicle integration technology. To analyse this TIS the functions of innovations systems are going to be used. However the TIS is only a part of the research and so the method for analysing the data needs to be broader.

As discussed the functions of innovations systems (Hekkert et al., 2007) can be used to describe and analysis the innovation and the (technological) innovation system around it. Markard and colleagues (2009) propose a method for the prospective analysis of technological innovation systems that consists of three parts: basic analysis, context analysis and variation analysis. In the basic analysis the innovation itself is looked into (e.g. technological, market, socio-economic and environmental aspects) as well as the stakeholders, institutions and networks in the TIS.

The context analysis part of Markard and colleagues' method (2009) is used as proposed for analysing the landscape developments, (changes in) socio-technical regimes and complementary as well as competing innovation (systems) and is mainly used to get insight in the surrounding context of electric vehicle integration.

The variation analysis part is used to distinguish the variations in the technology innovation and determine the value perception of the different stakeholders with those variations.

Added to it is the analysis of stakeholder engagement with the innovation variants. This last part of the analysis will consist of analysing the level of engagement stakeholders have with (a certain variant of) the innovation and if stakeholders can be mobilised. Mobilisation is analysed considering the value perspective of the different stakeholders. Important in this part of the analysis is the difference between bricolage and breakthrough aspects of the stakeholders' engagement, see Figure 5.

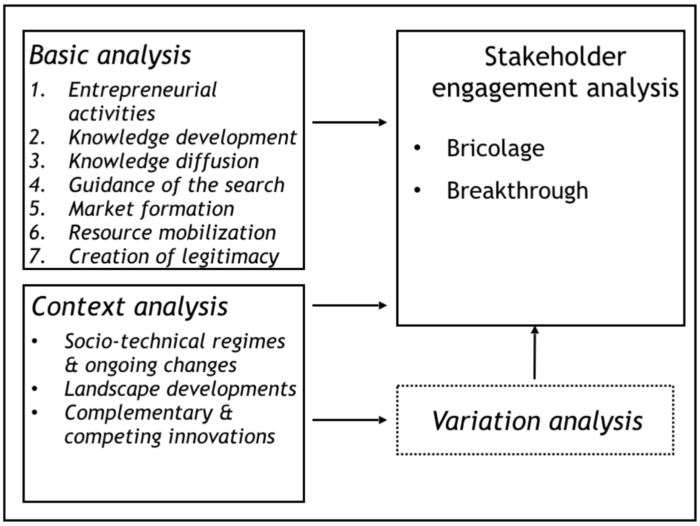

Figure 5 Research method

3.5 Operationalisation

In this final part of the method chapter a clarification is given on what aspects of the innovation (process), the technological innovation system and stakeholder engagement will be looked into.

3.5.1 Innovation and associated TIS

The first part of the research looks at the innovation of electric vehicle integration technology and the associated technological innovation system. For this basic analysis the functions of innovations systems will be used. The results will give important information about the working and performance of the technological innovation system and the innovation of electric vehicle integration itself. The functions of innovations systems are explained in detail in Appendix D and here each function will be operationalised to see what data is needed for this part of the research.

Function 1: entrepreneurial activities

The working of the entrepreneurial activities function can be looked into by analysing the number of new players that participate in the technology field, the diversification activities of incumbent stakeholders and the number of tests that are done with the innovation.

Function 2: knowledge development

The performance of the knowledge development function can be looked into by analysing the amount of R&D projects, patents and investments in R&D.

Function 3: knowledge diffusion through networks

The working of this function of innovation systems can be examined by analysing the number of conferences and meetings about the innovation and the quality and quantity of network connections, for example in the form of industry associations.

Function 4: guidance of the search

The functioning of guidance of search can be indicated by looking into the general expectations that exist on the innovation or new technology (e.g. more positive or negative papers in professional journals), another indicator could be targets that governments or industries set regarding the use of a specific technology (Hekkert et al., 2007)

Function 5: market formation

Niches for specific applications of a technology and also favourable tax regimes can help to establish a market, so the number of niche markets and specific tax regimes can indicate the performance of the market formation function of innovation systems (Hekkert et al., 2007)

Function 6: resource mobilisation

Financial and human capital resources can be made available with R&D funds, so the amount of funds is an indicator of this function, another is the perception of core stakeholders that access to resources is a problem or not (Hekkert et al., 2007).

Function 7: creation of legitimacy/counteract resistance to change

How successful the interest groups of the new technology are in their lobbying activities to create legitimacy for the innovation determines the implementation of the innovation. Analysing those interest groups (e.g. number and size) can give an indication of the performance of the last function of innovation systems.

3.5.2 Context elements

First those factors need to be examined, that have influence on the technological innovation system of electric vehicle integration technology, complementary TIS and the incumbent regimes, but are not influenced (easily) the other way around. These factors form the landscape. Typical aspects that need to be examined according to Geels and Schot (2007) are economic growth, demographic aspects, cultural values and issues like climate change, unemployment and security. The developments in these aspects need to be addressed.

Which technologies that exist already can fulfil the socio-technical function that is also fulfilled by electric vehicle integration technology, this can be the whole socio-technical function but also parts of it. These established technologies and their associated institutions and infrastructures form the socio-technical regimes the TIS of electric vehicle integration technology has to compete with.

Last part of the context is a very broad overview of possible complementary and competing innovations, to put value perspectives of stakeholders in a frame of reference. Competing innovations can (partly) fulfil the same socio-technical function as electric vehicle integration. Complementary innovations help the electric vehicle integration TIS to replace parts of or whole incumbent regimes.

3.5.3 Value perception of socio-technical variations

Value perception of stakeholders differs between the different socio-technical variations of electric vehicle integration. To distinguish the different socio-technical variations of electric vehicle integration technology, the key dimensions of these variations need to be clear. From the preliminary research two important dimensions of different electric vehicle integration technologies became clear. Whether or not the integration is bi-directional (only charging is controlled vs. charging and discharging) and at what location or level in the grid the electric vehicles are integrated. These key dimension have great impact on the perceived value of electric vehicle integration, as the advantages, disadvantages and barriers to adopt and use the integration technologies are different.

When looking at the bi-directionality dimension there are two forms of electric vehicle integration. First is the directional integration, which means that only the charging is controlled, this is often called smart charging. Second is the bi-directional integration, where besides controlled charging the electric vehicle can also discharge energy, this is often called vehicle-to-grid. The location/level dimension of integration can also be divided in mainly two categories. First is the integration of electric vehicles at the homes of electric vehicles owners, which is technically speaking not part of the power grid (because it is behind the electricity meter). Second is the integration of electric vehicles at the power grid level, which can be at neighbourhood level or primary/secondary substations.

Roughly there are four variants and they need to be evaluated at key characteristics that are important for electric vehicle integration technologies. From the preliminary research became clear that implementation costs, technology readiness, perceived benefits and general expectations of the technology are important for distribution network operators and innovating organisations. However for electric vehicle owners the barriers and disadvantages of the electric vehicle battery use are important triggers for value perception, because range anxiety and battery degradation have great impact on the way people use their electric vehicle. Understanding the ability to mobilise these stakeholders is done by examining the level of perceived benefits for electric vehicle integration that offset these barriers and disadvantages.

3.5.3 Operationalisation stakeholder engagement

Stakeholders' involvement with the innovation process is different for several stakeholder groups.

Designers and producers engagement

Collaborative networks between designers, producers and suppliers with reliability as important criteria. Or are those collaborative networks not evident and is not reliability of the innovation but efficiency the most important criteria. Several scale-up steps and in between them development processes. The collaborative networks between designers, producers and suppliers can be measured by looking into the amount of industry associations that are formed, the amount of producers, designers and suppliers taken part in them and the perceived collaboration by the stakeholders involved in them.

Users

Multiple users that give direct learning input, maybe incentivised to give that critical input. Can be measured by the amount of users that is involved with the design, production and evaluation process of the innovation. Another indication is the perceived influence groups of users have on the innovation process and if the input is direct or indirect. Mobilisation of the users in an association that can compare performance of different innovations. Also the presence of incentives for user (groups) to participate in the innovation process is in indicator of a bricolage or breakthrough approach.

Evaluators

Evaluation of new technology development is important for diffusion of knowledge in a technology field. Evaluators that are engaged in the process use a co-development approach, which means that evaluators not only select a good innovation but also co-develop innovations to improve them. If testing standards co-evolve with technology development, a better evaluation of new technology development can be done and stakeholders have more insight in technology development. In the electric vehicle integration field this could mean that not only smart charging is evaluated but also the newer vehicle-to-grid solutions. The engagement of evaluators can also be looked into by examining if test and research centres (e.g. stichting ElaadNL) only select innovations on certain criteria or are they working together with producers and designers to improve concepts to obtain a better performing end result.

Regulators

Regulators can strategically steer activities of several stakeholders, maybe with the help of incentives in the form of grants, subsidies or specific policies. So the best indicator for regulators involvement with the innovation process is the amount and magnitude of grants, subsidies and specific policies that are in favour of electric vehicle integration technology. Furthermore it is important if the grants and subsidies are constant and give stakeholders more certainty for investments in the technology. The effectiveness of favouring policies can be determined by the overall involvement of the other stakeholder groups (e.g. producers, users and evaluators) that it has provoked.

4. Results

In this chapter the results of the research will be summed up. The structure is as follows: first the value perception of stakeholders with regard to different socio-technical variations are described, second are the results about stakeholder engagement and mobilisation, after that the innovation of electric vehicle integration technology and the associated technological innovation system.

4.1 Value perception of different socio-technical variations

The value perception of the different socio-technical variations of electric vehicle integration will be discussed in this section.

The perceived value for stakeholders is the difference in benefits stakeholders perceive and the perception of costs electric vehicle integration brings with it. There is consensus about the high costs for hardware and software that needs to be controlled and the ICT and communication needed. In addition electric vehicle integration can have impact on the battery of the electric vehicle, because it is used in other ways then initially intended by the car manufacturer. Another point to take in mind is reliability. Reinforcing the grid by adding copper wires and increasing transformer capacity is very reliable. Instead this is replaced by ICT systems that have a lower reliability, “ICT has a lower reliability by definition” (Verheijen, Innovator at Enexis). Lower reliability of the grid could cause more outages, which have to be taken in account when calculating the costs of electric vehicle integration.

Distribution network operators agree there is a connection between grid status measurements and the need for stabilising measures. If somewhere on the network congestion takes place, the charging or discharging of electric vehicles on that part of the network can be controlled. This connection is not direct, but divided in several layers, “with communication between those layers using the Open Smart Grid Protocol” (Fidder, expert asset manager at Stedin). Distribution network operators are not directly going to control the charging point. This has influence on value perception and mobilisation of DNO’s. The distribution network operator provides information about the congestion on the grid enabling energy providers to align energy pricing on certain times of the day with the rate of congestion. Consumers decide when to use how much energy and whether to use energy from the energy supplier or from their own PV-system. All these signals and information are combined by a central operator or aggregator to form a flexibility market. It is not yet clear who is going to fulfil the aggregator role. Possible organisations are the mobility service providers/ charging point operators (e.g. GreenFlux, EV-Box and The New Motion) or energy suppliers. The central operator or aggregator is needed for a correct working of electric vehicle integration. If it is clear which organisations are going to take that role it has a positive impact on mobilisation of distribution network operators.

4.1.1 Smart charging

Smart charging is a modern term for controlling the rate an electric vehicle is charging when it is connected to a charging station. The dimension of which level the electric vehicle integration is taking place is not very useful or applicable, because it does not matter significantly where the smart charging electric vehicle is located. The fact that the electric vehicle is smart charging instead of dumb (fasted charge rate possible from beginning till electric vehicle battery is full) means that it is less a burden on the network. Bierman (Project manager electric vehicles at Liandon) states: “if electric vehicles are charged at different times and distributed locations the usage of the network can be improved”. The network being connected everywhere means smart charging at a low level in the power grid is as good as smart charging at higher levels.

The distribution network operators indicate that the power grid in the Netherlands is fairly solid and is at the moment not giving any problems regarding charging the electric vehicles on the road today. With current electric vehicle adoption, no value is added regarding to preventing grid problems related to electric vehicle charging. Depending on the type of electric vehicles and the type of district problems can arise starting at ten electric vehicles charging at the same time. Those problems mainly occur at the low and medium voltage networks and not at the high voltage networks. This was recently shown in a test in Lochem, where several charging electric vehicles in combination with high demand of other appliances caused the power grid to fail (Energeia, 2015).

The caused disturbance on the low voltage network was visible on the medium voltage network, however not causing any problems, neither at the substations.

4.1.2 Vehicle-to-grid

Vehicle-to-grid differs from smart charging through the bi-directional link between electric vehicle supply equipment (EVSE) and the electric vehicle, making controlled charging and discharging of the battery possible. Degradation of the battery particularly plays a role when batteries of electric vehicles are used to supply energy back to the grid. However it strongly depends on the speed and depth of discharge. The impact and cost of discharging have to be tested in practice. “The electric vehicle is used differently than specified by the manufacturer, making predictions about battery performance difficult” (Bierman, project manager electric vehicles at Liandon). That is why distribution network operators work together with car manufacturers like Mitsubishi in vehicle-to-grid projects. However as of today the impact and costs are not yet clear. This has significant impact on the value perspective of several stakeholders (especially electric vehicle owners and manufacturers). The lower range of electric vehicles compared to internal combustion engine vehicles resulted in range anxiety. Lack of clarity about impact and costs of battery degradation has significant negative impact on value perception for electric vehicle owners if it is not offset by financial compensation. Mobilisation of electric vehicle owners depends on this compensation. More about the value perception in the next section.

4.1.3 Value perception of electric vehicle integration technology

There are several ways to look at the balance between costs and benefits of smart charging and vehicle-to-grid solutions, which could give insight in the value perception of stakeholders. Smart charging seen from the point of view of the distribution network operator shows a scale tipping in favour of smart charging. For vehicle-to-grid this is not so clear yet, because of aforementioned lack of clarity about battery degradation costs. “Also the acceptation of electric vehicle owners of smart charging and vehicle-to-grid plays a vital role in the value determination” says Fidder (expert asset manager at Stedin). However electric vehicle integration needs to be in favour for all stakeholders that are involved with it. For the system as a whole it must be estimated if local storage capacity is valuable. The suppliers of the capacity (electric vehicle owners) need to be compensated for it. If electric vehicle integration means reinforcements of the grid are not needed, this means costs are avoided. Because distribution network operators in the Netherlands are compensated for their costs, avoided costs benefit the whole society. For a working system these avoided costs need to flow back to the stakeholders that make those savings possible, the electric vehicle owners who participate. This could be done with variable tariffs for charging and/or discharging on certain moments. However this is not allowed yet with today’s legislation. More about this in the next section about stakeholder engagement, in the paragraph about regulators.

The distribution network operators agree that it is difficult to indicate the value of smart charging and vehicle-to-grid. The estimated value is in the billions, however the calculations are complex and many assumptions are done. On one hand the increased demand of electric vehicle charging can be met by reinforcing the distribution grid. This means putting enough copper wires in the ground to meet the demand when everybody plugs in their electric vehicle at 6 p.m., which is very costly. On the other hand are solutions like smart charging and vehicle-to-grid. These solutions bring costs too, however much less than all the copper needed to reinforce the distribution grid. The distribution network operators give several additional reasons for the difficulty of calculating the value. Often only the costs of electric vehicle charging are taken into account, however the grid connection needed for a charging station has to be paid to the distribution network operator. Depending on the type of connection this can be 200 to 800 euro annually. Also is it not clear yet if the smart solutions

> *“Netverzwaringen kunnen worden uitgesteld, maar daarmee is nog niet bekend welke waarde dit heeft, omdat het lastig te kwantificeren is.”*
> *H. Fidder – Expert Asset Manager at Stedin*

are needed at all, depending on the adoption of electric vehicles. Furthermore the quality of the grid and adoption of fluctuating sustainable energy sources plays a role also. Wires with three phases that are not connected in the right way can burden one phase disproportionally, easily overloading it when electric vehicles are charged at this phase. Resolving the phase imbalance can reduce the load on the network and prevent the need to reinforce the grid. Smart charging is less complicated than vehicle-to-grid, because only the charging process is controlled, however it is very valuable for distribution network operators. The development of smart charging plazas ensures that several electric vehicle charging stations can be combined at one grid connection point.

The most important stakeholder groups that are involved with the integration of electric vehicles in the power grid are electric vehicle owners, distribution network operators, regulatory organisations and innovating organisations. Electric vehicle owners are the users of the electric vehicle integration technology and are therefore critical for innovation process and implementation. The main benefits of electric vehicle owners are lower costs for charging and efficient use of their own sustainable energy production (e.g. with a PV-system). Important barriers are possible lower range of their electric vehicles and degradation of the electric vehicles battery. Distribution network operators are also users of the technology but next to being user, DNO's are designing/producing and evaluating technological innovations. Distribution network operators are therefore a very important stakeholder group in the innovation process of electric vehicle integration. Benefits for DNO's are the prevention of capacity and power quality problems, more efficient use of the current power grid capacity, and more flexibility in the power grid. Innovating organisations can be car manufacturers diversifying and organisations focusing on electric vehicle integration technology. They take the role of designer and producer of electric vehicle integration technology. Diversifying car manufactures can increase the value and demand of electric vehicles, drawbacks are the degradation of the battery that is used for more than mobility only and lower range. Regulatory organisations also play a significant role in the innovation process. Regulations prohibit the working of some electric vehicle integration technologies and also exceptions have to be arranged to even test new innovations. Regulations in the form of net metering greatly enhance the use of PV-systems, a complementary technological innovation system, which would work in favour of electric vehicle integration technology. However on the other side the same regulation suppresses the demand for vehicle-to-grid and other energy storage technologies in a way not imaginable. "Distribution network operators are discussing with regulators about exceptions for experimenting with controlled charging" (Verheijen, Innovator at Enexis). Regulatory organisations and their regulations have a lot of power and are of great influence on the TIS of electric vehicle integration and its surroundings.

The difficulty of quantifying the averted distribution network investments, through uncertainty about grid quality, sustainable energy and electric vehicle adoption, leads to uncertainty about perceived benefits and lowers perceived value. The impact of this perceived value on engagement and mobilisation of stakeholders is elaborated in the next section.

4.2 Stakeholder engagement and mobilisation

In this section of the results chapter the details about encountered approaches to stakeholder engagement and mobilisation of stakeholders.

Producers and designers

Every single one of the interviewed distribution network operators worked on smart charging, this cannot be said about vehicle-to-grid. However, distribution network operators not working on vehicle-to-grid, work closely together with the network operators that are investigating V2G. Not being competitors allows the distribution network operators to work together and use their resources efficiently. An example of this collaboration between distribution network operators is ElaadNL. In this knowledge and innovation centre an overview is acquired of the measures to be taken to ensure that with the emergence of electric driving and sustainable charging the network remains reliable and affordable (ElaadNL, 2015).

The lower engagement of distribution network operators with vehicle-to-grid is due to complexity and uncertainty technically and legal wise (Verheijen, Innovator at Enexis), also “it remains a question what the added value of vehicle-to-grid will be”. Among other things since the costs of vehicle-to-grid are not clear. That is why collaborative networks arise between electric vehicle manufacturers and network operators. The impact and cost of discharging have to be tested in practice. Distribution network operators work together with car manufacturers like Mitsubishi in vehicle-to-grid projects. Bierman (project manager electric vehicles at Liandon) states “Mitsubishi executes field tests to see the impact of vehicle-to-grid in terms of battery degradation, to get insight in the costs of vehicle-to-grid.” When the costs of vehicle-to-grid are clear, stakeholders can gain a better understanding of the value of vehicle-to-grid for them. This could increase mobilisation of stakeholders for vehicle-to-grid.

Users

Electric vehicle owners need to be actively asked about the value propositions they see, conditions they have, what they think are acceptable costs and what benefits making available an electric vehicle should yield. Nearly all interviewed electric vehicle owners state they would participate in electric vehicle integration programmes, under the condition the disadvantages are offset with financial compensation. Electric vehicle owners could often not indicate what an appropriate compensation would be, some indicated free charging at off-peak times would be a good incentive. With regard to vehicle-to-grid electric vehicle owners are very cautious. Mainly because of two reasons, first not seeing the benefit of partly discharging an electric vehicle and secondly the uncertainty about costs of battery degradation. This has significant negative impact on the mobilisation of electric vehicle owners for vehicle-to-grid. Electric vehicle manufacturers play a role in mobilising electric vehicle owners. By offering electric vehicles to integration projects and leasing batteries to owners, electric vehicle manufactures take care of the uncertainty and risk of battery degradation. Stakeholders with the same interests bundle their activities in interest groups. Examples of interest groups participating in the integration of electric vehicles are branch organisation DOET (Dutch Organisation for Electric Transport), eViolin (charge station operators and service providers) and the Formula E-Team (public-private partnership).

These associations mobilise stakeholder groups and can together give critical input on the different innovation developments. It is also important to look at connections between different innovation projects that are being carried out. Projects can complement each other; however several projects

> *“Weet jij hoe ik deze nieuwe auto kan opladen aan deze paal?”*

with exactly the same goal and way of working towards that goal have to be avoided. Especially if the projects are funded with government grants, too much duplication of work could be waste of public money. Some overlap between projects cannot be prevented and is not needed either, because it can be a base for competition. This is beneficial for the outcomes of the projects. As mentioned before the engagement and mobilisation of electric vehicle owners is important. However emphasising too much on the consumer/driver could limit the range of options that is being explored. Options need to be shown to consumers, since their needs are not always known even by themselves states innovator Verheijen (Enexis).

Evaluators

The distribution network operators in the Netherlands are combined into the branch organisation Netbeheer Nederland. In this branch organisation several options for integration of electric vehicles are discussed. A first evaluation of electric vehicle integration options can be found in Appendix B.

> *"Hier bij stichting E-laad testen we laadpalen en smart charging oplossingen"*
> *Onoph Caron – CEO at Stichting E-laad*

Regulators

Apart from dividing the work on electric vehicle integration, there is another reason for some distribution network operators not to work on vehicle-to-grid. This reason is the legal complexity that comes with vehicle-to-grid solutions. This complexity does not only hold back distribution network operators but also electric vehicle manufacturers and innovating companies, states Omar Mansour (manager product development at Locamation). Basically someone using an electric vehicle to feed back into the grid becomes an energy supplier, with all the legal obligations that come with it. Solving these legal problems takes time and collaboration between several stakeholders. Smart charging is less complicated, because only the charging process is controlled. Engaging stakeholders with the integration of electric vehicles in the distribution grid is often done by consultation with these various stakeholders. Furthermore stakeholders work together on pilot projects. In these projects often new technologies are developed and new services are tested in practice. Frequently the projects are funded partially by grants of national or European government. For example the grant of the Ministry of Economic Affairs for the IPIN (Innovation Program for Intelligent Networks) project in Lochem (NL Agency, 2012). The stakeholders in pilot projects are a combination of technology suppliers, charging station suppliers, smart (energy) system suppliers, and sometimes car manufacturers and governments. Municipalities participate less often, however they want to be involved in some way and be kept informed about what is planned in their municipality. It can be said that the engagement of regulators is important for the mobilisation of other stakeholders in the innovation process.

The Innovation Program for Intelligent Networks is a great example of a government policy that engenders a large amount of stakeholders to be involved with the innovation. It is an obligation for distribution network operators to give a reinforced grid connection if needed for the connection of a charging point. Impediments for the integration of electric vehicles in the distribution grid are a negative business case for public charging stations resulting in not enough public charging stations, legislation prohibiting variable tariffs for energy and legislation prohibiting distribution network operators to control charging. Distribution network operators are in discussion with national government and regulator to get permission to experiment with controlled charging. In addition if variable tariffs are permitted they could be used to incentivise owners of electric vehicles to charge at other times or other places, resulting in more efficient grid usage. The only variability in tariffs allowed at the moment is the difference between day and night tariffs. Especially for vehicle-to-grid the expected change in net metering policies can have significant influence. Today owners of a PV-system can use energy supplied back into the grid to offset energy used from the energy supplier (Elektriciteitswet, 1998). This means the fee solar penal owners get for energy supplied back to the grid is equal to the price they pay for using energy from the energy supplier. If net metering policies are changed and fees for supplying back energy into the grid are lowered it becomes more interesting to store energy locally for later use. It is important to work together with stakeholders like national government departments and regulators to stay informed about possible changes in policies and the influence it might have on electric vehicle integration.

4.2.1 Breakthrough or bricolage approach

The integration of electric vehicles in the grid often involves car manufacturers like Mitsubishi, Nissan and Mercedes. In addition ICT companies, energy suppliers, program managers, distribution network operators, charging station suppliers, mobility service providers, universities, and research institutions are involved. Also local governments like provinces and municipalities and national government departments like the Ministry of Economic Affairs participate. For example the municipality of Amsterdam participates in a vehicle-to-grid project indirectly as part of the Amsterdam Economic Board. Consumers and owners of electric vehicles can be engaged in various ways. In Lochem consumers are united in cooperative LochemEnergie, which actively participates in various projects. Distribution network operators agree it is important to engage owners of electric vehicles in electric vehicle integration project. However there is no consensus about whether electric vehicle owners themselves have a clear understanding of their needs, now or in the future. If the solutions that are developed have no value in the view of electric vehicle owners, implementing them becomes difficult. This gives a clear indication of whether a bricolage or breakthrough approach is being used with the innovation of electric vehicle integration technology.

If the innovation organisations choose for rapid developing of the design that is the most efficient and works the best in their opinion, without using the critical input of other stakeholders (in this case the users) the design may fail in the end if electric vehicle owners see no added value in it. This would be titled as a breakthrough approach. However the network operators agree on the importance of involving owners of electric cars and state that reliability for the users is an important criteria for selecting development choses.

4.3 Electric vehicle integration technology

This part is about the innovation of electric vehicle integration technology and the technological innovation system that surrounds it.

The electrification of the transport sector is seen as a development that will have a major impact on the distribution grid. Expectations about how many electric vehicles the distribution network operators have to deal with in the coming years vary. However in the energy agreement (*Energieakkoord*) is stated that as of 2035 every new sold passenger car should have the ability to drive without emitting any local CO_2 (Sociaal-Economische Raad, 2013). The majority of the car manufacturers respond developing electrified models and introducing either full or hybrid electric vehicles in their line-up (Dijk, Orsato & Kemp, 2013). Distribution network operators agree it is important to look into the specific impact of electric vehicle adoption on operating the distribution network. It is the distribution network operator's task to distribute energy to consumers in a reliable, efficient and economically justified way. The power needed to charge an electric vehicle is high, if many electric vehicles charge at the same time it results in a power spike on the network. Simply reinforcing the power grid to offset the added demand is not efficient and grid operators agree they have to look into smart solutions and electric vehicle integration technology.

4.3.1 Functions of the electric vehicle integration TIS

Function 1: entrepreneurial activities

Not every distribution network operator is working on vehicle-to-grid. However electric vehicle integration is on the agenda of all the distribution network operators. Distribution network operators, not working on vehicle-to-grid, work closely together with the network operators that are exploring V2G.

The distribution network operators can be seen as incumbent stakeholders, because they are part of the centralised energy generation/distribution regime. The activities of network operators in the field of electric vehicle integration can be seen as diversification activities. The electric vehicle integration technology could help to overthrow the incumbent regime of centralised energy generation/distribution, leaving network operators with much less work. By diversification of their activities they become part of the electric vehicle integration TIS also. This really shows the complexity of the transition and how interwoven the stakeholders of the different regimes and innovations (TIS's) are. Another stakeholder group that is showing forms of diversification are the car companies. For example Nissan that is not only building cars anymore but also designing and producing V2G systems. The fact that Nissan is building electric vehicles that are capable of bi-directional energy flows, instead of electric vehicles that can't, or even instead of cars with an internal combustion engine is clear example of diversification of an incumbent stakeholder and a move from stakeholders out of the regime and in different technological innovation systems.

The Netherlands Enterprise Agency published a list of players in the smart grid sector in the Netherlands (Netherlands Enterprise Agency, 2014). This publication lists over 100 organisations participating in the technology field of smart grids. A lot of these organisations are also looking into the integration of electric vehicles in that smart grid. The vehicle-to-grid project in Lombok Utrecht is a good example of a live V2G project, an example of a smart charging/grid project is Lochem. The Joint Research Centre (JRC) of the EU states that there are 78 projects about the storage of energy in electric vehicles that received funding of one of the EU member states or from the EU itself (JRC, 2015).

Function 2: knowledge development

As mentioned in the first function the amount of Research and Development projects in Europe receiving funds from the EU or it states is 78. A search for patents about vehicle-to-grid delivered an amount of 129 patents that included statements about vehicle-to-grid. Patents about smart charging where even more abundant. The exact amount of patents related to smart charging technology for electric vehicles could not be determined because smart charging is often related to a range of topics around electric vehicles and also other systems (e.g. efficient energy flows to the battery to prevent battery degradation). Not being able to determine the exact amount of smart charging patents also means no exact number of patents for electric vehicle integration technology. However the amount of 129 patents solely for one electric vehicle integration technology variation, namely V2G, means the technology field is active and knowledge is being developed. These patents are global and gives an indication of the state of the technology field of electric vehicle integration in the world.

Function 3: knowledge diffusion through networks

The quality and quantity of network connections can give insight in the knowledge diffusion networks. Stakeholders with the same interests bundle their activities in interest groups and industry associations, forming network connections. Examples of interest groups participating in the integration of electric vehicles are branch organisation DOET (Dutch Organisation for Electric Transport), eViolin (charge station operators and service providers) and the Formula E-Team (public-private partnership). Amount in total is not measured.

Function 4: guidance of the search

The general expectations that exist on the innovation of electric vehicle integration technology can be found in literature and studies on this technology field. An assessment of this literature is already done in the preliminary research that preceded the main part of this research. Broadly it can be said that scholars are positive about electric vehicle integration in general, however the opinions about specific variants of electric vehicle integration technology differ greatly. Especially vehicle-to-grid divided the opinions and results of scholars and studies. About another variant, smart charging of electric vehicles, is more consensus, in the future it can be very important and beneficial (Garcia-Valle & Lopes, 2012).

> *"We praten met heel wat belangenverenigingen, zoals DOET, eViolin en het Formule E-Team."*
> *L. Verheijen – Innovator at Enexis*

Even the scholars that are sceptical about vehicle-to-grid see that the integration of electric vehicles is going to be needed (Mullan, Harries, Bräunl and Whitely, 2012). Mullan et al. state that the most feasible option is that of demand side management and smart charging and that this is recognised by grid operators around the world. The distribution network operators in the Netherlands confirm this, all the DNO's have electric vehicle integration on their agenda. If they are not working on vehicle-to-grid themselves they work together with DNO's that are investigating vehicle-to-grid. Targets that governments or industries set regarding electric vehicle integration could not be found, the government targets are set regarding the use of electric vehicles and the deployment of charging equipment. These targets have great positive influence on the innovation of electric vehicle integration. The fact that distribution network operators are obligated by law to operate the distribution networks in the most efficient way enforces DNO's to look into electric vehicle integration to avoid the need of more capacity of electricity cables in the ground.

Function 5: market formation

In line with the government targets, discussed above, the specific tax regimes that could indicate the formation of a market are for the use of electric vehicle and the deployment of charging equipment. The favourable tax regime for PV-systems in the form of net energy metering is a great example of the complexity of the technology field of electric vehicle integration. Net metering greatly increases the use of PV-systems for renewable energy generation and more distributed energy generation improves the business case for electric vehicle integration technology. However net metering is also the main reason that owner of PV-systems have no need to store energy generated from their solar panels, because delivering back energy is valued equally to energy consumed from the grid. More about net metering in the regulators part in the results section about stakeholder engagement (Chapter 4.4). ZigBee Alliance (2010) estimated that the global V2G technology market will grow from 1.5 billion dollars in 2015 to 10.5 billion dollars in 2020.

Function 6: resource mobilisation

The distribution network operators state that not being competitors allows them to work together and use their resources efficiently. To fully understand the resource mobilisation function of the electric vehicle integration TIS it is useful to look into the amount of (R&D) funds that are available for projects and organisations operation in this innovations field. In Appendix A the complete results of this exploration can be found. In general it can be said that there are plenty of opportunities for funds for electric vehicle integration in the Netherlands.

Function 7: creation of legitimacy/counteract resistance to change

There are no interest groups that specifically focus on the integration of electric vehicles. Most interest groups in the Netherlands take a broader perspective and focus on electric mobility. So it is difficult to analyse the successfulness of the interest groups towards the integration of electric vehicles.

> *“Wat bijvoorbeeld mee zal spelen is de verwachte versombering van de salderingsregeling”*
> *P. Bierman – Project Manager electric vehicle related projects at Liandon/Alliander*

4.3.2 Context elements

This part will consider the different context elements that surround the TIS of electric vehicle integration technology. Divided in the landscape factors, incumbent regimes and complementary as well as competing technological innovations (systems). At the end of this part the theoretical framework can be filled in.

Landscape factors

Biggest landscape factor in favour of the electric vehicle integration innovation is climate change. It has not only direct influence on the TIS of electric vehicle integration technology but also a large influence on complementary TIS's like the electric vehicle TIS and the renewable energy production TIS. To be more specific climate change can be divided into separate landscape factors, like global warming and CO^2 levels in the earths atmosphere.

Expectations about how many electric vehicles the distribution network operators have to deal with in the coming years vary. However in the energy agreement (*Energieakkoord*) is stated that as of 2035 every new sold passenger car should have the ability to drive without emitting any local CO_2 (Sociaal-Economische Raad, 2013). The majority of the car manufacturers respond developing electrified models and introducing either full or hybrid electric vehicles in their line-up (Dijk, Orsato & Kemp, 2013).

Incumbent regimes

Incumbent regimes are the transportation regime that is based on the combustion engine and the centralised energy production system. Other regimes that are working against the electric vehicle integration technology TIS are the current technologies used for balancing the grid. Examples of these technologies are the ramping up and down of generating gas plants and the demand side management of large quantities of energy using companies.

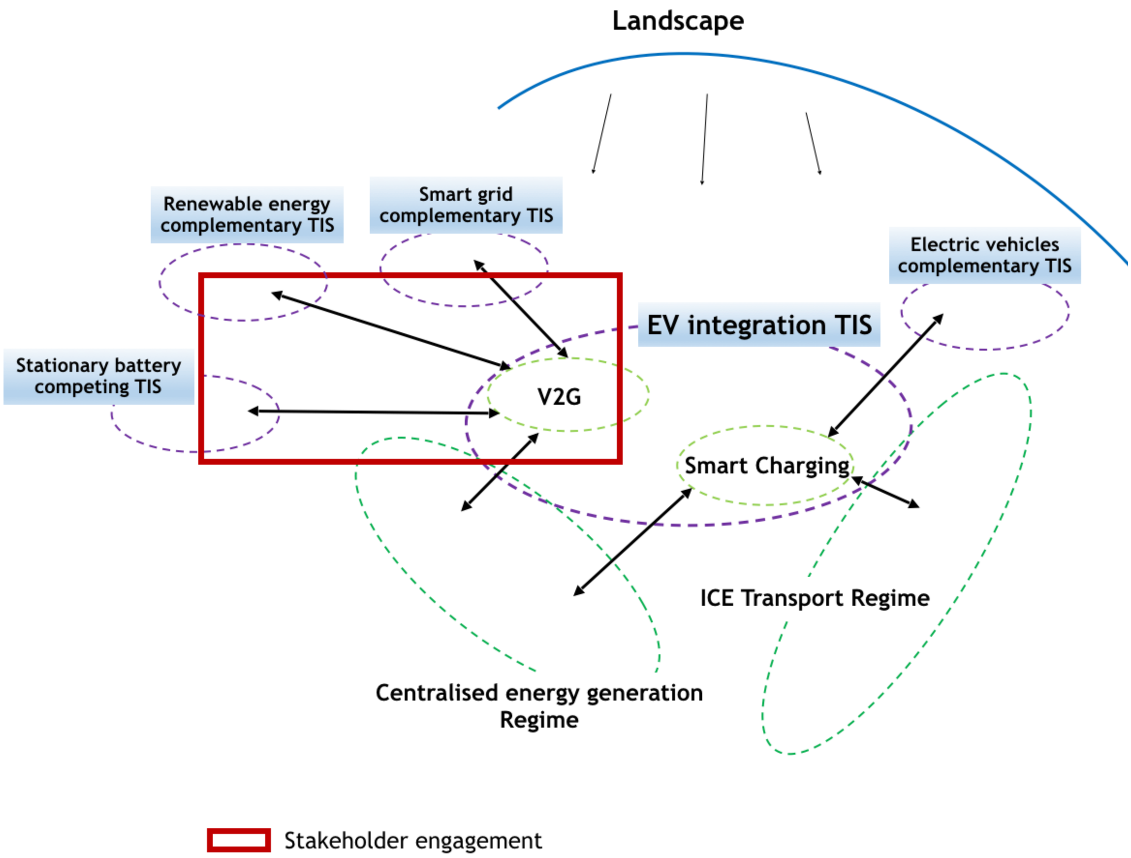

Figure 6 Electric vehicle integration TIS and context elements

Complementary and competing innovations

Complementary are the innovations that can be bundled as smart grid technology, the innovations that can be bundled as distributed renewable energy production and of course the electric vehicle innovation itself. Competing to some part are stationary battery systems, both at the level of households and the level of neighbourhood and higher levels of the grid. Competing are also other new grid balancing technologies.

Vehicle-to-grid solutions are especially usable together with distributed sustainable generation. In a district with many homes delivering back energy using PV-systems the low voltage network could be overloaded. By storing this energy in the batteries of electric vehicles and exchanging it locally the load on the distribution network is limited. “If a great amount of energy is exchanged locally, hence individual homes that can generate and also store energy, capacity problems can be avoided” (Bierman, project manager electric vehicles at Liandon). Today net metering causes the fact that there is no need for energy storage for PV-system owners yet.

It is agreed upon that for smart charging and/or vehicle-to-grid solutions measurements have to be done in substations and therefor automation and digitalisation of substations is needed. Current and voltage levels have to be measured with a 15 minute interval to be able to determine the status of the network. It may not be necessary to measure current and voltage levels in every district. If districts are very similar in size, type of housing and type of cables measurements in one district could be used for other districts with an uncertainty margin. The expensive measurement equipment makes it profitable to explore if this uncertainty margin can be taken for granted. In addition local weather forecasts are needed to correlate measurements of the grid status with the amount of solar radiation. With all this information the smart charging and vehicle-to-grid systems can be adjusted to stabilise the grid.

5. Conclusion

What is the value of electric vehicle integration for the various stakeholders that are involved in the development of electric vehicle integration technology and how can these stakeholders be mobilised in order to shape the direction of the outcome of the innovation process?

The sub-questions for the research are answered to give a legitimate answer to this complex research question.

What is the perceived value of stakeholders with regard to the different socio-technical variations of electric vehicle integration?

The two main technological trajectories for electric vehicle integration are smart charging and vehicle-to-grid. Smart charging being controlling the charge rate when an electric vehicle is plugged in, vehicle-to-grid being controlled charging and controlled discharging possibilities. Roughly speaking vehicle-to-grid has the largest possible benefits, is the most complicated (technical and legal wise), takes the most time and resources to apply in practice, and has some distinct disadvantages like battery degradation. Smart charging on the other hand has less possible benefits, is easier to implement (technical as well as legal), could be realised faster and with less resources, and has no distinct drawbacks. There is consensus about the fact that electric vehicle integration is important to keep the gird balanced. Smart charging, having no distinct drawbacks and several benefits, has higher perceived value compered with vehicle-to-grid. Smart charging being the relative less difficult approach to electric vehicle integration engages more and a broader spectrum of organisations. Many organisations have not yet heard much about the specific working of vehicle-to-grid, which forms their perspectives towards V2G less positive, followed by lower engagement levels.

Perceived value of electric vehicle owners with regard to electric vehicle integration differs for smart charging and vehicle-to-grid. The uncertainty about battery degradation costs and lower range makes value perception of vehicle-to-grid dependent on the amount of financial compensation. Lower charging costs through smart charging electric vehicles is perceived valuable under the circumstance that range is not lowered. Distribution network operators have positive perceived value of electric vehicle integration, however the difficulty of quantifying the averted distribution network investments, through uncertainty about grid quality, sustainable energy and electric vehicle adoption, leads to uncertainty about perceived benefits and lowers perceived value.

An innovating company already operating in the technological innovation system of smart grids, has a significant advantage when considering to invest in a technology that is in a complementary TIS. Because of mutual stakeholders and networks, influencing factors and other aspects that are already known to the company in the smart grid TIS. The mutual stakeholder group that really stands out are the distribution network operators. In the smart grid TIS the DNO's are the users as well as the designers, producers and partly also evaluators of the technology. And the DNO's are starting to take the same place in the electric vehicle integration TIS. Furthermore electric vehicle integration and smart grids are interdependent, without a smart grid electric vehicle integration is not possible and electric vehicle integration technology is directly and physically connected to the smart grid. The connection between substation automation specific for Locamation and electric vehicle integration is less strong. Definitely substation automation is needed to have insight in the grid and to see where electric vehicle integration may be needed. However several electric vehicle integration variants are not at the level of (primary) substations, but at lower levels in the power grid, even lower than secondary substations, at the level of neighbourhoods and individual houses. Value perception and engagement of organisations working on a specific level in the power grid, for example Locamation on primary substation level, is significantly influenced by the level (in the power grid) at which electric vehicles are integrated. The value perception of innovating organisations is also significantly dependent on the value perception of users (distribution network operators and electric vehicle owners) and lowered by legal complexity and uncertainty about important regulations (e.g. net metering regulations, see Chapter 4.4).

To what extend can the value perception of stakeholders in the innovation process of electric vehicle integration technology be influenced in order to mobilise these stakeholders?

The role of producers and designers of electric vehicle integration technology is taken on by three different types of organisations. Firstly are the electric vehicle producing companies that diversify and start to design and produce electric vehicle integration systems, if perceived as an beneficial addition to electric vehicles, for example the vehicle-to-grid/home system of Nissan. Other electric vehicle producing companies start to perceive greater value in electric vehicle integration, moving them towards engaging in the innovation process of electric vehicle integration. Secondly the network operators who try to integrate the electric vehicles directly into the distribution networks they control. Thirdly are innovating technology companies who do not produce electric vehicles, but solely focus on the technology to integrate electric vehicles.

The role of user is not surprisingly taken by the owners of electric vehicles. However they are not the only user, because the system of integrated electric vehicles is used by distribution network operators to mediate the load of electric vehicles on the power grid and may possible be used to even balance the power grid. Both user groups, electric vehicle owners and DNO's, are highly involved with the innovation process of electric vehicle integration technology. The distribution network operators have already the partial role of producer/designer and user, but the DNO's also evaluate different electric vehicle integration technologies (ElaadNL). Evaluators are not only selecting best options for the technology, but are working together with producers and users to improve designs. Mobilisation of electric vehicle owners depends on the compensation to offset costs of battery degradation and lower range. Increasing compensation increases value perception and mobilisation of electric vehicle owners. Positively increasing value perception can also be done by the involvement of electric vehicle manufacturers. They can provide electric vehicles for electric vehicle integration projects and lease batteries, to take risk and uncertainty away from electric vehicle owners. When the costs of vehicle-to-grid are clear (by collaboration with electric vehicle manufacturers), stakeholders can gain a better understanding of the value of vehicle-to-grid for them. This could increase mobilisation of stakeholders for vehicle-to-grid.

The last stakeholder group of regulators is important in the innovation process of electric vehicle integration. Regulations obligate DNO's to look into the most efficient ways to operate their distribution grids, this is resulting in DNO's investigating electric vehicle integration instead of just increasing the capacity of the networks to meet up with the increased demand caused by electric vehicles. Net metering regulations (see Chapter 4.4) however are the main reason why vehicle-to-grid and other energy storage innovations are not really viable at this moment.

The overall involvement of the stakeholders with the innovation of electric vehicle integration technology can be labelled as bricolage rather than breakthrough. Network operators agree on the importance of involving owners of electric cars and have reliability for the user (electric vehicle owner and DNO) as an important evaluation and selection criteria. Collaborative networks can be seen between electric vehicle manufacturers and network operators. Projects where innovations are tested and implemented most of the time involve electric vehicle owners, DNO's, electric vehicle manufacturers and regulators. Associations of stakeholders give critical input on the technological innovations and the input is used by producers and designers. Also evaluators give input on possible improvements rather than just selecting best options.

The involvement can be increased by evaluating regulations that hinder the innovation process. A clear example is the net metering regulation. However this is very complicated because regulations are favourable for distributed renewable energy generation with PV-systems. Forming industry associations could jointly improve the engagement of other stakeholder groups in the innovation process. User groups have to be incentivised to give critical input on the various innovation technologies and to determine the future value of an innovation option. Distribution network operators are very important stakeholders in both the electric vehicle integration TIS and the smart grid TIS and next to evaluator being user and partly producer/designer in the electric vehicle integration innovation process. Teaming up with one or more DNO's on electric vehicle integration could dramatically improve stakeholder involvement.

6. Discussion

In this chapter a discussion can be found on the used theory and the contribution this research has to these theories. Next to the theoretical contribution the limitations of the research is discussed. The chapter concludes with research that is needed in the future.

This thesis contributes to the empirical testing of the combined framework of multi-level perspective and innovation system approach. As Markard and Truffer (2008) state not so many studies have been using this combined approach and it has to be tested in many different innovation fields. This research adds the electric vehicle integration innovation field to that list. This further illuminates the benefits of this combined approach and the possible improvements. One of these improvements is the lack of focus on stakeholder engagement. Another is the difficulty of formulating good and strict boundaries for the research, more about this in the next section about discussion of the limitations and further research.

Next to the further development and acknowledgement of the combined framework this research adds the concept of stakeholder engagement to this framework to make it a more complete framework to analyse the innovation process. This is beneficial because stakeholders take up a significant role in the development of innovations. Having insight in the involvement of stakeholders with an innovation can help to predict future direction and also rate of the innovation. This further enables the prospective power of the framework of Markard and Truffer (2008).

Giordano and Fulli (2012, p. 253) stated that the adoption of electric vehicle integration is depending on different stakeholders with different interests and “Distribution System Operators (DSO) [are] interested in ‘vehicle-to-grid’ services but cautious about investments”. The results of this study show that distribution network operators are not longer cautious to make investments. A great amount of pilot projects are going on in the Netherlands. Furthermore when taking a better look at the role as stakeholder in the electric vehicle integration innovation process, distribution network operators take a central role and increase the engagement of other stakeholders in the innovation process.

To understand the roles of different stakeholders in the innovation process and the engagement of these stakeholders this research used the stakeholder engagement theory of Garud and Karnøe (2003). It is useful for determining whether a breakthrough or bricolage approach is used in the innovation process and how stakeholders are engaged. However the categorisation of stakeholders in the domains of design/production, use, evaluation and regulation sometimes proved to complicate matters. Since for example distribution network operators acting as designer/producer as well as user and evaluator of electric vehicle integration technologies. The results of this study show a better focus is needed on each specific stakeholder, their value perspective and their role in the innovation process. This adds to the understanding of stakeholder engagement in innovation processes, which can be very different for each specific stakeholder.

6.1 Limitations and further research

In this section the limitations and further research will be discussed to give a reflection and point to improvements, as well as what further research is needed.

The subject of this research is the stakeholder engagement in the innovation field of electric vehicle integration technology. It is quite difficult to formulate appropriate boundaries for a study like this, because the innovation process of the technology is happening globally but still the research is working towards practical implications for organisation operating in the Netherlands.

This research gave insight in the innovation process of electric vehicle integration, with focus on the engagement of stakeholders with that process. The results about how to influence the engagement of stakeholders with electric vehicle integration have a somewhat general nature. Meaning that the results about how to improve engagement of stakeholders is more at the level of how a whole nation (for example by government regulations) can improve the engagement of several stakeholders with the innovation process to increase the rate and direction of the innovation that benefits the whole society. This was partially the aim of the study, but it was also a goal to have strong recommendations for specific innovation organisations on how they could drastically improve the engagement of stakeholders with the innovation process of electric vehicle integration. The results of the study are partly recommendations for specific innovation organisations (e.g. Locamation), but a complete strategy for improving the engagement of all relevant stakeholders cannot be formulated.

By exploring the benefits and barriers for the different stakeholder (groups) associated with electric vehicle integration an indication is given of the value of electric vehicle integration and the direction and rate the innovation of electric vehicle integration is going. However the research did not get a clear view of the absolute value electric vehicle integration technology has. Some figures became known about the monetary benefits electric vehicle integration could give and the costs (investments in the power grid) that could be averted. But exact figures for all the stakeholder groups (e.g. electric vehicle owners) about how much absolute value integration of their electric vehicle is going to give could not yet be determined.

Many research has been done on the integration of electric vehicles in the power grid. However most of these studies are quite technical and do not focus on the innovation process of electric vehicle integration. This research contributes to these studies with a focus on stakeholders in the innovation process. Besides this research connects electric vehicle integration with the focus of many innovating organisations on smart grids (and specific on substation automation). By linking the technological innovation system of electric vehicle integration technology with the complementary TIS of smart grids the linkages between the two innovation systems became clear. This is a great benefit for innovating organisations that are already active in the innovation systems of smart grids and are looking into the TIS of electric vehicle integration technology.

Markard and Truffer (2008) state that the combined framework of multi-level perspective and innovation system approach is only used to study the innovation fields of smart buildings, stationary fuel cells, biogas power plants and membrane technology in the sanitation sector. As mentioned in the theoretical contribution this research adds the innovation field of electric vehicle integration to that list of studied innovation fields. However the list of innovation fields studied with the combined approach is not yet sufficient to thoroughly evaluate the use of the combined approach. This indicates that more research is needed that uses the combined approach to study innovation fields. The more research is conducted with this approach the more insight it can give on the performance of the approach.

As mentioned in the discussion about the results of the research, the recommendations have a somewhat general nature, instead of really focussing on specific innovating organisations. Further research is needed on how a specific innovating organisation can improve the engagement of stakeholders with the innovation process that they are embedded in.

For the research on electric vehicle integration, more research is needed on the absolute value electric vehicle integration could have for various stakeholder (groups). For instance how much money is an electric vehicle owner going to receive from integrating the electric vehicle that is on the driveway? For smart charging this is not the most relevant, because the starting point should be that the electric vehicle owner will not have (large) disadvantages with for example range. Looking at vehicle-to-grid it can be very hard to implement without any disadvantages for electric vehicle owners. Opposite of these disadvantages need to stand clear benefits for the electric vehicle owner before involvement is guaranteed. So further research is needed on absolute benefits for various stakeholder groups for different electric vehicle integration technologies.

7. Practical implications

In this chapter the practical contribution of the research is described, supporting innovating organisations in the strategic decision making about whether or not to invest or further research the electric vehicle integration technology field.

Being part of the technological innovation system of smart grids is an enormous advantage when considering to diversify to electric vehicle integration technology. The technological innovation system of electric vehicle integration is complementary to the smart grid TIS. Besides the complementary aspect of the technological innovations systems of smart girds and electric vehicle integration, the TIS's share some important stakeholders. The most important shared stakeholder group are the distribution network operators. This means that the organisation is already familiarised with important stakeholders and could most likely integrate more smoothly into the electric vehicle integration TIS.

Before making a decision on working on electric vehicle integration and especially on the vehicle-to-grid variant of the technology more involvement of the regulatory stakeholder group is needed. Because this group has such a significant impact on the innovation process and the demand for the technology in the first place. The influence, which industry associations can have on regulators, became clear while visiting the meetings of electric vehicle association DOET. Decisions of regulators on the regulations about electric vehicles and their integration was influenced directly by the association, by stating positions and views on legislative proposals (e.g. Auto brief II, legislation about fiscal regulations for electric vehicles). This kind of lobbying activity influences the regulator directly and also improves the engagement of regulatory stakeholders with the innovations. In line with the aforementioned recommendation to influence and engage regulatory stakeholders it is of utmost importance to have a clear view of the direction of key regulations and legislation about electric vehicle integration. The road taken by regulatory bodies about for example net metering regulation is going to determine for the most part if some electric vehicle integration technologies are ever going to see the light in the Netherlands behind the niche they are in today.

If innovating organisations are starting in a new (to them) technological innovation system it is important to join the industry associations that are already in place. If such an industry association is not formed yet, because the technological field is very new or not properly engaged with all the stakeholders yet, the innovating organisation should start that industry association or persuade other stakeholders to construct an industry association. From that industry association other important stakeholder groups (e.g. users, evaluators, and regulators) can be engaged with the innovation process and ultimately be influenced. This could have a significant impact on the direction and rate of an innovation. In short; form an industry association for organisations working on electric vehicle integration. This will improve the engagement of regulatory stakeholder groups and other stakeholder groups with the innovation of electric vehicle integration. The research revealed that distribution network operators in the Netherlands are a very important stakeholder when it comes to electric vehicle integration. DNO's are not only designer/producer but also user and evaluator (e.g. ElaadNL, funded together by the Dutch DNO's) of technology for electric vehicle integration. Besides DNO's are already an important stakeholder in the technological field of smart grids. For innovation organisations, already present in the smart grid TIS, it is very wisely to team up with one or more DNO's. Not only in the field of smart grids, but also for the possible future entering of the electric vehicle integration technological innovation system. Furthermore to improve the engagement of the user stakeholder group (especially electric vehicle owners) with the innovation process of electric vehicle integration incentives could be used for involving them in test programs, pilot projects and evaluation studies. The engagement of electric vehicle owners is critical to keep the bricolage approach that is being used today in the electric vehicle integration TIS and stay away from a breakthrough approach.

List of abbreviations

A	Ampere
AC	Alternating Current
CAES	Computer Architecture for Embedded Systems
DC	Direct Current
DNO	Distribution Network Operator
DOET	Dutch Organisation for Electric Transport
DSM	Demand-Side Management
DSO	Distribution System Operator
EDV	Electric-Drive Vehicle
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
G2V	Grid-to-Vehicle
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IPIN	Innovation Program for Intelligent Networks
JRC	Joint Research Centre
MLP	Multi-Level Perspective
NEA	Netherlands Enterprise Agency
OSGP	Open Smart Grid Protocol
PV	Photo-Voltaic
R&D	Research and Development
RFID	Radio-Frequency Identification
SME	Small and Medium-sized Enterprise
TIS	Technological Innovation System
TKI	Top consortium on Knowledge and Innovation
V2G	Vehicle-to-Grid

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Appendix A: Funds study

In this appendix the results of the study on available funds can be found, because the results where to broad to fit in the main body of this thesis paper.

The electrical grid is of vital importance to the modern day society. For the electrical grid to meet the requirements of near future developments (e.g. strong adoption of local PV-systems, wind power and electric vehicles) the grid has to become 'smart'. Therefor local and national governments have several funding programmes to aid research and development in this domain. At national level the Netherlands Enterprise Agency (NEA) implements policies of the Ministry of Economic Affairs to support projects in the smart grid domain (Top Sector Energy, 2012). The elaboration of this is the 'Top consortium on Knowledge and Innovation' (TKI) Switch2SmartGrids (Top Sector Energy, 2014). In 2014 the NEA carries out the 4^{th} tender for the TKI Switch2SmartGrids with a total amount of 3.7 million of government support for smart grid projects (NEA, 2014). From earlier tenders several testing grounds arose for electric vehicle (integration) and smart grid related projects. One of these testing grounds is 'Intelligent network in sustainable Lochem' in which Locamation was coordinator. Several organisations (e.g. University of Twente, Locamation and Alliander) worked together to experience in practice "the incorporation of renewable energy which is generated in a decentralised way into an existing network" (NL Agency, 2012, p. 1). For Locamation it was an opportunity to link the innovative SASensor technology to the users' energy management system. Further goals where to develop and implement a smart charger for electric vehicles. However this goal was not met and changed during the duration of the project. The government funding, implemented by the Netherlands Enterprise Agency, are grants for vast public-private collaborations like large pilot projects. However the funding by national government is not only directly provided to projects by the NEA. Local governments also get, and have, resources to decentralise government funding.

Province Overijssel created the Energy Fund Overijssel in which they allocate funding to local small and medium enterprises (SMEs) ultimately to fulfil province Overijssels ambition of 20 percent renewable energy in 2020. For this allocation process several funding mechanisms are formed. To name a few (Province Overijssel, 2014):

- Renewable energy production and reduction subsidy
- Money back for energy saving measures
- Enterprise energy loan
- Feasibility studies new energy and energy scans subsidy

The funding of these programmes ranges from 2,500 up to 200,000 EUR. The intention of the feasibility studies new energy and energy scans subsidy could also be used for projects that work on electric vehicle integration with renewable energy production and smart grids. The feasibility studies new energy and energy scans subsidy is the most appropriate funding and is for research on the feasibility of the use of innovative technology and energy reduction at companies. This research should examine whether the application is technically suitable or economically viable, with a focus on technical, logistical, architectural and organisational aspects (Province Overijssel, 2014). A project on electric vehicle integration technology application in a smart grid fits this profile. Especially when the feasibility of using battery capacity of electric vehicles to store renewable energy of, decentralised, PV-systems or wind turbines will be studied. The maximum subsidy for the feasibility studies new energy program is 15.000 EUR with the subsidy being not more than 50 percent of the total eligible costs of the project. For 2014 the subsidy limit of 300.000 EUR was reached.

Appendix B: Electric vehicle integration measures

In this appendix a figure is presented in which the distribution network operators give an insight about which variants they prefer.

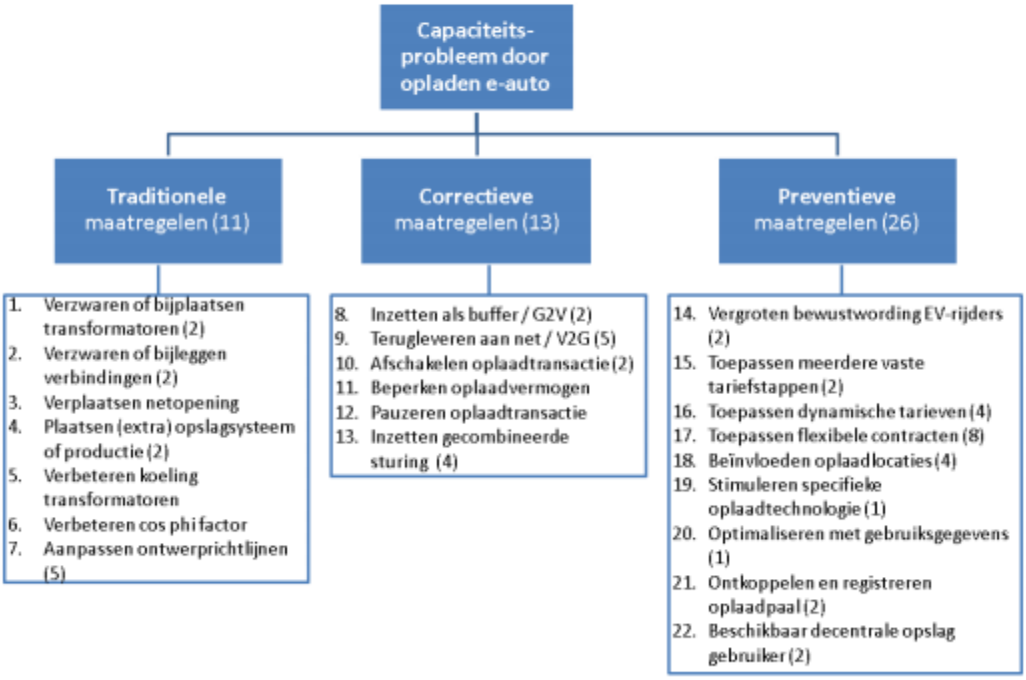

Figure 7 Measures for improvement with the integration of electric vehicles (Netbeheer Nederland, 2013)

Appendix C: Sub-case "Intelligent net" IN4Energy

Together with 11 other projects "Intelligent Net" from the consortium IN4Energy was selected for the Innovation Program for Intelligent Networks (IPIN) of the Ministry of Economic Affairs, Agriculture and Innovation. The general aim of the project was gaining practical experience with the incorporation of renewable energy which is generated in a decentralised way in to an existing network (NL Agency, 2012). Part of the project was (initially) devoted to the integration of electric vehicles with the smart grid and in particular the substation (IN4Energy, 2012):

In the project roadmap is stated that the innovation aspect compared to conventional charging stations is that the charging station developed by Locamation will be integrated with Smart Grid control, making possible a higher quality standard in energy management. During short circuit situations electric vehicle systems will also be influenced to support energy balance. Given that it is most important in the first 100 milliseconds, makes conventional charging stations unusable. The charging stations are not smart and will only fulfil energy measurements, under supervision of a control unit in the substation, forward communication with the car to the substation and be able to shut off power for load control and fraud management. An additional communication unit is needed in the substation for these purposes. Optional could be a checkout or identification system in form a card reader or RFID chip reader. Essential is a linkage with the virtual distribution data management system for energy balancing and protection (IN4Energy, 2012).

However as the project IN4Energy was carried out the electric vehicle integration aspect of the project slowly faded to the background. The main cause for this to happen was intellectual property issues with the distribution network operator that was involved in the project. The distribution network operator did not allow other companies to use network information that was needed for integration of electric vehicle charging points with the substation. Other reasons for choosing standard charging equipment instead of developing smart charging equipment were the scope and approved time for the project, the current stance of technology in the field, the current regulatory guidelines and the need for the development.

For electric vehicle charging integration with substation automation the protocols used for both should be interoperable. For substation automation often the IEC 61850 standard is used. This standard is created to enable interoperability between different devices in the substation and

Er is gekozen voor standaard laadpalen, mede door het tijdsbestek, stand van de techniek, de regelgeving en de behoefte omtrent deze ontwikkeling "
B. Mooijman – Product Marketing Manager at

facilitating the use of future networking technologies (Pedersen, Hauksson, Andersen, Poulsen, Træholt & Gantenbein, 2010). For the electric vehicle charging equipment to work together with the substation automation devices, several values of the charging process and the electric vehicle itself have to be communicated. For example size of the battery, maximum and current charge rate and state of charge of the battery. Pedersen et al. (2010) state these values can be read from the charging point via the IEC 61850 interface.

Involved stakeholders

The following stakeholders participated in the IN4Energy consortium as stated in the initial project roadmap (IN4Energy, 2012):

Locamation

As developer and producer of innovative smart grid automation solutions, Locamation views participating in the IN4Energy consortium as an opportunity to apply new smart grid products in a real world smart grid project and test new concepts together with all stakeholders in the energy market. Furthermore the project is seen as a platform to develop novel innovative smart grid products that have economic perspective in the changing energy generation and distribution market.

Distribution network operator Alliander

Alliander operates the distribution network in Lochem and is preparing the grid for new forms of energy generation, for example PV-systems and wind turbines, and solutions for charging electric vehicles. With that purpose Alliander develops technological innovations and the IN4Energy consortium enables multiple stakeholders to come to a common standard for smart grids. The intention is to involve the end consumer in the project in order to realise reduction in energy use with innovative technologies.

Cooperative LochemEnergie

LochemEnergie is a cooperative formed out of a consumer initiative and represents many households (and later on also businesses) in Lochem that are interested in generation of sustainable energy. The goal of this cooperative is to generate sustainable energy on behalf of its members. LochemEnergie joined the IN4Energy consortium to speed up the transition towards sustainable energy. For this transition to be successful it is important that not only the production aspect of energy is looked into, but also the consumers are involved in projects with various other stakeholders of the energy transition.

University of Twente

The Computer Architecture for Embedded Systems (CAES) group of the Faculty of Electrical Engineering, Mathematics and Computer Science of the University of Twente participates in the IN4Energy consortium.

Technology company Eaton Industries

As developer, producer and vendor of electrical systems and components for medium and low voltage power networks, Eaton participates in the IN4Energy consortium to expand its knowledge about smart grids and improve the connection between Eaton components and systems of utility companies. In these projects close cooperation is needed between various stakeholders, for example consumers, the distribution network operator and other companies involved in the industry.

Energy supplier Trianel Energie

The last participant in the IN4Energy consortium is energy supplier Trianel Energie, which supplies green energy to households in Lochem.

Appendix D: Functions of Innovation systems

As mentioned above many scholars used functions of innovations systems to look into the dynamics of (technological) innovation systems. However the functions proposed by these scholars all differ to a greater or lesser extent. Hekkert, Suurs, Negro, Kuhlmann and Smits (2007) looked into all those categorisations of functions and proposed a set of functions that can map the key activities in (technological) innovation systems. As these functions will be used to some part in the theoretical framework to analyse the performance of the technological system, the functions will be further elaborated first.

Function 1: entrepreneurial activities

Entrepreneurs are at the base of the innovation system because entrepreneurs pick the innovations they want to pursue and develop. Van de Ven et al. (1999) state that a new idea of an entrepreneur (that can be a recombination of old ideas) is the starting point of the innovation process. Entrepreneurs, like new entrants or diversifying incumbent companies, take risk by experimenting with new technologies and applications to gain knowledge and take advantage of new business opportunities (Hekkert et al., 2007). The working of the entrepreneurial activities function can be looked into by analysing the number of new players that participate in the technology field, the diversification activities of incumbent stakeholders and the number of tests that are done with the innovation.

Function 2: knowledge development

As mentioned in the first function, entrepreneurs take risk by experimenting with new technologies to gain knowledge. This latter part is the essence of the second function, knowledge (development). Mechanisms of learning are at the essence of the innovation process and that is why knowledge development is needed in the innovation system, whether it is learning by doing or learning by searching (Hekkert et al., 2007). Together with the third function this function can be seen as the first key issue Jacobsson and Johnson (2000) see in the transformation process, namely the creation of variety in the knowledge base. The performance of the knowledge development function can be looked into by analysing the amount of R&D projects, patents and investments in R&D.

Function 3: knowledge diffusion through networks

For an innovation system to perform efficient the knowledge that has been developed at a certain part of the system must diffuse through the whole system. This knowledge diffusion is done through networks, and this is the third function of innovation systems. Carlsson and Stankiewicz (1991, p. 103) point out another aspect for knowledge diffusion through networks, namely that the more complex the innovation and or task, the more one may be forced to rely on the expertise (competence) of others. The exchange of information is important to keep policy decisions of governments consistent with the latest technological insights in the market and R&D agendas with changing norms and values (Hekkert et al., 2007). The working of this function of innovation systems can be examined by analysing the number of conferences and meetings about the innovation and the quality and quantity of network connections, for example in the form of industry associations.

Function 4: guidance of the search

Characteristic about innovation activities in the beginning of the innovation process is that they are diverse and in multiple directions. This is positive for the knowledge development, as indicated with the second function of innovations systems. However for an innovation to be further developed and implemented it is important to combine the power and resources of multiple stakeholders. To make this happen selection of technological options based on the preferences of technology users is needed. The tricky part is that those preferences are not always known or articulated. The functioning of guidance of search can be indicated by looking into the general expectations that exist on the innovation or new technology (e.g. more positive or negative papers in professional journals), another indicator could be targets that governments or industries set regarding the use of a specific technology.

Function 5: market formation

As seen in the multi-level perspective innovations are brought to life in niches. In these niches the innovations are shielded from the selection criteria in the normal market (Geels, 2002), because innovations often have difficulties competing with embedded technologies over these criteria.

Niches for specific applications of a technology and also favourable tax regimes can help to establish a market, so the number of niche markets and specific tax regimes can indicate the performance of the market formation function of innovation systems (Hekkert et al., 2007)

Function 6: resource mobilisation

As indicated in the fourth function about guidance of search activities, it is important to have enough resources to develop and eventually implement a new technology. So these resources need to be mobilised and this process is partially depending on the expectations of a new technology. Important to notice in the function of resource mobilisation is what Jacobsson & Johnson (2000) call "prime movers". These prime movers are technically, financially and/or politically powerful enough to contribute greatly in the innovation process. Financial and human capital resources can be made available with R&D funds, so the amount of funds is an indicator of this function, another is the perception of core stakeholders that access to resources is a problem or not (Hekkert et al., 2007).

Function 7: creation of legitimacy/counteract resistance to change

For an innovation to fully develop and grow out of the niche stage it has to become part of the incumbent regime or replace it, interest groups could catalyse this process by for example lobbying for resources or favourable tax regimes (Hekkert et al., 2007). However the regime is also backed up by interest groups that favour the incumbent technology and those groups will put a lot of pressure on for example policy makers to keep the regime intact (Geels, 2002). How successful the interest groups of the new technology are in their lobbying activities to create legitimacy for the innovation determines the implementation of the innovation. Analysing those interest groups (e.g. number and size) can give an indication of the performance of the last function of innovation systems.

Appendix E: Innovation process

More insight in innovations starts by unravelling the process in which an innovation is developed. Van de Ven et al. call this innovations process the innovation journey, it's five key concepts are described below (Van de Ven et al., 1999):

- *Ideas*
  The first concept of the framework is ideas, an idea is the starting point of an innovation. The creation of a new idea is described as invention. The difference between innovation and invention is that innovation covers more, also the development and implementation of a new idea. A distinction can be made between technical innovations and administrative innovations. Examples of technical innovations are new technologies, products and services; administrative innovations could be new procedures, policies and organisational forms. However important for understanding the management of innovation is recognising that the administrative and technical aspects of innovation are closely related to each other.

- *Outcomes*
  To get a good view of the outcomes of an innovation it has to be evaluated after the innovation is realised. However organisations and people involved in an innovation process require evaluation of the process while it is going on. To do so they can make use of provisional evaluation criteria for assessment of the process.

- *People*
  In the innovation process many stakeholders are involved, the level of their involvement differs over time. Stakeholders have their own reference frame and therefor interact with the innovation process in different ways.

- *Transactions*
  The stakeholders mentioned above interact in a network of different transactions or relationships. Relationships can vary from working together to develop an innovation, commitments to acquire resources, to subcontracting work between organisations.

- *Contexts*
  The last concept of the framework is contexts, which can be seen as economic, political and market infrastructures. These infrastructures create an environment that can influence the process of innovations.

Garud & Karnøe (2003) describe four key elements in the innovation process:

- *Design and production*
  With their knowledge and understanding of designing and producing technological artefacts, producers and designers shape a new technology.

- *Use*
  Users are involved in the technology emerging process based on their beliefs in products with regard to forms, functions and usability value. The feedback of different users gives insight in the strengths and weaknesses of a design or product in use.

- *Evaluation*
  Grounded on assessments and standards that are needed for comparing various products, evaluators are engaged in the technology development process. These standards and assessments give an objective view of the performance of different products and act as selecting mechanisms.

- *Regulation*
  Regulators are involved in the innovation process by enacting laws according to their view on the effectiveness of for example subsidies or grants for steering the path of the innovation process. These regulatory policies govern interaction between all the stakeholders that are involved in the technology emerging process.

Garud and Karnøe take a different approach to innovation in comparison with Van de Ven and colleagues. Where Van de Ven et al. take a broad view of the whole innovation process, with ideas, outcomes, people, transactions and contexts, Garud and Karnøe focus mainly on the different stakeholders and how they interact with each other. That is in line with the aspects Van de Ven et al. describe as people and transactions. There is also overlap between the regulation domain and context concept. Both deal with environment aspects that have influence on innovation.

Appendix F: Technological transitions approach

Socio-technical landscape

The highest (macro) level in the multi-level perspective is formed by the socio-technical landscape. It can be seen as an external structure with heterogeneous factors (e.g. oil prices, cultural and normative values and environmental problems) that form the context for interactions of actors (Geels, 2002). The socio-technical landscape is not easy to change so developments in the socio-technical landscape evolve in a slow matter and can put pressure on the socio-technical regimes. For example increasing oil prices and growing concern about carbon dioxide emissions puts pressure on the current socio-technical regime of transportation and internal combustion engines. Socio-technical regimes are described in the next part.

Socio-technical regimes

In the middle (meso-level) of the multi-level perspective are the socio-technical regimes. A regime is a set of rules that is semi-coherent for several groups of actors and consists of stable and existing technological developments (Geels, 2002). A comprehensive definition of socio-technical regimes is given by Rip and Kemp (1998, p. 338): "A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems – all of them embedded in institutions and infrastructures". This definition seems relative abstract, however it becomes clearer when looking for example at the car mobility regime, components of the regime are, skills of car maintenance workers, fuelling infrastructure and manufacturing processes for internal combustion engines. In the next part is clarified how innovation in niches can influence the socio-technical regime.

Technological niches

The lowest (micro) level in the multi-level perspective is formed by the technological niches. Technological niches are places insulated or shielded from normal market selection in the regime, where new technologies are protected and learning processes and social networks supporting innovations (e.g. supply chains and user-producer relationships) can be fostered (Geels, 2002; Schot, 1998). For example in the transition towards electric vehicles, small city cars are a niche for electric vehicles because lower requirements are set for the range a vehicle has to be able to drive before recharging is needed. Processes within the niche and developments at the level of the existing socio-technical regime and the socio-technical landscape govern the success of a new technology (Geels, 2002).

Appendix G: Innovation systems approach

Carlsson and Stankiewicz (1991) state that for understanding technological systems it is important to understand that technological systems are defined in terms of knowledge/competence flows rather than flows of ordinary goods and services.

Jacobsson and Johnson clearly define three topics that need to be recognised to understand and eventually influence the formation of a new technological system (2000). The first is the creation of variety in the knowledge base, second the process of institutional change and third the formation of "prime movers". These topics can be seen as important indicators for the performance of the technological system. However as Jacobsson and Johnson state themselves that these are not the only topics that are important for the dynamic and performance of a technological system.