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Master's Thesis Internship – M.Sc. Sustainable Business and Innovation

TRANSITION TOWARDS ELECTRIC MOBILITY

The role of Business Model Innovation for Electric Vehicle Charging in Germany

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Abstract

The prevailing mobility system is in a transitional phase, whereby emerging technologies such as fast charging infrastructure for electric vehicles become an eminent factor for the success of systemic change. Simultaneously, business model innovation (BMI) is increasingly seen as a mean to promote sustainable production and consumption. Whilst business model components concern the focal firm as well as their networks, the role of businesses in wider transformative processes, such as the conceptualisation of the technological innovation system (TIS), remains unclear.

This research addresses the delineated issue by combining BMI components (value proposition, value network and value capture) with the concept of the TIS of fast charging. A theoretical framework depicts the role of BMI and its influences on the TIS, in a socio-technical transition process. Based on the case study of fast charging infrastructure in Germany, a dynamic structural-functional assessment of the innovation system revealed systemic weaknesses. The analysis of 18 conducted expert interviews, with businesses being engaged in the establishment of fast-charging infrastructure allowed to identify sources of inertia for BMI, which can be overcome by alterations of the TIS structure. The findings show that an integration of the firm-perspective can decrease redundant activities of actors and ameliorate the effectiveness of resource mobilisation. Subsequently, coordination efforts are regarded as an enhancing factor for the functionality of the system: If businesses are included in the earlier formative stages of the TIS, structural misconceptions are avoided and system performance is benefited throughout. The findings have led to business and policy recommendations.

Keywords*: technological innovation systems; business model innovation; electric mobility*

Preface

The following presents my Master Thesis Transition towards '*Electric Mobility: The Role of Business Model Innovation for Electric Vehicle Charging in Germany',* which has been authored to obtain a Master of Science degree in the course Sustainable Business and Innovation at the Utrecht University. The thesis has been written in the time span from February to November in 2017, which entailed a 7-month internship at Allego *GmbH/BVBA.*

I would like to thank my team and colleagues at Allego, who have helped me to work in a dynamic environment and to face the challenges that such an emerging field brings with it. In particular, I want to thank my supervisor Remco Köhne for providing me with feedback and guidance in the process. I would also like to thank him for the opportunity to contribute to substantial EU projects, that facilitate the transition towards electric mobility.

Further, I would like to thank my supervisor dr. Simona Negro for giving me the opportunity to do this research under her supervision. Her expertise, timely advise and honest character helped and guided me throughout the process. I would also like to thank my second reader, Joeri Wesseling, for giving valuable recommendations during the proposal phase.

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List of Abbreviations

AC/DC	Alternate Current/Direct Current
BEV	Battery Electric Vehicle
BM	Business Model
BMI	Business Model Innovation
cf.	*confer* (compare)
CP	Charge Point
CPO	Charge Point Operator
EV	Electric Vehicle
e.g.	*exempli gratia* (for example)
EVC	Electric Vehicle Charging
FC	Fast Charging
GHG	Greenhouse Gases
ibid.	*ibidem* (in the same place)
ICE	Internal Combustion Engine
i.e.	*id est* (that is to say)
IS	Innovation System
MLP	Multi-Level Perspective
MSP	Mobility Service Provider
OEM	Original Equipment Manufacturer
OCPI	Open Charge Point Interface
OCPP	Open Charge Point Protocol
PHEV	Plug-in Hybrid
POI	Point of Interest
R&D	Research and Development
SLP	Standardlastprofil
SOC	State of Charge
REEV	Range Extended Electric Vehicle
RLM	Registrierende Leistungsmessung
SQ	Sub-Question
TIS	Technological Innovation System

1. Introduction

The global world is facing a multitude of challenges, such as the decline of fossil fuel reserves, increasing commodity prices, climate change and local air pollution. This leads to an increasing demand for measures to overcome these difficulties. One of the most urgent topic for global societies is the reduction of fossil fuel consumption (IEA, 2007). Besides industrial production as a main polluter, the transport sector has a great impact on the emission of greenhouse gases (GHG). With a share of 14% of global GHG emission and a projected increase to as much as 50% in 2030 (Egbue and Long, 2012; IEA, 2007), the importance of change towards cleaner mobility becomes eminent for the future. New technologies are being developed to establish more efficient and sustainable modes of mobility.

The development of electric powered vehicles is expected to play a fundamental role in this transition, as it has been identified as a promising technology to resolve the aforementioned issues (Steinhilber, 2013). Acknowledging this, the German Federal Government articulated the “National Electro-Mobility Development Plan” in 2009, aiming towards one million electric vehicles (EV) to be registered in Germany by 2020 (BMVI, 2009). At the beginning of 2016 however, only 25.502 EVs were registered (KBA, 2016). It is notable that the uptake of the novel technology has been impeded despite a predominantly positive perception of EVs in general, in particular with regards to their low environmental impact (Philipsen et al., 2015). Initially, governmental actions have predominantly focussed on the support of the automotive industry in Germany, to maintain the competitive advantage of the local economy (Wesseling, 2016). Later, governmental incentives have been introduced to overcome barriers for EV uptake (NPE, 2011), such as the limited range and connectively long charging times, which are regarded as major impediments. Consequently, the aim of creating a dense electric vehicle fast-charging (EVC) network in Germany has been articulated (*ibid*.). The mode of fast-charging is promised to make an important step towards the recognition of EVs as a promising alternative to fossil fuelled cars as it enables long-distance travelling.

The short delineation of the dilemma actually entails a high degree of complexity. Initially, the ideal of a transition towards sustainable technologies implies the guiding principle that todays’ and future generations develop in a way that enables them to meet their ecological, economical as well as their social needs (WCED, 1987). For societies to follow this principle, they need to restructure prevailing systems. Businesses are the organisational form that is able to resolve problems by innovation, since they enable highly complex forms of societal cooperation (Beckmann and Schaltegger, 2014). Therefore, businesses have the capability to initiate so-called sustainability transitions that aim to restructure prevailing systems (Farla et al., 2012). Businesses however do not innovate in isolation; they are part of an innovation system (IS), which is defined as “all institutions and economic structures that affect the rate and the direction of a certain technological change in a society” (Edquist and Lundvall, 1993). It is this systemic character of technological change, that often causes transitions to become slow processes that are difficult to steer (Hekkert et al., 2007). Dependencies on *inter alia* regulation, consumer practices, cultural influences and infrastructure can impede the process (*cf*. Bidmon and Knab, 2014; Elzen et al., 2004).

For example, the mobility sector as we know it, has developed through a path-dependant and co-evolutionary process, involving positive feedback among the technological infrastructure, its organisations and institutions. Throughout, the dominant design of fossil-fuelled cars has been influencing the transport sector ever since. The constant investment towards incremental improvements on the existing design led to a lock-in at firm level. Simultaneously, the interlinkage with institutions led to a similar occurrence on institutional level.

This inertia can only be escaped from by fostering innovation within the entire system. Several studies have outlined sustainable transition as a process of technologies emerging in small niches, such as the EVC market. These technologies are generally impeded on their way towards acceptance in socio-technical regimes (Geels and Schot, 2007). Simultaneously, other studies demarcate the potential set-up of innovation systems and their respective functions (Hekkert et al., 2007), which foster the diffusion of such a niche technology. A common characteristic of both streams of studies is to frame transitions from a systems perspective (Farla et al., 2012) and translate findings into policy tools. However, the approaches fail to include a more actor-oriented analysis, which becomes essential with regards to abovementioned potential of businesses. Exploring the role of businesses for socio-technical transitions can contribute to our understanding of how a socio-technical system can transit towards increased sustainability (*cf*. Bidmon and Knab, 2014, Farla et al. 2012).

A descriptor of firm-level activities is the concept of the business model (BM) (Baden-Fuller and Morgan, 2010). It is defined as the set-up of the business with which it can create value, deliver it and implies value capturing mechanisms (*ibid*.; Teece, 2010). The concept is directly linked to the business strategy and its ability to innovate (Chesborough and Rosenbloom, 2002). The influence of niche businesses however, is limited and their objective at this point should be to grow (Hockerts and Wüstenhagen, 2010), to successfully influence others and to positively affect the aforementioned transition (Schaltegger and Wagner, 2011). The relevance of business models, to achieve market growth, has been widely acknowledged. However, the dynamic role of businesses in the transition process of markets has not been examined in depth and is of scientific relevance, especially when considering the crucial role businesses play in this process (Sarasini, 2017; Schaltegger et al., 2016, Bidmon and Knab, 2014; Farla et al., 2012).

In this context, the assumption is made, that the respective business models of firms in the innovation system of EVC in Germany have a direct influence on the transition towards electric mobility. Given the implementation of incentives by the German government, the innovation system for charging seems to be promising. Yet, businesses do not appear to be able to establish a market for the technology, without governmental support (Steinhilber et al., 2013). Hence, it is fundamental for businesses involved, to innovate their business models in the market for electric vehicle charging in order to positively influence the restructuring of the prevailing system. By combining specific firm-level perspectives, *i.e.* business model innovations, with the overarching system approach, it becomes possible to point out influential factors and to analyse the relationship. Therefore, following research question is derived:

How can business model innovations stimulate the development of the fast charging innovation system in Germany?

The research has been conducted with the host organisation Allego *GmbH*/ Allego *BVBA*. The charging point operator has offices in Germany, the Netherlands and Belgium and is operating diverse types of charging infrastructure. Besides fast chargers, the portfolio of the company entails charging solutions for company fleets, public transport, municipalities and retailers. By outlining the role of business model innovation for the company and simultaneously illustrating their role in an innovation system and the transitional process, the company gets valuable information on how to strategically engage further.

The research is structured as follows: the second chapter will outline a theoretical framework, delineating the aforementioned theories in a more detailed manner. This entails the specific form of innovation systems, namely the technological innovation system (TIS). On that basis, the TIS approach is put into context with the overall socio-technical transition. In addition, the role of business models, more specifically business model innovation, within the transition process is delineated. Moreover, sub-questions are derived from the theoretical framework, which lead to a conceptual model of the research. By providing a brief context of fast charging, the third chapter allows the reader to gain a general understanding of the charging process. Moreover, it demarcates the technology and sets the boundaries of the research based on a definition of fast charging. Further, the fourth chapter introduces the methods, which are used to answer the main research question as well as necessary sub-questions. After the presentation of findings and their analysis in the fifth chapter, the sixth chapter is then discussing those findings in the light of the theoretical framework. Finally, the seventh chapter is concluding the research paper and gives recommendations for businesses and policy makers.

2. Theoretical Framework

In the following, the theoretical framework for the research is depicted. Theories on socio-technical transitions and the role of technological innovation systems, describe the systemic character. Further, the firm-perspective is included by introducing business model theories. Eventually, the two strands of theories are merged into a conceptual framework that ought to guide the research.

2.1 Multi-Level Concept of Transition

In order to achieve a transition of sustainable consumption and production patterns of today's society, a systemic change is needed. A societal function such as mobility, must undergo large-scale changes to achieve such a transition, as they are heavily dependent on fossil fuels, leading to negative environmental effects.

Technological innovations are interrelated with the development of involved stakeholders and are object to a co-evolutionary process, which changes technologies, social practices and institutions towards more sustainable characteristics (Boons et al., 2013). Therefore, the potential technological innovation is part of a larger system. It is important to utilise systemic instruments, which focus on an innovation system level instead of focusing on a specific part, to influence the speed as well as the direction of innovation processes (*ibid*.; Dewald and Truffer, 2011).

Moreover, the ability of a technological innovation to stimulate the change of a prevailing system is considered to be embedded in a multi-level perspective (MLP) (*cf*. Geels, 2002). The MLP delineates the transition based on an interplay of processes at different levels. The niche-level of the MLP, at which the sustainable technology usually evolves, represents the originating level of the innovation process. This can also be referred to as an incubation room, where new technologies emerge and are developed in isolation from market pressure and regime (Kemp et al., 1998).

This socio-technical regime is utilised to place certain technical developments in perspective to markets, user practices, policies and cultural importance (Geels and Schot, 2007). Hence, the regime constitutes for an impactful source as it represents the "selection environment" (Markard and Truffer, 2008: *603*) for a technological innovation. Thereby, it becomes a significant barrier with regards to the diffusion of an innovation (*ibid*.). The self-stabilisation through alignment within the dimensions of policy, culture, science, technology, market user preferences and the industry, is regarded as a critical factor in the ability of regimes to select *inter alia* sustainable innovations (Hockerts and Wüstenhagen, 2010; Geels and Schot, 2007). Thus, the prevailing regime dimensions are concentrated around the technology of *i.e.* fuel-based vehicles and are far developed in each of the dimensions, all whilst creating a barrier. Regimes can generate incremental innovations, however, only to strengthen the prevailing system (Markard and Truffer, 2008). Moreover, the alignment can be influenced by pressure from the development at the landscape level (Geels and Schot, 2007) or internal dysfunctions (Geels, 2011). Throughout, a 'window of opportunity' is created, which can be preferable for innovations from the niche-level (Geels and Schot, 2007). Therefore, it might enable the diffusion and development of a more sustainable innovation (Markard and Truffer, 2008).

Finally, the socio-technical landscape depicts the exogenous landscape of a regime (Geels and Schot, 2007). This level is naturally reacting slowly to changes from lower levels. Then again, developments at this level put great pressure on socio-technical regime levels to adjust (*ibid*.). Moreover, the landscape can influence the niche level by putting emphasis on *e.g.* climate change issues. Consequently, it triggers societal expectations due to increased awareness towards that issue.

As this strand of theory building is rather focused on broader transition processes at a more aggregated level, it is involving a variety of innovations. A technological innovation can be radical and thus stimulate a transition. To analyse the dynamics of technology at the niche level and its influencing factors of the prevailing regime as well as from the macro level, it is relevant to focus on the system directly affecting the innovation at hand, the technological innovation system.

2.2 Technological Innovation System

An innovation system (IS) is defined as the network of actors and institutions that directly affect the rate and direction of an innovation in a society (Bergek et al., 2008; Hekkert et al., 2007; Edquist and Lundvall, 1993). Therefore, the concept of innovation systems has been developed to be able to analyse all societal subsystems, actors and institutions contributing in various ways, directly or indirectly, intentionally or unintentionally, to the emergence or production of an innovation (Hekkert et al., 2007). Several innovation system approaches have been brought forward, differing by regional, national, sectoral or technological scopes (*ibid*.). The relevant unit of analysis for this research will be the technological innovation system (TIS)[1] which is regarded as "a network of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse and utilise a technology" (Carlsson and Stanckiewicz, 1995: *94*). As opposed to the MLP, the approach

[1] The focus on Germany provides a geographical scope for the research and should not be regarded as National Innovation System approach. The focus lies on the technology on EV fast-charging and justifies the unit of analysis. Furthermore, the TIS analysis allows the opportunity to include the international context to some extent.

helps to describe and understand an emerging technological innovation in its dynamic evolvement, and not *ex-post*. Hence, it captures barriers and drivers for the development in a preferable way for this research (Wieczorek et al., 2014).

2.2.1 Structural Dimensions

The agents that are referred to in the definition, namely actors, institutions, their interaction and infrastructure, compose the structure of a TIS. The structural composition of the system is based on mapping these elements and evaluate their presence and capacity to stimulate the functioning of the TIS (Wieczorek and Hekkert, 2012).

Actors contribute to a technology directly (*inter alia* suppliers and consumers) and indirectly (*inter alia* regulators and financiers). Furthermore, actors' choices and actions generate, diffuse and utilise a technology. The specific role of an actor in a systemic approach is not easily identified as the distinction of producers and users is increasingly blurred at this phase (Smits and Kuhlmann, 2004). Thus, actors are defined based on their role in the economic activity (Wieczorek and Hekkert, 2012) such as civil society, federal government, non-governmental organisations, businesses, knowledge institutes (e.g. universities, research centres) or other supplementary parties (e.g. consultancies, legal organisations). Thereby, all the actors can fulfil different roles in the system (Wieczorek and Hekkert, 2012). Furthermore, it should be noted that if a novel technology provides a solution for urgent problems in a regime, it is likely that the actors as well as institutions from this regime will play a major role in the emerging technological field. This is to be expected in the realm of electric mobility (*ibid*.).

As *interaction* is a dynamic factor, it may not be considered as a structural element. Interaction takes place in networks (Jacobsson and Johnson, 2000), considering that networks depict channels, which are important for the exchange of tacit and explicit knowledge and additional resources between actors (Jacobsson and Johnson, 2000). Moreover, networks can be related to markets and therefore contribute to the identification of problems and the development of technical solutions. Simultaneously, they can be unrelated to a specific market and focus on knowledge sharing (Musiolik et al., 2012). In both ways, networks constitute an important role in the formation and enlargement of a TIS (*ibid*.).

Institutions refer to a set of habits, routines and shared concepts that regulate interactions between actors. Formal institutions encompass rules, laws and regulations (hard institutions), while informal institutions include visions, customs and established and repeated practices (soft institutions) (Crawford and Ostrom, 1995). The capacity and set-up of institutions is determined by spatial and social-cultural specificity (Lipsey et al., 2005), as opposed to organisations (Edquist, 1997), which are types of actors.

Lastly, *infrastructure* is part of a TIS' structural composition. The role of infrastructure is not conclusively agreed upon in literature, as infrastructure can be allocated to the institutions as 'framework conditions' (Schmoch et al., 2006; Kuhlmann, 2004). Drawing back on the research question, a demarcation of tangible physical and financial infrastructure is of great importance for the TIS. Physical infrastructure includes *inter alia* roads, instruments and existing technologies *(i.e*. grid system) (Wieczorek and Hekkert, 2012). A deficiency of these tangible assets play a crucial part in the success of the innovation of charging systems. For example, an unstable grid connection would be a direct harm to the diffusion of charging infrastructure. Furthermore, the availability of financial infrastructure for the innovation, such as venture capital, funding schemes and subsidies are eminent (O'Sullivan, 2005).

Taking the delineation of the structural composition of a TIS into account, a first sub-question is derived. As it is substantial to map the current structure, based on capabilities and presence of the described components, the following sub-question is derived:

SQ 1: How is the innovation system for fast charging in Germany structurally composed?

2.2.2 Functional Dimensions

The structural composition of a TIS is directly influencing how a TIS is functioning. Mapping of functional performance enables the delineation of dynamics within the TIS. The research focusses on a set of key system functions, which can interact and influence each other positively as well as negatively (Hekkert et al., 2007). Therefore, they can lead to positive or negative feedback loops (*ibid*.; Jacobsson and Johnson, 2000). Positive feedback loops build up momentum, enabling creative destruction, and may, in turn, influence a prevailing system (Hekkert et al., 2007), whereas negative feedback increasingly hinders the diffusion of the technology (*ibid*.). The functions are delineated in detail hereafter:

Function 1: Entrepreneurial Activities

Entrepreneurial activities play a substantial role in the economical as well as the technological development of the system (Hekkert et al., 2007). Entrepreneurs are able to translate knowledge into specific business opportunities and innovations, while simultaneously being responsible for the generation of technology, and the early diffusion of products and services (Van Praag and Versloot, 2007). The performance of market oriented experiments has the potential to establish change for both, the emerging technology and the connected institutions. Examples for this are projects with a commercial aim, presentations and portfolio expansions. Small and medium-sized firms as well as incumbents can fulfil this function, with the former being regarded as more flexible and more likely to take risks, *i.e.* engaging with the novel technology.

Function 2: Knowledge Development

The function involves learning activities connected to the emerging technology, the market, network and users. The accumulated knowledge can be either of 'tacit' or of 'explicit' nature. It implies 'learning by searching' as well as 'learning by doing' mechanisms (Lundvall, 1992). The former includes R&D activities, the latter involves learning in a more practical matter. Research projects as well as pilot projects are examples for knowledge development activities. Furthermore, 'learning by using' involves learning, which is based on the direct experience of users.

Function 3: Knowledge Diffusion

Interaction amongst interdisciplinary actors enhance innovations, when information is exchanged and therefore accumulated (Carlsson and Stanckiewicz, 1991). Conferences, Workshops and alliances are activities allocated to this function. Communication and exchange within networks and alliances can facilitate and foster the development of standards, norms and a dominant design of the technology (Axelord et al., 1995).

Function 4: Guidance of Search

Activities with a positive effect on the visibility and clarity of specific needs, requirements and expectations among actors become crucial as the technical development implies variation and a selective process (Nelson and Winter, 1982). These activities help creating a direction of development, whereby the development is also influenced by a strategically visible choice through shared expectations, promises made, policy targets, standards and concrete research outcomes. Society, industrial actors and governmental bodies are creating their own perceptions, and thus a guided awareness formation becomes crucial to avoid misconceptions (Borup et al., 2006).

Function 5: Market Formation

Emerging technologies rely on the support and the creation of markets as they face competing technologies (Porter, 1997). Tax exemptions and other market regulations such as favourable conditions, are regarded as activities, which create a protected environment for novel technologies, whilst strengthening the position of the TIS (Hekkert et al., 2007).

Function 6: Resource Mobilisation

The allocation of financial, material and human capital is important to generate a competitive advantage (Teece, 1986). The sufficient availability of assets (materials, capital, human resources) and capabilities, is facilitating the technological development. The importance of each resource differs depending on the respective stage of development. In later stages of development, it is foremost the coordination of resources being crucial to uphold the competitive advantage and disrupt a prevailing regime (Teece, 1986).

Function 7: Creation of Legitimacy

For a disruption of a current regime, the combination of certain delineated functions with a sufficient degree of legitimacy is needed. If this is given, favourable attitudes and societal expectation can be generated (Bergek et al., 2010). The engagement of society and different stakeholder groups benefits the TIS as it supports the conflict with interest groups of the prevailing system and creates a legitimacy to diffuse and develop the novel TIS (Hekkert et al., 2007).

Both, the individual fulfilment of each system function and their interaction, are of importance. Hence, if the dynamics and performance of the emerging TIS should be evaluated, a fulfilment of the functions needs to be analysed. Drawing back on the research question, the following sub-question is derived:

SQ 2: How is the innovation system of fast charging in Germany functioning, regarding its formative stage?

A structural-functional assessment enables the mapping of key activities and the structural components on which the functional activities are based (Jacobsson and Johnson, 2000). Thereby, the analysis allows the identification of barriers and drivers for the growth of the TIS. While the functions are more evaluative in character and allow to assess the performance of a TIS, the structure needs to be altered for better system functioning (Hekkert et al., 2011). These adjustments are connected to the technological development of the emerging technology and its market diffusion. Figure 1 shows that a TIS moves through formative stages in which it grows in the amount and capacity of its structural components. In order to ‘move’ to a next stage, a TIS needs to fulfil a certain set of functions as well as their interaction (Hekkert et al., 2011).

The interaction of functions constitute for the dynamic of the system, whereby changes in functions tend to influence other functions. As aforementioned, positive or negative feedback loops are being created, so-called virtuous or viscous cycles (Suurs, 2009). These patterns of interaction stimulate the diffusion and thereby move a TIS to the next stages. Several combination patterns of the functions can occur, as so-called motors of innovations.

A deeper understanding of these patterns is necessary to identify the incentives and barriers of the system development.

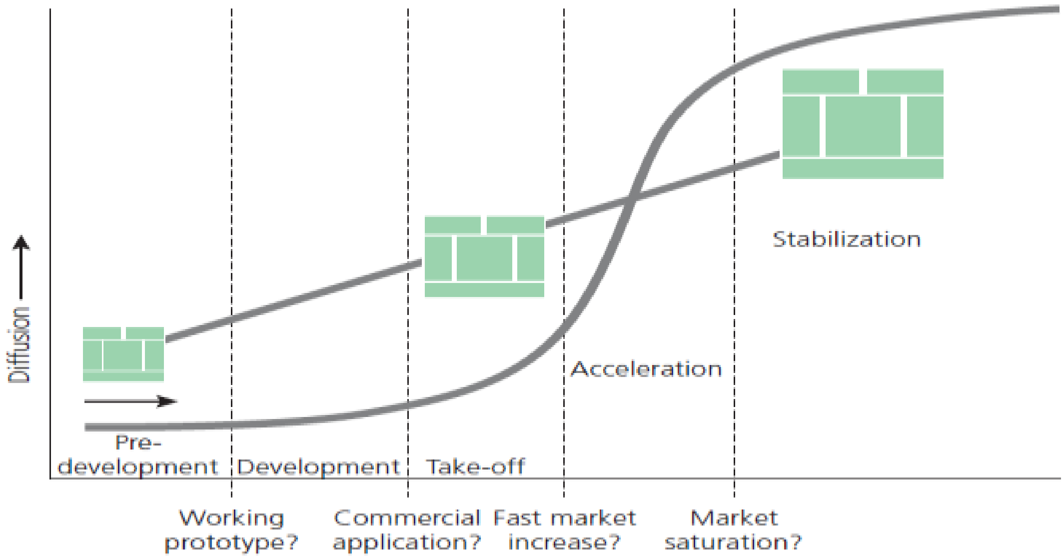

Figure 1 Formative stages of a technological innovation system (Hekkert et al., 2011: 9)

In order to assess the system performance and subsequently its incentives and barriers, it needs to be considered that changes in the structural set-up of the TIS unfold much slower than changes in the functions. The performance and interconnectivity of functions is however based on the structure. Consequently, the structural analysis (*SQ 1*) plays a crucial role for the identification of functional barriers and drivers (*SQ 2*), as notion is that the system components are the altering factor for the latter. Hence, presence and capacity of *inter alia* agents result in functional performance of the TIS.

2.3 Integration of transition theories

This research emphasises the disruption of a prevailing system, namely the fossil-fuelled mobility system. A TIS may be regarded as effective, when the emerging technology reaches a certain level of diffusion, while influencing the society (Hekkert et al., 2011), and in this case, promoting a sustainable technology (*ibid*.). Yet, the transition towards that point however, is influenced by a larger socio-technical system delineated in section 2.1. Markard and Truffer (2008) conceptualised an integrated framework, which entails the location of a TIS in the context of a multi-level-perspective (MLP) (*Figure 2)*. The concept is preferable for the research, as it depicts the role of a TIS in the transition towards a change in the prevailing system.

Furthermore, the MLP allows the integration of the role of firm-specific strategies and specifically business models (Bidmon and Knab, 2014), which are introduced hereafter. The integrated framework entails all aforementioned theoretical implications regarding the MLP and TIS. Subsequently, the role of a complementary innovation system is introduced, *i.e*. other alternative fuels for mobility. The focal TIS is either competing with, or complemented by another TIS. If the purpose of the other technology is similar to the focal one, they are likely to compete, whereas if they are supporting each other (*e.g*. network technologies) the interaction is complementary. Notably, a competition between two TIS may enhance a positive effect as a prevailing system is increasingly disrupted (Markard and Truffer, 2008).

Moreover, the illustration suggests that a niche is a fully integral part of a TIS, which is not always the case as they might bridge different innovation systems (*ibid*.). Besides this, a TIS usually encompasses several niches. These are different application contexts, such as different use cases for charging, *e.g*. slow charging in cities, fast charging for long distance travel or charging for public transport. Whilst the framework is a valuable contribution to transition theory, it has a significant shortcoming: it fails to considerate how firms influence the dynamics within the system transformation (Sarasini and Langeland, 2015). The 'micro level of innovating actors' (Markard and Truffer, 2008: *444*) is being neglected and needs to be put into consideration (*ibid*.: *448*).

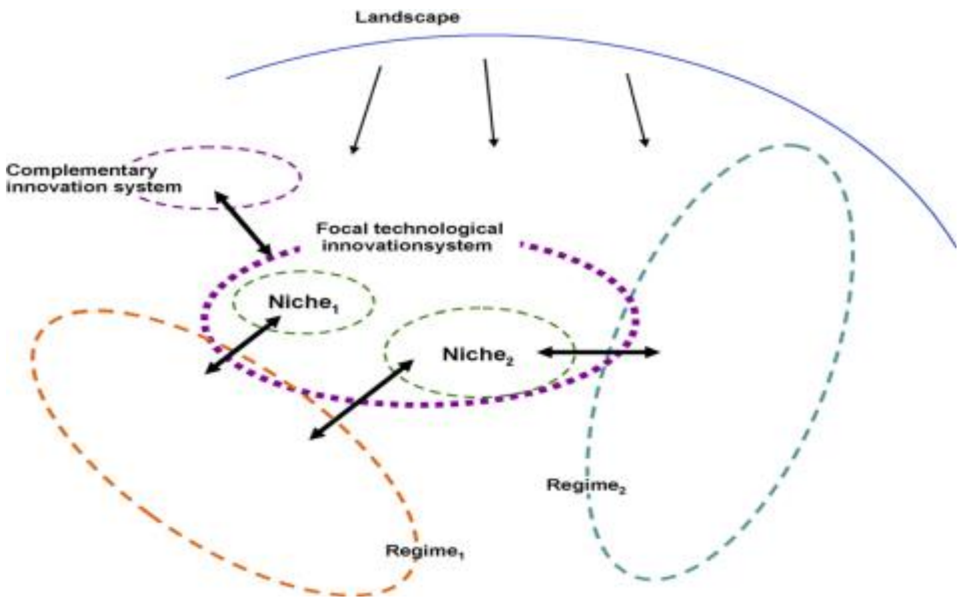

Figure 2 Technological Innovation System and interactions with the multi-level perspective (Markard and Truffer, 2008: 612)

2.4 Business Model Components

It is substantial to integrate the firm-level perspective into the framework to show mutual dependencies as well as influences between firm- and system level. Innovation and strategies, which have an impact on the wider system and *vice versa*, can be linked by the concept of the business model (BM) (Chesbrough and Roosenbloom, 2002). The analysis of a BM reflects realised strategies of businesses (Casadesus-Masanell and Ricart, 2010).

Furthermore, the boundary spanning nature of the BM allows a leverage effect for novel technologies (Bidmon and Knab, 2014). In the following, a business model is defined as:

"A business model describes the design or architecture of the value creation, delivery and capture mechanisms employed. The essence of a business model is that it crystallises customer needs and ability to pay, defines the manner by which the business enterprise response to and delivers value to customers, entices customers to pay for value, and converts those payments for profit through the proper design and operation of the various elements of the value chain." (Teece, 2010: 179)

Through diverse components (*Figure 3*), the BM enables the respective businesses to identify the link between the individual and the larger production system and connectively the consumption system (Boons et al., 2013). First, businesses must address the component of value proposition, without which a business cannot not exist (Morris et al., 2005). It refers to the content of the offered product or service (Bohnsack et al., 2014) and the targeted customer segment (*ibid.*) Customers are satisfied, if the offering implies a requisite quality and, simultaneously, an acceptable price (Teece, 2010). Second, the value network delineates the management of the value chain (Bohnsack et al., 2014). Internally, the value chain incorporates the internal resources, activities and competencies (Osterwalder and Pigneur, 2010). Externally, the business must position itself though relationships and partnerships with suppliers, competitors and its customers (Morris et al., 2005). Third, a BM also consists of value capture mechanisms. It represents how costs and revenue models are designed, which depend on value exchanges with suppliers and customers (Richardson, 2008).

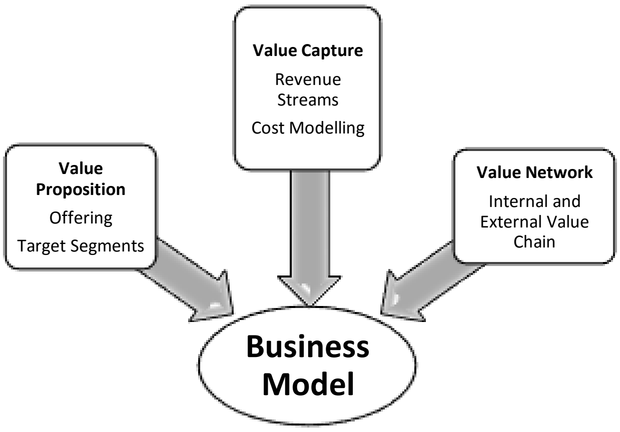

Figure 3 Business Model Components (based on Teece, 2010; Morris et al.,2005; Osterwalder and Pigneur, 2010; Richardson, 2008)

Sustainable innovations are typically connected to high costs and network externalities, which make them unattractive for current business model set-ups (Schaltegger et al., 2016). However, it is necessary to innovate the BM regularly over time, considering volatility of markets and the emergence of new technologies and regulatory frames (Teece, 2010). These changes are increasingly connected to issues regarding sustainability[2]. For that reason, the business model innovation (BMI) ought to address sustainability (Bocken et al., 2014). Here, BMI may address innovations which create a significant positive or reduced negative impact for environment and/ or society, through changes in the organisational business model (*ibid*.).

At the same time, BMI is originally aiming for a redefinition of the business model. To which extent the BM should be innovated is discussed in literature, whereby a more radical innovation, which should exceed incremental adjustments to the current BM (Schneider and Spieth, 2013), is regarded as having a greater effect on transitional processes (*ibid*.). Other strands of literature (*cf*. Schallmo, 2013; Zollenkop, 2006) regard adjustments to just some BM components as sufficient. Essential to both is the alteration of value proposition and value network implications (Casadesus-Masanell and Ricart, 2010).

Drawing back on the research question, the current landscape of businesses in the realm of fast charging must be identified, based on the delineated business model components. Moreover, necessary alterations of the components must be found. Thus, the following sub question was derived:

SQ 3: What type of business model innovations are approached by companies in the fast-charging market?

[2] Markets adapt to pressure from the 'landscape' as well as customer needs (Bocken et al., 2014)

2.5 Business Models in the socio-technical transition

Business model innovation (BMI) is primarily focusing on the internal strategies of firms, However, they are increasingly affected by the innovation system in which firms operate (Zott and Amit, 2007). Nowadays, BMI is increasingly recognised as vital in societal transition towards a more sustainable state (Schaltegger et al., 2016; Bocken et al., 2014; Bidmon and Knab, 2014; Boons and Lüdeke-Freund, 2013), which is commonly accompanied by regulatory or technological turbulences (Christensen et al., 2006). In this case, BMI is important in harnessing infrastructural technologies and ensure a seamless functioning of the technology (Zott et al., 2011; Gambardella and McGahan, 2010). Thus, if the BMI is regarded as a subject of innovation, it becomes possible to outline the way in which firms reshape value propositions, capture mechanisms and the value chain network to meet these requirements and ultimately support the transition of a predominant regime (Sarasini, 2017). Bidmon and Knab (2014) located the role of business model innovation in the transition process (see illustration in Figure 4):

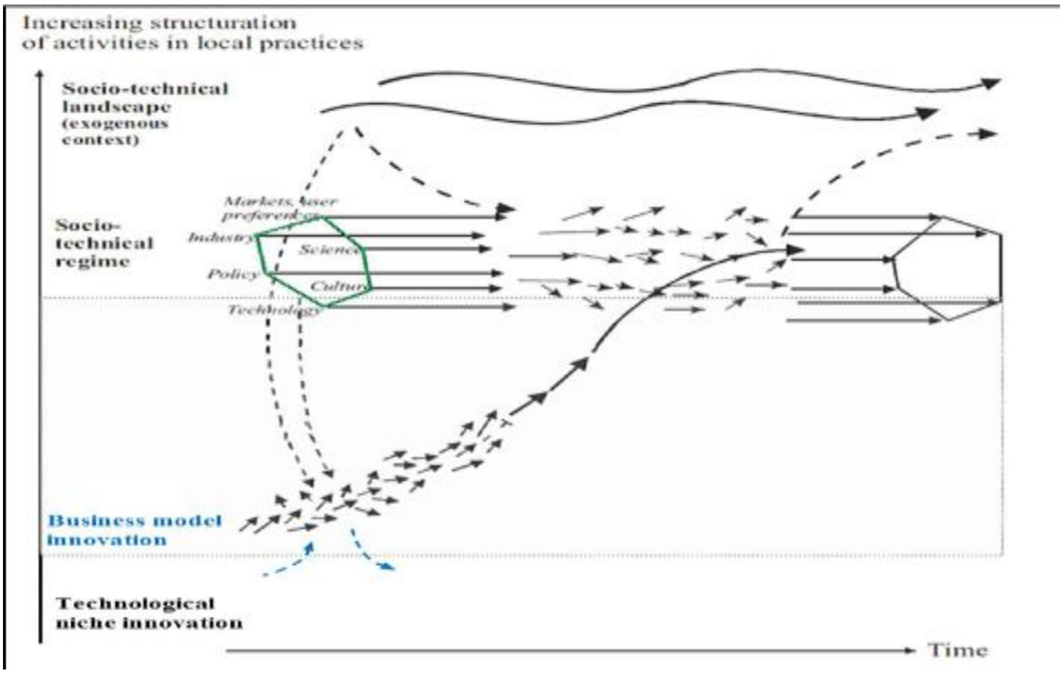

Figure 4 Business Model Innovation in a Transition Process (Bidmon and Knab, 2014: 8)

First, BMI must include commercialisation devices that promote and disseminate the technological innovation (Bidmon and Knab, 2014). Consequently, the BMI supports the diffusion of a technology directly, and subsequently the build-up of a TIS by aiming to refine a particular innovation through entrepreneurial activities (F1) (Sarasini, 2017). Furthermore, the business model can support the stabilisation process of technological innovation, namely the building of networks and systems, fostering of learning processes (F2) and articulation of expectations among actors (Bakker et al., 2015; Musiolik et al., 2012; Geels and Schot,

2010) and therefore stimulate the knowledge diffusion (F3) within a TIS. Moreover, the narrative nature of a business model is described to promote collective sense making (Doganova and Eyquem-Renault, 2009). This component is essential to attract financial resources and to create legitimacy among stakeholders, similar to the functions F6 and F7 of an innovation system (Hekkert et al., 2007), and thus essential in the transitional process. Regarding this role of BMI, it can be located as an intermediate between the niche level and the regime level.

Second, as noted in previous sections, regimes are supported by structural elements (e.g. regulation, infrastructure, interaction patterns, actors). A dominant business model logic is one of these elements, "regarded as an integral part of the current socio-technical regime" (Bidmon and Knab, 2014: *6*). The dominant business model logic is referring to the generic scheme of value creation and capture, which is shared amongst actors in a specific industry (Sabatier et al., 2012). Here, the business model components tend towards stability over time (Sarasini, 2017). Thus, well-established contracts and organisational routines can interfere with BMI (Doz and Kosonen, 2010). It is to be accepted that the automotive regime is increasingly established, so that reconfiguration of value networks is impeded. Moreover, such changes span firm boundaries, whereby coordination challenges become significant for BMI (Berglund and Sandström, 2013). Coordination is regarded as essential in the transition processes as redundant activities can be minimised by the firms as well as effective use of resources (Planko et al., 2017). Therefore, responsibilities need to be arranged within the firm (*ibid*.) and with other businesses alike (Klang and Hacklin, 2013). As trade-offs may result in profitability as well as sustainability matters, businesses take a determining role in the coordination (*ibid*.), which is a substantial element for the transition process (Planko et al., 2017). Regarding the focal TIS at the niche level, coordination of actors and their activities is an enabler to improve functionality of the system (Musiolik and Markard, 2011). While functions such as the Guidance of Search (F4) or Market Formation (F5) include alignment objectives, the role of coordination as an accelerator has been highlighted in previous research (Planko et al., 2017).

The options are twofold: on the one hand a novel technology may be coupled to a BM that fits the current regime and is therefore able to exploit the prevailing infrastructure of the regime (Haxeltine et al., 2008). Still, this is regarded to have less of an effect on the way business is done within the system (Bidmon and Knab, 2014) and would not benefit the transition to *i.e.* cleaner mobility in a great extent (*ibid*.). Notably, some evidence suggests that business model innovation, which is maximising its opportunities based on the existing regulatory conditions can provoke shifts in the legitimacy of these conditions and hence effect the functionality of an innovation system in positive or negative ways (Huijben et al., 2016). On the other hand, the innovation of the BM itself allows a more radical change to how business is done within an industry. Yet, it is opposed to higher resistance by the regime (*ibid*.). Here it is highlighted that the institutionalised business model logic is able to act as a source of inertia within the regime as it is aligned to system elements such as regulations or infrastructural settings (Sarasini, 2017). Besides, incumbent firms in the regime, which view radical change as threat to their interests, are becoming a barrier as they use their resources and power to maintain the status quo (Augenstein and Palzkill, 2015; Markard et al., 2012).

In summary, Figure 4 illustrates the role of BMI in the transition process of a technological innovation (*cf*. Bidmon and Knab, 2014; Geels and Schot, 2007). It shows that the innovation of the firm's business model is the intermediate between the niche and regime level. Furthermore, the socio-technical regime entails a current business model logic (highlighted in green), which influences the business model innovation in the niche and may impede the transition as described (*ibid*.). However, the regime and landscape level of the system do not only impede the process as shown: with regards to sustainability, involvement of incumbents (regime) and regulatory changes in the landscape can foster the potential of BMI through a co-evolutionary process (Schaltegger et al., 2016; Elzen et al., 2004)[3]. The dotted black arrows delineate these influences. The blue arrows delineate the persistent mutual influence between the technology development on the niche level (i.e. the TIS) and the BMI that equally adapts to novel technological developments (Calia et al., 2007). At large, the integration illustrates how businesses can influence transitions by innovating their business model (Bidmon and Knab, 2014) and subsequently directly affect the currently dominant regime structure. Connectively, BMI is important to harness an infrastructural technology such as EVC and ensure seamless functioning for a user (Zott et al., 2011; Gambardella and McGahan, 2010). Therefore, in order for BMI to influence the system performance at the niche level, it must have a direct influence on the structural composition and subsequently the function fulfilment of the system. Simultaneously, the development on the technological niche level will affect the BMI. Drawing back on the research question, the following sub-question is derived:

SQ 4: How do business models have to be innovated in order to stimulate the system development?

[3] The authors identify co-evolutionary pathways for shaping BMI to reach a mass market: *inter alia* growth through joint replication, replication with collaborations and mimicry (Schaltegger et al., 2016) and simply the involvement of incumbents in the niche that reinforce spill-over effect to a mainstream market (Elzen et al., 2004).

2.6 Conceptual Model

Figure 5 illustrates the conceptual model guiding this research. The model summarises outlined theories and incorporates the derived sub questions that have been described. The technological innovation system is depicted at the niche level, whereby the structural set-up influences the functional and ultimately the overall system performance. Over time, the TIS is expected to develop in size and diffusion of the technology and thus influence a change at the regime level. As previously mentioned, the business model innovation is introduced as an intermediary level (Bidmon and Knab, 2014). BMI entails mechanisms to harness the infrastructural technology and ensure seamless function and thereby facilitate the technology to influence a regime level (Zott et al., 2011). Thus, BMI plays a vital role in influencing the regime level during times of turbulences (Christensen et al., 2006) or the so-called 'window of opportunity (Geels and Schot, 2007). The socio-technical regime also includes a dominant business model logic (illustrated as the green hexagon) (Bidmon and Knab, 2014) and incumbent interests (Markard et al., 2012) as prominent sources of inertia. Moreover, the landscape level is applying pressure on the current regime and can therefore create opportunities for business model innovation ('*windows of opportunity*') (Geels and Schot, 2007) and further the niche level (*i.e*. TIS) (Markard and Truffer, 2008). In the specific case, the regime in the mobility sector is destabilised, as the focus in legislation has shifted towards the fostering of cleaner mobility, and thus benefit from the roll-out of EV in general, and connectively charging infrastructure in specific. The model entails the necessity to consider the business model of a firm as subject to innovation (Bidmon and Knab, 2014) in order to create a higher leverage on systemic change and, consequently, the recreation or creation of a regime (orange hexagon).

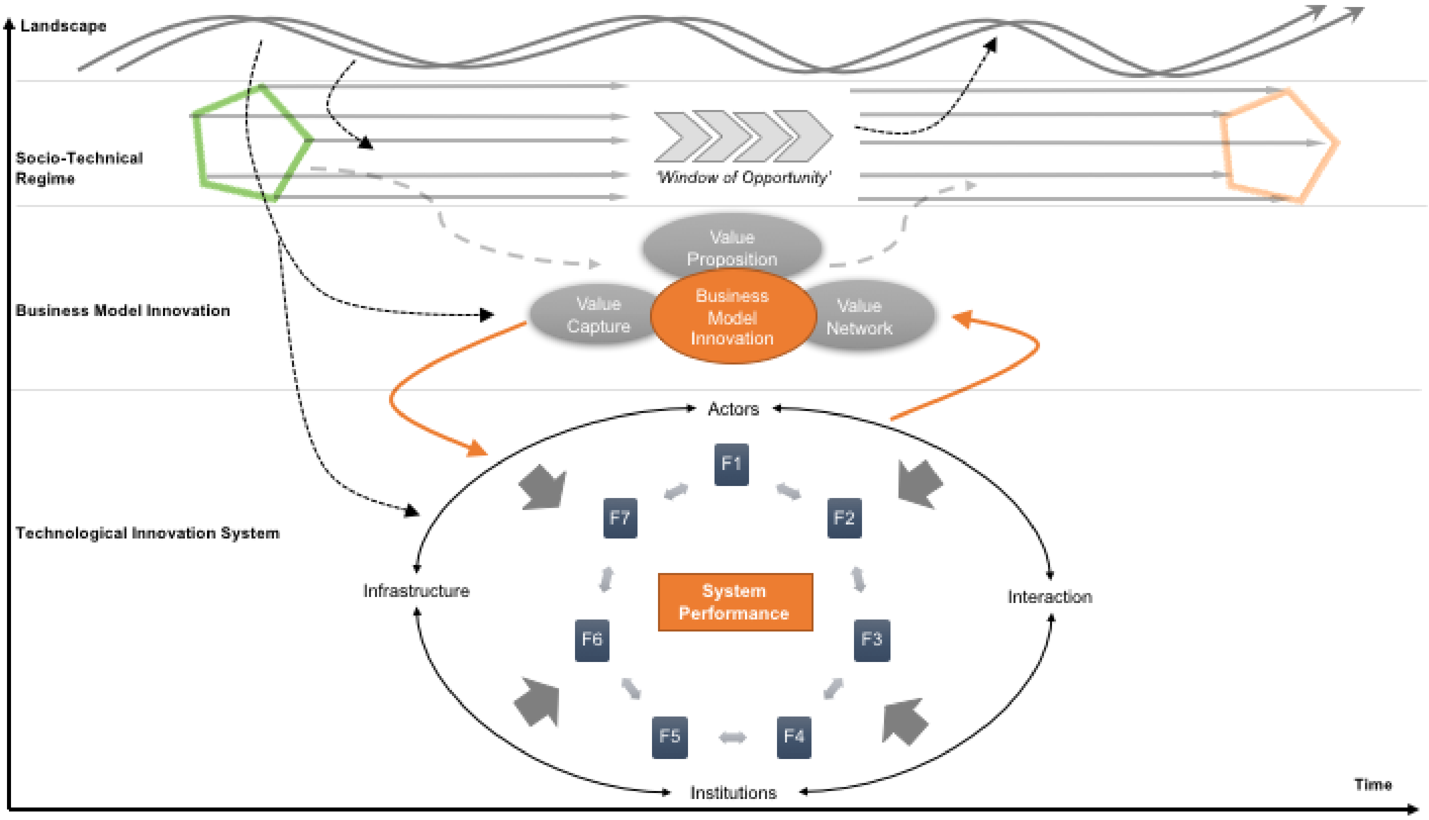

Figure 5 Conceptual Model (adaption of Bidmon and Knab, 2014; Markard and Truffer, 2008; Hekkert et al., 2007; Schot and Geels, 2007)

The development of such a business model is affected mutually by the focal TIS (structural and functional), on the one hand (indicated by the orange arrows), and prevailing socio-technical regimes, on the other hand (Markard and Truffer, 2008). As BMI for infrastructural technology aims to harness the technology first and foremost, implications from intermediate level can foster the development of the TIS. This is achieved by following the derived sub-questions. The structural-functional assessment (*SQ1/SQ2*) examines the systemic performance (indicated in orange). The assessment is complemented by an identification of the dynamics on the intermediary level (*SQ3/SQ4*). Here, it becomes important to analyse current approaches of actors in the EVC system in terms of their business model set-up and further how business models should be innovated to stimulate the commercial viability and seamless availability of the technology. Thereby, the development of the TIS is concurrently affected as necessary changes in the structure can be derived, that ultimately stimulate the functionality of the TIS (indicated by orange arrows).

3. The Concept of Fast Charging

As the research is based on the concept of fast charging for electric vehicles, it becomes important to demarcate fast charging (FC) from other types of charging infrastructure and to clearly point out the use case which is being investigated and to define the research subject.

The research exclusively focuses on electric vehicles for individual transport. This includes all (fully) battery electric vehicles (BEV), plug-in hybrid vehicles (PHEV) and Range Extended Electric Vehicles (REEV) that meet the technical requirements of fast charging. In the following sections, these are referred to as EVs. Batteries of EVs are momentarily charged by conductive charging[4] (with a cable) or through recuperation[5]. The batteries can be charged via alternate current (AC) or direct current (DC). A major economic difference between these two technologies is that in the case for AC, the power converter is located in the EV, whereas in the DC case, the power is converted by the charging station itself. Hence, an AC charger incurs additional costs for a car manufacturer in comparison with a DC charger (Yilmaz and Krein, 2013). Different power levels and respective charging speeds are classified in regular charging (≤11 kW), semi-fast charging (22-24 kW) and fast charging (< 43 kW). Generally, only DC charging modes are capable to have these charging powers[6] and respectively a charging time of around 30 minutes. Furthermore, the defined use case of fast charging is concentrating on public and semi-public spaces (e.g. supermarkets), as the charging time is facilitating a recharge opportunity on long-distance travels. As of now, fast charging still has a great influence on the lifetime of the battery and is therefore not preferable for home charging or at charging at the work place, i.e. if the battery is regularly exposed to high charging current. In summary, the research defines fast charging as 'conductive DC charging processes with a charging power of ≥ 43 kW for a recharge in public spaces up to approximately 80%[7] SOC (state of charge)'.

Until now, the defined fast charging function is only provided by a selected number of cars, such as the Renault Zoe, BMWi3, Nissan Leaf and Volkswagen e-Golf. These cars are using different plug-in systems, which are evaluated in the analysis section. All cars are downward compatible with other charging powers. Currently the only EVs that can charge at >50 kW are Tesla models.

[4] Other ways are being researched but not yet applied in public spaces: Inductive mechanisms (contact-less charging) are being researched and tested as well as the exchange of the whole battery set. Both charging types shall not be in the scope of the research.

[5] Recuperation appears whilst the car is breaking. Kinetic energy is being converted into energy while the EV is slowing down. This energy is then returned to the battery (Hildebrandt, 2016).

[6] AC is capable to a certain extent; however, the on-board charging equipment is increasing in size, weight and costs and would result in less range capability of the EV.

[7] From a technical perspective, the charging power is decreasing in correlation with the state of charge. Thus, the last 20% of the charging process would imply a greater amount of time and thus charging processes would normally end at around 80% SOC (Hölk, 2010)

Figure 6 summarises a charging process of an EV driver in general. It shows that the EV approaches a charging station, which is run by a specific entity. In most cases, the driver is not a direct customer to the charging point provider. He is contracted with a mobility service provider, who receives information of the charging process and in turn pays the charging point operator for the charged energy. The service provider then bills their customer accordingly. To provide a user-friendly landscape, e-roaming platforms have been established. On the one hand, these connecting platforms are used as communication tool for service provider and charge point operator. On the other hand, the platform facilitates interoperability of charging locations. Thus, customers who are contracted with a specific service provider can use other charge points, which are not directly part of the respective network.

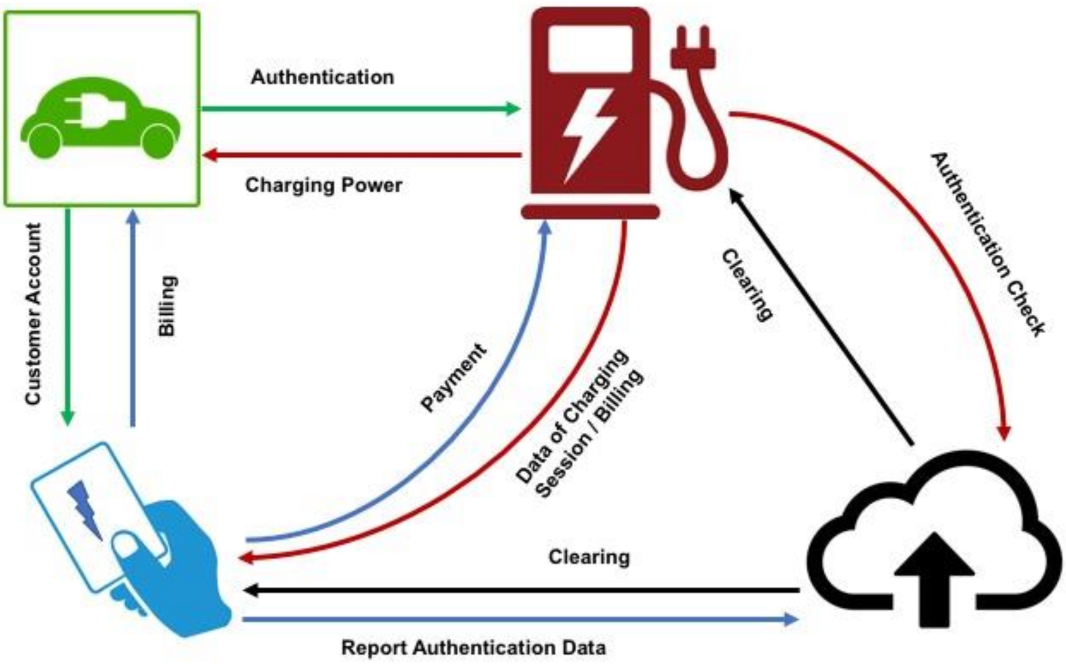

Figure 6 General Charging Process

The contextualisation describes the examined niche in the TIS of electric charging infrastructure. It supports the demarcation of the system and the business model landscape by pointing out what activities are performed, how they are linked and who is performing them (Zott and Amit, 2010).

4. Methodology

4.1 Research Design

The research explored the role of business model innovation in overcoming barriers in the technological innovation system for fast-charging infrastructure in Germany. The case of Germany has been chosen for different reasons: firstly, a spatial delimitation is preferable for the research as the complexity of the system delineation would exceed the scope of the research. Secondly, Germany is perceived as an important country in terms of mobility. It was to be expected that a diverse environment of established networks and institutions can be found. Further, due to its importance in a global context, development of electric mobility in Germany has a great potential for leverage on a global scale, as the mobility sector in Germany has a great influence on the international market. Thirdly, the demand-side-oriented policies in the context of more sustainable and cleaner mobility are increasing, which indicated a change in the landscape-level of the German innovation system, resulting in opportunities for business model innovation to be more successful. The importance for a political change in Germany is high as the supply-side oriented strategy in the past (Wesseling, 2016) has not led to a diffusion of the technology. To meet climate goals and contribute to a sustainable development, adaptions are needed.

Based on the presented theoretical framework, the research design consists of several steps (see Figure 7). The structuration of these steps is adopted and combined based on approaches by different TIS analysis (*cf*. Wieczorek and Hekkert, 2012; Suurs, 2009; Bergek et al., 2008; Hekkert et al.,2007; Negro, 2007). As the first step, the system structure was identified. Here, actors, institutions, networks and the infrastructure are explored. Throughout, the system boundaries can be drawn. A technological system may include several technologies and practices; thus, the structural definition of the system sets a boundary in this regard. Additionally, the geographical boundary of the system is included. Strict boundaries support the identification of all system elements (Carlsson et al., 2002). In the case of the research, the focus lies on fast-charging infrastructure for electric vehicles, which is available in public spaces. Thus, the TIS implies all elements that participate in the formation and development of these charging locations in Germany. The geographical boundary has been set to include the national level as well as the inclusion of international actors that are engaging in the charging infrastructure system in Germany. As the second step, the functionality of the system has been examined. The functions of the system are suggested by Hekkert et al. (2007) and have been identified based on the historical development of the system. The importance of the single functions has been derived from the stage of development of the TIS. The identification of this developmental stage followed the suggested approach by Bergek et al. (2008) (Step 3).

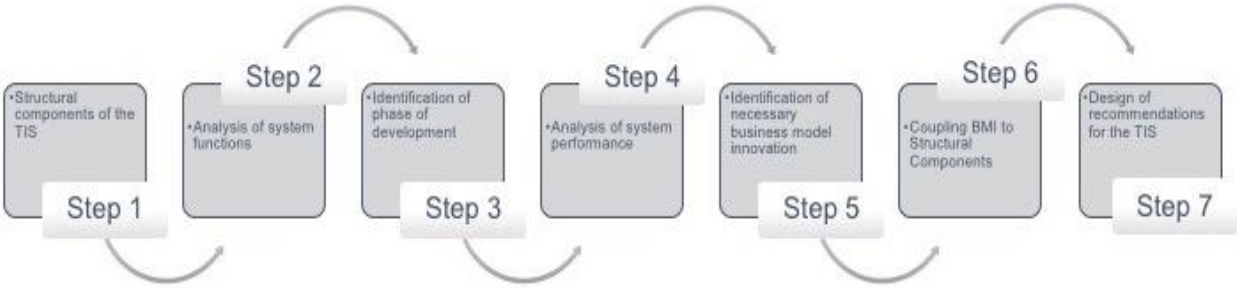

Figure 7 Research Steps

These steps led to the analysis of the overall system performance, which was thus based on the observation of the system development and the interrelations between the functions (Step 4). Throughout, system mechanisms have been identified that not only relate to a sole function, moreover to the overall system dynamics (Suurs, 2009). Thereby, the system barriers and drivers that depend on the respective relation between functions can be identified. As a fifth step, the research has identified the necessary business model innovations for a harnessing of the technology (Zott et al., 2011). The elements of value proposition, value capture and value network of relevant actors have been analysed accordingly. Thereafter, the findings are coupled to the outcome of the fourth step, whereby it was possible to allocate business model innovations to structural components of the TIS and hence influence its functionality. Likewise, the mutual relevance has been outlined, as structural deficits constitute a barrier for BMI. Lastly, recommendations for policy makers and businesses alike have been derived from the results (Step 7).

4.2 Data Collection

The data collection methods are based on the research step that is being undertaken. The identification of the system structure, data has been collected by desk research, literature review on previous research. Furthermore, data bases such as the Web of Science, EU regulation and federal government regulation databases have been utilised in the desk research. Daily newsletter by websites dedicated to electric mobility, helped to map the dynamic changes in the structural set up of the system, whereby the search terms ‘fast charging’ and respectively ‘Schnellladen’ have been utilised.

Steps two and three have been analysed based on an Event History Analysis. The type of data collection is based on a process approach whereby certain sequences of events were systematically collected and reflected complex longitudinal data. Events depict the actions of certain structural components of an innovation system or what they are effect by (Hekkert et al., 2007). Historical events have been retrieved from sources such as journals, newspapers and websites (Negro et al., 2007; Suurs, 2009). The reconstructed development has been ascertained from 2009 till 2017, whereby the time frame is based on the initiation of the *National Development Plan for Electro mobility* in Germany. It was expected, that events regarding fast-charging occur later than 2007. The events were then stored in a database that allowed the systematic allocation and classification of the events to the specific system function (*ibid*.). Table 1 illustrates the types of events that indicated certain functions of the TIS (*cf*. Suurs, 2009: 69).

Table 1 Description of Events (adaption of Suurs, 2009; Negro et al., 2007)

System Function	Description of Event	Indicator
Entrepreneurial Activities (F1)	Projects with a commercial aim, demonstrations of product, portfolio expansions of incumbents	- No. of Projects started (+) or stopped (-)
Knowledge Development (F2)	Studies, Pilot projects, development of prototypes	- No. of stopped (-) or started (+) research projects - Successful improvement of technology (+) - Published studies on technology
Knowledge Diffusion (F3)	Conferences, workshops, alliances, joint ventures, branch organisations	- No. of conferences, actor forums, networks etc. (+) - Lack of networks (-)
Guidance of Search (F4)	Articulated expectations, promises, policy targets, standardisation	- Positive/Negative regulation on charging infrastructure and/or electric mobility (+/-) - Expressed positive/negative expectations (+/-)
Market Formation (F5)	Regulations that support the niche market, tax exemptions, obligatory use of technology	- Favourable tax regimes and standards (+) - Expressed lack of such (-)
Resource Mobilisation (F6)	Subsidies, investments, infrastructure developments (i.e. grid, street etc.)	- Subsidies, investments on charging infrastructure, electric mobility and physical infrastructure (+) - Lack of financial support and infrastructure development (-)
Creation of Legitimacy (F7)	Lobbies, Advisory (Government, Industry, Institutions)	- Lobby activities for improvement of charging (technical, institutional, financial) (+) - Lack of lobbying activities, expressed lack of advisory support by e.g. government (-)

These indicators guided the allocation of events in the database. Hence, the data collection allowed to operationalise the functions and further to measure them. Additionally, an evaluative score (+ or -) is included that allows to measure the impact of a certain event on the system. Events may have a negative contribution to the development of the technology, such as the expression of disappointment or opposing forces (Negro et al., 2007). The data set was finally summarised and illustrated in a graphical way, by plotting the data per year and respective system function. It needs to be noted that only the occurrence is illustrated in this way (Negro, 2007). The explicit content of events and their impact on the TIS is included in a historical narrative, which is based on the plotted event data (*ibid*.). Based on the occurrence of events, the narrative includes different time spans, which are determined based on trigger events This narrative captures the sequential development of the systemic functionality. Throughout, barriers as well as drivers were revealed as the results have been measured against the proposed set of system function for the certain phase of development of the technology (Step 4).

The data collection for the fifth step of the research was twofold. On the one hand the relevant actors have been identified in the first step of the research. A thorough desk research on the business models of the identified actors has been done. Thereby the current market model has been outlined, based on features of value propositions, value capture and the value network as delineated in the theoretical framework. On the other hand, the findings of this step have been validated by semi-structured interviews.

The semi-structured interviews have been conducted for several reasons. On the one hand, interviewees have been asked a set of diagnostic questions, whereby they have been introduced with the concept of the TIS. Furthermore, triangulation was applied by comparing the results of the interviews with desktop research. The interviewees have been asked to link identified barriers (based on the diagnostic questions) to possible business solutions and the potential role of businesses. Conclusively, the interviewees have been asked to evaluate the functionality of the system on a scale from 1 (absent) to 5 (excellent). 18 interviews have been conducted with a length of 45 minutes up to two hours, depending on the spare time of the interviewee. The interviewees were representatives of leading industries and relevant knowledge institutes, moreover the interviewees have all been in strategic positions in the business to allow a valid reflection on the business model and the understanding of the surrounding system. Besides, the interviewees have been chosen to reflect actors of the TIS as best as possible and along the entire value chain. The interviewees are presented anonymously, based on their work title only (see Table 2). The interviews will be referenced in the results section, based on the interview number. Besides, the interviews have been conducted in German language, to minimise language barriers and avoid misinterpretations. All interviews were recorded to ensure transcription. If the interviewee did not agree to be recorded (three cases), notes were taken per hand. Some interviewees had concerns regarding confidentiality matters, thus the author prepared the signing of a non-disclosure agreement and anonymisation in the final report. Finally, the interviews were made available to the interviewee to confirm the validity of the information and to provide another opportunity to include missed points.

Table 2 Overview of Interviewees

Company/ Institution	Work Title	No.
Knowledge Institution	*Research Associate*	1
Hardware Supplier	*Process Manager*	2
Charging Association	*Chairman*	3
Association of Original Equipment Manufacturers	*Project Manager*	4
Original Equipment Manufacturer	*Senior Manager*	5
Knowledge Institution	*Research Associate*	6
Hardware Supplier	*CEO*	7
Roaming Platform	*CEO*	8
Federal Agency	*Project Manager*	9
Mobility Service Provider	*CEO*	10
Media Platform	*CEO*	11
Charging Point Operator	*COO*	12
Software Supplier	*Product Manager*	13
Distribution System Operator	*Project Manager*	14
Mobility Service Provider	*CEO*	15
Charging Point Operator	*Project Manager*	16
Mobility Service Provider	*Project Manager*	17
Mobility Service Provider	*Senior Manager*	18

4.3 Data Analysis

The transcripts that were obtained have been analysed using a qualitative content analysis approach. A category system is a central instrument of the qualitative content analysis as it can put objectives of the analysis into more concrete terms (Mayring, 2010). However, how those categories are defined is open to the author as a clear definition is lacking (Krippendorff, 2004). Three aspects have been considered when creating the categories. Firstly, a definition of the categories determines, which part of a text underlies a certain category. Secondly, 'anchor-examples' (Mayring, 2010: 62) show a concrete passage that concerns a category. Thirdly, coding rules are set that enable a demarcation of the categories (*ibid*.). Moreover, sub-categories have been included to ensure a detailed allocation of assertions. As the categories derive from the theoretical framework, the categorisation still is open to adjustments. When novel information was found, the categories had been adapted (Gläser and Laudel, 2010). As the amount of data and the structuration is highly complex, the software tool NVivo™ has been utilised. The tool allowed the structuration of categories (namely nodes in the tool) and a quick allocation of content. The category system is twofold: on the one hand, the categories follow the system functions and their implications. Hereby, the categorisation follows the classification scheme of the event analysis. On the other hand, the categories were derived from business model literature and subsequent indications. The content analysis was based on the need for business model innovation, thus proposed changes to the current market model have been allocated to the categories. The categorisation system is depicted in The categorised content entailed indications of business model activities i.e. firm-level perspectives on needed alterations. These executed or planned business model innovations are directed towards harnessing the technology of fast charging in the most preferable way for user and businesses alike. By linking the business model innovations to the structural components of the analysed TIS, the identified barriers for increased functionality of the TIS can be stimulated.

*Table **3***, and the interviewees propositions have been coded based on this categorisation system. The categorised content entailed indications of business model activities i.e. firm-level perspectives on needed alterations. These executed or planned business model innovations are directed towards harnessing the technology of fast charging in the most preferable way for user and businesses alike. By linking the business model innovations to the structural components of the analysed TIS, the identified barriers for increased functionality of the TIS can be stimulated.

Table 3 Category System for Qualitative Content Analysis

Category	Sub-Category	Definition	Example
Value Proposition	Offering	Statements on charging as a product and/ or service	*“Visibility is a huge topic. Currently, there is no type of branding for charging infrastructure. The people do not recognise, what is in a fare away corner.”*
	Target Segment	Statements on the target segment for fast charging	*„Many E-drivers, that driver around today, are financially well situated – but I think that to really accelerate, you have to observe who are the next ones. And then the price will play a huge role.”*
Value Capture	Revenue	Statements on how revenue is generated	*“In general, people do not like monthly subscription fees and I am not sure whether this is going to work.”*
	Cost Structure	Statements on the barriers in terms of operational and capital costs	*“The CPO could be a lot cheaper if they only have direct payment because you don’t have all these IT interfaces to implement you can save a lot of operational cost.”*

Value Network	Position	Statements on the value chain	*"If we talk about direct payment, it is also the question: do we need to have all these roaming platforms? Because it is quite complicated and expensive to connect to all these roaming platforms."*
	Value Creation	Statements on the specific key competence regarding the market	*"With us the cost per bill is extremely low: not 25€, more like 25 cents. That already describes the whole problem that this industry has with processing payments – we have automated everything, or most of it."*

4.4 Quality of Research

The quality of research is being assessed based on internal validity, external validity, construct validity and reliability (Bryman, 2008).

Internal validity is achieved when a causal relationship between the variables is established (*ibid*.). The technological innovation system mechanisms that are being investigated are popularly used and verified within other researches. Thus, a relation between concepts is given. Yet, the novel introduction of the role of business model theory in the TIS construct is weakening the internal validity of the research, as the synthesis of two exceptionally diverse fields of research is approached. External validity, whether a result is generalisable (*ibid*.), is limited. As the analysis of the technology is specific in its nature and the respective market model as well, a generalisability of the outcomes is restricted. Nevertheless, it is assumed that the outcomes and the theoretical framework can be generalised for similar cases in which a TIS reached a formative stage wherein business strategies have a greater leverage effect. Furthermore, construct validity is proven when the performed measurements are accurately reflecting the introduced concepts (*ibid*.). Hence, the derived indications must fit the scheme. As the concept of TIS is well researched and implies a straightforward definition and guidance on how to perform such an analysis (*cf*. Wieczorek and Hekkert, 2012; Suurs, 2009; Bergek et al., 2008; Hekkert et al., 2007), the research is benefiting from this in terms of construct validity. Reliability accounts for repeatability and objectiveness of the research (Bryman, 2008). As the fourth section clearly outlines the methodical steps regarding the derived sub-questions (section 2), it is feasible to assume a high degree of reliability.

5. Results

5.1 Structural Analysis

The section presents the structural configuration of the innovation system at hand. It includes the actors, interactions, institutions and required infrastructure. The structural components should be present on the one hand. On the other hand, actors and institutions must have a certain degree of capacity, networks and infrastructure must be of sufficient quality.

5.1.1 Actors

Actors in the system of fast charging can generate, diffuse and utilise a technology, based on their choices and actions (Wieczorek and Hekkert, 2012). Different categories of actors have been investigated in the research: governmental bodies, knowledge institutes, educational organisations and industrial actors *i.e.* supply and demand side of the technology. Involved actors until mid-2017 are in the scope of the research. As the system entails a pan-European objective, actors partially stem from other European countries.

Governmental bodies in Germany have been active in the support of electric mobility in Germany and subsequently fast charging infrastructure. The Ministry of Economic Affairs and Energy[8] (BMWi) is involved in the regulation for renewable energies and the electrical infrastructure, such as the grid, in Germany (BMWi, 2017). The ministry is split in several federal offices which act accordingly and mainly take an administrative role, such as the Federal Office for Economic Affairs and Export Control[9] (BAFA) (*ibid*.). Moreover, the Federal Ministry of Transport and Digital Infrastructure[10] (BMVI) is directly involved in the development of concepts, strategies and impact assessments for charging infrastructure in Germany and are directly responsible for the road constructions and subsequently building permission regulations (NPE, 2015b). Additionally, in 2010 the BMWi and BMVI established a Joint Agency for Electric Mobility (GGEMO), together with the Federal Ministry of Transport, Building and Urban Development (BMVI, 2010; *ibid*.). The agency has been established to bundle and coordinate the governmental tasks regarding electric mobility and the governmental strategy (BMVI, 2010). Furthermore, the Federal Ministry for Education and Research (BMBF) and the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) are involved in legislation that is indirectly effecting the system for fast-charging (NPE, 2015b).

Knowledge institutes include universities, technology and research centres and other

[8] Bundesministerium fuer Wirtschaft und Energie (BMWi)
[9] Bundesamt für Wirtschaft und Ausfuhrkontrolle (BAFA)
[10] Bundesministerium für Verkehr und digitale Infrastruktur (BMVI)

institutes. As the technology of fast charging has its origin in electric engineering, many institutes contributed to the development of the technology (Interview 7). Many technical universities in Germany are relevant in the frame of electrical engineering and automotive research and had an influence in the technology development, such as the TU Berlin, TU Munich, University Stuttgart and RWTH Aachen[11]. Furthermore, the Fraunhofer Society has contributed vastly to the development. The Fraunhofer Society is made up of 69 research institutes across Germany of which several are linked to topics such as renewable energy and electric mobility, such as the Institute for Systems and Innovation research (Fraunhofer ISI) and the Institute for Industrial Engineering (Fraunhofer IAO) (Fraunhofer, 2017). The Fraunhofer Society has often been directly involved in pilot projects and other research projects in the funding scheme of the governmental bodies. Furthermore, the Karlsruhe Institute of Technology (KIT) has produced several publications (KIT, 2017).

To map the *industrial actors*, the following will delineate a value chain within the system. The depicted value chain excludes subordinated actors in the value chain of OEMs as well as for the Hardware suppliers. Their presence is sufficient and their influence on the system in general is limited.

The transport and the distribution of electricity is operated by transmission system operators (TSO) and distribution system operators (DSO). As charging infrastructure is directly connected to the distribution system, only the DSO becomes relevant as an actor (Hildebrandt, 2016). Germany has around 900 DSOs, who are monopolists in their coverage area and together cover the whole country (*ibid*.). In a coverage area, a DSO must make electricity supply accessible to everyone. In the distribution networks only alternating voltages are occurring with a maximum of up to 380 kV (*ibid*.). Furthermore, there are the high-and medium voltage networks with 1-110 kV and the low voltage network with 230 to 400 V. These DSOs are partially privately-owned companies or publicly-owned. The number of DSOs becomes a barrier as the contracts with DSOs are not based on standards and therefore the process of grid connections varies per area (*ibid*.; Interview 1).

Hardware suppliers (EVSE) offer the charging technology on the market in different models. Currently, several fast charge models are installed across Germany. Three suppliers are based in Germany (ABB, EBGcompleo and Bosch). Other hardware suppliers are Delta Electronics, IES (both from The Netherlands), EFACEC (Portugal), EVtronic (France) and Tritium (Australia).

As the construction and installation at the charging locations does not require specialised actors, installation partners in the value chain are regular installation companies of which several are across Germany (Interview 7).

[11] Most acknowledgeable knowledge institutes regarding fast charging technology, based on a Web of Science search. A vast amount of universities in Germany is researching on topics around fast charging such as battery technologies. These are indirectly influencing the TIS, however do not fall in the scope of the research.

The hardware is purchased by the charging point operators (CPO). The CPO acquires the hardware and manages the location securement and installation of the chargers. Furthermore, the CPO is responsible of operation and maintenance of the installed chargers (Hildebrandt, 2016; Schroeder and Traber, 2012). The CPOs are closely linked to multi service providers (MSP), as the CPO sells and accordingly invoices charging services to the MSP. The MSP is in general responsible and offers charging services to the end customer (Hildebrandt, 2016). In turn, the MSP pays the CPO for the charging services that the MSP's customers have obtained at the CPOs charging stations (*ibid*.). The MSP manages end customer accounts and issues e-mobility tokens (e.g. RFID cards) or provides smartphone apps that customers can use to unlock charging stations. Several actors in the market act as CPO and MSP simultaneously. Table 4 shows the current CPOs and MSPs in the market for fast-charging infrastructure in Germany. More international companies have announced to deploy fast charging infrastructure in Germany in the near future, *i.e*. FastNed (Netherlands) and ChargePoint (USA) (Interview 11).

Table 4 Overview of deployment (based on desk research; June 2017)

Company	MSP	CPO	Operational Fast- Chargers in Germany
EnBW (GER)	X	X	68
Innogy (GER)	X	X	?
Ladenetz (GER)	X	X	13
Smatrics (AUT)	X	X	4
Tesla (US)	X	X	56
BMW ChargeNow (GER)	X		-
VW Charge & Fuel (GER)	X		-
PlugSurfing	X		-
Allego (NL)		X	116
DG-Verlag		X	18

Any transaction in which charging (CPO) and end customer billing (MSP) are provided by different entities requires communication between the two parties for the authentication, authorisation and clearing of the charging process. In this case, the CPO needs to check with the MSP whether the end customer that requests to charge at the CPO's charging station can charge, i.e. whether they have a valid contract with the MSP (authentication) or not. If the MSP report approval, the CPO authorises the charging session. After charging is finished, the CPO bills the charging session to the MSP, who is clearing the balance on behalf of its end customer. This data interchange is called e-mobility roaming (Hildebrandt, 2016). Two roaming platforms have been established in Germany, namely Hubject and eClearing (NPE, 2015a).

On the other side of the fast charger are the original equipment manufacturers (OEM), i.e. the car manufacturers. As they produce and distribute the electric vehicles that are supposed to charge at a fast charger, their influence is eminent. The cars must entail certain software and hardware features to be able to charge at the locations (Hildebrandt, 2016; San Román et al., 2011). A specialised OEM is Tesla, who is currently deploying charging infrastructure on their own. This infrastructure is not usable and accessible for other EVs and therefore not regarded as publicly accessible (Hildebrandt, 2016; Bakker et al., 2015). Several OEMs are active in the system, however the amount of EVs available in the market that can charge at a minimum of 43 kWh is very limited. The OEMs have great capacities, however are not utilising them (Interview 9). A structural deficit lies in the value chain of OEMs, as the production of batteries is regarded as critical (Interview 4, Interview 9). This has an indirect influence on fast charging, as the EV production is hindered. On the one hand, it is regarded as being environmentally damaging due to its carbon emissions during the production (cf. Bräuninger et al., 2017). Media portrayals of electric mobility often use this argument to defend ICE vehicles (e.g. Schwarzer, 2014). Besides, rare materials such as cobalt are scarce and are harvested under questionable circumstances at times (Bräuninger et al., 2017; *ibid*.). As the production of EVs increases, cobalt will become a critical factor whether electric mobility is sustainable or not (*ibid*.). On the other hand, Germany tends to fall behind in the production of batteries (Bräuninger et al., 2017). Experts mention that for German OEMs to remain economically viable in the future, battery production and research must be accelerated in order to keep a leading position in the global market and thus stay independent from mainly Asian producers (Interview 3, Interview 4, Interview 18).

5.1.2 Interaction

Apart from the presence and capacities of the delineated actors in the system, it becomes important that cooperation and interactions are present between the actors. This may take place within actor groups (such as OEM only), bi-lateral (i.e. universities with industry actors) or across the whole system. Several networks are engaging in the technology of fast charging in Germany and contribute to its development.

In 2008, the National Organisation for Hydrogen and Fuel Cell Technology (NOW) was set up. Its main purpose is the promotion and commercialisation of hydrogen and fuel cell technology products. However, the public-private partnership, which is scheduled for 10 years, also includes research projects conducted by academic institutions and industry to develop the charging infrastructure for EVs (NOW, 2017).

The National Platform for Electric Mobility (NPE) was initiated by the government in 2010, to coordinate the development of electric mobility regarding infrastructure, standardisation and coupled changes in the educational system (NPE 2017b; NPE, 2015b). The NPE combines industrial actors, research institutes and civil society organisations and governmental bodies and is continuously producing studies and roadmaps that are guiding the market (*ibid*.).

Furthermore, the Charging Interface Initiative e.V. (CharIN e.V.) has been founded by incumbent actors, namely Audi, BMW, Daimler, Mennekes, Opel, Phoenix Contact, Porsche, TÜV SÜD and Volkswagen. The interaction is based on the shared goal to establish the Combined Charging System (CCS) as the standard for EV charging (NPE, 2017a; Jar et al., 2016). Similarly, the CHAdeMO Association has been founded earlier by mainly Japanese OEMs to support a different standard for fast charging systems (Hildebrandt, 2016; Jar et al., 2016). Both initiatives entail an exclusive access of its members to communication protocols and specifications of the loading standards (*ibid*.). Working groups in the initiatives consist of diverse members and further develop the specific standard in alignment with the demand of the members (*ibid*.; NPE, 2017a).

Hubject, the aforementioned roaming platform, has been founded in a collaborative act and has several industrial incumbents as shareholders, namely BMW Group, Bosch, Daimler, Innogy, EnBW, Volkswagen Group and Siemens (Ried et al., 2013).

Moreover, the automotive industry is interconnected in almost all areas. The German Association of the Automotive Industry (VDA) is consolidating the opinion and interest of the automotive industry in Germany (NPE, 2015b). The collaboration activities in the automotive industry are being criticised in many regards. The proximity of the incumbent car manufacturer is regarded as being too close (Maisch, 2013). The collaborative approach and speed at which the industry is engaging with electric mobility is a structural barrier in terms of interaction. Moreover, the criticism is implying, that the networks influence on governmental bodies is further impeding the development (*ibid*.).

5.1.3 Institutions

Institutions encompass a set of common habits, routines and entail shared concepts. These are utilised by humans in repetitive manners and are organised by rules, norms and strategies. The presence and the capacities of an institutional set up are eminent to the development of the TIS. The following outlines the most significant institutions that apply to the fast charging TIS. EU institutions play a significant part in the set-up and are therefore included.

The European Union articulated significant strategies and rules on a transnational level, as significant share (around 25%) of the greenhouse gas emissions in the European Union is caused by the transportation sector, rendering it the second largest emitting sector after the energy industry (EC, 2009). Around 70% of these emissions are caused by road traffic. Hence, this sector promises a great potential of CO2-reductions. In the Commissions' white paper, entitled "Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System", the reduction of greenhouse gases by 60% of 1990-level should be achieved by 2050 (EC, 2011). For the EU to achieve this goal, a binding target of reducing emissions by at least 40% compared to 1990 levels by 2030 has been set. The obligation to develop a strategy (EC, 2009) for appropriate, sustainable and renewable powered charging solutions is reflected in the Alternative Fuel Infrastructure Directive (AFID) (Hildebrandt, 2016). In accordance with Commission's Europe 2020 strategy for smart, sustainable and inclusive growth', the 'Roadmap to a Single European Transport Area - Towards a Competitive and Resource Efficient Transport System' (EC, 2011) aims to reduce emissions and the dependence on fossil fuels by distributing green power in the transport sector. Therefore, the AFID establishes a sufficient framework to safeguard the deployment of EV infrastructure in the European Union by defining minimum requirements, which need to be implemented into the national policy framework of the Member States (EC, 2014). As of today, Germany still has not fully implemented AFID into national law (Hildebrandt, 2016).

Simultaneously, to the development on EU level, Germany has published the National Development Plan for Electric Mobility in 2009 (NPE, 2015a), in which a national strategy concerning research, development and market formation for electric vehicles, has been formulated. Hence, the strategy was to combine climate goals with industrial development and make Germany a leading market (*ibid*.). A goal of having one million EV registered in Germany by 2020 was set, whereby fast-charging was initially not included as a part of the plan.

An important funding scheme for the purchase of EVs has been initiated in 2016: the funding scheme entails an abatement of 4000 Euro for BEVs and 3000 Euro for PHEVs for private people and corporate fleets, whereas most of the EV funding programs are addressed to commercial fleet operators (NPE, 2017a). However, subsidies are limited to the maximum purchase price of 60.000 Euro per car. Furthermore, the purchase subsidies are on a first-come first-served basis, and are limited to a total of 400.000 cars (EAFO, 2017).

Moreover, Germany implemented the 'Elektromobilitätsgesetz' (EmoG) in 2015 (Wappelhorst, 2016). The law offers privileges for EVs, such as the usage of public bus lanes, entry to areas where access for conventional cars is limited or prohibited, specific parking allowances, and waiving of parking fees (*ibid*.). Moreover, EVs are exempt from paying vehicle taxes for ten years. In addition, there is an exclusion of tax duties for the electric power consumption of EV-using employees at their workplaces (*ibid*.). Both institutional developments are indirectly influencing the system of fast-charging infrastructure, as the purchase of EVs is being stimulated.

In 2016, the BMWi enacted the charging pole regulation (*Ladesäulenverordnung – LSV)*, which formulates the minimal requirements of a public charging station (BMWi, 2017b) and is therefore directly influencing the fast-charging TIS. The LSV has been adapted in June 2017 to enable direct payment at charging locations, however only affects charge poles that are being installed as of December 2017 (*ibid*.). *Inter alia*, the LSV requires DC charge points to have a CCS plug-in (*ibid*.).

For a DC charging process, the Combined Charging System (CCS) has been established as a standard in Europe (Jar et al., 2016; Schäuble et al., 2016). The CCS includes the Combo-2-Plugwhich can use the same two pins for communication as for AC charging, hence an additional plug in the EV is unnecessary (*ibid*.). The CCS has been introduced in 2012 by German and US OEMs (Audi, BMW, Chrysler, Daimler, Ford, General Motors, Porsche and Volkswagen). The standardisation has been pushed by the American automotive association (SAE) and its European equivalent (ACEA) (*ibid*.). In 2014, the CharIn e.V. was founded as a consortium in order to support the diffusion of the CCS standard (see section 5.1.2) (NPE, 2015b). In 2009 already, Mitsubishi, Nissan, Toyota and others developed a charging standard which was introduced in an organisational form in 2010, as the CHAdeMO consortium (Hildebrandt, 2016). Members of either consortium have exclusive access to data exchange and development schemes of the industry standard. A third relevant standard for the plug-in system has been developed by Tesla (Jar et al., 2016). The depicted standards are incompatible amongst each other (*ibid*.; Schäuble et al., 2016).

As of the 1st of March 2017, the BMVI issued a support programme for the development of public charging infrastructure in Germany, with a prioritisation of fast charging (NPE, 2017a). Charging points must meet the requirements of the aforementioned LSV. Hereby, the hardware, grid connection and the installation can be subsidised. The program is based on a “first come, first serve” principle, however, the programme is taking a demand analysis by the RWTH Aachen into consideration, whereby a maximum of fast charge locations per federal state is set (*ibid*.). If the demand is met, requests will be rejected. Fast charging points with up to 100 kW capacities are being subsidised with 60% of the costs and a maximum of 12.000 Euro. If the capacity is more than 100 kW a maximum of 30.000 is granted[12] (NPE, 2017). For the grid connection 60% are being subsidised, with a maximum of 5.000 Euro for a connection to the low voltage network and a maximum of 50.000 Euros for a connection to the medium voltage network (*ibid*.). A total of 300 million Euro will be granted until the end of the programme in 2020 (*ibid*.).

[12] It is important to note, that these subsidies are per charge point, whereby one charge location includes two charge points. Hence, the depicted subsidies are doubled per charge location.

5.1.4 Infrastructure

Firstly, the *physical infrastructure* is being identified based on the current amount of public fast charging locations, the amount of EVs and the grid. Table 5 shows that the fraction of EVs on the total passenger car stock of Germany only results in 1.71 EVs per 1000 passenger cars. Simultaneously, with one charging point every 100 km, the density would also be insufficient (NPE, 2017a). Moreover, the ratio of 11 EVs per charging point reveals an evident demand of charging infrastructure. The EU framework (AFID) suggests a ration of 10 to 1 (BMVI, 2016a).

Table 5 Statistics Physical Infrastructure (KBA 2017, BMVI, 2016a)

Category	Amount
Population	82,175,684
Size (km^2)	357,375
Street km	645,000
Passenger Vehicle Stock	45,196,626
Electric Vehicles	77,153
PHEVs	32,994
BEVs	44,159
Charging Points	7,407
DC	292
AC`	7,115

Moreover, the numbers do not reflect the network density, as most of the charge points are located in metropolitan areas and other areas lack the physical infrastructure. Figure 8[13] illustrates an overview of the current network density in Germany and shows an imbalance within the country (blue spots indicate fast charging options). Except for the greater cities of Berlin and Hamburg, the East and North of Germany seem not to be well-equipped with charging stations, whereas in the South and West, the network is much denser.

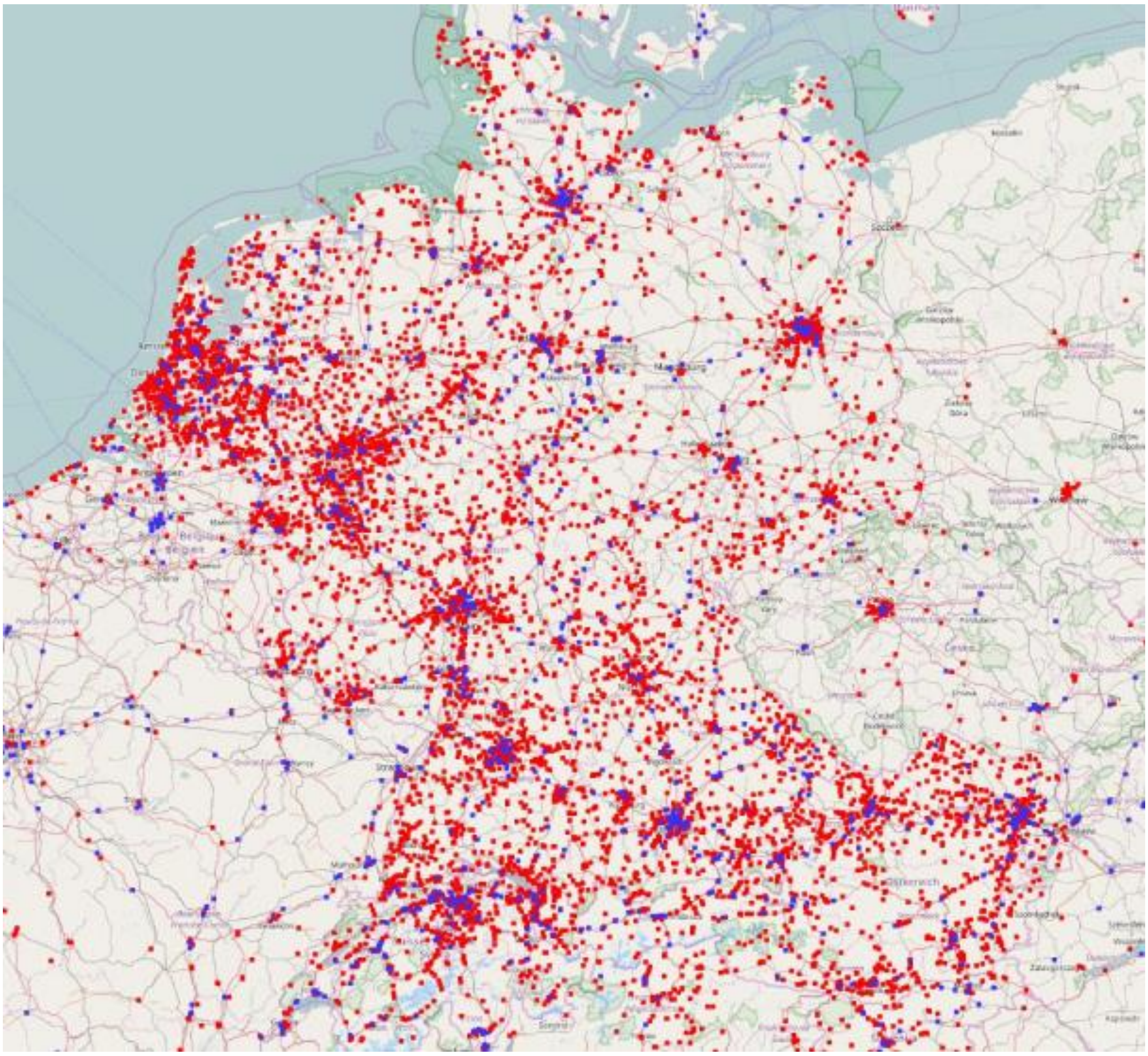

Figure 8 Network Density (based on desk research)

Next to the installed charging infrastructure, the electric grid is eminent for the innovation system. The medium voltage network in Germany is sufficiently developed and does not impede the innovation system. The set-up of the grid connection is not a physical barrier, rather the tariff scheme and different pricing schemes are hindering the TIS.

[13] The illustration is based on desk research from charging location maps and internal data provided by the host organisation

Financial infrastructure is an important element of the TIS as it is needed for R&D activities and further investments in the charging infrastructure. Apart from market related activities in the roll-out of infrastructure, several projects have been funded by the government with different amounts of budget (BMVI, 2016a). For example, the project SLAM (Schnellladenetz für Achsen und Metropolen) is a collaborative approach by OEMs (BMW, Daimler, Porsche and VW), CPOs (EnBW, Allego) and research institutes (Fraunhofer IAO, University Stuttgart and RWTH Aachen) with the goal to set up 400 fast-charging locations across Germany (*ibid*.). The budget of the project is around 20 million Euro and shall be finalised in 2017. Other structural elements in terms of a financial infrastructure have been described in the chapter 5.1.3, such as the governmental subsidy scheme for fast-charging infrastructure with a budget of 300 million Euro until 2022. Further funding has been granted in the scheme of the *Schaufenster Elektromobiliät* projects, which included several pilot projects including not only research and development activities but also installation of fast-chargers (NPE, 2017a).

5.1.5 External Factors

In the analysis of the structural set-up, it became evident that a competing TIS is influencing the fast charging technology. As the government as well as the industrial actors are searching for alternative fuelling systems (BMVI, 2016a), the technology of the fuel-cell engine became popular. Here, the common infrastructure for refuelling can remain, whereby an additional hydrogen fuel system is being added (*ibid*.). The technology is still in an earlier research phase and maybe five to ten years behind electric mobility (Interview 4) but is regarded as a competing TIS. The reason for a delay in the roll-out of fuel-cell vehicles is similar to battery vehicles, as OEMs mention the lack of infrastructure as a reason (*ibid*.; Hildebrandt, 2016). The influence on the researched TIS is mainly reflected in the funding schemes. Both, the federal government as well as the European commission, follow the guiding principle of technology neutral funding (BMVI, 2016a; EC, 2011). Thus, the fuel-cell technology funding amount is similar to the aforementioned financial infrastructure.

5.2 Functional Analysis

The following will delineate the functioning of the TIS. The depicted results are based on the findings of the historical event analysis and expert opinions. The functions (F1-F7) have been described in the theoretical framework and will be marked accordingly. Figure 9 illustrates the findings of the event analysis. Here, the plotted events depict the occurrence of positive and negative effects, regarding function fulfilment. The different time spans are determined by changes in the dynamics through a certain trigger event that effects the direction of the development. As it is difficult to measure the lack of knowledge development and knowledge diffusion through the collection of events, those functions are not being evaluated based on a negative score. The specific content and impact on the TIS elaborated in the following narrative (Negro, 2007).

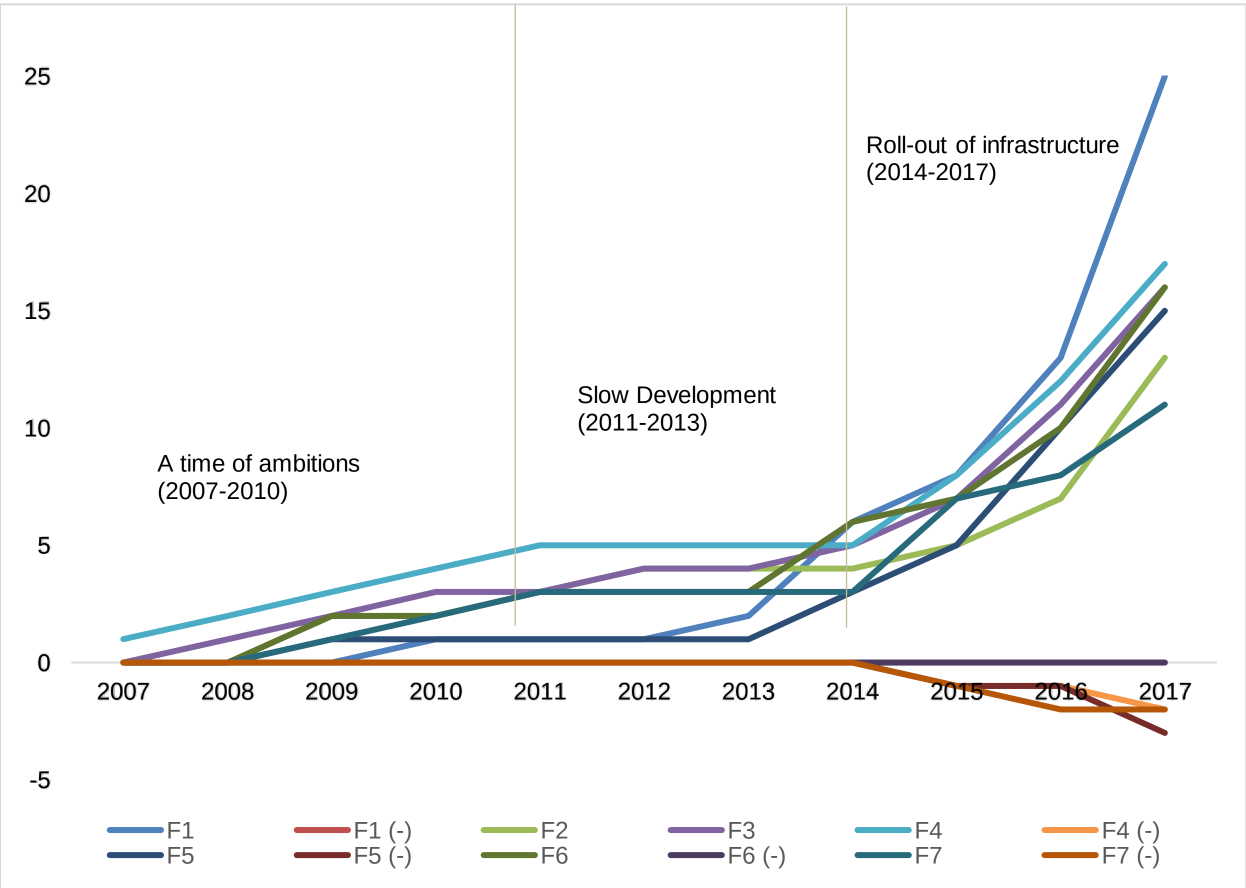

Figure 9 Graphical representation of system function fulfillment over time

5.2.1 A time of ambitions (2007-2010)

In 2007, the federal government of Germany defined for the first time, that electric mobility is an essential part in the integrated energy- and climate program (IEKP), to achieve the nations climate goals (F4) (BMUB, 2007). Moreover, the need for a nationwide infrastructure was included (*ibid*., NPE 2015a). The integration did not result in quick reaction by the federal government and research institutes, however the strategy was to be developed in the following year. In 2008, the first National Conference Electric Mobility (F3) took place (BMUB, 2008), whereby four governmental departments that were responsible at the time, showed their willingness to support a more comprehensive package of support measures (F4) (*ibid*.). Yet, fast charging infrastructure was not specifically substantiated in the strategy of the federal government. The technological development however had already started earlier. The technical components and set-up of the hardware had been developed in the modular- and switching engineering realm (Interview 2; Interview 7). The conference in 2008 was regarded to have paved the way for the National Development Plan for Electro mobility, published in 2009 (BMVI, 2009a). The plan involved the infamous target of one million EVs to be registered until 2020, which had a clear effect on the industrial actors in the field of fast charging. The actors drew motivation (F4) from the declaration, saw it as an indirect reason to invest (F7) (Interview 2, Interview 5) and the internal development of fast-chargers begun (*ibid*.). The Plan also included the set-up of eight model regions in which the network of knowledge institutes and industrial actors (F2) is stimulated by funding schemes (around 130 million in total) (F6) for their projects, that ought to test several research fields in connection to electric mobility in general (BMVI, 2009a; BMVI, 2009b). Only one of the model region was directly involved in the research on charging infrastructure, whereby fast charging was not an explicit integral part (-F2) (Interview 1; BMVI, 2009b). The facilitation of these model regions is coordinated by a newly deployed organisation, the NOW[14] (F3) (NOW, 2017; BMVI, 2009b). Furthermore, the forum for electric mobility was created, whereby the Fraunhofer Institute took the authority (Forum Elektromobilität e.V., 2017). Several topics where declared to be researched (F2) and the project time line was set until 2011 and had been funded with 30 million Euro (F6) (*ibid*.; NPE 2015a). The vision of the federal government and the strategic creation of research networks in the model regions triggered the founding of the National Platform for Electric Mobility (NPE) (F3) (NPE, 2017b). The platform consists of more than 150 representatives of industry, research, politics and institutions and are coordinated into several working groups (F3) (*ibid*.). The platform is creating recommendations for the federal government, based on these groups (F4) (*cf*. NPE, 2015b). Several developments were triggered, such as pilot projects at research institutes in

[14] Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie (NOW)

cooperation with OEMs, e.g. the aforementioned 'Schaufenster' projects (NPE, 2011). Simultaneously, the standardisation process for plug-in systems was increasingly accelerated (Interview 4) on a European level (F4) (*ibid*.).

In summary, the time span from 2007 until 2010 was determined by the formulation of aspirations and the set-up of funded pilot projects. The governmental support and the market development on a global scale (i.e. Tesla as a new automotive manufacturer) have triggered the network building in the realm of electric mobility. However, the active involvement of OEMs was regarded as passive (-F7) and especially the build-up of charging infrastructure was regarded as a topic, where the government should solely be responsible for (-F4). The OEMs took a great part in the set-up of collaborative projects and to some extent contributed financially (*cf*. NPE, 2015a; Interview 3). However, the actual build up was left unattended by this powerful actor. The expectation of the federal government being solely responsible did not seem to be shared amongst political actors (Interview 1) and thus the 'burden' of responsibility was being discussed (*ibid*.). Consequently, the discussion was based on the dilemma of what should be developed first, the EVs or the respective infrastructure. Subsequently, both were using the lack of development of the other to deflect criticism (Interview 5; Interview 11).

5.2.2 Slow development (2011-2013)

The NPE proposed several strategies to the governmental agencies. In 2011, the BMWi introduced regional showcase models (F3, F6), based on previous research activities (Hildebrandt, 2016), that included the planned deployment of fast chargers along the A9 highway and a DC charging station in Munich (F2) (SAENA, 2012; GTAI, 2016). The model regions have been chosen by a jury and include a diverse amount of pilot projects (GTAI, 2016). The federal government funded the showcase projects with 180 million (F6). Additional project partners added to the funding, resulting in a total of 300 million Euro (NOW, 2014).

Simultaneously the automotive industry successfully lobbied for the standardisation of the CCS as the plug-in system that future cars will support (F7, F4) (NPE, 2011). Hence, the charging standard was clarified before the cars were even on the market. This lead to the following vicious cycle: as the funded pilot projects only included the CCS standard in the charging locations, other E-drivers were discriminated (-F5). During this time, the CHAdeMO standard has already been a standard for over a year and was integrated in all Japanese cars (CHAdeMo Association, 2015). Subsequently, the Nissan Leaf, the most popular car at that time, was not able to charge at the locations. Several media reports on charging infrastructure and the positive expectations that have been connected to the projects reversed negatively (Interview 11, Interview 15), as for example media reports on the deployed chargers used a CHAdeMO supported EV for their test drives. Thus, the portrayal ended up being negative and damaged the public opinion on electric mobility in general. Therefore, the sole funding of the CCS standard is regarded as a negative market formation by some (*ibid*.), however others, and mainly the German automotive industry supported the approach (Interview 4, NPE 2017a) as it supports their development of fast-charging capable cars at the time. The short vicious cycle was overcome by CPOs action. After completion of the pilot project, the operationalisation is normally handed over to certain CPOs. In most cases, the CPO added a CHAdeMO charging option to the chargers to resolve the standardisation issue. The cost for this are regarded as moderate, considering the added value (Interview 11).

In 2012, a joint venture was founded (F1, F3). *Hubject* was established to achieve a level of interoperability by building up a roaming platform (Krapp, 2017). The roaming activities were only focused on metropolitan regions at first, whereby the few fast chargers for long-distance travels did not benefit immediately (-F5) (*ibid*.). The BMWi initiated a new technology competition, in which projects could apply for funding (F6) (RWTH, 2012). Among others, seven municipal utilities cooperated as '*econnect Germany'* and won the respective funding (F3) (*ibid*.). The research project included the role of fast charging in municipalities and for long distance travels (F2). In 2013, the first public CCS charging stations have been installed at the grounds of Volkswagen and BMW (F1) (BMW, 2013). The OEMs used the charging locations *inter alia* for the testing of the VW e-up and the BMW i3, which was later introduced to the market (Interview 5; *ibid*.).

The depicted time frame was still highly influenced by the willingness of the automotive industry (F4, F7). The funding strategy of the governmental agencies was regarded as counterproductive by e.g. the *Deutsche Umwelthilfe e.V*. (DHU, 2009), as only incumbents are benefiting from the funding scheme for questionable prestige projects (-F4). The small and medium sized companies as well as the customers should have been funded in a more excessive way during this time (Interview 1, Interview 6). Nevertheless, the standardisation efforts have been regarded as vital for the roll-out of charging infrastructure (F5) (Interview 3, Interview 5).

All in all, the event sequences that have been observed during this time span indicate a diverse occurrence of stimulating events. The sequence in this time span is characterised by F1-F3. As F4 (standardisation (F5), public expectations by OEMs) and the lobbying (F7) by the OEMs are supporting the emergence of fostering regional projects are lobbying for financial resources to the federal government. Positive outcomes of the projects have raised positive expectations and more projects are being pursued, as electric mobility and the role of fast charging appear to have a great potential.

5.2.3 Roll-out of infrastructure (2014-2017)

The year 2014 started with the announcement of the SLAM project, a project which is funded by the BMWi with 16.4 million Euro (F6) (SLAM, 2015; BMWi, 2014). The project involves a cooperation of several industrial actors and research institutes and has set a target of 600 installed DC chargers across Germany until 2017 (*ibid*.). Besides the subsidised installation of infrastructure, the project involves research projects in terms of business opportunities and network planning (*ibid*.). In May of 2014 the eight fast charge locations, which have been installed within the scope of the model region projects, have been made accessible for the public (BMVI, 2014). Several media discourses and public debates around the deployed CCS locations revealed the weaknesses, such as findability at sites (POI data) and functionality issues, of the current system and led to negative expectations (-F4) (Interview 9). Besides the sole deployment of the CCS standard (-F5), the technical failures of the pilot project were apparent (-F2), mostly connected to the premature roaming protocols at the times resulting in problems with RFID cards of the customers (Interview 11). Other model regions, connected to the aforementioned showcase regions, showed the same effects. Nevertheless, the projects are not regarded as failures and novel regional projects such as 'Schnell-Laden' in Berlin are set up, where several industrial actors cooperate with the TU Berlin (F3) (GTAI, 2016) to develop fast charging solutions in the metropolitan area (F2).

Nevertheless, the standardisation efforts for the CCS continued and peaked in the founding of the CharIN e.V., which is a strong lobbying tool for the CCS (F7) with members from a broad industrial spectrum (CharIN, 2017). Simultaneously, the OEMs yearly car show, the IAA in Frankfurt, raises the expectations by bringing a handful of fast charging capable cars to the market, such as the BMWi3 and the Volkswagen e-Golf (F4) (NPE, 2015a; Grüneweg, 2014). Roaming at that time is still remarked as a great barrier, as outlined in the structural analysis. As of March 2015, the BDEW, hands out uniform identification numbers for a public charging station. CPOs can request such a number for a newly installed station to support the roaming system (F5) (NPE, 2015a). The NPE published an important paper that recommends the installation of 7100 charge points[15] in Germany until 2020, based on the one million EV target (*ibid*.). The network analysis is a reasonable target and raises positive expectations amongst industrial actors. The event affected the involvement of incumbent OEMs in the build-up of infrastructure: a joint venture of the biggest OEMs has been announced (F1) (BMW, 2016)[16]. The industrial actors do not see the sole responsibility in the hands of the government anymore (F4) (Interview 4), in contrary to the impeding

[15] One charge pole consists of two charge points; hence the recommendation includes the installation of around 3500 locations.

[16] The joint venture was official founded on the 10th of October 2017 with the name European High Power Charging GmbH & Co. KG and the market name Ionity (FAZ, 2017)

behaviour in the first depicted time span. However, the joint venture will most likely skip the fast-charge technology, in the form it is researched here, and leapfrog to a next generation of charging[17] (Interview 4; BMW, 2016; FAZ, 2017). This has the negative sequential effect, that OEMs also plan their roll-out of EVs accordingly to the next generation of charging and the researched TIS is being left unsupported. However, in September of 2015, the Volkswagen emission affair was being unveiled (BMVI, 2016b). US agencies found that combustion engines had been intentionally programmed so that emission control software was only active during testing schemes (*ibid*.). The same was found for other OEMs and lead to a sequence of negative events for the automotive industry and the ICE vehicle in general (*ibid*.; Interview 3). Thus, the need for electric mobility and the role of OEMs in the acceleration of the transition became a political as well as public debate (F4/F7). The TIS at hand profited as positive expectations on the role of electric mobility increased and market formation efforts by the federal government tried to stimulate the purchase of EVs (NPE, 2017b)[18]. On the contrary, the OEMs tried to protect the Diesel technology and defended the cleanliness of the technology (Interview 3; Vieweg, 2017). Simultaneously, they could steer the political discourse in a way that the automotive industry was not to be harmed, but to be protected because of their economic importance for the country (Interview 6; Vieweg, 2017). OEMs pledged to roll-out more EVs in the future, but on the same hand blamed a lack of infrastructure as a barrier (Interview 4).

Furthermore, the NPE simultaneously requested the sole standard of CCS at all required locations and increased the discrimination of international EVs (-F5) (NPE, 2015a). In 2016, the BMWi translated the recommendations into the biggest funding scheme yet, which includes the subsidisation of fast chargers until 2020 with 200 million Euro (F6) (GTAI, 2016). The subsidies can be applied for and work based on a ‘first come, first serve’ model. Several businesses and regional cooperation applied for the funding and the roll-out for fast chargers has been stimulated (F5) (GTAI,2016; NPE, 2017a). The funding scheme is also open for international actors, which attracted new businesses from e.g. the Netherlands to migrate their fast-charging business into the German market (F1) (Interview 11). Next to hardware costs, the subsidies are also aimed at the grid connection costs, which is regarded as very positive (Interview 5; Interview 17; Interview 18).

Simultaneously, a TEN-T project of the EU, called *fast-E*, started. The project includes the installation of 241 fast chargers across Germany (F5) and is partially funded by the EU (approx. 18 Mio.) (F6) (EC, 2014). Shortly after, the BMWi cooperated with the *Tank & Rast GmbH*, a company that facilitates rest areas along German highways (BMVI, 2016a). The agency of the BMWi is funding the deployment of 400 fast chargers until the end of 2017

[17] The next generation is referred to as High Power Charging, consisting of higher voltages and charging capabilities with up to 350 kW.

[18] See section 5.1.3

(*ibid*.). This had a cumulative effect as the financial support (F6) led to involvement of incumbents in the deployment of those fast chargers (F1). Furthermore, other potential location partners, such as gas stations and supermarket chains are showing an increased interest (F1) in the deployment of fast charging infrastructure and throughout the aforementioned funding scheme becomes more efficient (Krapp, 2017; GTAI, 2016). To structure the accelerated roll-out, the governments enacted the LSV, which set the requirements for a charge point (BMWi, 2017b). However, intially the LSV was assessed quite critical, and subsequently led to a decrease in investment legitimacy (-F7, -F5) (Krapp, 2017; Interview 11; Interview 12). Besides an excessive additional bureaucracy, it has been remarked that the definition of public spaces is including private house owners that make a charging option available (*ibid*.; BSM, 2015). By creating a burden of regulation for those, the supportive function of these charging points has been diminished (BSM, 2015).

The depicted time span shows the transgression of the TIS towards a more market driven system. Results from research projects (F2), such as the required network of fast charge infrastructure, had been published through the NPE (F3) and other pilot projects, that have been initiated in earlier phases were successfully finished. The market formation (F5), e.g. the funding scheme of the federal government, is a sequential effect of these finished projects. Simultaneously, the funding triggered entrepreneurial activities (F1). As the NPE is a joined platform of incumbents, the roll-out plan of the federal government was very much based on the set requirements and speed of these actors. On the one hand, the federal government is thereby able to stimulate incumbent businesses to act and get involved in the transition. On the other hand, a great dependency has been created which is partially reflected in the relevant standardisation efforts, which had a negative effect on the early deployments of infrastructure.

5.2.4 Systemic Problems

The table below provides a summarised overview of the functional assessment of the technological innovation system at hand. It entails an overview of inducement and blocking mechanisms that delineate the functional performance. Furthermore, the functions are evaluated using a 5-tier scale from absent to excellent. The structural components may be targeted to improve the system functions – it is assumed that the alteration of the structural elements and thus the functions can be achieved by business model innovations, which are outlined in the following section (see section 5.3).

Table 6 Overview Systemic Problems

Function	Fulfilment	Supporting Mechanisms	Impeding Mechanisms
Entrepreneurial Activities	**3 (moderate)**	- Large number of OEMs involved - DSOs are diversifying and develop their portfolio with mobility services - Successful CPOs migrate to Germany	- High standards for deployment (e.g. LSV and Eichrecht) - Long permission procedures - Location partners lack cooperation - Diversity of involved businesses leads to complications
Knowledge Development	**4 (strong)**	- Scientific research is centred around a few central institutes - Charging technology is market ready	- Knowledge development is based on industrial actors and knowledge institutes play minor role
Knowledge Diffusion	**4 (strong)**	- Collaboration amongst actors and institutions is implied in national association set-ups such as the NPE - National collaboration is strong as well as collaborative activities on an international level (see CharIN e.V.) - Great amount of venues and projects	- External scientific research (i.e. universities, educational organisations) is regarded as rather unimportant
Guidance of Search	**3 (moderate)**	- Positive expectations of market potential and future necessity - Incumbent industry is strong and resourceful - Technology is reliable and costs are decreasing - Governmental guidance with an articulated mission and fitting strategy as an outcome of a collaborative approach (NPE) - Harmonised regulation (LSV)	- Societal discourse on the role of electric mobility - Technology neutral behaviour on national and international level - Subsidy schemes for EVs are ineffective - LSV as a barrier for deployment and diffusion in semi-public spaces
Market Formation	**3 (moderate)**	- Project roll-out (Tank & Rast, fast- E, SLAM) - Subsidies on installation, grid connections and hardware costs - Public tender - Tax regulation for EV drivers	- Tax exemptions for ICE vehicles still ongoing - Installed capacity still insufficient - Building permission process - Standardisation issues - Concentration on metropolitan areas can evolve in insufficient infrastructure in rural areas - Costs of grid connection (*e.g.* price variety of DSOs)
Resource Mobilisation	**3 (moderate)**	- Availability of funding schemes - Stable grid supply in the country	- Lack of human resources - Funding more applicable to incumbents
Legitimacy creation	**2 (weak)**	- Societal recognition for transition - Expectation of rising number of EVs and thus FC infrastructure - International development (e.g. Norway, Netherlands, China)	- Societal resistance towards long distance EV travel - ICE lobbying strong - Lack of OEM support - High dependence on OEMs

To ensure which function is forming a barrier, the analysis should be put into relation with the development phase of the innovation system, as the importance of functions is shifting. The TIS at hand is currently in the so-called take-off phase, wherein the technology is diffused on a larger scale and the market is growing (Hekkert et al., 2011). Entrepreneurial activities are regarded as critical in this phase, whereby entrepreneurs should act as system builders (*ibid*.). Thus, the creation of legitimacy becomes important to counteract resistance to the build-up. Guidance of search, resource mobilisation and market formation schemes are regarded as supportive functions. Hence, knowledge development and diffusion become less important. The analysis showed that the knowledge development and diffusion has moved to the background and market activities are currently the most relevant.

Against the background of the developmental phase of the innovation system it can be concluded that entrepreneurial activities are regarded as moderate. On the one hand, incumbent firms (mainly DSOs) become active in the field of fast charging and drive the diffusion of the technology in Germany, in collaboration with OEMs. Moreover, smaller firms emerged, such as roaming platforms and MSPs (i.e. TheNewMotion, Plugsurfing). On the other hand, the creation of legitimacy is rather weak and thus impeding F1. As the FC market is highly depended on the OEMs, their lack of engagement in terms of roll-out of EVs is impeding the system function immensely (F7). Consequently, societal recognition of fast charging technology is rather negative, as a lack of infrastructure is often not put in relation with the lack of EVs in general. Moreover, the market formation (F5) can only be regarded as moderate as the installed capacity is insufficient and a favourable environment for FC is not yet fully given. The functioning of F1 is further based on a moderate to strong resource mobilisation, through diverse projects and funding schemes which benefit the engagement of aforementioned entrepreneurs. However, the strong performance of the function will not sustain if the other functions are not improved. As the obstacles are mainly manifested in the structural set-up of the system, it becomes substantial to identify the necessary alterations, related to the impelling functions in the take-off phase.

5.3 Business Model Impact

The research emphasises the impact of business model innovation on the development of the TIS. The systemic problems have been identified based on the structural-functional analysis. Furthermore, expert insights on necessary business model innovation on the one hand and barriers for such on the other hand, indicate necessary alterations of the systems structure and means to overcome barriers. Consequentially, the functionality of the system is fostered. Hereafter, the business model innovations are allocated to the structural components of the systems.

5.3.1 Actors

As firms are embedded in the composition of actors, their perception of the market model and especially value perception is a stimulating factor. In general, experts perceived the current structure of the value chain as preferable. Nevertheless, especially changes in how the technology is offered was remarked as important as well as potential changes in market model set-up. Table 7 provides an overview of the quality of the offering and the subsequently the network reach of actors.

Table 7 Fast-Charging Service Overview (based on desk research; July 2017)

Company	Renewable Energy	24/7 Emergency Hotline	Customer Advisory Hotline	FAQ	FC accessible via roaming (Amount)[19]
EnBW	Yes	Yes	Yes	Yes	Yes (n/a)
Innogy	Yes	Yes	Yes	Yes	Yes (1483)
Ladenetz	Some	Yes	Yes	Yes	Yes (n/a)
Smatrcis	Yes	Yes	Yes	Yes	Yes (90)
BMW	n/a (MSP)	Yes	Yes	Yes	Yes (311)
VW Charge & Fuel	n/a (MSP)	n/a	Yes	No	Yes (150)
Plugsurfing	n/a (MSP)	No	Yes	Yes	Yes (n/a)
TheNewMotion	n/a (MSP)	Yes	Yes	Yes	Yes (n/a)
Allego	Yes	Yes	Yes	Yes	Yes (n/a)

Aside from the fact that there are not enough charging locations/stations which, in addition, many times are blocked by non-EVs, two major problems that are perceived by experts are the erratic authentication of charging sessions (card/contract not always accepted) and the lack of price transparency *(price system is too complicated'* - Interview 11). In fact, both difficulties more or less relate to interoperability and roaming topics.

Finding a charging station that can be used with a certain contract requires valid POI data. However even the quality of only *static* POI data is poor (Interview 1, Interview 3, Interview 8, Interview 11). This has mainly two reasons: a pluralism of independent POI databases and the non-existence of a standard POI data structure. Additionally, some CPO players simply do not provide high quality POI data (especially small CPO players) (Interview 8, Interview 18). Simultaneously, the chargers are inappropriately positioned at the locations. A charger at a 'scruffy area' (Interview 3) is not ideal for a customer and inhibit the uptake and customer experience alike (Interview 3, Interview 4, Interview12). Consequently, it has been regarded as useful to invest in branding of locations to enhance the findability.

[19] The amount of accessible fast chargers are in the whole of the EU

Examples of international CPOs have been brought forward as well as a comparison to fast-food restaurants branding nearby highways (Interview 4, Interview 11).

Going one step further, the exchange of dynamic POI data requires real-time enabled roaming protocols and the connection of all players by one way or the other – which is currently not the case. Roaming protocols also play a role in enabling price transparency: only if the price info from the MSP can be transmitted to the CPO via the protocol, it can be displayed to the customer at the charging station – just like it is done at conventional fuel stations. The issue is less urgent when authentication is done via smartphone, because then the MSP can immediately display the price in their own app. Still, price transparency problems continue after charging has finished: Apparently, it often takes months until customers know how much they have been charged, which makes it difficult for them to check their bill. This delay is sometimes attributed to the low maturity level of MSP companies (Interview 1, Interview 8, Interview 12).

As mentioned already above in the analysis of public charging offers, there is another challenge in price transparency, or price comparability rather. Different MSP may, at one and the same charging station, offer different pricings models (per kWh vs. per minute). Depending of the actual charging speed of the car, one or the other may be cheaper. And even if the car's standard charging behaviour is known, a calculation needs to be done to make the prices comparable.

Besides these adjustments in the offering of the technology, the structure of the system should adjust due to a challenge that relates to the economics of network markets: management of transactions with other players that are required to perform a service, i.e. as a CPO, connecting MSP players, and as an MSP, connecting to CPO players. While all experts generally confirm that an aggregator makes sense, they are not happy that there is a multiplicity of roaming platforms: *the idea of one hub is that you only need one hub – there are already four, so that kills the whole hub idea* (Interview 12). In addition to being connected to several platforms, some players have also set up bilateral connections via OCPI (e.g. Allego, TheNewMotion) or their own protocols (Plugsurfing). Market participants acknowledge that they would prefer to only connect to one platform and only implement one roaming protocol (Interview 10, Interview 12, Interview 14). While some believe that the market will find a solution sooner or later (Interview 4, Interview 12, Interview 18), others think that the legislator needs to act, and at least govern the transition (Interview 11, Interview 14). Massive efforts are needed not only to implement these various interfaces, but also to keep them up-to-date and aligned with one's own back-end system. If there was only one IT interface that needs to be managed and operated, this could significantly decrease interoperability cost (Interview 13, Interview 14). However, this problem is fostered by the fact that different roaming platforms offer different service levels or some players have reservations regarding certain platforms (Interview 8). Regardless of how roaming is set up on the IT side, the roaming partners still need to manage their commercial relationships and handle the billing, efforts that also must not be underestimated (Interview 16).

Subsequently, almost all experts agree that the roaming platform should be organised as a non-profit organisation rather than being provided by a company with an ‘additive business model’ (Interview 5) that makes electric mobility even more expensive. Especially from the perspective of big players, peer-to-peer roaming is considered a viable alternative to roaming platforms: By bilaterally connecting to a handful of major players, they can cover 90% of the market without being dependent on a roaming platform (Interview 8, Interview 18). However, it is also criticised that the initiative comes at a later point in time and that it rather fosters isolation than openness, particularly for smaller players and new entrants (Interview 1, Interview 6, Interview 10).

Connectively, the fact that roaming is so complicated certainly also plays a role for CPO players that have decided to act as an MSP as well and *vice versa*. Several experts brought forward, that an integrative approach would be beneficial for the system value chain. Only if a company integrates both roles, it can completely run through the customer experience from A to Z (Interview 18), which avoids price and service confusion with the EV driver (*ibid.*). Utility companies (*e.g.* EnBW, Innogy), moreover, already have an existing customer base that they can build on to maximise utilisation of their infrastructure. From a CPO perspective, an integrated CPO+MSP player is independent from third parties, especially regarding the marketing of their chargers, i.e. the presentation of POI data to potential users so that these can be found and used. From an MSP perspective, integrated CPO+MSP players see their charging stations as bargaining chips in roaming negotiations with other CPO+MSP players (Interview 8, Interview 18). Another advantage of integrating both roles is seen regarding the diversity of insights into the market that can be used to improve both sides of the business (Interview 14). Indeed, user and usage data are considered a huge asset by some companies (*inter alia* Interview 12, Interview 16, Interview 18).

On the contrary, many experts stress that operating complex (physical) infrastructure requires a very different skill set than providing (digital) end customer services. Thus, integrated CPO+MSP companies may lose focus, whereas specialised companies can develop specific competencies. As integrated CPO+MSP players are not dependent on roaming, this may also affect their efforts and care in properly implementing and maintaining interoperability interfaces. In addition, and contrary to the ‘bargaining chips’ argument stated above, some experts think that playing on both sides and thus not being neutral can even be a disadvantage in roaming negotiations (Interview 9, Interview 12, Interview 14). Eventually, this could decrease the flexibility of the market and lead to the generation of ‘inaccessible islands’ (Interview 10, Interview 12).

Another topic that was mentioned in the CPO-MSP-context is the circumstance that in reality the CPO role is sometimes split up: while one company is the commercial owner of the charging station (e.g. Aldi Süd), another (e.g. Innogy) is responsible for its technical operation. Currently, it is hardly transparent who is doing what and who is responsible in case something happens.

Finally, the role of OEMs has been touched upon as the relevance of EVs in the value chain is indispensable. Regarding the electric vehicles that are currently available in the market, two things are highlighted. Firstly, they are too expensive: even if the total costs of ownership may be cheaper, many people are deterred by the high purchasing prices. Secondly, there is no diversity of models: one can buy a small entry-level or a premium car, but there is no offer in between. Another challenge regarding prices is the almost non-existence of a second vehicle market: it would, on the one hand, supply more affordable cars and, on the other hand, also help dealerships to determine accurate leasing rates (Interview 11).

The identified alterations from a firm perspective are mainly related to business model components of value proposition and value network. As the overall role of MSPs is promising and thus attractive for new entrants, the development of roaming must be altered in order to stimulate more entrepreneurial activities (+F1). The multitude of platforms is leading to diverse problems as well as stronger bi-lateral connections. This in turn is negatively affecting the chances of new entrepreneurs. More essentially, the alterations would benefit the legitimacy (+F7) and connectively the market formation (+F5) as it would increase the price transparency and findability of charging stations. Consequently, societal acceptance would increase and hence more businesses would engage in the technology (+F1).

5.3.2 Interaction

Interaction within the market is regarded as beneficial. The successful standardisation of the CCS plug is considered a good development for the market and is reflecting a joint effort of the companies (*inter alia* Interview 3). Similarly, OCPP is generally seen as a decent protocol and accepted as the industry standard for connecting the charging station to the CPO back-end. Similarly, it is regarded as a sign of a 'healthy' interaction within the system (Interview 12). However, the opinions get more ambivalent when talking about interoperability protocols and roaming platforms. The general problem here is that already more than four different protocols exist. These have been developed independently in bi-lateral relations. This is regarded as a barrier that should be overcome by a collaborative act, however the diversity is precarious as there *"is no way that you create a standard that does not hurt at least half of the market*" (Interview 2).

Interaction between industrial actors is crucial in the further development of the system. New generations of charging capabilities as well as communication protocols with the next generation EVs are being developed in several working groups within established networks, which include the OEMs. However, the role of OEMs is regarded as critical for the development. OEMs tend to collaborate with other incumbent firms and neglect smaller ones (Interview 6). Moreover, the joint venture of OEMs that has been announced is a potential barrier as it may increase the secrecy of OEMs in terms of the roll-out of EVs (*ibid*.; Interview 12). Simultaneously to the proximity of OEMs, their influence and collaborative approach in influencing governmental bodies is regarded as highly impeding (Interview 6, Interview 11).

Interaction alterations are connected the value network components. Currently, no alterations are urgent from a firm perspective. Future developments such as the introduction of reservation of charging spots as well as Plug & Charge features (ISO 15811) should stem from a collaborative act. However, the high dependency on OEM activities is regarded as crucial and might influence future entrepreneurial activities. Moreover, the secrecy of OEMs is impeding a legitimisation of fast charging (F7). In a rather extreme example, one can see OEMs as fully integrated energy-mobility-companies. Rather than only being a mean to the ends of the oil industry, the automotive industry could make much bigger profits if it controlled an entire ecosystem: from energy production and car manufacturing over operating the charging infrastructure to managing the end customer interface. In fact, Volkswagen already today is one of the biggest energy producers in Germany, while BMW is planning an energy-self-sufficient plant (Interview 11). Another transportation company, the German railway company *Deutsche Bahn*, is also producing electricity in its own power plants (*ibid*.). This trend is seen with Teslas approach and could be a prominent example for OEMs to follow up on.

Although the depicted business model innovation would impede interaction amongst companies, it would have a great leverage on entrepreneurial activities (+F1) as well as the creation of legitimacy would benefit (+F7). This is due to the resourceful incumbents, *i.e*. the OEMs, shifting their business model towards a fully integrated actor. Moreover, the great amount of resources that could be deployed in the build-up of fast charging infrastructure could stimulate the development further (+F6).

5.3.3 Institutions

Institutional components should be altered according to experts. One major topic is a ‘legal vacuum’ regarding DC metering: especially the German calibration law (Eichrecht) is very hard to comply with, due to high data integrity standards (Interview 7, Interview 10, Interview 12) and calibrated DC meters are hardly available yet and additionally are very costly (*ibid*.).

For a long time even, it has not been clear whether calibration laws apply to kWh-based billing only, or whether they also apply to time-based billing. Therefore, some companies make use of this legal grey area. This explains why different pricing components are found across different CPOs. Thus, current solutions on the market are not complying with the calibration law and need to meet the high standards to achieve a more standardised and transparent billing for the end customer (Interview 7, Interview 12, Interview 14, Interview 18). It is expected that these alterations will foster F1 and F7, as legal grey areas are perceived as an investment barrier (Interview 7, Interview 4; Interview 12). Simultaneously, the issue has a direct effect on the cost structure of actors (value capture) as the metering and conformity will increase the hardware costs and potentially the installation costs (Interview 10, Interview 12, Interview 18). To illustrate the delineated dilemma, the following analysis outlines the current pricing scheme for fast charging.

For the four companies that act solely as MSPs, an eminent difference needs to be stated: whereas BMW ChargeNow and VW Charge&Fuel demand the same prices at all their CPs, the tariffs of Plugsurfing and TheNewMotion vary significantly. Therefore, the analysis includes a rather random sample of CPs of these MSPs[20]. The integrated MSP/CPO actors are generally demanding a uniform tariff at their own CPs. If customers are charging at CPs of roaming partners the prices may differ. Moreover, the payment methods differ, as some businesses offer ad-hoc payment methods or contract-based payment (only MSPs) with or without a monthly fee. Moreover, the charging prices consist of three different components that are usage depended in a way: Firstly, a set price per charging session, often referred to as 'starting fee' [21]. Secondly, a price per kWh that the EV is charging can be imposed. Thirdly, a price per minute of charging can be imposed by service providers[22]. Due to the aforementioned 'legal vacuum' a CPO can apply different price components and therefore complicate the analysis. Table 8 exemplifies this based on the tariffs for fast charging stations of the CPO *Allego GmbH*. The indicated prices are based on an average charging session, whereby 7,7 kWh are charged in 21.6 minutes[23].

[20] When possible, the same charging station (same location and same CPO) has been selected for both MSPs to increase the validity.

[21] If the fee is combined with other price components

[22] Additional price components do exist as for instance a connection fee (when payment per minute) or certain discounts for loyal customers. The price components are not considered in the analysis as it does not allow comparability.

[23] The average session has been calculated based on internal usage data. Furthermore, the pricing scheme is of July 2017

Table 8 Price Variance CPOs

Entity	Payment Method	Start Fee	Per kWh	Per Min.	Total
CPO	Intercharge Direct			0.416€	9.07€
MSP	PlugSurfing	0.35€	0.69€		5.70€
	TheNewMotion	0.35€	0.69€		5.70€
	BMW			0.30€	6.50€
Mean					6.74€

The analysis excludes monthly contract fees as only a few actors offer the service. The price comparison is thus on a charging session level based on the abovementioned average charging session. The range of prices is depicted in Figure 10 shows the ad-hoc prices at CPOs per session.

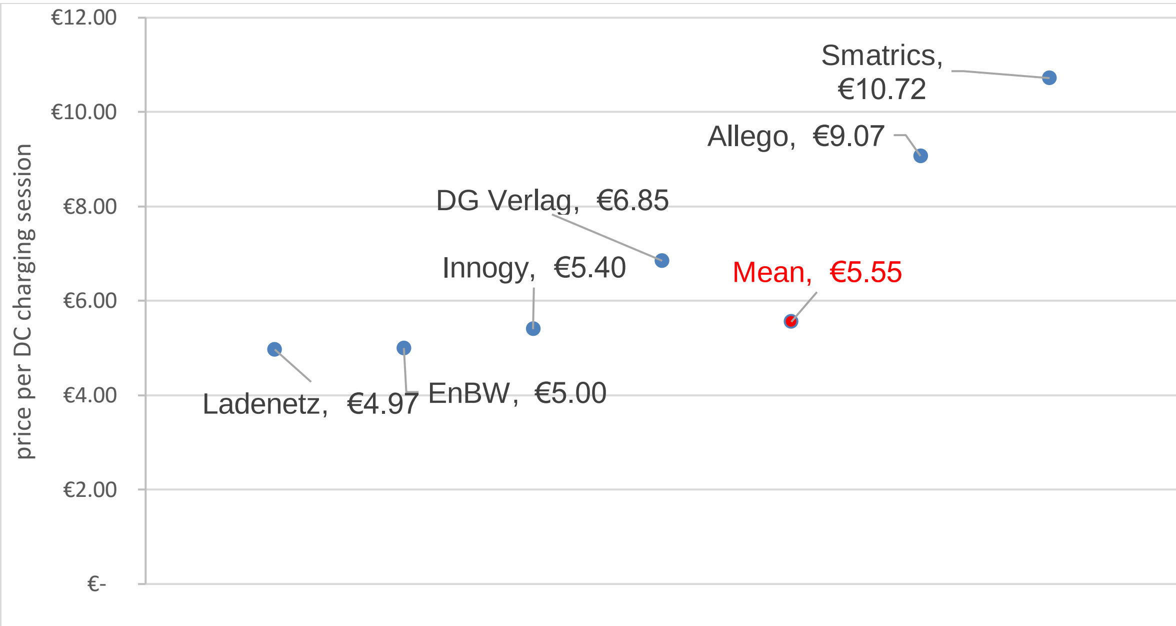

Figure 10 Price scheme - per charging session (based on desk research; July 2017)

Ad-hoc prices however are in mean regarded as more expensive than contract-based costs (Interview 8,11). As indicated, considering the offers of MSPs the pricing scheme differs. BMW and Volkswagen demand the same prices at all stations and provide contract based payments, whereby they charge per minute. The mean price of the two is 5,40 Euro and therefore slightly cheaper. BMW's offer is slightly more expensive (0.30 cents per min. compared to Volkswagens 0.20 cents per minute), however they provide access to a greater number of fast chargers[24]. The other MSP prices have been illustrated in Table 8. However, significant price differences between Plugsurfing and TheNewMotion (TNM) can also be observed in combination with other CPOs: for a default fast charging session at one location

[24] EU wide: BMW 311 compared to 150 with Volkswagen as MSP (as of July 2017)

of Innogy, the price is 2.84€ via Plugsurfing and 4.70€ via TNM. At EnBW chargers, the price difference is even bigger: 2.38€ via Plugsurfing vs. 11.15€ via TNM – while EnBW's contract-based price would be 7.56€. This demonstrates that a price for roaming can even be cheaper than the price immediately asked by integrated CPO/MSP players. However, in general roaming procedures involve higher pricing for the end-customer.

Furthermore, some experts highlighted that the public awareness and perception of electric vehicles is often quite negative (*inter alia* Interview 11), and more good press is required. Here, actors perceive the institutional guidance as not being in tune with the reality and thus the societal opinion is misled. It is recommended that communication campaigns, closer to real numbers, should be extended and not only being used by CPO's but also by authorities to educate public institutions that are involved in e-mobility infrastructure (Interview 11, Interview 16). Thereby, information processes for users is put in the hands of institutions. Nevertheless, media portrayals of electric mobility are increasingly impeding the transition as misleading facts are being published (Interview 11). Furthermore, the portrayal is often attached to doubts and apprehension, which is considered to be typical for innovative processes in Germany (Interview 3, Interview 11). Considering these alterations, it is expected that the guidance of search (F4) would be stimulated.

Long permit times are particularly harmful to the attractiveness of investing in fast charging infrastructure, as the high cost for civil works among others need to be recovered as quickly as possible (Interview 12, Interview 18). Not only miss CPO players up to 'one year of revenues' (Interview 12) because they must wait for a permit, they also have to adapt to different procedures in the different districts they operate. Thus, it is suggested to 'simplify, slim down, and harmonise' (Interview 8) these processes. Another cost factor that is also impeding the installation roll-out is the building cost tariff (*Baukostenzuschuss*) in Germany, which could be alternated if the system ought to be developed (Interview 14). This tariff is paid by the consumer (i.e. the CPO) to a grid operator to finance the expansion of the electrical grid. The tariff is paid per kW above 30 kW[25]. The one-time charges are paid when a grid connection is installed. The cost per kW vary per grid operator and per voltage level. Of the several grid operators researched, prices ranged from 18.44 Euro per kW over 30 kW to 107.44 Euro per kW over 30 kW.

The outlined propositions entail components of value capture and value network, where changes are perceived as influencing the system performance in a favourable way. The alterations of the DC metering are urgent from a firm perspective as they are affecting the pricing scheme. The legal vacuum led to diverse pricing components, which in turn negatively affected the user perception of fast charging. Creation of legitimacy can thus be benefited, if a clear calibration law (which is adapted to the charging process of EVs) is

[25] Connections under 30kW are not subject to this tariff system

introduced (+F7). Furthermore, the permission processes must be accelerated in order to fit the current market phase. Hereby, market formation (+F5) and entrepreneurial activities (+F1) would be positively stimulated.

5.3.4 Infrastructure

Main concerns have been articulated by the experts on the matter of funding schemes. The majority of monetary support is focusing on capital expenditures. The NPE provided a cost breakdown for a DC charge which is guiding the financial support scheme of the federal government. Herein, hardware costs 25.000 Euro, grid connection costs of 5.000 Euro, permits and planning costs of 1.500 Euro and the installation costs with 3.500 Euro are detained as capital expenditures. Hence, a charge pole is assumed to cost 35.000 Euro in total (NPE, 2015a). Simultaneously, they assume a decrease of those costs until 2020 by 10.000 Euro, which is reflected in the experts' opinion the costs for hardware will decrease based on economies of scale (Interview 7, Interview 10, Interview 18). It needs to be noted that grid connection costs are varying depending on the location. The grid connection costs of 5.000 Euro for example, are regarded as too low (Interview 12, Interview 18). Further, the costs for location securement are highly significant and are not included. Locations partners tend to demand one-time payments[26] and overhead costs due to long planning processes and permission flaws are increased (Interview 12).

Apart from these additional costs, other operational costs are bared by the CPOs and in turn increase end-customer prices. As these prices need to decrease to *vice versa* increase societal acceptance, structural deficits must be overcome. As the physical infrastructure of grid connection is vital for the system development, alterations would induce the development of the system from a firm perspective. The biggest bottleneck here seems to be the operational costs of grid connection. Here, it is important to note that there are two potential tariff systems that are applied: a mostly kWh-based tariff (SLP) or a more kW-based tariff (RLM). RLM is commonly used for larger connections as SLP is used for smaller ones. The application of the tariff system is automatically done by the grid operator and is therefore sometimes rather random (Interview 12, Interview 14, Interview 18). However, this decision has a great impact on the operational costs in the end. Figure 11 shows a yearly impact between SLP metering and RLM metering with varying peak charges on a CP with an annual usage of 10.000 kWh and a maximum power of 90 kW per year. The figure shows that the tariffs have a great impact on the long-term operational costs. Furthermore, grid costs are varying throughout the country from 2 to 100 Euro per kW. Throughout, many feasible locations become economically unfeasible and are not approached by businesses.

[26] Opposed to other European countries, location owners tend to demand payment (Interview 12)

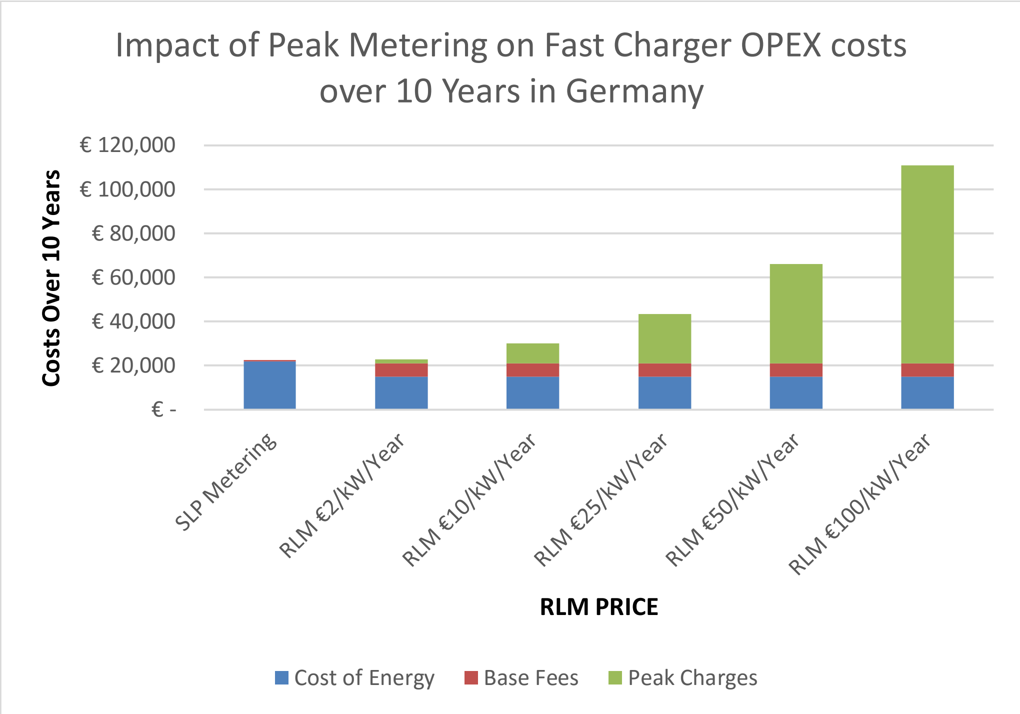

Figure 11 Grid Tariff Diversion

The opinions on how to approach this problem, which ultimately has a direct effect on societal perception since it increases the charging prices, are diverse. Some experts suggest shifting this burden to the grid side and socialise it among all grid users, assuming fast charging stations to be part of the provision with basic supplies (Interview 1, Interview, 14, Interview 16). Another, less radical suggestion is the introduction of much more flexible (and usage-dependent) grid tariffs (Interview 2, Interview 12). Currently, the tariffs are very static and mostly refer to the maximum power that a charging station can drain from the grid. Thus, a CPO always pays the full fee, even though a peak load may only occur once a week. Moreover, grid tariffs are usually independent from the overall grid load induced by other electricity consumers, i.e. there is no incentive for peak shifting, for instance by local battery storage. Especially battery storage is an important feature in the future build up as it can lower grid costs and provide a more stable grid (Interview 7). Finally, the fact that energy regulations and grid tariffs are not harmonised in the country makes things even more difficult. This is connected to the identified cost factor of location planning, as CPO players consider location planning to be a lot of effort. It could, for example, be made easier if a map was provided by the grid operator that displays the available grid capacities (Interview 9, Interview, Interview 12, Interview 18).

The depicted arguments are connected to components of value capturing and value network. The need for smart charging system (*incl*. peak shifting) and energy storage concepts are some prominent innovations amongst businesses, and are regarded as future requirements. However, alterations in the infrastructure are needed to stimulate the market formation. On the one hand, the financial infrastructure should be adapted to reflect the diverse costs of grid connections and thus benefit the market formation (+F5), *i.e*. the increase in installed capacity and avoid negligence of more expensive sites. This would otherwise lead to a non-ideal network formation of the charging infrastructure. On the other hand, the tariff system must be adapted to benefit cost structure, whereby investment legitimacy would benefit (+F7) and new entrants would be attracted (+F1). Additionally, physical infrastructure needs to be altered in a way that grid capacities are made more transparent to enhance planning capability and thus benefit a preferable market formation (+F5) and attract new market entrants (+F1).

5.3.5 External Factors

From a firm perspective, the mentioned co-evolution of fuel cell technology and the connected infrastructure is not perceived as a structural barrier. The principle of governmental technology-neutral funding is respected amongst actors and is even regarded as positive for the overall transition towards cleaner mobility (e.g. Interview 11). Simultaneously, the complementary evolution of the technology is perceived as being in an early research phase as it is expected to compete with the FC system (if even) in the far future (Interview 4). Far more impeding is the lack of EV support in general and subsequently the protection of carbon-based mobility. Several experts suggest that carbon-based mobility still is too affordable and that it should be made more expensive by legislators. In turn, further financial incentives are seen as helpful. Specifically, rather than one-off buyer's premiums when purchasing an EV, there should be enduring tax advantages – especially for company fleets. However, further (financial) subsidies for electric vehicles are also seen sceptically, as they could indicate that the technology is not mature yet (Interview 6). Running in a similar direction, one expert endorses a general speed limit on (German) highways[27], which would help make ICE vehicles relatively less attractive (Interview 17).

[27] This debate has been picked up in the political debates prior parliamentary election in Germany in September 2017

6. Discussion

The findings revealed several mutual influences of business model innovation of firms and their surrounding environment, *i.e*. the TIS. The research showed that the structural set-up of the system, especially formal institutional arrangements act as a source of inertia for the innovation of business models. Simultaneously, the findings at firm and interfirm level (*i.e*. value network) can stimulate the system as redundancies and potentials for more effective resource use have been identified. Currently, business model innovation is constrained by structural components of the TIS. If these obstacles are overcome, innovations such as smart charging, improved payment services and additional mobility services at site, can be introduced by companies. Furthermore, it is to be expected that the business to business market will grow, whereby companies such as warehouses and retailers will add charging options as an added service. These would increase the diffusion of the technology immensely and would lead to a sufficient network density.

The findings of this research contribute to the field of transition theories. As of now, the functional approach of the TIS has mainly been applied top-down from a policy perspective (*cf.* Planko et al., 2017; Sarasini, 2017). By merging strands of transition theory and theory on business models into a conceptual framework, the research proposes an initial step towards systemic analysis of business strategies in transitional processes. Although firms have been recognised by MLP and TIS to perform certain activities, both concepts do not include a robust theory of a firm and their influences on broader systemic transformations such as mobility (Sarasini, 2017).

Nonetheless, business model innovation cannot enable system change on its own. The analysis of the alignment of these businesses and their interdependencies with the socio-technical regime showed, that it is a valuable approach not only in the later stages but also in earlier formative stages of a TIS, to prevent structural misconceptions. The analysis supports an argument that has been examined recently (*cf*. Planko et al., 2017): the role of coordination. The misconception of the market model has been perceived as a barrier, because it led to double efforts amongst actors (*i.e.* MSP and CPOs). Hence, redundant activities can be overcome by coordination and adaption of activities in the value chain (*cf*. Musiolik and Markard, 2011) and ultimately lead to increased functionality of market formation (F5) and legitimacy of investments (F7). As many future technologies will increasingly combine energy sector related issues with other societal functions, the role of coordination might become even more substantial, *e.g.* in the analysis of urban developments, so-called smart cities.

Constituting that in the case study incumbent and resourceful companies are acting as system builders and pursue strategies accordingly, it is important to point out that these resources are diverse. In the case study of fast charging infrastructure, it is shown that the role of OEMs can diverge into an all-deciding form. The OEMs tended to just act as supportive force in the early build-up of the TIS. Therefore, business model innovations that fostered collective sense making and proved the political sphere of a business model (Doganova and Eyquem-Renault, 2009) were most prominent. These stimulated institutional settings and benefitted resource mobilisation (F6) and creation of legitimacy (F7). For example, the involvement of diverse companies in pilot projects lead to follow-up efforts and further funding schemes. Moreover, a collective effort for standardisation proved to be valuable. Notably, public infrastructure is constituting a highly-politicised topic due to its large scale, capital intensity and first and foremost societal function (Sarasini, 2017). Thus, the political sphere of business models is found to have a great impact in the case study, *e.g*. in the standardisation process of the CCS. However, as financial risks are decreasing (*e.g.* through accessible funding schemes) the OEMs shifted towards a more active role and seem to innovate their business models accordingly. In doing so, they might become an autarchic actor by providing a full-service model to future customers.

As of now, no radical innovations have been taken place as the position in the value chain of respective actors did not allow it. As infrastructural technologies aim for seamless integration, it is to be expected that radical innovations would not have the same effect as delineated in transition theory (*cf*. Huijben et al., 2016). Moreover, it can be assumed that the innovation of OEMs business models in Germany will have a much greater effect on the transition. The example of companies such as Tesla™, shows how an OEM can entail a holistic provision of mobility and surrounding services such as fast charging infrastructure, despite the influence on other actors in the market. Yet, the lack of incentives of car manufacturers in Germany, despite their opportunities (*cf*. Wesseling et al., 2013) hindered the build-up of electro mobility and further, the TIS at hand. The *'Diesel-Gate'*- affair and changes in legislation in other countries (*e.g.* Chinas import policy changes) led to a reaction of OEMs. Diverse amounts of announcements and investments in *e.g.* battery cell research and roll-out of EVs, show that German OEMs tend towards a fast-follower strategy (Seidel et al., 2005). However, the automotive system in Germany continues to exhibit profound regime stability, whereby the vested interests maintain the stability and thus build up resistance to change, which is not only emerging from the niche level but also the landscape level (Wells and Nieuwenhuis, 2011). These vested interests of OEMs in the regime are constituting a greater source of inertia, as incumbents are currently defending these interests. On the one hand, car manufacturers do not rush the introduction of fast-charge ready EVs to the market, which has a direct effect on the TIS as F1, F6 and F7 are impeded. On the other hand, the automotive lobby is successfully protecting the ICE vehicles on an EU-level and the national level. Just recently, the European Commission withdrew plans of a mandatory percentage of

EV sales for OEMs (ZEIT, 2017). It seems, that under the veil of technology neutrality, lobbying actions are able maintain the *status quo*. At the same time, regulations must support diverse sustainable innovations, *i.e*. alternative fuels, and exert technology neutrality. However, unsustainable technologies should not be supported simultaneously. This seems to be a reoccurring theme in the case of Germany. In several transitional processes, *e.g.* the build-up of a renewable energy system, the government is not committing fully towards new technologies. The reasoning is similar in most cases, as a technological neutral behaviour of the supporting schemes is communicated, whereby the guidance of search (F4) is generally impeded. Furthermore, the prevailing attitude is that the labour market is relying on the current regime and a transition would have a detrimental effect concerning the labour market. Increased opportunities of labour in new markets seem to be neglected.

Moreover, the research showed that strategic system building is highly influenced by roles of competition and conflicts therein. Collaboration amongst actors and institutional organisations may be regarded as a strong asset in the case of fast charging, however less resourceful actors may have unintentionally fortified the structure (*cf.* Schuitmaker, 2012) by creating a high dependency on OEMs rather than generating a supporting environment for users as well as other actors in the value chain. Successful CPOs and MSPs from other countries are migrating to Germany (*i.e.* FastNed and Charge Point). It is expected that these businesses have developed in an innovation system that is less depended on the role of car manufacturers. In turn, these businesses have been less confronted with sources of inertia stemming for a regime level and are further developed in their capabilities.

A point of critique of the TIS concept is, that it obscures influences such as user perspectives (Geels, 2004). It is shown, that by investigating the role of business models, the value proposition and ultimately the perceptions of end-users are included as BMI entails commercialising, which naturally intends to meet the needs of its users (Zott et al., 2011). Connectively, it is found that the role of media has a great effect on user perspectives. Misleading comparisons with prevailing technologies (*e.g*. Diesel) seem to increasingly harm the evolution of the TIS, whereby the media is catalysing this effect.

6.1 Future Research

It has been found that a multitude of businesses in the TIS, stem from other regimes. Businesses from the energy sector and IT related fields exploit the window of opportunity. As the disruption of energy and transportation is increasingly connected, the relation between adjacent regimes and innovation systems at the niche level should be further researched. The role of coordination therein (*cf*. Planko et al., 2017) should be included, as it increases in importance. It is suggested that the function of coordination is introduced in the transition theory (*ibid*.). This research supports this notion and suggest further research in

technological-based disruptions, that include an overlap of sectors. For example, the role of smart charging and thus smart grids will be substantial in the future.
Further, the development of the TIS seems to be accelerated, as OEMs become more active. Another analysis, in due time, would be recommended to investigate the effect of business model innovations of OEMs on the TIS. It can be the case that disruptive BMI such as the offering of free electrical charging, similar to Teslas Supercharger Network, evolves. This would have a great effect on the researched TIS.

6.2 Limitations

The research includes several limitations, which must be put into consideration. The system of charging is in a later stage of the innovation system development and thus entails an immense amount of interests and actors. Thus, the feasibility of analysing this system as a single researcher must be regarded as sensitive. Simultaneously, the methodical approach of introducing the dynamics of the TIS in the analysis is rather novel and should be applied in other cases to improve usability. Furthermore, the external factors in Germany have affected the findings. The interviewees regarded the OEM 'Diesel' affair as highly effective for the system development by, solely based on expectations rather than on factual figures. Here, it is worth noting that a measurable effect has not occurred yet. The high expectations might have led to misleading perceptions of the overall development. Moreover, the research is based only on a single case and thus generalisability is limited. The analysis of business models in the realm of electric charging is a sensitive topic as many businesses showed limited willingness in disclosing relevant information on business model innovation.

As two sectors are being confronted in the development of charging infrastructure, the role of coordination might be more important than in other TIS analysis. Moreover, the analysis included a diverse number of roles in the system. This increased the complexity of the research on the one hand and led to a less specific analysis on the other hand. Further research may investigate a specific role in the transition as such would give a more streamlined approach.

7. Conclusion

The research examined firm perspectives, based on the concept of business model innovation, within the TIS of fast charging in Germany. The system performance has been assessed by a structural-functional analysis. Structural alterations, to overcome impeding mechanisms, have been found from the perspective of business model innovation. Relating to the research question 'How can business model innovations stimulate the development of the fast charging innovation system in Germany?', the analysis of business model perceptions can have a direct effect on the structural composition of a TIS. Thereby, the functional fulfilment can be stimulated further and benefit the diffusion of the technology.

It is shown that in the later formative stages, a firm-perspective is inevitable for the development. In retrospective, the TIS of fast charging has been mainly build up by incumbent organisations. The national strategy, resulting from EU level decisions, included incumbent firms in project developments and pilot projects from the beginning onwards. Several working fields have been funded by governmental bodies and the technology has very quickly moved through the first developmental stages. It can be constituted that the rapid build-up was not impeding the technology but the market model that has been built around it. Main obstacles for business model innovation and a successful charging infrastructure are seen in the arrangement of roles in the market. Thus, the alterations and perceptions of businesses are highly relevant for the transition process as they improve the functionality of the TIS.

Regarding the governance of transitions, which is outlined in the theoretical framework of this research, the lines of inquiry derived in this thesis intend to encompass a multi-actor approach, whereby the public sector (*i.e.* TIS findings generally translated into policy instruments) and businesses, bring about systemic change. Hence, the following derives recommendations for policy and businesses, which are based on the findings of this research.

7.1 Policy Recommendations

Insights of this research lead to implications for policy makers. Most importantly, the policy in Germany should be more orientated towards the demand side in order roll-out fast charging and stimulate the uptake. Moreover, the long-distance travel will ultimately become a pan-European project, whereby a non-discriminatory charging infrastructure should be established. Hence, national policy making should be aligned with European funding and projects. German federal institutions should push information channels further, that raise awareness about existing incentives for switching to an electric vehicle. Support schemes such as free parking, access to bus lane or congestion zones, should be made more visible to the public. Furthermore, local activities play a significant role in this matter as big cities have been platforms for pilot projects and significant public-private partnerships (e.g. car sharing activities coupled with infrastructure deployment). These topics should be followed up by long-term initiatives.

Focusing on charging infrastructure in general, some recommendations can be made. First, the harmonisation and simplification of application procedures and throughout short process times need to be tackled.

Second, the grid tariff needs to be adapted to the usage pattern of fast charging infrastructure and future generations of charging. Close cooperation with CPOs will enable a more coherent solution in this matter. At the same time, energy market rules need to be made more flexible in order to enable CPO and MSP player to develop offers that will help manage grid load even when EV mass market adoption will lead to much bigger utilisation of fast charging infrastructure.

Third, to insure the efficiency of market transactions, standardised roaming protocols or at least a standardised format for POI data should be promoted.

Finally, the build-up of semi-public infrastructure in and around residential buildings needs to be fostered to enable private owners to install fast charging infrastructure. A key to this is the role of joint ownership in residential laws, which needs to be adapted to the case of charging infrastructure.

7.2 Business Recommendations

Besides policy recommendations, implications for businesses in the market can be derived, which benefit the market and the socio-technical transition. As this compilation does involve several actors, the recommendations are more general.

Interoperability must be independent of strategic decision to enable a non-discriminatory market and to benefit usability of long-distance charging. Experts pointed towards the threat of ‘inaccessible islands’ that may be created by strategically driven decisions in roaming negotiations. Thus, roaming needs to be improved. Here, roaming platforms may become a non-profit organisation and enable more real-time features. Simultaneously, businesses need to lobby for the standardisation towards a unified EU-wide roaming protocol as a pan-European aspect must be considered in the case of long-distance travel for electric vehicles. Here, increased collaboration between OEMs and energy companies is a mean to have the highest leverage and ability to apply pressure on policy-making. Further, the division of CPOs and MSPs must be clearer. Through coordinative and communicative behaviour, double efforts in the market can be avoided.

Moreover, the proposition of charging can be adapted. In the future, businesses need to find a way to ensure that their infrastructure is not blocked by non-EV drivers. Besides, the authentication needs to be simplified, through further development of applications as well as the possibility of ad-hoc payment at the site (when economically viable). In the long term, the Plug & Charge technology needs to function seamlessly. Connectively, the CPOs role will change as competition between companies will increase. Reliable fast chargers at the right locations are needed as well as the provision of accurate POI data. If alterations are being perceived, CPOs become able to balance the grid load and maximise utilisation at their stations. Throughout, they will become ‘e-mobility brokers’, by adapting their prices in real-time depending on supply and demand.

The price system is currently perceived as too complicated, due to the outlined mix of pricing schemes. Moreover, customers often do not know the exact prices at the charging stations they use, and in many cases, it takes quite some time until they learn how much they will be billed. According to experts, these inconveniences are mainly related to interoperability and regulatory challenges: As many roaming protocols do not transmit price information, immediate price feedback at the charging station is technically not possible. A collaborative fostering of the policy indications has thus to be induced by companies.

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Appendix A – Interview Guideline

Introduction

Within my master thesis I am analysing the current innovation circumstances for fast-charging in Germany. This entails an analysis of the institutional activities on the one hand, and a more actor specific view on the other hand. This interview shall be conducted in order to get an insight into how businesses in the market see the market and prospect an ideal future for charging solutions in Germany.
[In advance of the interview, the interviewee will be asked whether it is okay to record the interview – if necessary a declaration of consent can be signed at the end of the interview. The questions in grey are optional and/ or comments for the interviewer only.]

General Introduction

1. Kindly introduce yourself and elaborate on your position in the company/institution.
2. Please describe the main business activity of your company/ institution in terms of EV fast charging
   a. What kind of propositions are on the market?
   b. Target group – B2B or B2C
   c. Specific internal (value chain) processes needed?
3. What are reasons for a fast-charging network in Germany from your perspective?
   a. Fast-chargers as primary tool to achieve this?
   b. What would you consider as a preferable distance between locations?
   c. Time spent at fast-chargers preferable?

Innovation System

Entrepreneurial Activities

4. Is the number of industrial actors in the system sufficient?
   a. What part of the market is lacking actors?
   b. Do they innovate sufficiently in terms of quality?
5. Are new entrepreneurs (also incumbents) entering the market?
   a. What types of businesses get involved and with what products at hand?
   b. Diversification of new entrants and established firms?
   c. Does the degree of experimenting hinder the diffusion of fast-charging?
6. Do you see entrepreneurs leaving the market?
   a. Including incumbents that diversify?

Knowledge Development

7. Is enough knowledge being development for fast-charging infrastructure?
8. How would you assess the quality of the development?
   a. Is there a great amount of projects, patents and articles?
   b. Is it more incremental developments or a streamlined development?
9. What actors are particularly active in this regard?
10. How is this financed?

Knowledge Exchange

11. Are there strong relationships within the system and between whom?
    a. Is there a shared belief in the technology?
    b. Is the development of knowledge demand driven?
    c. Do specific targets and regulations from the government benefit the development?
12. How would you assess the relationship of science and industry in terms of fast-charging?
13. Is the knowledge exchange across boarders sufficient in your view?
14. Do you see problems in the exchange of knowledge within the system? (i.e. strong competition)
15. Are you satisfied with the availability of resources in the market?

Guidance of Search

16. Is there a clear vision on how the industry and market should develop?
    a. In terms of growth?
    b. In terms of the technological design?
17. What are the expectations regarding fast-charging in the future?
    a. Are there clear policy goals regarding this?
    b. Are these goals regarded as reliable from your position?
18. Are the visions and expectations for all actors sufficiently aligned?
    a. Does this shared expectation (or the lack of it) block the development of fast-charging in Germany?
19. Does the vision fit the existing legislation?

Market Formation

20. How would you assess the current market for fast charging (i.e. projects installed etc.)?
21. Do you regard the overall size of the market as a barrier for development of fast-charging?
    a. Still a niche or a developed market?
22. Who is taking the lead, public or private parties?

Resource Mobilisation

23. Are enough human resources/ financial resources available?
    a. If not, does this inhibit the development?
24. Are there (scarce) physical resources that might hamper the diffusion?
25. Can companies easily access the resources of i.e. public funding?

Legitimacy Creation

26. Is an investment in the fast-charging market seen as a legitimate decision?
27. How would you assess the degree of resistance towards fast-charging in Germany?
    a. What kind of resistance?
28. Are coalitions being formed?

Future Outlook and Role of Businesses

The amount of EVs in Germany is supposed and will be increasing in the next decade. This is preferable for the market on the one hand, as more EVs result in increased uptake for fast-chargers. However, on the other hand current barriers need to be overcome.

29. Customers say that charging is too expensive still – How and where can costs be decreased?
30. Which further barriers do you see for increased uptake of the EV market?
    a. Legal/ Political/ Interoperability and Standardisation/ Technical
    b. How to improve in these activities?
31. How can the main barriers be overcome?
    a. Who should act?
    b. How?
32. What are the prospects of your company/ institution in the field of fast-charging?

Wrap- Up

Thank you sincerely for your time and valuable input. The valuable findings from this interview can be anonymised if agreed upon. I gladly provide you with the results once the thesis is finished! To ensure a valid transcription, I might send you a transcript of the interview and kindly ask you to check if it reflects the interviewees statements and arguments in the most accurate way.