E-Mobility as a Sustainable System Innovation

Insights from a Captured Niche

Dissertation

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List of Abbreviations

BEV	Battery-Electric Vehicle
BMBF	German Federal Ministry of Education and Research
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (former BMU)
BMVBS	German Federal Ministry of Transport, Building and Urban Development
BMVI	German Federal Ministry of Transport and Digital Infrastructures (former BMVBS)
BMWi	German Federal Ministry of Economics and Technology
CHP	Combined Heat and Power
e-mobil BW	State Agency for Electric Mobility and Fuel Cell Technology e-mobil BW GmbH
FCV	Fuel Cell Vehicle
GGEMO	Joint Agency for Electric Mobility of the German Federal Government
GHG	Greenhouse Gases
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
IEKP	Integrated Energy and Climate Program of the German Federal Government
MLP	Multi-Level Perspective
NEPE	National Development Plan for Electric Mobility of the German Federal Government
NOW GmbH	National Organization for Hydrogen and Fuel Cell Technology
NPE	National Platform Electric Mobility
OEM	Original Equipment Manufacturer
OPEC	Organization of the Petroleum Exporting Countries
PLS	Regional Project Coordination Agency
SME	Small and Medium Sized Enterprises
SNM	Strategic Niche Management
TIS	Technological Innovation System
TM	Transition Management
V2G	Vehicle-to-Grid
WRS	Stuttgart Region Economic Development Corporation

ABSTRACT

In 2009, the German government launched its "National Development Plan for Electric Mobility" which, in an attempt to integrate economic and environmental strategies, aims at developing Germany as a lead market for electric mobility and set the concrete target of having 1 million electric vehicles on the road by 2020. However, there have been hypes around e-mobility before and even if this goal were to be reached, a merely quantitative aim of a certain number of electric vehicles will not suffice to contribute to a more sustainable development in transport. This requires a more comprehensive vision of sustainable e-mobility including the development of renewable energies as electricity source, reduction of the volume of privately owned cars and new mobility patterns, i.e. a system innovation. Thus, the question addressed in this thesis is: How can we assess – at this critical early stage – whether there is potential for e-mobility developing as a sustainable system innovation? A theoretical framework will be developed for assessing the potential of a wider transition at an early stage by analyzing current patterns of socio-technical co-evolution and embedding these in a wider framework of the structural dynamics involved in transitions. It will be applied to the case of the German region Baden-Württemberg, where two of the largest demonstration projects for e-mobility are taking place. The aim of the analysis is to identify whether 'system-innovative' projects do emerge in this specific case and what patterns (e.g. in terms of specific actor constellations, institutional adjustments etc.) can explain this. It will be shown that the system-innovative potential of this e-mobility niche remains limited, due to the powerful influence of incumbents, conflicting political goals and traditional science approaches. A few more system-innovative activities emerge where powerful actors from outside are involved, who are capable of viewing mobility in a more systemic way (e.g. actors from the public transport or housing sector). It is argued that the role of large demonstration projects is important, but they need to be designed as transdisciplinary research projects from the beginning.

1 INTRODUCTION

The transport sector currently represents one of the key challenges for future sustainable development, while at the same time efforts of making mobility more sustainable have an enormous potential for more sustainable societies. Personal mobility is a central feature of modern societies; the freedom and the affordability of the means to ‘move around’ are highly valued achievements with many positive effects on personal and social well-being. Global passenger and freight traffic has brought the world closer together. Simultaneously, the transport sector has emerged as a heavy burden on the natural environment. Almost a third of total global energy consumption can be allocated to the transport sector (IEA, 2013, p. 246) and more than 90% of this energy is generated from fossil sources, oil in particular (p. 510). This directly links the transport sector to the more basic challenge of an energy transition, breaking out of carbon lock-in (Unruh, 2000) and taking a new path based on renewable energy sources. The fact that in Europe more than half of all CO_2-emissions are caused by transport, electricity and heat generation (EEA, 2013, p. 14 f.) shows that an integrated approach to an energy transition (including the transport and the energy sector) could have a substantial environmental effect and would possibly even benefit from synergies and spill-overs. The pressure exerted by increasingly strict climate and environmental regulation, especially regarding CO_2-emissions, has led to at least some concern and effort towards sustainability-oriented change in the transport sector. Typically, this type of change is hoped to be achieved with the help of technology-based innovations such as the battery-electric vehicle (BEV) as a technological fix that combines the reduction of emissions and the achievement of economic success with an innovative vehicle while preserving established mobility patterns. Additionally, in the case of e-mobility there is a prospect of integrating energy and transport transitions in mutually beneficial ways. Thus, it is hoped that the electric vehicle, a not so new innovation in automobility, will be the boundary object connecting (and solving) economic and environmental problems in the way we provide our societies with energy and mobility.

Against this background, the German government launched its “National Development Plan for Electric Mobility” in 2009. The aim is to integrate economic and environmental strategies, in order to develop Germany as a lead market for electric mobility. A somewhat symbolic target has been set of having one million electric vehicles on the road by 2020. However, a brief historic overview shows that there have been hypes around e-mobility before and it seems questionable whether the current one will be the exception and manage to persist.

Electric vehicles were invented already during the 19th century in the early days of the automobile age. A commonly referred to milestone for the automobile age is the appearance of Carl Benz' first motorcar, which was demonstrated publicly in 1885 for the first time. At that time, alternative drive technologies were developed simultaneously, i.e. electric, steam engine and internal combustion engine (ICE), and all competed for market success. Especially battery-electric cars were common in large European capital cities and in New York as part of commercial fleets, e.g. taxi, garbage collection, postal or delivery services. While the internal combustion engine car began to force electric vehicles out of the market over the course of the 20th century, they were temporarily revived during the two World Wars. This was mainly due to gasoline shortages, since ICE vehicles and fuels were primarily used for military purposes. However, already before the outbreak of World War II, the production of electric vehicles had almost ceased to exist during the economic crisis in the late 1920s. Until the mid-20th century, electric vehicles had more or less disappeared from the scene (Høyer, 2008, p. 63 ff.).

When public awareness for environmental problems rose from the mid-1960s onwards, the electric car was beginning to re-emerge as a potential solution especially to local air pollution and resource scarcity. The oil crisis in the early 1970s stimulated debates about the finite nature of fossil resources and the OPEC oil embargo showed that this could have very real consequences, e.g. the introduction of "car-free" Sundays and speed limits in Germany in 1973. However, early attempts of re-developing electric vehicles during the 1970s did not achieve any visible momentum apart from various R&D efforts that eventually failed to produce marketable results (Canzler & Knie, 2011, p. 102; Høyer, 2008, p. 66). Still, the electric vehicle did not completely vanish from the agenda, because environmental problems persisted and were increasingly discussed in a more global perspective and in the broader terms of sustainability and energy transition – which links up with the question of alternative fuels and drive technology. At the same time, local problems of air pollution in metropolitan areas also aggravated, a prominent example being Los Angeles, and the Californian zero-emission regulations of 1990 are commonly referred to as an important milestone in the resurfacing of the electric vehicle during the 1990s (Canzler & Knie, 2011, p. 102 f.; Høyer, 2008, p. 67). It spurred a phase of more serious R&D efforts and in Europe large demonstration projects for e-mobility were carried out in Germany, France and Switzerland. These were hoped to lead to market breakthrough for electric vehicles, which however did not materialize (Hoogma et al., 2002, p. 67 ff.; Weider et al., 2011b, p. 108).

Even though the circumstances as well as the motivation for developing electric vehicles have differed across the past 150 years, the reasons why e-mobility has failed time and again have not changed substantially. Compared to conventional ICE cars, electric vehicles have always performed worse as regards range, price and charging time. Since this has held true for a considerable amount of time and in spite of various attempts to politically support the introduction of electric vehicles, it is reasonable „to ask whether these are necessary structural limitations, and whether the electric car can really become more than a niche vehicle for some limited urban use purpose“ (Høyer, 2008, p. 71)? And indeed, when analyzing the potential of e-mobility as a solution for today's sustainability challenges in the transport sector, the perspectives according to industry- and technology-oriented discourses seem rather bleak – even though there have been increased efforts to foster the development of electric vehicles since roughly 2005. Not long after the last phase of hype and eventual disappointment around BEVs during the 1990s, there is now a renewed interest, due to an increasing awareness of problems such as climate change and peak oil and their implications for policy and prices. However, why has the current phase in developing e-mobility already persisted for a period of roughly ten years, when there is broad skepticism, no real breakthrough, and a rich history of trial followed regularly by error?

Fig. 1: Battery-electric vehicles from 1880-2010 (BMVBS, 2011, p. 5)

A number of factors and their simultaneous occurrence and interlinkages may play a role here. A window of opportunity has emerged in the intensified debates about climate change and research scarcity that have reached a peak in public and political attention around the mid-2000s. E-mobility re-appeared as a possible solution because it promises emission-free mobility and independence from oil (and oil producing countries). Due to a broadening and more integrated perspective on sustainability, as compared to the earlier sustainability discourse of the 1980s, e-mobility offered additional advantages. It would not produce some of the problem shifts, for instance those associated with bio-fuels that threaten to cause a competition with food production for arable land (cf. Bringezu et al., 2009; 2012). Furthermore, e-mobility was also increasingly seen as a central element, or even a catalyst, in the context of the transition to renewable energies (Canzler & Knie, 2011, p. 109 f.). However, environmental concerns alone have so far not been decisive for developing e-mobility, and they probably will not be this time.

A difference may be detected by looking at a number of additional factors surfacing during the mid-2000s that set this period apart from earlier phases of developing e-mobility. For one thing, the global economic and financial crisis severely hit the automotive industry (Schwedes, 2011, p. 13). In combination with environmental concerns, these economic difficulties created pressure not only for the industry, but especially also for politicians to search for alternatives. Since at that point electrification seems to be the more viable technological option for the future – as compared to bio-fuels or hydrogen fuel cell technology – governments have decided to invest in research and development of this technological field. Apart from the general recession, many car manufacturers are faced with saturated markets (at least in the industrialized countries) and thus attempt to diversify their strategies (Orsato et al., 2012, p. 210; Orsato & Wells, 2007, p. 999). Incentives for public or private investment in research and development of BEVs are further created by the improvements in battery technology achieved during that phase. Even though the basic characteristics and technological components of electric vehicles have been invented more than 100 years ago, those recent leaps in battery performance have caused hopes, not of radically different and new opportunities, but of finally coming closer to solving the age-old problem of a BEV's limited range and gradually developing electric vehicles that can compete with conventional ICE cars (Schwedes, 2011, p. 14). In accordance with the observed combination of environmental and economic concerns as well as geopolitical strategies, e.g. in relation to oil-producing countries and emerging economies (especially China), government spending on developing e-mobility is usually part of economic recovery plans, especially in countries where the automotive industry is central for the national economy. Germany is a typical case in this respect. It has an important automotive industry and the government has launched a comprehensive funding program around e-mobility for, mainly, economic reasons, but also in the context of its sustainability-related efforts.

So far, these hopes have not materialized. In the German case, the point of market breakthrough for BEVs and substantial diffusion of innovative e-mobility concepts seems far away and there are major uncertainties with regard to the success of supporting measures and efforts altogether. Apart from regulatory and infrastructure issues, a major obstacle is perceived to be the technological shortcoming of the battery as drive technology with regard to its range and price. Thus, despite some serious efforts, there are no signs of breakthrough on a broader scale and electric vehicles remain confined to small (market) niches and often publicly funded demonstration projects. Pilot and demonstration projects have emerged as the method of choice when it comes to investing in R&D for e-mobility (next to economic incentives for consumers to reach higher diffusion rates). The problem with demonstration projects is that due to their important function as a protected space, they usually amount to nothing more than a "temporary meeting ground" (Schot et al., 1994, p. 1073). They are quickly being dissolved again once the circumstances change, such as e.g. falling oil prices once the oil crisis had been overcome in the 1970s, and commitment by industry or public investors is lost (ibid.).

Nonetheless, the role of pilot and demonstration projects can be crucial, especially if they are designed as 'experiments' that focus not only on technological improvement but also social learning processes. For instance, it can be shown that dissatisfaction with the limited range of electric vehicles decreases among test users, because practical experience shows that a BEV is sufficient for most trips in everyday life (Weider et al., 2011b, p. 111). Processes of social learning are also important because from a sustainability perspective a purely technological solution, in this case electric vehicles substituting for conventional ICE cars, will not suffice to meaningfully address the complex challenges the transport sector is facing. Adopting a broad conceptualization of sustainability, transport-related problems include ecological issues such as greenhouse gas emissions and resource use as well as congestion in urban areas, issues of land use and spatial planning, and social issues of access to mobility and social equity.

Assuming that at least part of the goal of developing e-mobility is to contribute to sustainable development, then the question is whether a more comprehensive perspective can be aligned with a technological perspective on electric vehicles? What is clear at least is that even if improvements in battery technology result in competitive BEVs with similar range and prices as conventional cars, a merely quantitative aim of achieving specific diffusion rates and numbers of electric vehicles on the market will not contribute significantly to sustainable development. What is needed is a more comprehensive vision of sustainable e-mobility, which includes technological as well as social change, e.g. in terms of new mobility patterns, infrastructures, policies and business models, and an integration with the development of renewable energies. Such a complex and fundamental change process can be described in terms of a 'system innovation'. The specific strength of experiments shielded from market pressure is that they can in principle facilitate learning processes including these various technological and social aspects, much rather than for instance economic incentives for consumers to buy electric vehicles.

Some developments indicate that the circumstances for e-mobility developing as a system innovation contributing to sustainable development are favorable at the moment, as opposed to earlier attempts in the past decades. First of all, it is noteworthy that the term “e-mobility” has gained prominence in the relevant discourses. This indicates that the perspective has shifted beyond isolated views on the battery-electric vehicle itself. This was common during earlier periods where the focus was more exclusively on developing alternative drivetrains and vehicles (Canzler & Knie, 2011, p. 102.). Second, a broadening of perspective can also be observed with regard to the interlinkages of debates about e-mobility and the energy transition to renewable energies. While during the 1990s the electrification of cars was a project clearly confined within transport policy and the automotive industry, this has currently changed to some degree. Environmental problems in the transport sector are increasingly framed as part of the wider energy transition challenge. E-mobility thus becomes one of the strategies fostering the transition from a carbon-based to a renewables-based society (Weider & Rammler, 2011, p. 6). In practice, this means that developing e-mobility is no longer an issue only in the automotive industry but also includes new actors, especially from the energy sector (Canzler & Knie, 2011, p. 103).

This implies that a comprehensive perspective on sustainable mobility can well be aligned with the development of electric vehicles. In fact, it is not an artificial burden (analytically or in practice) to focus on issues of broader sustainability when dealing with e-mobility, a broadened perspective may much rather be a new context for electric vehicles, where it is more likely that they will not disappear after a short hype, because they might evolve as a central technology in a new energy system. This is very different from a situation where the electric vehicle is developed as a perfect substitute for conventional cars. Thus, such a broad reframing in terms of electric mobility (instead of ‘vehicle’) may help shaping better strategies for improving the environmental performance of the transport sector and may also become crucial for achieving an overall energy transition. Of course, it is highly uncertain whether such a potential can actually be realized and may be compared to the early days of the automobile age where cars were in the beginning referred to as “horseless carriages” (Høyer, 2008, p. 64). Reflecting on the massive consequences that the diffusion of the automobile had in the following and how it shaped many aspects of modern societies, it is clear that what can be observed currently is at most a transitional phase that is only beginning to take shape, where it is still a major challenge to begin to re-think '(auto)mobility' in general. Against the background of its turbulent history, this implies that the electric car can be characterized as a radical innovation and, in principle, this has two possible consequences: the electric car may either trigger the kind of paradigmatic change characterizing sustainability transitions (or the emergence of automobility at the beginning of the past century); or it may fail altogether and never be able to become more than a technological niche, as has already been the case in history several times before.

1.1 Research Questions

Since the current momentum in the electrification of the car, together with the emergence of broader concepts of e-mobility, seem to fuel hope for a transition in mobility, the question addressed in this thesis is:

How can we assess – at this critical early stage – whether there is potential for e-mobility developing as a sustainable system innovation?

What can be observed is an "old" innovation, the electric vehicle, that has failed several times before and is now being rediscovered, facing familiar problems (limited range, long charging times, high price) but also promising new opportunities and synergies in the context of interlinked sustainability challenges in the fields of mobility and energy. The scope of the research question thus goes beyond an issue of diffusion of a technological innovation; here, the concept of system innovation is central. The research thus builds on a long-standing tradition of economic scholarship on innovation, looking beyond specific markets or individual firm profit, but rather aims at understanding the way that novelty enters the world, the emergence of groundbreaking change and how technological innovation is embedded in and interrelated with its social context. These basic lines of thought have been an important influence on innovation scholars of different denominations studying the potential for change and innovation in the emerging field of sustainability transitions research. Since sustainability is a contested and ambiguous concept, involving large degrees of uncertainty, it is important to be specific on the way it is defined for the purpose of this thesis, in order to guarantee transparency and avoid normative distortions of the research. It is thus asked:

- What is “e-mobility”, when understood as a sustainable system innovation? What are the different dimensions of such a concept?
- How can a sustainability dimension be included in a meaningful way?

Based on these clarifications regarding the concept of e-mobility as a sustainable system innovation in theory, the central motivation for this thesis is finding a way of assessing whether current developments in the field of e-mobility may or may not indicate a potential towards the emergence of a system innovation. This question is relevant for many other empirical cases in the field of sustainability transitions research, focusing on technological innovations, such as alternative drivetrains or renewable energy technologies. The theoretical framework developed in this thesis aims at a better understanding of how technological innovations and social practices interrelate and how it can be assessed early on whether emerging system innovations are producing sustainable outcomes.

- How can potential for system innovations to emerge be assessed *ex ante*?

Such an assessment will have to account for case-specific conditions and influencing factors and the theoretical framework will be explored in a case study of developing e-mobility in Germany. For this specific case it is asked:

- What are forces and barriers of a sustainable system innovation developing around e-mobility?
- How do different types of actors involved in developing e-mobility and their specific strategies foster or hinder the potential for system innovation? Since e-mobility crosses sectoral boundaries (especially automotive and energy), what types of cooperation patterns play a role?
- What are relevant framework conditions? In how far do public R&D funding programs and demonstration projects contribute to the development of system-innovative potential?

In order to address these questions, a theoretical approach is needed that transcends the logic of incremental innovation and clearly conceptualizes processes of systemic socio-technical change.

1.2 Research Approach and Contribution of the Thesis

This thesis is positioned as a contribution to the field of sustainability transitions research. Transitions are long-term and fundamental change processes in socio-technical systems and they are the core of this young field of research, which has emerged from various disciplinary backgrounds, and focuses on innovation and transformation processes towards more sustainable energy and transport systems (as well as other relevant societal domains in the context of sustainable development, such as water or agri-food systems). Transitions in these societal sub-systems are captured in terms of system innovation, i.e. the interplay of technological innovations and changes in social practices and institutions. Processes of socio-technical co-evolution lead to radical and paradigmatic change in the way that specific societal functions, e.g. mobility or energy provision, are being fulfilled. The emergence of such new functionalities depends not only on technological innovation, or only on behavioral change. Neither will it be possible to introduce system innovation in a top-down fashion through command-and-control policies or straightforward management, just like bottom-up initiatives alone will in most cases fail to affect structural change. The concept of system innovation thus aims at capturing the interplay of technological and social innovation across different levels and interlinked sub-systems involved in fulfilling certain societal functions, such as energy or transport. For an analysis of whether and how e-mobility may contribute to a more sustainable transport system, i.e. in terms of reducing emissions and resource intensity as well as addressing issues of congestion, socially just access to mobility and interlinkages with the transition to renewable energies, system innovation is thus a useful concept addressing the inherent complexities.

The research approach of this thesis, and most of transition studies in general, is therefore decidedly interdisciplinary, exploratory and based on broad heuristic analytical frameworks. This can be challenging with regard to methodology but the aim is to close a long existing research gap in more traditional scientific approaches of studying sustainability problems in the transport sector. Traditionally, there is a sharp separation between research on technological innovation and research on behavioral or institutional change as two completely separated means of addressing environmental problems caused by transport (Lyons, 2012, p. 30). This has to do with the fact that "[t]ransport research on climate change mitigation tends to revolve around the reduction of carbon use given existing economic, social and political systems and ideals" (Schwanen et al., 2011, p. 1004). Within such 'given' structural conditions, disciplinary science often focuses on clearly delineated elements of such systems in separate strands of research. Most pronounced is the separation between a technological perspective on emissions reduction through alternative drivetrains or fuels, and a social perspective on behavioral change and new mobility patterns. Such disciplinary perspectives are important, in order to advance knowledge in each of these areas. What is missed, however, is an understanding of the interlinkages between both domains. Whether or not a technological innovation will in fact produce environmental benefits depends to a large degree on the way that it is applied in a concrete social context. In turn, the social context also cannot be characterized as a 'given', because technological innovations may give rise to changing social practices and preferences (Schwanen et al., 2011, p. 1000). Thus, it is important to gain a better understanding of such co-evolutionary dynamics, especially from a sustainability perspective. There may be mutually beneficial socio-technical dynamics, increasing the potential for better environmental performance, while there may also be detrimental mechanisms where the potential benefits of a technological innovation cannot be realized due to an unexpected way of applying it, or vice versa. These interlinkages are to some extent studied in economic approaches in the field of innovation studies, focusing for instance on dynamics in innovation systems, market dynamics, diffusion and user acceptance. However, these approaches also tend to remain limited to their specific economic context and a market-based logic of supply and demand as the 'given' framework conditions, rather than a part of the research question.

Apart from these disciplinary traditions, the specific empirical field of transport and mobility also contributes to the described research gap, because due to the fact that "the automobile is both a sacrosanct icon of popular culture and an essential requirement of everyday life, strategies to manage its adverse effects have always been tentative and partial" (Cohen, 2006, p. 29). Thus, it might be argued that the technological lock-in of car-based transport systems is coupled with a disciplinary lock-in of research approaches of studying this system. Alternative problem-framing and scientific approaches rarely emerge, especially when these "are difficult to quantify with commonly used tools" (Schwanen et al., 2011, p. 998).

A transitions perspective on system innovation allows for such a broadening of perspective, because studying the emergence of new functionalities through socio-technical co-evolution specifically aims at understanding deep-structural change that crosses disciplinary boundaries and questions societal framework conditions that are usually treated as 'given'. Such a perspective is useful with regard to the research question of this thesis: When interested in the potential of e-mobility as a contribution to more sustainable transport systems, it is important to look beyond processes of diffusion of electric vehicles, because it can be assumed that the BEV will not smoothly emerge as a substitute for conventional cars (as indicated by its troubled history) and as a pure substitute it will most likely not produce substantial environmental benefits. Therefore, an assessment of whether e-mobility has system-innovative potential is relevant with regard to the success of electric vehicles, which most likely depends on a changing social context, and with regard to questions of sustainability, which also depend on the emergence of new functionalities as a result of socio-technical co-evolution. A research approach centered on the concept of system innovation thus allows for studying e-mobility as a new interface between mobility and energy systems, as a trigger for changing perspectives on the role of the car and redefining 'mobility' in general.

This already broad approach is further complicated, because the phenomenon of interest, the system innovation, does not exist and it will hardly be possible to judge with certainty whether it will exist in the future, and if so, what it would look like in detail. Nonetheless, considering the current momentum in developing e-mobility and the hopes for sustainable solutions connected to it, it is crucial to find a way of assessing at least the potential inherent in these developments and arrive at recommendations for policy and business for fostering e-mobility as a system innovation. Since transitions, or system innovations, are complex long-term processes emerging from contingent and interrelated dynamics, the question is how to assess the potential connected to a specific technology at an early stage of development. With regard to the relevant variables and influencing factors, "[r]esearch shows that it is impossible to isolate any single factor, and that accidental causation has a role to play as well" (Schot et al., 1994, p. 1061). It is therefore important to opt for exploratory research designs that do not unduly limit the set of possible influencing factors and that account for contingency by being cautious with extrapolating observed trends. At the core of a system innovation are the co-evolutionary dynamics emerging between a technological innovation and its social context and therefore, in order to assess the potential for system innovation is it imperative to "pay more attention to the minutiae of the practices in which technologies become enrolled" (Schwanen et al., 2011, p. 1000). This calls for an approach that is case-specific, thus tracing how e-mobility is taken up and dealt with by the involved actors in a concrete setting, and carefully considers the contextual factors having an impact on developments and which may change over the course of time.

The central theoretical concept used in transition studies is the multi-level perspective (MLP), which provides a useful heuristic for analyzing system innovations in such a comprehensive way. However, with regard to the research question of this thesis, two specific weaknesses need to be addressed. First, since the MLP has been developed based on historical case studies it is difficult to apply it to on-going transition processes. Second, the heuristic character of the MLP precludes a focus on micro-level processes of transitions. This is problematic because a central element of a system innovation is the emergence of new functionalities, i.e. paradigmatic change in the structures and practices of a system as a result of socio-technical co-evolution on a micro-level. In order to address these weaknesses, a theoretical framework is developed in this thesis based on the MLP and introducing the concepts of transformative capacity of a new technology (do BEVs trigger 'social' innovations, e.g. new business models, political regulations or use patterns?) and system adaptability (how inert or open to change is the mobility system?) (based on Dolata, 2009). These concepts provide a way of analyzing the basic dynamics of a system innovation on a micro-level and give an indication of its actual potential in an *ex ante* situation.

This type of exploratory research based on heuristic frameworks is a typical approach in qualitative social sciences and the basic premises of this research tradition apply to this thesis as well. The basic aim of qualitative social research is to study social phenomena in such a way that the complexity involved in human action, societies and specific social groups can be grasped as comprehensively as possible. It is argued that in the social sciences, "explaining" ("Erklären") laws and causalities, as in the natural sciences, is not possible, because human behavior and social phenomena simply are not subject to universal laws. The focus is instead on "understanding" ("Verstehen") the logic of actions, interpretive schemes and social structures (Flick et al., 2009, p. 14). This does not necessarily mean that in qualitative social research it is generally not possible to test theories and formulate precise hypotheses, as is discussed in controversies about whether fundamental differences exist in the methodologies of quantitative and qualitative research approaches in the social sciences. Following Gadenne (2001), it is argued here that based on a critical and open attitude, research design and methods should always be appropriate in light of the specific research question and object of study (p. 18). This is a scientific imperative, independent of the respective scientific or methodological tradition. In cases where the object of study is not well known and when there is little empirical data, formulating precise hypotheses will usually not make much sense (p. 21 ff.). E-mobility is such a case, at least when approached from a system innovation perspective. Empirical evidence exists with regard to various aspects of e-mobility, e.g. it has been shown that, from a purely technological point of view, the electric vehicle is an 'old' innovation, in economics and innovation studies basic mechanisms in the diffusion of innovations in general, market dynamics or factors determining user acceptance of new technologies have also been studied to quite some extent. For these disciplinary research (sub-)questions, formulating precise hypotheses and applying quantitative methods may be useful. However, the scope of the research question addressed in this thesis is broader and interdisciplinary in nature, because it focuses on concepts of system innovation and sustainability, which "are inextricably linked to such issues as the organization of contemporary societies, the role of transport therein, justice and ethics" (Schwanen et al., 2011, p. 1004). Apart from this broad perspective, the concrete empirical focus of the thesis is on processes of socio-technical co-evolution in the field of e-mobility. These are case- and context-specific and the empirical basis is limited, because e-mobility is still a small market niche and mainly observable in pilot and demonstration projects. Therefore, an exploratory approach is useful, which aims at understanding a phenomenon in depth, in order to identify relevant variables in the first place, which may then lead to the formulation of more general hypotheses.

Still, in order to utilize and build on general theoretical insights in the field of transition studies (and its rich theoretical backgrounds in other fields) and in order to avoid the theoretical "blindness" often critical in grounded theory approaches, basic theoretical propositions will be developed that guide the case study analysis. The basic methodology, the case study design and the combination and triangulation of methods applied will be laid out in detail in chapter 4.1. In sum, the research approach of this thesis is exploratory and builds on a heuristic theoretical framework, in order to meet the requirements of "understanding" as a crucial principle in qualitative social science traditions.

The contribution of this thesis is twofold. First, it aims at providing a theoretical contribution to the field of sustainability transitions research and the research gap identified above, i.e. in terms of providing a more systemic and interdisciplinary perspective on e-mobility as a potential solution for environmental problems in the transport sector. Based on a comprehensive literature review, the various strands of literature dealing with e-mobility are systematized. It can be shown that research on e-mobility is largely structured along disciplinary lines and within sustainability transition studies, which provides a more comprehensive perspective on system innovations, there is a need to refine existing theoretical approaches in such a way that they can improve the analysis of potential system innovations at an early stage. A theoretical framework is developed based on the MLP and Dolata's (2009) concepts of transformative capacity of technologies and adaptability are integrated, resulting in an adapted framework. By facilitating an explicit focus on processes of socio-technical co-evolution related to a specific technology, against the background of multi-level dynamics of broader structural change in sustainability transitions, this framework can improve *ex ante* analyses of potential system innovations. A focus on the concrete interrelations between the introduction of electric vehicles and the way they are dealt with by different groups of actors facilitates a better understanding of the patterns that may lead to successful and system-innovative applications of e-mobility. Analyzing these dynamics with a view to structural change, as conceptualized in the MLP, and guided by an explicit sustainability perspective allows for identifying and assessing in detail the drivers and barriers for e-mobility as a sustainable system innovation. By applying this framework, e-mobility is also introduced in a novel way in transition studies. So far, electric vehicles have been discussed as one possible alternative to ICE cars among many technological options, while the specific potential of e-mobility in combination with newly emerging business models and use patterns (e.g. carsharing or intermodal mobility), and as a technology at the interface of transport and energy systems has not been studied extensively, yet. Furthermore, e-mobility is not the typical "green technology niche" in transition terms, because in many countries its development is supported by the government and large car manufacturers are involved – as is the case in Germany as a prominent example in this respect.

Second, this thesis provides an early evaluation of current developments in the field of e-mobility in Germany, which is still at an early stage as regards the public funding programs and demonstration projects starting in 2009. Due to the focus on e-mobility as a sustainable system innovation, it provides an addition to conventional accompanying research, which is more disciplinary in nature and focusing on specific aspects of e-mobility in separated research projects (e.g. focusing on life-cycle assessments of electric vehicles, user acceptance, energy management or grid integration concepts etc.). It is thus the first analysis from a comprehensive sustainability perspective evaluating current efforts from a more systemic perspective, thus offering recommendations for policy and business on how to increase the potential for e-mobility to evolve as a sustainable system innovation. In short, it will be concluded that while overall system-innovative potential currently is low, this could be improved by adapting the current funding programs in such a way that actors from outside the realm of (auto-)mobility get involved more ("powerful outsiders", e.g. from the fields of public transport, housing, information and communication technology (ICT)), creating framework conditions that foster direct cooperation between actors from the automotive, energy and ICT sectors, establishing networks with strong and independent coordinating agencies at the center, and by designing demonstration projects in more inter- and transdisciplinary ways.

1.3 Structure of the Thesis

In the following, the structure of the thesis will be outlined in detail and Fig. 2 provides a basic overview of the five main chapters and highlights the basic course of investigation.

In **chapter 2**, e-mobility will be introduced as a field of innovation and a strategy for solving environmental problems in the transport sector. It will be shown that addressing sustainability challenges of modern transport systems requires a broad approach, going beyond technological innovation of vehicles or fuels. It is thus argued that a concept of e-mobility is needed that is not limited to a focus on the diffusion of electric vehicles, but also includes a perspective on long-term and fundamental change in infrastructures, institutions, business models, individual travel behavior and mobility patterns. This sets the stage for the central question of this thesis, i.e. whether e-mobility can potentially emerge as a system innovation and be part of a transition to sustainability.

As a starting point, some basic definitions are provided in **chapter 2.1** and e-mobility is defined as a system of personal mobility, including different kinds of electric vehicles but also the social context in which they are used. Adding a more specific sustainability perspective, visions and concepts of sustainable mobility are introduced in **chapter 2.2** and these are related to the concept of e-mobility as a system innovation. It is shown that applying a broad definition of sustainability in the field of transport requires strategies of increasing efficiency of vehicles and fuels, but also strategies for reducing the volume of transport and achieving modal shift. While e-mobility is mostly discussed as a strategy of increasing resource efficiency and reducing emissions, the aim of this thesis is to connect e-mobility to a broader understanding of sustainable mobility (e.g. new business models in the field of e-carsharing, integrating electric vehicles in intermodal mobility chains and in new forms of city and land use planning). In **chapter 2.3** it is shown that a broadening perspective on e-mobility does not only go beyond issues of technological innovation, it even transcends the boundaries of the transport sector. In general, e-mobility can be understood as part of a wider energy transition, moving from fossil resources to renewables, in order to satisfy societal needs for heat, electricity and mobility. At a more concrete level, there are some direct interlinkages: the boundaries between the automotive and the energy sector become blurred in a system where cars are powered by electricity. Furthermore, sustainability transitions in the field of renewable energy and e-mobility depend on each other's success, while at the same time each can significantly contribute to the success of the other: The energy sector by providing ‘green’ electricity for electric vehicles and the automotive sector by providing electric vehicles, the batteries of which can be a means of temporarily storing electricity in an energy system based on fluctuating renewable sources.

In **chapter 2.4**, the complexity of the many interlinkages of e-mobility with general aspects of sustainable mobility and with the energy transitions as an important background is integrated in the concept of e-mobility as a sustainable system innovation. The concept of system innovation is introduced and applied to the case of e-mobility, and a sustainability perspective is added. Based on this, “three traps” are identified that need to be overcome, if e-mobility is to emerge as a sustainable system innovation. These are, first, a quantitative trap, i.e. there needs to be a certain rate of diffusion of electric vehicles; second, a qualitative trap, i.e. new functionalities need to emerge in the way that mobility needs are fulfilled or the way that electric vehicles are integrated in the energy system, including new business models, use patterns, regulation and symbolic meaning related to mobility; third, a sustainability trap, i.e. new system configurations should deliver sustainability benefits, in the case of e-mobility this would be achieved through renewable energy sources for powering vehicles and integrating electric vehicles in carsharing services or intermodal transport systems. These three traps will in the following serve as a guiding concept for the analysis of the empirical case and for reflecting on the results.

In **chapter 2.5**, a literature review is presented, which aims at identifying whether there are already fields of research or theoretical approaches that focus on e-mobility and relate it to broader definitions of sustainability. The three traps are used to guide and systematize the results of the literature review, in order to show what specific aspects (e.g. technological innovation and diffusion, processes of socio-technical co-evolution, sustainability assessment) are dealt with and asking whether approaches exist that can capture the complex phenomenon of e-mobility as a (potential) sustainable system innovation. It can be shown that currently research on e-mobility is largely dominated by disciplinary perspectives on technological and economic issues relevant for the diffusion of electric vehicles. What is lacking is a perspective on the interrelations between technological change in its social context, specifically tailored to the case of e-mobility, and with an explicit perspective on sustainability.

In **chapter 3**, the theoretical background for the thesis is presented and an analytical framework will be developed for analyzing e-mobility as a sustainable system innovation. The thesis builds on theoretical approaches developed in the field of sustainability transitions research. This newly emerging field of research explicitly focuses on sustainability-oriented system innovations, or transitions, and a brief overview will be given in **chapter 3.1**, including basic definitions and concepts, their origins in other fields of research, and the different theoretical approaches for studying transitions (**chapter 3.1.1**) as well as a discussion of the role of technology and innovation in this context (**chapter 3.1.2**). The Multi-Level Perspective (MLP) on sustainability transitions as the central theoretical approach in this field will be discussed in detail in **chapter 3.1.3**, focusing on how it conceptualizes fundamental change based on Giddens' structuration theory (**chapter 3.1.3.1**) and providing an overview of the different dynamics and mechanisms involved in transition processes (**chapters 3.1.3.2 – 3.1.3.4**). A critical reflection of the MLP regarding its scientific value and shortcomings in general, and with regard to its applicability to the research question of this thesis will be presented in **chapter 3.1.4**.

A major challenge is the question of how to deal with "transitions in the making", such as the case of e-mobility. An *ex ante* analysis is needed and this requires a specific focus to be added or emphasized further in the MLP, which serves as a broad heuristic framework. **Chapter 3.2** is dedicated to this issue and two, more "future-oriented", approaches in transition studies are introduced, i.e. Strategic Niche Management (**chapter 3.2.1**) and Transition Management (**chapter 3.2.2**). It will be shown that these approaches focus on processes of steering and managing transitions in practice (**chapter 3.2.3**), while they are less suited as analytical tools assessing on-going developments. The aim of this thesis is to find a way of analyzing the potential inherent in currently observable dynamics in the light of an envisaged sustainable system innovation (**chapter 3.2.4**).

Therefore, a theoretical framework – building on the MLP and addressing its weaknesses discussed earlier – is developed in **chapter 3.3**. Based on a discussion of the relevant unit of analysis in studying system innovations (**chapter 3.3.1**) and a specific conceptualization of system innovation (**chapter 3.3.2**), Dolata's (2009, 2011, 2013) concepts of the transformative capacity of new technologies and adaptability are introduced in **chapters 3.3.3** and **3.3.4**. An integrated analytical framework will be developed in **chapter 3.3.5** by integrating these concepts into an overarching multi-level perspective on transitions and it is shown that this provides a way of analyzing the basic dynamics of a system innovation at a micro-level and give an indication of its actual potential in an *ex ante* situation.

In **chapter 4**, the integrated analytical framework will be explored by tracing the dynamics of the German innovation system for e-mobility, focusing especially on the 'automotive state' of Baden-Württemberg. The aim is to gain insights regarding the conditions for increasing system adaptability or barriers impeding it – as a way of assessing the potential of this particular e-mobility niche and its chances for future up-scaling. The methodology guiding the empirical analysis is laid out in chapter **4.1**. The analysis proceeds along three steps.

First, the theoretical concept of a sustainable system innovation will be delineated as an ideal-type for the case of e-mobility in **chapter 4.2**. To that end basic criteria of sustainable forms of e-mobility will be deducted from the discussion of sustainable mobility in chapter 2 and these criteria will serve as an orientation for the overall analysis and as selection criteria for system-innovative e-mobility projects later in the case study. Ideal-typical elements of sustainable e-mobility identified in that way are the emerging interlinkages between e-mobility and the broader context of a transition to renewable energies (**chapter 4.2.1**), e-mobility and less car-dependent forms of mobility in fleet applications (**chapter 4.2.2**), intermodal transport concepts (**chapter 4.2.3**), and innovative business models in the field of carsharing (**chapter 4.2.4**).

Second, the transformative capacity of the battery-electric vehicle will be assessed in **chapter 4.3**. Based on a set of qualitative criteria developed in the theoretical framework it will be analyzed in what ways the BEV affects the technological profile, institutional structure, patterns in market relations, R&D, policy making and user behavior, patterns of interaction, and the boundaries of the socio-technical system of (auto-)mobility. Since the electric vehicle is an 'old' innovation, secondary sources exist on these issues and are used as the basis of the analysis.

Third, the concept of system adaptability will be explored in a case study of e-mobility development in Germany, and Baden-Württemberg more specifically in **chapter 4.4**. The basic rationale for choosing a case study has been laid out in the methodology section and the concrete case study design, the combination and triangulation of methods is described in **chapter 4.4.1**. An overview of the German innovation system for e-mobility is presented in **chapter 4.4.2** with a particular focus on political initiatives at the federal level (**chapter 4.4.2.1**), the actor structure determining the strategic perspective of the German government (**chapter 4.4.2.2**), and the development of funding programs (**chapter 4.4.2.3**). A closer look will then be taken at the 'automotive state' of Baden-Württemberg in **chapter 4.4.3**. A brief overview is given on the state of Baden-Württemberg in general and the e-mobility initiatives taking place during the period of investigation from 2009 until today (**chapter 4.4.3.1**). In a network analysis, the dominant actors and cooperation patterns in the context of developing e-mobility in Baden-Württemberg will be analyzed (**chapter 4.4.3.2**). Subsequently, basic frames of reference in relation to e-mobility shaping the overall discourse in this network are analyzed, in order to complement the insights on different levels of influence of specific actors with their respective views, guiding principles and the resulting strategies (**chapter 4.4.3.3**). In **chapter 4.4.3.4**, a closer look is taken at specific e-mobility projects carried out in Baden-Württemberg that can be characterized as system-innovative. These projects are selected based on the ideal-typical criteria identified for e-mobility as a sustainable system innovation and analyzed in order to show where and how concrete system-innovative approaches emerge (e.g. regarding involved actors, cooperation patterns, motivations and goals). In-depth expert interviews have been carried out with actors involved in these projects and with actors responsible for coordinating the innovation system as a whole. The results of the case study of Baden-Württemberg are presented in **chapter 4.4.3.5** and they are discussed in the larger German context of developing e-mobility in **chapter 4.4.4**. The empirical findings are then discussed in relation to the theoretical framework and reflected with regard to the three traps of a sustainable system innovation in **chapter 4.5**. The results of the case study are taken up and discussed against the background of the theoretical concepts of transformative capacity and system adaptability and the basic theoretical propositions regarding the potential for system innovations to emerge based on the MLP. The case of Germany provides a number of lessons as regards the potential of e-mobility to develop as a sustainable system innovation and these will be discussed here. For instance, the analysis has shown that the system-innovative potential of this specific e-mobility niche remains limited, due to the powerful influence of incumbents, conflicting political goals and traditional science approaches. A few more system-innovative activities emerge where powerful actors from outside are involved, who are capable of viewing mobility in a more systemic way (e.g. actors from the public transport, ICT or housing sector). It is argued that the role of large demonstration projects is important, but they need to be designed as transdisciplinary research projects from the beginning.

Conclusions will be drawn in **chapter 5** and an outlook is presented, including recommendations for improving R&D funding programs and demonstration projects for developing e-mobility as a sustainable system innovation as well as future research needs in the field of transitions to sustainable mobility.

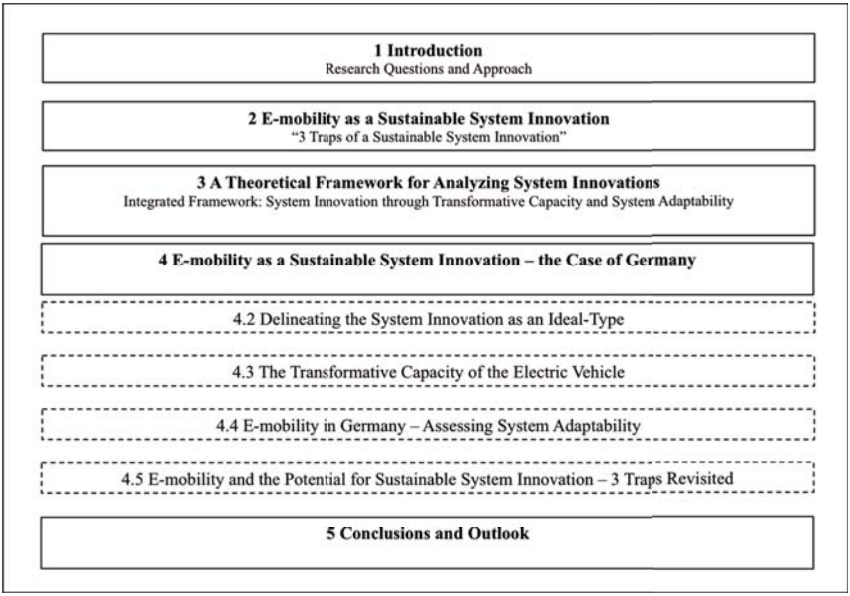

Fig. 2: Structure of the Thesis - Main chapters and course of investigation.

2 E-MOBILITY AS A SUSTAINABLE SYSTEM INNOVATION

"Mobility" plays a special role in the debate about future sustainable development and the great transformation of modern societies. This is not only due to the fact that the transport sector has a large direct and negative impact on global eco-systems, but also because mobility is such an integral part of modern societies and is thus an element of the root causes and hazardous effects of current unsustainable development. As Høyer puts it, "the fossil society and the mobile society have grown like Siamese twins" (2008, p. 68). Modern transport systems facilitate a globalized economic system, the car industry and its related sectors and supplier networks are of key importance to many national economies, urban infrastructures have facilitated as well as themselves been shaped by the increasing dominance of car-based individual mobility, and the car as an artifact is a symbol of modernity and prosperity (Cohen, 2006, p. 29; Norton, 2011; Pel & Boons, 2010, p. 1250; Rammler, 2011, p. 23). These many interlinkages of modern forms of mobility with various aspects characterizing (mostly Western) industrialized economies make it extremely difficult to envision substantial change and shows that a broad perspective is needed. At the same time, this also means that a transformation towards a more sustainable form of mobility may serve as a "Trojan horse" for an overall transformation towards a more sustainable, decarbonized society. Especially an electrification of transport systems should then be advanced in terms of a change from a fossil to an overall "solar" culture (Weider & Rammler, 2011, p. 6).

The need to reduce the environmental burden caused by currently fossil-based transport has been recognized and the pressure exerted by increasingly strict environmental regulation, e.g. regarding CO_2-emissions, has led to at least some concern and efforts towards sustainability-oriented change. Typically, this type of change is hoped to be achieved with the help of technological innovations such as the battery-electric vehicle (Høyer, 2008, p. 68). However, in most industries, technological innovations usually follow so-called 'technological trajectories'. They build on the existing technologies in their design and function and often remain limited to incremental changes in this basic technology, an add-on or particular improvement. Thus, innovations in this sense seldom have a substantial impact on the already existing infrastructures, use patterns or business models related to a specific technological field (Elzen & Wieczorek, 2005, p. 653).

As in many other cases, such a technological trajectory can be observed in the automotive industry. The basic design of the car and its core technology, the internal combustion engine, has essentially remained the same (Weisshaupt, 2006, p. 22). Numerous innovations have been developed, that can be characterized as linear, in the sense that they have improved the basic technology in various ways. Engines have become more powerful and more efficient, safety has been improved through airbags and electronic driving assistance systems, environmental performance has been improved by introducing the catalytic converter and exhaust filters (Weisshaupt, 2006, p. 85 f.).

At present, many of these innovations are aimed at meeting increasingly strict CO_2-emission standards set by the EU as well as national governments and, more generally, find a way of making motorized individual transport more sustainable. However, the effects of technological improvements have begun to reach their limits, due to the absolute number of vehicles and volume of traffic and transport, which continue to grow larger. As a consequence, the total environmental impact of cars is increasing in absolute numbers. Apart from that, air pollution and emissions are not the only issues that have to be tackled. Due to its oil-dependency, the modern car-based transport system will in the long run be affected by resource scarcity. From a global point of view, it seems doubtful whether broad access to mobility in large and livable cities can be possible at all with a car-based system of individual mobility, which involves increasing levels of congestion, of local air pollution and an increasing need for space taken up by parked cars (Elzen & Wieczorek, 2005, p. 653 f.; Köhler et al., 2009, p. 2986; Weisshaupt, 2006, p. 86).

Battery-electric vehicles could solve part of these problems, especially those related to local air pollution, CO_2-emissions (depending on the sources of the used electricity) and oil-dependency, since in this particular respect they provide an alternative to conventional cars powered by fossil fuels. A number of problems impede their widespread introduction and diffusion, though. First, from a consumers' point of view, BEVs do not perform as well as conventional cars, especially with regard to vehicle range and charging time. Second, the charging infrastructure for BEVs needs to be built up in the first place. Third, BEVs involve high costs for consumers and producers since in this early phase they cannot benefit from economies of scale (van Bree et al., 2010, p. 534). These problems are generally viewed as the typical challenges of an immature technology.

However, even if these could be solved, by improving battery technology and developing fast-charging systems, the mere diffusion of BEVs does not guarantee a sustainability benefit per se. It may even worsen the situation in the transport sector by adding vehicles that are energy- and CO_2-intensive, depending on the electricity source for powering BEVs (Schallaböck et al., 2012; Zimmer et al., 2011). Another problem is resource intensity, especially when considering the production of batteries (Kushnir & Sanden, 2012, p. 102; Stamp et al., 2012, p. 104) and the potential of BEVs being used as the eco-friendly additional private car. Finally, issues such as congestion and sustainable mobility in dense urban areas would remain untackled (Vallée & Schnettler, 2013, p. 34 f.).

This implies that a more radical change is needed: The focus on a technological innovation, such as the BEV (or, for that matter, biogenic fuels, hydrogen fuel cell vehicles etc.), will hardly suffice to deal with the problems inherently connected to the modern car-based transport system. What is needed is a system innovation, which can be defined as *a combination of technological and social innovations that merge into a co-evolutionary process of substantial change in a socio-technical system* (such as the car-based transport system) *over the long term* (Geels, 2005a, p. 6, p. 10 ff.). In the case of transport, a system innovation would include "new vehicle technologies, new infrastructures, new logistics, new legislation and change of travel behaviour" (Elzen & Wieczorek, 2005, p. 654). In this sense, the buzzword "e-mobility" already points to a system innovation that transcends the electrification of the car and its technological implications (Canzler & Knie, 2011, p. 101 ff.; Rammler & Sauter-Servaes, 2013, p. 48). The question thus is, can "e-mobility" be more than the introduction of BEVs and rather a system innovation towards a future, more sustainable mobility system?

2.1 Definitions

The aim of this section is to clarify what is meant by electric mobility or "e-mobility" in the context of this thesis. The common understanding of e-mobility is in terms of a shorthand for 'electrified automobility'. The technological artifact at the center of this type of mobility is a vehicle that is driven by a battery-powered electric motor, the battery-electric vehicle. The term usually includes all road vehicles with at least three wheels, thus including different kinds of private cars, commercial vehicles and busses (Sauter-Servaes, 2011, p. 25; Weider & Rammler, 2011, p. 5). The most significant difference of the BEV as compared to other types of alternative drive technologies or fuels is that it can be characterized as a radical innovation that differs from conventional vehicles with regard to basic characteristics and ways of functioning.

The current system of personal mobility is built around privately owned cars, which are designed as general purpose vehicles, i.e. fulfilling all kinds of mobility needs in terms of length and purpose of trips. They are embedded in an extensive road, parking and refueling infrastructure that facilitates established patterns of motorized private transport. The basic characteristics of this system are not in principle challenged by the introduction of biofuels, for instance. Even though in this case current fuels would be replaced and new fuel producers would enter the market, the basic infrastructure and use patterns would remain intact. With regard to alternative vehicles, the fuel cell vehicle (FCV) challenges the system in terms of the established drive technology and it would require a completely new refueling infrastructure based on hydrogen filling stations. However, FCVs would not amount to more than a replacement of one sort of general-purpose vehicle by another. In principle, the way that FCVs could be used and marketed would not differ from today's cars. They can be used for short and long trips and the refueling infrastructure and process would function much like today's gas stations. Similarly, the different types of hybrid electric vehicles are also all aimed at fulfilling the same needs as a conventional car powered by an internal combustion engine. This is not to say that the diffusion of FCVs or hybrid electric vehicles is not a challenge. It would require various technological innovations in drive technology and new forms of cooperation as well as an adjustment of industry structures to create the links with electricity or hydrogen as power sources. Nonetheless, the basic infrastructure design, mobility patterns on the part of users and business models on the part of car manufacturers would remain similar (Nilsson et al., 2012, p. 61; Weider & Rammler, 2011, p. 6).

In contrast, the pure BEV is much more difficult to integrate into the current transport system. It will most likely not become feasible for a BEV to compete with a conventional car powered by an internal combustion engine with regard to range and price, thus with the currently dominant idea of the car as a universal, ‘all-purpose’ vehicle. The BEV thus challenges the dominant paradigm where personal mobility is guaranteed by the privately owned car. While any type of a hybrid or fuel cell electric vehicle rather represents an evolutionary or even incremental innovation, in the sense that they fulfill the same functions as a conventional car in similar ways, the pure BEV points towards a more paradigmatic change in the transport system (Weider & Rammler, 2011, p. 6).

This is not to say that the BEV, once it emerges, will automatically lead to fundamental changes in modern transport systems. From a historical point of view it can be shown that the BEV has failed before. However, this also shows that the BEV can only be successful when evolving in terms of a more systemic change towards e-mobility. The technological shortcomings of the BEV as compared to conventional cars in the context of today’s car-centered transport system become irrelevant or may even turn into advantages when the BEV is envisioned as part of a system innovation towards *e-mobility* (Weider & Rammler, 2011, p. 6, 10).

The term e-mobility is thus used to capture the concept of such a paradigmatic change, or the vision of it, which goes beyond a technological innovation, in the sense that it has implications for the way this innovation is used, marketed, regulated and embedded in cultural contexts. Therefore, the concept of e-mobility used in this paper focuses on the BEV as the central technological artifact around which a certain type of mobility evolves. This may potentially take forms that are markedly different from current mobility patterns dominating the transport system. The BEV may contribute to a transition towards new forms of mobility, because it can be characterized as a radical innovation. The term e-mobility consequently captures a multi-facetted network of innovations around the car as a product, the way it is used and embedded in spatial, social and cultural structures (Rammler, 2011, p. 14; Schneidewind, 2011; Weider et al., 2011a, p. 52). Such a perspective allows a perspective on the BEV where it can be viewed as an artifact that transcends traditional sector boundaries and connects a society’s need for energy and mobility. Visions of new forms of urban mobility and innovative mobility services embedded in new energy infrastructures emerge around the BEV (cf. Dennis & Urry, 2009; Mitchell et al., 2010). This also implies that e-mobility as a system innovation takes the BEV as point of departure but also needs to include new types of vehicles, such as pedelecs or segways, as well as long-established forms of electrified mobility, such as trains and trams (Weider & Rammler, 2011, p. 6, p. 10).

For the purpose of this thesis, *e-mobility is defined as a system of personal mobility where different types of battery-electric vehicles have replaced conventional cars and have become part of an overall electrified transport system, and where electric vehicles have become embedded in new transport infrastructures and policies, behavioral patterns by users, market and industry structures as well as mobility cultures*. In order to focus on personal e-mobility, freight transport is excluded and the focus on battery-electric vehicles is broadened insofar as public transport or other electric vehicles, such as trains or pedelecs, are considered as parts of the mobility system in general and possibly as elements that gain importance in a future sustainable mobility system, where the role of the privately-owned (electric) car loses importance.

2.2 Visions and Concepts of Sustainable Mobility

Apart from a systemic perspective on e-mobility, including the infrastructural, socio-economic and cultural context of the battery-electric vehicle as a technological innovation, a view on sustainability needs to be included, if new forms of e-mobility are to contribute to the solution of environmental problems in the field of transport. Therefore, the concept of e-mobility as a system innovation needs to be connected with concepts of sustainable mobility in general.

Awareness for environmental problems related to transport rose significantly from the 1960s onwards, especially in Western countries. In the beginning, negative effects of transport were perceived largely in terms of pollution in local settings and as a problem of the intensity of transport, especially in cities. With increasingly growing volumes of transport, problem perceptions broadened and apart from local pollution also included emissions by the transport sector on a global level, continued increases in energy demand for passenger and freight transport as well as problems of congestion (Høyer, 2008, p. 68). The environmental impact of transport on global ecosystems is severe: The amount of energy consumed in the field of transport amounts to almost 30% of total global energy consumption (IEA, 2013, p. 246). Fossil fuels have remained the dominant energy source, with approximately 95% of energy use in the field of road transport being based on oil - a share similar to the situation in the 1970s (p. 510). Thus today, the transport sector, together with the generation of electricity and heat, are responsible for more than 50% of the EU's total CO_2-emissions (EEA, 2013, p.

14 f.). Looking at the car as the dominant means of individual transport, it can be shown that from a life-cycle perspective on an average car, not only emissions and pollution caused during its use are critical. In the production stage of one average car 26.6 tons of waste and 922 m^3 of polluted air have been produced, and, this production phase preceding actual car use, together with the final disposal stage, cause 20% of a car's total environmental impact (Orsato & Wells, 2007, p. 1001). Apart from such direct environmental harm induced by modern transport systems, the problem of congestion, especially in cities, also amounts to a severe hazard caused by modern transport systems. The International Energy Agency projects that between 2011 and 2035, the number of vehicles worldwide will have doubled (IEA, 2013, p. 71). In accordance with this broadening perspective on the many dimensions of problems that modern transport systems are facing, envisaged strategies for improvement have also evolved, from technological innovation and improving ecological performance in industry supply chains (cf. Seuring et al., 2003) to a broader outlook on mobility per se. While in the beginning the focus was predominantly on technological improvements of vehicles, fuels and emission control, increasingly broader perspectives have begun to also look at the infrastructures, politics and lifestyles that are connected and intertwined with the transport sector causing not only environmental problems, but also social problems regarding access to mobility, land use and livable cities (Cohen, 2006, p. 27).

Thus, as a result of the multitude of problems connected to modern transport systems, broader visions of sustainable transport or sustainable mobility emerged in public and academic discourses. Even though 'sustainability' can mean a plethora of different things, it is commonly understood that sustainable mobility should provide social and economic welfare, in terms of societal access, personal mobility and trade, without damaging the environment, in terms of emissions and pollution as well as resource depletion, or otherwise causing harm to humans (Nykvist & Whitmarsh, 2008, p. 1373). While the term sustainability per se includes such a holistic perspective, it makes a difference whether it is applied in terms of sustainable transport or sustainable mobility. While the focus on sustainable transport mainly relates to specific types of vehicles and transportation infrastructures, sustainable mobility is a more comprehensive concept with a focus on the societal context within which people or goods are moving (Høyer, 2008, p. 68; Schneidewind & Zahrnt, 2013, p. 88 f.).

In the seminal paper by Banister (2008), sustainable mobility is introduced as a concept that amounts to a new paradigm in the theory and practice of transport policy and planning. According to this approach, strategies for increasing the sustainability of modern transport systems should be adopted across four basic principles or action domains. First, the principle of substitution is the basis for strategies aiming at a reduction of the need to travel. In a situation where the sheer volume of transport is problematic, it seems obvious and straightforward to directly decrease this high volume by decreasing the amount of trips undertaken. Developments in the field of Information and Communication Technologies (ICT) are important in this context because they facilitate virtual forms of communication across spatial distances, thus, in principle, reducing the need to travel in order to communicate face-to-face. Substitution therefore means that a specific trip (to work, for shopping or leisure activities) is replaced by a technology or an activity that does not involve the need to travel (Banister, 2008, p. 75). However, some caution is warranted, since the possibilities offered by various ICT applications may also generate new travel activity or lead to a substitution of many shorter trips by fewer, but longer trips (Lyons & Kenyon, 2003, p. 30; cf. also: Banister & Stead, 2004; Kenyon & Lyons, 2007).

Second, where trips cannot be replaced entirely, sustainability-oriented strategies should aim at encouraging modal shift, i.e. a shift to other means of transport that have less detrimental effects on the environment. The basic strategy thus is to make the trips that cannot be replaced entirely as environmentally friendly as possible. In our current mobility system this basically means a reduction in the use of cars and a shift towards public transport or even cycling and walking (Banister, 2008, p. 75; cf. Böhler-Badeker et al., 2012; Bongardt et al., 2013; Koska & Böhler, 2008; Reutter, 2010; Reutter & Jansen, 2008; Wilke & Böhler, 2007).

Third, strategies addressing the infrastructural context in which mobility takes place, i.e. city and land use planning, should aim at reducing trip lengths. This can be achieved by designing infrastructures and buildings in such a way that density and concentration is relatively high and that different functions (work, home, leisure) can be fulfilled within mixed-use areas. Such planning strategies are aimed at creating high-quality environments especially in cities and they are linked with strategies of substitution and modal shift. Intelligent planning of urban infrastructures would mean close spatial proximity of various day-to-day activities, thus making some trips superfluous and facilitating walking and cycling as well as an increased use of public transport – as a more attractive option as compared to the currently dominant use of cars (Banister, 2008, p. 73 f.).

Finally, a comparatively moderate and less radical approach for achieving more sustainable forms of mobility is an efficiency increase in the transport system. This entails the introduction of cleaner technologies in vehicle design, drive concepts, fuels and renewable energy sources for powering vehicles. Such technology-based strategies can be combined with efforts in city and land use planning, for instance, by restricting access to certain areas for vehicles that are seen as relatively less environmentally-friendly (Banister, 2008, p. 75).

Since the focus of this thesis is on e-mobility as a new form of mobility evolving around electric vehicles and the central question relates to the potential that this development entails for the emergence of future more sustainable mobility, issues and strategies of city and land use planning and substitution of trips through ICT applications fall outside the scope of this thesis. They are important for sustainable mobility in general, but for the case of e-mobility they are dealt with in a more implicit fashion, in terms of framework conditions for concrete mobility patterns evolving around electric vehicles. The other strategies of increasing overall efficiency through the use of alternative technologies and energy sources and encouraging modal shift are at the center of this thesis and their interlinkages, i.e. between technological innovation and changes in mobility patterns, are of particular interest here: Instead of using the car for the majority of trips, this would mean that people use combinations of different transport means to organize their specific trips in the most efficient ways. Apart from changes in infrastructure and technology (Lechtenböhmer et al., 2010, p. 7 ff.), this would especially require information services assisting in the organization of individual trips and changes in individual social practices with regard to travel behavior. This reduces the total negative impact of the most disadvantageous means of transport (with regard to emissions and energy usage) and increases overall efficiency of transport, when there is substitution of e.g. car use by a combination of it with walking, cycling and using public transport. In combination with increased forms of collective car ownership or carsharing services, an increase in intermodal mobility patterns would further reduce the resource-intensity of transport and would also further contribute to solving problems of congestion in urban areas.

Considering the multidimensionality and severe nature of sustainability challenges the transport sector is facing, it is widely accepted that a purely technological solution to these problems, e.g. through alternative fuels or drive technologies, is not feasible. While fundamental changes in urban infrastructures can only develop over the long term and a substitution of transport via ICT applications would be part of larger societal trends and developments, encouraging modal shift is perceived to be an approach towards overall sustainable mobility that seems more realistic and achievable in a short- to mid-term perspective. Strategies for achieving a shift to less harmful modes of mobility, e.g. walking, cycling and public transport, are usually combined with concepts of mobility services[1]. These include carsharing, thus integrating cars in multi-modal mobility chains, or software based services assisting in planning and paying for trips using different means of transportation in combination. A central role is attributed to this type of integrated intermodal mobility and here infrastructural and ICT-related aspects do play a role again. In a system where people rely on various means of transportation to make a specific trip ('chain mobility'), there is a need for facilitating suitable infrastructures, e.g. convenient stations for switching between modes, special parking spaces for carsharing systems, bus or car pool lanes, and ICT solutions, such as integrated internet platforms or smartphone applications for planning trips, making reservations, paying for trips and using information services (Cohen, 2006, p. 33; Kemp & Rotmans, 2005, p. 34; Vergragt & Brown, 2007, p. 1105).

An important aspect with regard to these types of strategies towards more sustainable mobility has not been mentioned explicitly so far. How can they be implemented in practice? The difficulty in changing the transport sector is not only a challenge in terms of the multitude of problematic aspects and their interlinkages, but also in terms of addressing these various problems in a coherent and comprehensive way (Cohen, 2006, p. 33; Leerkamp, 2014, p. 85 f.). All of the strategies outlined above, except maybe for increasing overall efficiency, are questioning fundamental societal values (e.g. decreasing the overall volume of travel is in conflict with a globalized economy and a global society characterized by individualization, especially in the Western world), they require fundamental rethinking of the way that cities and transport infrastructures have been planned and constructed over decades, and they are in conflict with very personal emotions connected to the car (e.g. the car as a symbol of personal freedom, status and wealth). What is more, even a strategy of increasing efficiency by introducing alternative vehicles or fuels constitutes a tremendous challenge – maybe not in all cases connected to fundamental guiding principles of modern societies, but at least requiring severe restructuring of industries and markets (Berg & Schneidewind, 2013).

These paradigmatic challenges involved in making the transport sector more sustainable are reflected in the way that the literature deals with sustainable mobility. There seems to be general agreement on the nature of the problems involved and on the ways that these should be addressed in terms of overall strategy and with regard to the range of policy instruments that can be chosen from. However, the empirical reality simultaneously shows

[1] Cf. Wilts & Rademacher (2014), Wilts et al. (2013), Leismann et al. (2012) for a discussion of the potential of increasing resource-efficiency and preventing waste through product-service-systems.

that not much is changing in practice and that there are many well-studied barriers for overcoming the current transport system centered on personal mobility guaranteed by the privately owned, fossil-fuelled car. Banister suggests that reducing car use cannot be achieved directly, but that there need to be more indirect push and pull measures that make other options more attractive and that, in general, people should be involved much more in research and policy making for sustainable mobility (Banister, 2008, p. 75 f.).

In sum, a transition towards sustainable mobility would include a number of aspects. First of all, the overall volume of transport would have to be reduced. This means that the need to travel should be reduced where possible (for instance by substituting travel needs with the help of the internet and ICT) and average trip lengths should be reduced, which depends largely on adequate forms of city and land use planning. Furthermore, efficiency of engines and fuels should be increased, in order to decrease the negative impacts of the amount of transport that cannot be reduced or substituted as much as possible. Finally, modal shift should be encouraged that reduces the level of car use and increases the proportion of walking, cycling and using public transport in the overall volume of traffic.

The definition of sustainable mobility used in this thesis and the envisaged solutions or strategies for achieving it are specific insofar as they can be grouped among ‘broad’ conceptualizations of sustainability – in contrast to ‘narrow’ sustainability definitions focusing on environmental impact of specific technologies in terms of emissions and ecological footprint. Research based on such a narrow conceptualization is typically more technology-oriented, rather employing quantitative and scenario analysis. While this type of research is no doubt important, it tends to disregard social aspects and misses the many interlinkages between technologies and their social and institutional surroundings (cf. Wilke, 2013). It may thus be argued that an exclusive focus on alternative fuels and vehicle technology addresses issues of sustainable mobility “in only the shallowest and most delimited sense” (Cohen, 2006, p. 34). Apart from that, a central argument in this thesis is that achieving even a narrowly defined form of sustainable e-mobility will not be feasible with the help of narrow approaches, i.e. narrowly delineated research questions and approaches staying within disciplinary academic boundaries. This is simply due to the fact that the environmental impact of modern transport systems is caused by the sheer volume of transport and the interconnectedness of technological issues related to vehicles and fuels with issues of lifestyles and social practices in modern societies, the necessities of everyday-life as much as political and economic institutions. Thus, aiming at reducing the ecological footprint of transport systems will necessarily require a socio-technical, broader approach towards sustainability aspirations.

Such a broader perspective can nonetheless mean that the starting point for analysis is the car as the central technological artifact in modern transport systems and especially personal mobility patterns. Technological lock-in and path dependencies have historically evolved with the automobile, extending over various dimensions ranging from infrastructures, vehicle design heuristics and engineering principles to markets and business models, policy, land use patterns, city planning and modern lifestyles (Cohen, 2006, p. 29; Pel & Boons, 2010, p. 1250). One may argue that in debates about sustainable mobility, the car is the boundary object that connects all these elements and to which actors from different fields can relate in their specific ways. In this context, it is important to note that the car is not only a technological, but also a cultural artifact, and that it is therefore important to address also the symbolic functions connected to cars, e.g. as status symbols or otherwise emotionally important objects (Barth & Jonas, 2011, p. 76). The car and the historical development of an 'automobile' society can thus also be an important starting point for discovering the root causes of the complex and deeply entrenched causes of current unsustainability. This may in turn mean that strategies towards more sustainable mobility systems require a move away from car-centered forms of mobility – which is implied by the principles of sustainable mobility discussed above. If car-dependency is indeed at the heart of the problem, then any technological optimization strategy or problem-solving approach working around the car, without at least questioning its role in modern transport systems and societies at large, may remain limited to a "self-defeating 'pseudo-solution'" (Pel & Boons, 2010, p. 1254). In sum, the general problem underlying the challenges as well as the advocated solutions for achieving sustainable mobility, is the need for paradigmatic change overcoming current forms of car-centered personal mobility and leading the way towards a post-fossil society.

2.3 E-mobility and the Energy Transition

Placing e-mobility in the context of larger transition processes and visions of a post-fossil society further broadens the perspective of this thesis: e-mobility is not only more than a project of technological innovation and diffusion, it also reaches beyond the boundaries of the transport sector. Especially in political discourses in the context of the German energy transition ("Energiewende", i.e. the political project of restructuring the German energy system towards a larger share of renewable energies and increased energy efficiency), it is often argued that an integrated approach is needed, focusing on e-mobility and renewable energies as “natural partners” (BEE, 2010, p. 3). The basic challenge is the same for the energy and the transport sector: both are faced with pressure for fundamental restructuring, if they are to contribute to future sustainable development. For both sectors this means not only technological change, but also a redefinition of basic guiding principles, new business models, use patterns, regulation and socio-cultural embedding (Schneidewind et al., 2013). Apart from those common challenges, the envisaged energy and mobility transitions are mutually interlinked at a more concrete level where the boundaries between the automotive and the energy sector become blurred in the actual provision of electricity for electric vehicles.

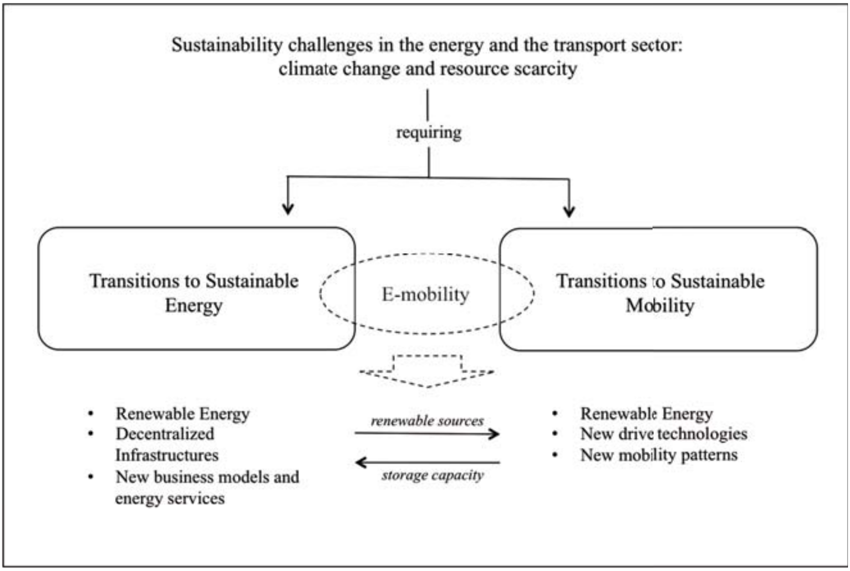

Fig. 3: Mutual dependency and interlinkages in the field of energy and mobility transitions.

The BEV is the tangible artifact at the interface of the energy and the transport sector and it illustrates and embodies not only the interlinkage between the two, but also their mutual interdependence: From a transport perspective, the introduction of electric vehicles would increase overall vehicle efficiency and contribute to a reduction of local pollution and noise. However, a more significant and meaningful contribution to a sustainable transport system would require that electric vehicles are powered by electricity from renewable sources – thus, e-mobility for sustainable development depends on a successful energy transition. In turn, the success of a wider energy transition crucially depends on the availability of short-term storing capacity for electricity from fluctuating renewable sources, which could be provided by the batteries of electric vehicles. Also, the term *energy* transition already indicates that this is an endeavor of restructuring the way societies produce and consume energy in general, not limited to the production of electricity, and definitely including the way we consume energy in the transport sector. Thus, in short, the energy and the mobility transition depend on each other's success, while at the same time each can significantly contribute to the success of the other (Rammler & Sauter-Servaes, 2013, p. 48).

In practice however, the case of Germany shows that 'energy transition' is often dealt with in terms of an "electricity" transition. It is somewhat neglected that another major field where primary (fossil) energy sources are being used and lead to greenhouse gas (GHG) emissions is the transport sector. In Germany, roughly 160 million tons of CO_2 are emitted by the transport sector each year, which amounts to approximately 18% of Germany's total GHG emissions (UBA, 2012, p. 44; UBA, 2013). Crude oil is the basis of conventional fuels, such as gasoline, diesel or kerosene, and is the primary energy source (90%) in the transport sector (Vallée et al., 2013, p. 77). Thus, a comprehensive and meaningful energy transition requires including a mobility transition.

What would this imply in practice? The basic idea is that introducing e-mobility based on renewable energy sources is a way of making transport more sustainable, while at the same time this could in turn contribute to an overall energy transition. The major aim of reducing CO_2-emissions caused by transport requires that BEVs are powered by electricity produced from renewable sources, such as solar or wind. At the same time, BEVs could become an important element fostering a transition towards a more decentralized energy system based on renewable sources. Their batteries could be used as small-scale storage units for electricity, in order to deal with the fluctuations in solar or wind powered electricity generation. In principle, BEVs could flexibly be charged when there is excess production of electricity and low demand, while they could feed electricity back into the grid when there is excess demand. Currently, the amount of BEVs is still too little and the feasibility of such 'vehicle-to-grid' (V2G) concepts depends on the development of smart grids and smart metering as well as billing systems (Dijk et al., 2013, p. 142; Rammler, 2011, p. 18 f.). Nonetheless, there is a great potential in this field and it shows that there are many concrete interlinkages between sustainability transitions in the field of transport and energy.

Whether this potential can successfully be exploited largely depends on a systemic approach for the integration of electric vehicles in the energy system. If electric vehicles are used as a means of providing grid stability, there needs to be a mechanism by which it can be guaranteed that electric vehicles are preferably being recharged when there is a high volume of electricity feed-in by photovoltaic systems or wind power stations. Various approaches are being discussed for managing such controlled charging as a contribution to stabilizing energy infrastructures needed in a situation where the share of renewable energy increases. Integrating electric vehicles in this way, i.e. as a "buffer" for fluctuating electricity feed-in, is already feasible with existing technologies and would already have meaningful effects with a relatively limited amount of electric vehicles, such as, for instance, the 1 million electric vehicles that the German government aims to have on German roads by 2020. The more advanced form of integration would be in the form of V2G concepts. Using electric vehicles not only as buffers taking up excess electricity but also as bi-directional storage elements that feed electricity back into the grid when needed, is much more technologically demanding. It also requires more advanced forms of controlled charging. This can be realized through flexible electricity tariffs that are adjusted to the respective grid situation and volume of electricity generation. An option may also be to include electric vehicles as power reserve in existing policy instruments fostering renewable energies, such as the German feed-in tariff by, for instance, providing compensation for guaranteeing grid stability. These measures show that it is central to adopt a systemic perspective on the electric vehicle and its role in the context of the energy system, in order to realize the potential of an integrated mobility and energy transition (Canzler & Knie, 2011, p. 48 f., p. 51; Turton & Moura, 2008, p. 1106; Vallée & Schnettler, 2013, p. 35).

A number of problems related to such controlled charging schemes point to the fundamental challenges that a more systemic approach is faced with and that highlight that the seemingly obvious synergies in achieving a mobility and an energy transition are impeded by deeply embedded structural constraints. For instance, the expectation that energy utilities would invest in public charging stations for electric vehicles has not been met so far. The current business model of these companies would require that this infrastructure investment could pay off via electricity contracts with owners of electric vehicles. This will not be feasible, not only because of the currently low numbers of electric vehicles in the first place, but also because refinancing expensive public charging stations would require electricity prices significantly exceeding household prices, thus the price for charging electric vehicles at home (Canzler & Knie, 2011, p. 66 f.). On the part of car manufacturers, the feasibility of an integration of BEVs in the energy system would require the technological development of batteries and battery management systems in vehicles to focus on the ability to function as a reliable means of storing electricity and feeding it back into the grid. However, the focus of R&D activities is much more on increasing range, longevity and cycle stability of batteries, because the business model of car manufacturers requires them to develop electric vehicles that can compete with conventional cars (Canzler & Knie, 2011, p. 54). Similarly, if electric vehicles are used in just the same way as today's conventional cars, it is doubtful whether private car owners would be willing to accept the restrictions that go along with controlled charging, i.e. charging preferably at certain times and making the car available as an electricity source at others (Canzler & Knie, 2011, p. 49 f.).

These very practical challenges clearly show two things. First, the energy transition and the envisaged goals of electrified mobility are interlinked, they cause hope for mutual synergies and benefits, and they even depend on each other for a more widespread success in both arenas. Second, however, it also becomes obvious that the potential that lies in these interlinkages requires a fundamental rethinking of various aspects that tend to be taken for granted. The way that an energy and mobility transition could materialize seems realistic only if there is room for adapting very basic assumptions in the way that business models for car manufacturers and energy utilities are being developed, the kinds of policy instruments that would be needed to foster systemic integration and, last but not least, the way that the car is perceived and used everyday. It would in fact amount to a fundamental transformation of the firmly "locked-in" fossil fuel-based modern energy systems with their long-established and firm ties between fossil energy sources, the way they are produced and marketed, the way they provide the foundation for various societal subsystems (not just the energy and transport sector), and the resulting lifestyles (Meadowcroft, 2009, p. 329). The severity of this challenge also implies that the electrification of the car can be perceived as a "Trojan horse for the post-fossil recultivation of planet earth, the transition towards a solar culture and the decarbonization of the energy flows of the societal metabolism"[2] (Rammler, 2011, p. 16).

2.4 E-mobility as a Sustainable System Innovation – 3 Traps

[2] Original quote in German: "[Aus dieser Blickrichtung könnte man die Elektrifizierung des Bedürfnisfeldes Mobilität als eine Art] Trojanisches Pferd der grundsätzlichen postfossilen Rekultivierung des Planeten Erde, des Umbaus der fossilen zur solaren Kultur und der Dekarbonisierung der Energieflüsse des gesellschaftlichen Organismus betrachten."

In sum, when looking at these aspects related to concepts and visions of sustainable e-mobility, it becomes obvious that a focus limited to the diffusion of electric vehicles is too narrow in the context of sustainability transitions. A perspective on e-mobility as a sustainable system innovation would focus on the BEV as the central technology but pertain to a more systemic change in infrastructure, business models, behavioral patterns and, more generally, a different perception of the role of the car. Including a sustainability perspective, a transition towards sustainable e-mobility would be characterized by more integrated and intermodal forms of mobility, concepts of collective ownership of cars or carsharing and renewable energies as the basic electricity source.

The question then is whether actual potential for this type of 'e-mobility' going beyond the mere diffusion of BEVs can be observed and how to approach this analytically. The concept of system innovation captures this type of socio-technical change and is defined as a change from one socio-technical system to another. It comprises three aspects:

> "One aspect of a system innovation is *technological substitution*, which comprises three sub-processes: (i) emergence of new technologies, (ii) diffusion of new technologies, (iii) replacement of old by new technology. The second aspect is *coevolution*. System innovations not only involve technological substitutions, but also changes in elements such as user practices, regulation, industrial networks, infrastructure, and cultural meaning. The third aspect is the *emergence of new functionalities*. When radical innovations have particular technical properties, this may enable the articulation of new functional characteristics. Radical innovations may then introduce new functionalities and change the way in which performance is measured" (Geels, 2004a, p. 19 f.).

This type of definition is especially useful when assessing transitions that have already been completed and can be studied ex-post, as historical cases (see for instance Geels, 2002, 2006a, 2006b, 2007). What about a case such as e-mobility, where various initiatives are currently on-going and at best indicate that we may be in an early stage of a wider transition? Hoogma et al. (2002) have argued that in these cases it is hardly possible to distinguish between innovations that will contribute to an optimization of established systems and others that will lead to substantial change – but that nonetheless an effort should be made to determine the potential for radical change, depending on the specific technology and its context. This would require "making an assessment, for each specific technology, of the likelihood that it could lead to co-evolutionary dynamics" (Hoogma et al., 2002, p. 36).

Looking at developments in the field of e-mobility, it is an open question whether there is a potential for the current momentum around BEVs to evolve as a sustainable system innovation. In order to focus on this question, three traps of e-mobility as a sustainable system innovation will be introduced as a way of guiding the analysis in the following. These traps are derived from the basic characteristics of a sustainable system innovation. According to the definition by Geels (2004a, p. 19), a system innovation is characterized by (1) the diffusion of a new technology and (2) by the emergence of new functionalities as the result of socio-technical co-evolution. In addition to these two aspects, a sustainable system innovation also needs to fulfill some sort of (3) sustainability criteria. When looking at the electrification of the car, these basic characteristics should serve as a heuristic for assessing the potential for a sustainable system innovation and can be reformulated in terms of traps that need to be avoided or surpassed.

The first trap, the *quantitative trap*, would be that there is no sufficient diffusion of BEVs – analogous to the first aspect of a system innovation: emergence and diffusion of a new technology. Obviously, diffusion is the basic process required for any technological innovation. Thus, it needs to be assessed whether there is sufficient diffusion and what might be particular barriers or driving forces. At the same time, it is clear that diffusion is more difficult for radical innovations that very clearly point towards a new system (Kern & Howlett, 2009, p. 394).

The second trap, the *qualitative trap*, would be that there are no new functionalities emerging – analogous to the second aspect of a system innovation: the emergence of new functionalities as a result of socio-technical co-evolution. Whether an innovation leads to a fundamental change depends on whether or not such new functionalities emerge. These result from the interplay of the new technology with other elements in their social environment, such as infrastructures, use patterns and business models, thus, co-evolutionary dynamics. It should be assessed whether patterns of co-evolution can be observed that involve new functionalities, i.e. re-defining needs and purposes, different ways of fulfilling needs and new criteria for measuring performance of a technology or a system as a whole. In the case of e-mobility, this would include new ways of fulfilling mobility needs, e.g. in an intermodal transport system where the role of the (electric) car has changed from the principal means of transport to an element in an integrated system guaranteeing mobility. Such a new functionality, i.e. a change in *how* mobility is provided, may also emerge at the interface of the transport and energy system and change the quality criteria of how well a system or a technological artifact performs: electric vehicles may not only be evaluated regarding their performance as a means of transport but also as a means of energy storage and how it integrates both functions. Both cases show that new functionalities emerging in the context of e-mobility will most likely imply changed perceptions of the role of the car in general.

The third trap, the *sustainability trap*, would be that the new system configuration does not deliver sustainability benefits. This 'sustainability trap' is included to deal with the fact that sustainability is a central premise or background of research questions in this field of study, while it often is not further reflected in its concrete and case-specific implications, obviously due to the concept's inherent uncertainties and ambiguities. However, for the case of e-mobility, dealing with this 'sustainability trap' would mean including concrete and case-specific sustainability criteria (e.g. renewable energies as electricity source, intermodality, carsharing).

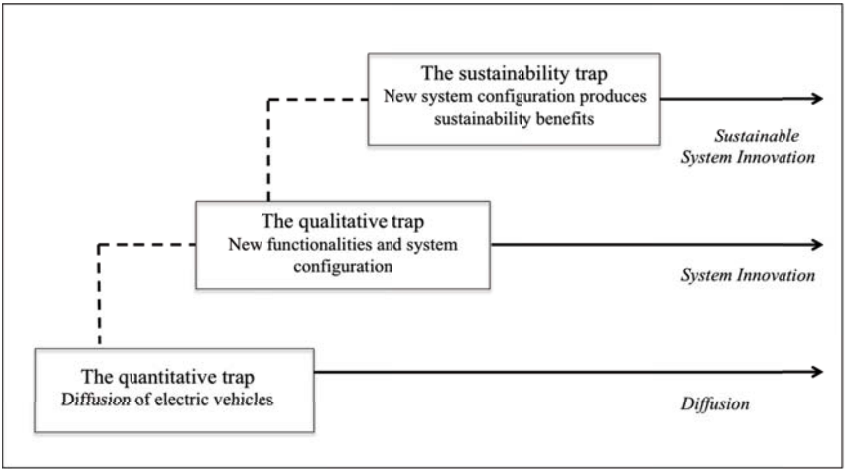

Fig. 4: Three traps of a sustainable system innovation.

When e-mobility is analyzed from the point of view of a potential future system innovation that might eventually contribute to sustainable mobility, it is helpful to assess early on whether current developments point in this direction and according to what criteria this can be determined. It is also important to note that the three traps that might preclude the emergence of a system innovation are interlinked in various ways. Looking at the process of diffusion, it is obvious that electric vehicles are still developed and operated in small and protected niches. They have to be, because they cannot compete with conventional cars as regards range and price. Thus, in order to foster diffusion, electric vehicles are tested in niche segments, such as publicly funded pilot or demonstration projects, municipal fleets or carsharing systems. Already at this point – even though critical levels of diffusion have not yet materialized – signs of the emergence of new functionalities can be observed.

In demonstration projects, public funding facilitates the building up of charging infrastructures creating the link between e-mobility and the energy system, which may induce a new perception of cars not just as means of transportation, but also electricity storage capacity. Corporate R&D projects create niches where innovative business models are tested, such as carsharing, battery leasing or battery-swap services, which may eventually pave the way towards new forms of mobility that do not solely rely on private car ownership (Tran et al., 2012, p. 332). Test users in demonstration projects experience electric vehicles in everyday social practices and it can be shown empirically that use patterns are adapted to the new technology while it is actually used – and often in ways that are different than had been assumed beforehand (Canzler & Knie, 2011, p. 42). Simultaneously, these processes may have an impact on diffusion rates. In science and technology studies as well as in technological sociology, it has been shown that technological change is always an inherently social and cultural process (cf. Bijker et al., 1987; Dijk, 2011). Whether a new technology becomes established depends on the cultural significance that is assigned to it. It can be successful if meaning is connected to it and if it is embedded in its social context. This can be achieved by proactive advocacy of influential societal groups or actors, or it may emerge through co-evolutionary processes linking a new technology with wider societal developments (Weider & Faul, 2011, p. 100 f.). Thus, developing electric vehicles in niches that give them a specific meaning (e.g. as an element in the energy transition) and link it with societal trends (e.g. young people living in cities that use carsharing services rather than buy a car) increases the chances for diffusion.

These examples show that socio-technical co-evolution plays a central role, because it may lead to the emergence of new functionalities (i.e. in fact a redefinition of the car). New forms of sustainable mobility are thus much rather the result of socio-cultural changes as a response to technological innovations, than of technological innovation alone (WBGU, 2011, p. 264 f.). Especially the electric vehicle as a radical innovation has the potential to initiate a process of redefining current conceptualizations of mobility (Vergragt & Brown, 2007, p. 1108; Vallée & Schnettler, 2013, p. 34 f.; Weider & Rammler, 2011, p. 5). From a historical point of view, Weider and Rammler (2011) argue that the pioneering element in Carl Benz's work was not per se the invention of the internal combustion engine, but rather the creation of the „automobile" principle, the ability to move autonomously as an individual (p. 3). However, as with many innovations, it is not clear whether the electric vehicle will evolve in the context of a wider system innovation, persist forever as a niche innovation, or vanish again completely. It is relatively certain that it will not replace the conventional car without any other changes, but there is still a variety of options ranging from e-mobility as a system innovation to electric vehicles being used primarily as a household's second private car or in small market segments, such as urban fleets or carsharing services (Kemp & Rotmans, 2005, p. 35).

These examples highlight the importance of considering the third trap, referring to the potentially unsustainable outcome of a system innovation, already at an early stage. The case of e-mobility clearly shows that a focus on the development and diffusion of electric vehicles does not necessarily produce sustainable results. It is important to adopt a systemic perspective and assess whether the emergence of specific types of new functionalities point to overall more sustainable results. The principles of sustainable mobility discussed in section 2.2 provide an orientation, emphasizing that an overall reduction in the volume of transport or shifts to other modes of transport are important elements. This means that it is, for instance, important to consider whether developing electric vehicles in niches eventually aims at creating a market for selling and using them in the same way as conventional cars, or whether carsharing and intermodal transport schemes lead to an ecologically beneficial modal shift – instead of additional demand for mobility. Analytically, an attempt should be made to assess whether activities in fostering e-mobility provide an alternative to current unsustainable patterns in fundamental ways, in the sense that „whatever future technological paradigms emerge over time in the future should be set in a ‚post-hydrocarbon landscape'" (Cooke, 2011, p. 107).

In sum, it is suggested that including the three traps can serve as a helpful analytical lense for the study of cases such as the electrification of the car, which are at best at an early stage of a wider transition. The three traps should in this way serve as a guiding concept for assessing system-innovative potential. The obvious difficulty of such an endeavor should not lead to neglecting these issues.

2.5 Current State of Research: Literature Review

A literature review has been carried out guided by the question of whether there are fields of research or theoretical approaches that focus on e-mobility and relate it to broader definitions of sustainability. The three traps are used to guide and systematize the results of the literature review, which aims to show whether approaches exist that can really capture the complex phenomenon of e-mobility as a (potential) sustainable system innovation. Therefore, literatures are searched that focus on e-mobility as defined in this thesis (ch. 2.1), i.e. centered on electric vehicles as a truly radical innovation as compared to hybrids or fuel cell vehicles, but not limited to electric cars. Various types of electric vehicles are considered relevant when e-mobility is understood as a systemic type of change in mobility in general. This also means that literatures are included that are dealing with issues of sustainability mobility primarily, but discuss e-mobility as well to at least some extent.

The method applied is a database search (conducted in July 2013) by keywords and is limited to peer-reviewed journal articles. It is further limited by excluding the purely technological disciplines (mechanical engineering, electrical engineering, chemistry) from the substantive analysis, because they exclusively focus on technological solutions. These literatures are only assessed, in order to identify the quantitative share of the exclusively technological aspects in the field as a whole. Other relevant literatures are transport and innovation studies as well as economics and business approaches focusing on the marketability of electric cars, new business models, the willingness of consumers to buy electric cars and the impact of this new technology on industry structures and national economies. Finally, the field of sustainability transitions research will be included as well. These literatures will be searched by a combination of keywords on e-mobility (electric cars, battery-electric vehicles etc.), sustainability as well as keywords from the field of sustainable mobility in general, as identified in the respective literature discussed in ch. 2.2 (e.g. Banister, 2008; Cohen, 2006). The results of the database search will be analyzed and publications will be systematized according to the extent that they address the three traps of a sustainable system innovation.

A search for articles in the Web of Science using the keywords "e-mobility*electric mobility" produced roughly 300 results. In order to exclude articles that are not related to e-mobility in transport (such as biochemistry, physics etc.) the term "electric vehicle" was included, which decreased the number of results to 148 articles. Screening the titles and abstracts of these 148 articles led to the manual exclusion of another 74 articles not related to the topic of "electric automobility" (but e.g. articles from the fields of electronics and communication technologies, medical science, chemistry, physics, biochemistry) as well as articles from the field of transport with a focus on biofuels or electronic traffic management systems, articles that focus exclusively on battery technology and only mention electric vehicles as one field of application, and articles that deal with specific military applications of e-mobility. Thus, a sample of 74 papers has been identified in this first step.

As a second step, the search was refined by including the terms "sustainability*transition*system innovation", in order to identify publications that focus on issues of sustainability and systemic types of change around the electric vehicle. This step reduced the original sample of 148 papers to 20 articles. From these 20, 8 articles from the fields of biochemistry and physics were manually excluded (as in step 1). Thus, 12 papers from the sample of overall 74 papers have been identified to be particularly relevant with regard to the focus and research question of this thesis.

As a third step, the Web of Science was searched by the terms "mobility*transport/strategic niche management*technological innovation systems*multi-level perspective*transition management", thus the different theoretical approaches in the field of transition studies (see ch. 3.1), in order to provide an overview of transition papers in the field of mobility in general. This step produced a result of only five papers, all of which had already appeared in the original search. One of these five papers (Berkhout et al., 2010) had already been excluded from the earlier sample, because it has no specific focus on (e-)mobility. Another paper by Hellsmark & Jacobsson (2009) is excluded because it deals exclusively with biogas as an alternative fuel. Thus, this step produced another three papers from the sample of 74 papers, which can be considered among the relevant papers, now counting 15 articles.

As a fourth step, the search terms used in step three were also used to perform a search in Google scholar, since many contributions from the still young field of transition studies are not (yet) listed in the Web of Science. This can be explained by the fact that transition studies is still a newly emerging field of research with a weak citation basis – which may be at least part of the explanation. The search in Google scholar (same search terms as in step 3) delivered more than 1,000 results. Scanning the first ten pages of search results, 13 papers from the field of transition studies were identified. This was done by identifying topical keywords, journals and authors that can be grouped among the field of transition studies according to the survey of the field of transition studies by Markard et al. (2012). Of these 13 papers, two had already turned up in the Web of Science search (Kemp et al. (1998), Köhler et al. (2009)) and have already been included among the more relevant articles. After this step, the total sample has increased to 85 articles and the more relevant among these are now 26 articles.

Finally, the journal "Environmental Innovation and Societal Transitions" as a new journal, established from within the field of transition studies has been scanned for relevant publications. This adds to the preceding Google scholar search and was done manually, because the journal is not appearing in the Web of Science yet. Two relevant contributions were identified, one of which had already turned up in the Google scholar search.

Thus in sum, the literature review produced a sample of 86 articles, of which 27 have been identified as particularly relevant with regard to a focus on "e-mobility as a sustainable system innovation". With regard to the distribution across disciplinary fields, it can be shown that a large share of the overall sample, i.e. 34 articles, can be assigned to the field of energy-related research. The majority of papers deal with e-mobility from an energy systems perspective, focusing on issues of integrating electric vehicles in energy infrastructures. The second-largest group of 20 articles can be associated with engineering disciplines, and the remaining papers can be grouped across transport studies (14 articles), environmental impact or life-cycle analysis (7 articles), and the field of transition studies (11 articles). This distribution pattern is depicted in Fig. 5.

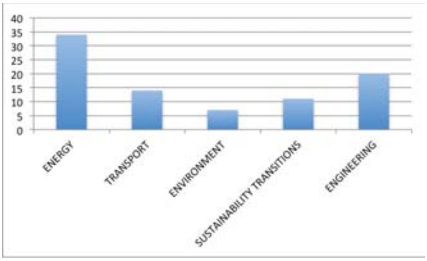

Fig. 5: Distribution of papers across fields of research.

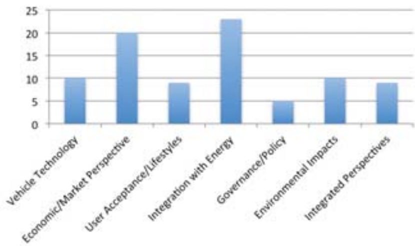

Fig. 6: Topical focus of papers.

By scanning the abstracts of the 86 articles for basic research questions, research design and results, an overview has been gained with regard to the basic topical focus of the different articles. Fig. 6 shows that a majority of the articles depart from either an economic or market perspective focusing on issues of diffusion of electric vehicles, user acceptance and industry dynamics, or from an energy system perspective. Issues of vehicle technology and environmental impact assessment of electric vehicles form another relatively large group. Policy-related aspects make up a small amount of the sampled articles and these focus predominantly on policies fostering innovation and diffusion processes of electric vehicles. A more integrated perspective on e-mobility can be found in only a few articles, mostly published in journals that can be associated with the field of sustainability transitions research.

A more detailed look has been taken at the 27 articles identified as particularly relevant in the context of sustainable e-mobility and system innovations. An overview of these articles is presented in Tbl. 1.

Author(s)	Title	Year	Journal
Åhman	Government policy and the development of electric vehicles in Japan	2006	Energy Policy
Axsen et al.	Lifestyle practices and pro-environmental technology	2012	Ecological Economics
Bakker et al.	Competition in a technological niche: the cars of the future	2012	Technology Analysis & Strategic Management
Bartolozzi et al.	Comparison between hydrogen and electric vehicles by life cycle assessment: A case study in Tuscany, Italy	2013	Applied Energy
Browne et al.	How should barriers to alternative fuels and vehicles be classified and potential policies to promote innovative technologies be evaluated?	2012	Journal of Cleaner Production
Christensen et al.	Can innovative business models overcome resistance to electric vehicles? Better Place and battery electric cars in Denmark	2012	Energy Policy
Dijk & Yarime	The emergence of hybrid-electric cars: Innovation path creation through co-evolution of supply and demand	2010	Technological Forecasting & Social Change
Dijk et al.	The emergence of an electric mobility trajectory	2013	Energy Policy
Falvo et al.	Energy management in metro-transit systems: An innovative proposal toward an integrated and sustainable urban mobility system including plug-in electric vehicles	2011	Electric Power Systems Research
Faria et al.	A sustainability assessment of electric vehicles as personal mobility system	2012	Energy Conversion and Management
Garcia & Javier Miguel	Is the Electric Vehicle an Attractive Option for Customers?	2012	Energies
Geels	A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies	2012	Journal of Transport Geography
Geerlings et al.	A renaissance in understanding technology dynamics? The emerging concept of transition management in transportation	2009	Transportation Planning and Technology
Hasegawa	Diffusion of Electric Vehicles and Novel Social Infrastructure from the Viewpoint of Systems Innovation Theory	2010	IEICE Transactions on Fundamentals of Electronics Communications and Computer Sciences
Kemp et al.	Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management	1998	Technology Analysis and Strategic Management
Köhler et al.	A transitions model for sustainable mobility	2009	Ecological Economics
Kühne	Electric buses - An energy efficient urban transportation means	2010	Energy
Magnusson & Berggren	Entering an era of ferment - radical vs incrementalist strategies in automotive power train development	2011	Technology Analysis & Strategic Management
Nilsson et al.	How do we govern sustainable innovations? Mapping patterns of governance for biofuels and hybrid-electric vehicle technologies	2012	Environmental Innovation and Societal Transitions
Nykvist & Whitmarsh	A multi-level analysis of sustainable mobility transitions: Niche development in the UK and Sweden	2008	Technological Forecasting & Social Change
Oltra & Maider	Sectoral systems of environmental innovation: An application to the French automotive industry	2009	Technological Forecasting & Social Change
Orecchini & Sabatini	Cars and the environment: a new approach to assessment through ISO 14001 certification of the car process	2003	Proceedings of the Institution of Mechanical Engineers Part D - Journal of Automobile Engineering
Schot & Geels	Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy	2008	Technology Analysis & Strategic Management
Sierzchula et al.	The competitive environment of electric vehicles: An analysis of prototype and production models	2012	Environmental Innovation and Societal Transitions
Stamp et al.	Environmental impacts of a transition toward e-mobility: the present and future role of lithium carbonate production	2012	Journal of Cleaner Production
Weber & Hoogma	Beyond national and technological styles of innovation diffusion: a dynamic perspective on cases from the energy and transport sectors	1998	Technology Analysis & Strategic Management
van Bree et al.	A multi-level perspective on the introduction of hydrogen and battery-electric vehicles	2010	Technological Forecasting & Social Change

Tbl. 1: Overview of papers with a focus on “e-mobility as a sustainable system innovation”.

These 27 articles have been analyzed with regard to their basic problem perceptions and the scope of their research approach in terms of the three traps of a sustainable system innovation developed in this thesis. It has been assessed whether these articles predominantly focus on issues of diffusion of electric vehicles ('the quantitative trap'), socio-technical co-evolution ('the qualitative trap'), and whether they include an explicit perspective on sustainability ('the sustainability trap'). It has also been assessed how broad or narrow their view on sustainability is and if some of them possibly also provide an integrated perspective on sustainable system innovations, thus addressing all three traps. An overview of the 27 articles and the distribution of articles regarding their scope in terms of the three traps is presented in Fig. 7. The more in-depth screening of the articles led to the exclusion of 5 articles, which provide more general conceptual perspectives on sustainable mobility with e-mobility being not more than a side note or just a very brief example (Geels, 2012; Geerlings et al., 2009; Kemp et al., 1998; Köhler et al., 2009; Schot & Geels, 2008).

Even though most of the remaining 22 articles adopt an integrated perspective of some sort, for instance by clearly positioning e-mobility as an environmental innovation (Oltra & Maïder, 2009), a majority, i.e. 12 articles, in essence deal with the problem of diffusion of electric vehicles and focus on industry and market dynamics, business strategies, or suitable policy instruments. For instance, Weber and Hoogma (1998) study different styles of innovation diffusion and emphasize that this approach "takes into account cultural aspects of management traditions, social interpretations of technologies and the influence of local circumstances" (p. 545). However, in their analysis the social elements in socio-technical co-evolution are not dealt with explicitly and the aim of the paper is to examine variables influencing the diffusion of innovations, thus remains limited to the first trap. Electric vehicles are predominantly discussed in terms of a technological substitute: "A high proportion of trips made for commuting, shopping etc. are short and could, in principle, be substituted by EVs" (p. 558). The question of whether and when diffusion processes may result in radical innovations is pondered upon only briefly. Similarly, in a more recent article by Sierzchula et al. (2012), the basic research question also deals with the "likelihood of EVs eventually becoming a legitimate competitor to ICE vehicles" (p. 51). The aim is to "understand the scope of the current transition" (ibid.), while this scope is envisioned to range from electric vehicles as a substitute for conventional cars at one end of the scale, to electric vehicles remaining a niche technology at the other. Thus, a transition is conceptualized as a diffusion challenge rather than a more fundamental system innovation resulting in new functionalities. There is no rethinking of the basic scale for assessing the possibilities of e-mobility and it remains limited to a market penetration framework: what is measured is a difference in degree (of diffusion), while differences in kind (system innovation) are outside the framework. A similar focus on innovation dynamics and developments in e-mobility as a technological niche can be found in the articles by Bakker et al. (2012), Hasegawa (2010), Magnusson and Berggren (2011), and Kühne (2010).

Apart from a focus on industry dynamics, technological development and related business strategies, the remaining papers that can be characterized as addressing predominantly the first trap study issues of user acceptance in the context of "sustainable lifestyle practices" (Axsen et al., 2012) or deal with the question of whether electric vehicles are "an attractive option for customers" (Garcia & Miguel, 2012). Another three papers in this group add to industry and market perspectives by introducing a focus on governance and, in particular, policies for supporting innovation and diffusion of electric vehicles. For instance, the paper by Åhman (2006) discusses the role of political support for technological development and early market introduction of alternative drive technologies in Japan. It adopts a systemic perspective insofar as it considers the whole policy context identified to be relevant, instead of an individual policy instrument, as well as other framework conditions, e.g. business attitudes and broader institutional settings (p. 434). However, the approach is not systemic in terms of the three traps, since it focuses on technological substitution and diffusion processes, assessing "the chances of a technology surviving the long journey from idea to competitive technology" (p. 442). The papers by Browne et al. (2012) and Nilsson et al. (2012) depart from a concern for environmental innovation in the transport sector and also employ a systemic perspective on governance approaches and patterns. However, policies are analyzed with regard to their ability to foster the diffusion of alternative drive technologies and, for instance, major barriers are identified to be "technical limitations, commercial feasibility and market availability" (Browne et al., 2012, p. 150), thus obstacles for technological substitution, rather than system innovation.

A broader scope and focus on socio-technical co-evolution can be identified for four articles. They look beyond market-based diffusion and technological development and may thus contribute to understanding the emergence of new functionalities, i.e. addressing the second 'qualitative trap'. For instance, Dijk et al. (2013) study the "emergence of an electric mobility trajectory", which is the result of interrelated technological and social dynamics, or, van Bree et al. (2010) analyze how the relationship between car manufacturers and consumers is influenced by socio-technical co-evolution in the field of hydrogen vehicles and e-mobility. The fundamental difference in these approaches, as for instance compared to Browne et al.

(2012) focusing on technological and market immaturities, can be shown by what are identified as crucial factors in the development of e-mobility: "developments in (1) infrastructure, (2) developments in mobility, (3) developments in the global car manufacturing regime, (4) developments in energy prices, and (5) developments in the electricity sector" (Dijk et al., 2013, p. 140). Similarly, Dijk and Yarime (2010) explicitly focus on "the role of techno-economic mechanisms alongside social and regulatory mechanisms (including the social meaning of an engine)" (p. 1371) in their study of the emergence of hybrid-electric cars. Cultural connotations and meaning of technological artifacts such as cars or car engines are an important element for understanding the concept of 'new functionality' resulting from processes of co-evolution and they are, in fact, the core of a system innovation. A more concrete case of new functionalities emerging in the field of e-mobility is presented by Falvo et al. (2011): an integrated urban mobility system, linking metro transit systems and electric vehicles via smart grids. Even though this article is more technology-oriented in nature, it includes a broad perspective on urban infrastructures and it implicitly points towards new functionalities emerging at the interface of public and private transport and the energy system.

Even though sustainability is mentioned as one basic rationale for developing e-mobility and a motivation for the research of most papers, it is more explicitly addressed and a central part of the analysis in only four articles. Life-cycle analyses are conducted to assess the environmental impact of electric vehicles depending on different energy sources, i.e. electricity mixes, for powering vehicles and comparing them to other types of alternative drive technologies (Bartolozzi et al., 2012; Faria et al., 2012). One article focuses on environmental management systems and ISO certification processes for hybrid electric vehicles (Orecchini & Sabatini, 2003) and the paper by Stamp et al. (2012) assesses the impact of different supply options for lithium carbonate and how this affects the overall ecological balance of electric vehicles. These articles explicitly focus on environmental sustainability concerns related to electric vehicles and therefore they do address the third trap, which is crucial when considering the heated debates about whether e-mobility can actually provide solutions to environmental problems in the transport sector. However, they do not integrate more systemic perspectives on sustainability, which are relevant in the context of sustainable system innovations.

The remaining two papers have been found to address all three traps, albeit in slightly different ways. In their case study of the company Better Place, Christensen et al. (2012) focus on socio-technical co-evolution in terms of a new business model developing around the electric vehicle as a ‘new’ technology. The potential for widespread diffusion as well as related environmental impacts are reflected upon. The basic question of developing innovative business models for e-mobility is placed in a broad context, addressing the problem of diffusion, arguing that “innovative business models may be a prerequisite to the success of new technologies in the market” (p. 499), of socio-technical co-evolution and the emergence of new functionalities by focusing on the need for fundamentally different business models and new forms of convergence between the automotive and the energy sector, and finally, of (environmental) sustainability as the second condition apart from market breakthrough determining the success of developing e-mobility. It is further shown that these aspects are interrelated: “If the model remains small, with just a few hundred BEVs in circulation, then it is likely to fail as a business but also will be insignificant as a contribution to more sustainable mobility” (p. 504). The second paper by Nykvist and Whitmarsh (2008) studies sustainable mobility transitions where technological innovations, e.g. electric vehicles, are one element of such a transition among others, such as modal shift and reduced travel demand. The argument is based on a broad definition of sustainability including not only environmental protection but also social and economic welfare (p. 1373). Diffusion of technology is addressed in terms of niche development (p. 1380 f.), which is however not limited to technological niche innovations, socio-technical co-evolution is addressed by exploring “institutional, behavioral and technological components of niche development” (p. 1375), and these issues are analyzed against the background of a broader sustainability transition in the field of transport (p. 1348).

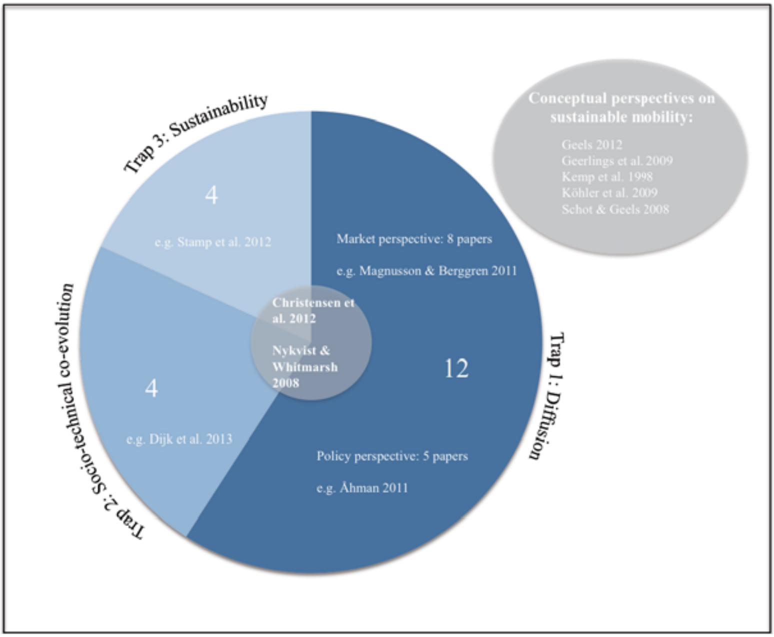

Fig. 7: Distribution of selected papers across "three traps".

In sum, the literature review has shown that research on e-mobility is dominated by disciplinary perspectives on technological and economic issues relevant for the diffusion of electric vehicles. Even in transition studies the focus often is on questions of greening technologies and diffusion, or on questions of adapting the socio-economic systems and political institutions around presumably green technologies (such as the electric vehicle). What is rarely found is a clear perspective on socio-technical co-evolution (How do electric vehicles trigger change in use patterns or business models? Can patterns be observed of how new functionalities do actually emerge?). Furthermore, a basic concern for sustainability appears throughout all of the papers and it is mentioned as the context in which electric vehicles are developed and studied. A more pronounced perspective on sustainability can be found in life-cycle assessments, but these usually remain limited to a narrow ecological dimension of sustainability. A broader perspective on sustainable mobility, assessing the degree to which electrified forms of mobility are potentially more sustainable, not only with regard to emissions and resource depletion but also including social aspects, is lacking. Two articles have been identified that are addressing all aspects of a sustainable system innovation. However, the paper by Christensen et al. (2012) employs a narrow environmental definition of sustainability, while the paper by Nykvist and Whitmarsh (2008) departs from a broad conceptualization of sustainability, but focuses on sustainable mobility in general where e-mobility is one aspect among others.

This implies that e-mobility is a field of research that is dominated by economic and technological approaches, possibly due to the fact that the electric vehicle as a technological innovation is central and currently high on public agendas and discourses in the context of economic potential for national industries. A parallel and largely unconnected research strand focused on sustainable mobility in general seems to exist that is reluctant to engage in a field dominated by market and technological perspectives, or does not realize that there are some crucial interlinkages. Seeing that e-mobility currently finds broad political support, at least partly out of a concern for more sustainable transport systems, it seems promising to focus on and re-evaluate e-mobility from the point of view of broader sustainable mobility and system innovation perspectives. A similar assessment with regard to the state of research has been made by Lyons (2012), showing that in transport studies two sharply separated strands can be identified, either focusing on behavior change, or on technological fixes in the context of sustainable transport. In order to deal with current challenges in the transport sector, Lyons (2012) suggests that "we have yet to embrace a socio-technical transition perspective that seeks to understand how technology and the behavior change of all actors (individuals, firms, policymakers etc.) dynamically interact and co-evolve" (p. 30). Another review of the literatures on climate change mitigation in transport has been presented by Schwanen et al. (2011). Here, it is also shown that economic and technological approaches are dominating this field of study and it is suggested that contributions from the social sciences, amongst others from the field of transition studies, could be useful for a more profound understanding of the sources for unsustainability in the transport sector and for providing more comprehensive approaches to solving current challenges (p. 933). This implies that in this particular field any "future research agenda needs therefore to understand more fully how embedded practices and technological change inter-relate in specific concrete conditions" (Wells & Nieuwenhuis, 2012, p. 1681). One aim of this thesis is to close this research gap and as a next step the literature on system innovations and sustainability transitions will be discussed as a possible framework for better understanding the potential e-mobility could develop in the context of more sustainable forms of mobility.

3 A Theoretical Framework for Analyzing System Innovation

Transition studies, or the field of sustainability transitions research, explicitly deals with sustainability-oriented system innovations, thus the paradigmatic change hoped for when envisioning future e-mobility. The aim of this chapter is to develop a theoretical framework for analyzing the potential of e-mobility to emerge as a sustainable system innovation drawing on concepts from the field of transition studies. A further aim is to position the thesis in the context of this particular field of research. The chapter is structured as follows.

An introduction and overview of “Sustainability Transitions Research” as a distinct field of research is presented in chapter 3.1, including an overview of basic definitions, their origins and the different approaches for analyzing transitions (ch. 3.1.1), and the specific role of technology and innovation in this context (ch. 3.1.2). The multi-level perspective on transitions as the central theoretical approach in this field will be discussed in detail (ch. 3.1.3), including a critical reflection on its scientific value, its shortcomings and applicability to the research question posed in this thesis (ch. 3.1.4). A major challenge is the question of how to deal with cases of ‘transitions in the making’, such as e-mobility where it is currently not clear whether developments in this field will eventually amount to a transition or system innovation contributing to future sustainable development. The aim of this thesis is to find a way of analyzing the potential inherent in currently observable dynamics in the light of an envisaged sustainable system innovation. Therefore, ch. 3.2 is dedicated to the issue of analyzing such transitions in the making. Subsequently, a theoretical framework – building on the multi-level perspective and addressing some of its weaknesses – is developed in chapter 3.3. Building on a discussion of the relevant unit of analysis in studying system innovations (ch. 3.3.1) and a specific conceptualization of system innovation (ch. 3.3.2), Dolata’s (2009, 2011, 2013) concepts of transformative capacity of a new technology (in this case: do electric vehicles trigger ‘social’ innovations, e.g. new business models, political regulations or use patterns?) and adaptability (here: how inert or open to change is the mobility system?) are introduced in chapters 3.3.3 and 3.3.4. It will be shown that including these concepts into an overarching multi-level perspective on transitions provides a way of analyzing the basic dynamics of a system innovation on the micro-level and give an indication of its actual potential in an ‘ex ante’ situation (ch. 3.3.5). In short, the aim of the following chapters is to arrive at a theoretical approach that transcends the logic of incremental innovation and clearly conceptualizes processes of systemic socio-technical change.

3.1 Sustainability Transitions Research

The field of sustainability transitions research builds on innovation studies, science and technology studies, complex systems and innovation systems theory as well as concepts from sociology and evolutionary economics to study fundamental and long-term change in socio-technical systems, such as transport, energy, water and agri-food systems (van den Bergh et al., 2011). The basic motivation tying together scientists from these different disciplinary backgrounds focusing on different empirical domains is a concern for sustainability. The shared observation is that current environmental problems related to climate change and resource depletion are hardly being solved and that a better understanding of the reasons for their persistence and more comprehensive approaches for addressing them are needed.

The basic problem, which is explicitly addressed in transition studies, is that sustainability problems or causes for unsustainability are deeply rooted in modern societal structures and thus "represent the dark side of dominant patterns of socio-economic-technological development" (Grin et al., 2010, p. 2). The sectors or socio-technical fields that are most relevant for the functioning of modern societies, e.g. energy, transport and food production, are the locus where change is needed most desperately and which at the same time are characterized by technological lock-ins and path dependency that explain their historical success and now preclude any substantial change. In any of these fields, dynamic stability arises from the many interlinkages and interdependencies between dominant technologies, existing infrastructures, political and societal institutions, markets and business models as well as lifestyles, cultural meaning and individual behavior. In these interlinked and complex configurations that have historically grown into relatively stable systems, change is usually limited to incremental innovation aimed at optimizing and preserving (and thus not threatening power positions and vested interests of central actor groups). This makes sense in so far as a specific system has proven to be successful over time and thus is willfully being sustained.

However, since current environmental problems are severe and directly caused by basic structural conditions and principles of today's system configurations, they cannot be solved by traditional means and strategies aimed at, basically, preserving current systems. Thus, a more radical type of change is needed that will possibly shake the basic foundations of modern energy or transport systems. This type of change is captured by the term 'transition', highlighting that "incremental changes will not suffice to cope with the prevailing sustainability challenges" (Markard et al., 2012, p. 955). This requires new approaches for integrated socio-technical change, that go beyond the development and diffusion of environmental innovations such as ‘green technologies’, and which also include more comprehensive policy approaches (Grin et al., 2010, p. 2 f.; Markard et al., 2012, p. 955; van den Bergh et al., 2011, p. 8).

The whole transition endeavor is guided (often even only implicitly) by a very broad notion of sustainability. Sustainability is the basic motivation for engaging in transition research and it serves as an orientation for concrete cases. In general, sustainable development is understood to be an open-ended search process, rather than a clear future vision. Assessments of specific policies, technologies or broader patterns of change with regard to their contribution to overall sustainable development are to be carried out on a case-by-case basis. This approach is presented as a specific strength of transition studies, because the basic tenets of the sustainability debate (based on the Brundtland definition and ensuing discourses) provide orientation, while concrete goals and strategies remain open to political negotiation, as is appropriate with regard to the many ambiguities inherent in the idea of sustainability (Grin et al., 2010, p. 2).

However, it is important to be aware of the fact that implicit understandings of sustainability can be very different with regard to images of a desirable future. They may range from visions of a green economy to concepts that question whether it is at all feasible to reconcile traditional market economies with principles of sustainability (cf. Kallis, 2011; van den Bergh, 2011; Victor, 2010). Such differing conceptualizations of sustainability have consequences for the notion of transitions towards sustainability that is used in different contexts. The term ‘transition’ can mean fundamentally different things depending on whether it is applied in varying science or policy contexts, or, for instance, in the “transition towns movement” (Hopkins, 2011). Thus, careful reading of what the underlying assumptions are of different usages of the term transition is imperative and it is important to note the varying implications they have with regard to power structures in specific socio-technical systems or modern societies in general. It can be argued that most transition studies in the specific field of research in focus here, do not fundamentally question basic premises of market economies and the need for economic growth. Based on the insight that many sustainability problems are directly linked to basic societal structures, it is advisable that the promises of economic growth and technological innovation – as a means to foster growth and reconcile it with environmental protection – should at least be scrutinized critically (Stirling, 2011; van den Bergh et al., 2011, p. 14).

Having pointed to these different contexts where the notion of transition plays a role, the specific field of sustainability transitions research, which is in focus here, has emerged from various disciplinary backgrounds and research traditions and a distinct scientific community has begun to emerge during the late 1990s. A bibliographical analysis carried out by Markard et al. (2012) to capture ‘Sustainability Transitions’ as an emerging field of research shows the dynamic development of this still young scientific community. Up until today, more than 500 publications can be assigned to the field and more than 6,000 citations until the beginning of 2012. Important thresholds in the development have been identified around the year 2005 when the number of yearly publications began to increase significantly and subsequent increases showed in the number of citations per year, from 235 in 2006 to 1815 in 2011 (Markard et al., 2012, p. 960 f.).

This increased interest in the field during the early 2000s can partly be explained by developments in the Netherlands at that time. Political efforts by the Dutch Ministry of Environmental Affairs in the field of sustainable energy were developed under the heading of ‘transition management’, developed together with scientists. Innovative approaches were introduced in the policy process, including politicians, researchers and other stakeholders, especially from the energy industry. The notion of transition thus spilled over to the political realm, which in turn had the effect of motivating further efforts by researchers to engage in this field (Chappin & Ligtvoet, 2014, p. 716). This particular role played by the Dutch political context may also explain the empirical focus emerging within transition studies. Looking at scientific publications in this field again, most of them focus on energy-related topics, followed by transport, water, and food production. Furthermore, most of the publications focus on empirical cases in the Netherlands and the UK, followed by the US and Germany (Markard et al., 2012, p. 961).

Even though the field of transition studies has grown significantly, it is still represented by a relatively small scientific community that can be characterized as more or less homogeneous as regards the focus of research strongly linked to the Dutch energy policy context and building on a relatively limited number of key references as well as the tightly interlinked networks of co-authorship. The field has also been formally institutionalized by holding yearly conferences, establishing an official network (Sustainability Transitions Research Network, STRN, www.transitionsnetwork.org), circulating a regular newsletter, and issuing a scientific journal specifically dedicated to transition studies (“Environmental Innovation and Societal Transitions”) (Farla et al., 2012, p. 991; Markard et al., 2012, p. 956). While all this may be considered a normal and necessary consolidation process within a young field of research, some critical thoughts have been voiced, especially with regard to homogeneous patterns of co-authorship and cross-referencing each other’s work. Openness with regard to approaches in other scientific communities and an awareness of existing theories and bodies of literature can help avoid a tendency towards unduly limiting the perspectives within transition studies (Chappin & Ligtvoet, 2014, p. 720 f.).

Similarly, critical voices have pointed out that 'transition' may be just a new buzzword for other, much older concepts. In fact, transition studies have emerged from various disciplinary backgrounds where similar notions and concepts pre-exist. For instance, in economics and in innovation studies, concepts of radical innovation and industrial transformation can be found. Structural change and transformation of economies or societies have also been dealt with in political science and sociology. Also, within interdisciplinary fields of environmental or sustainability research, concepts of ecological modernization have been developed. However, it is pointed out by proponents of sustainability transitions research as a distinct field of research, that none of these approaches can alone grasp all the dimensions that are relevant when looking at current environmental problems in broad socio-technical fields, such as energy or transport, while such a comprehensive perspective is needed, in order to address these complex real-world problems. Obviously, the problems in the transport sector cannot be meaningfully addressed by only focusing on technological innovation, or on market dynamics, or on political regulation, or on changes in consumer behavior. The basic rationale for a new approach of 'sustainability transitions research' is to provide a perspective where these different elements and their interlinkages can be grasped in a comprehensive way (Geels, 2012, p. 471 f.; Geels, 2011, p. 38; van den Bergh et al., 2011, p. 8).

Based on these considerations, it can be argued that the field of sustainability transitions research has its place, especially against the background of current and future sustainability challenges. However, the question remains, how exactly can transition approaches integrate all those different aspects in meaningful ways? This points to the dangers inherent in combining concepts and approaches from different research traditions and based on different ontological positions (Garud & Gehman, 2012, p. 980 f.). While some may relatively easily be integrated in a comprehensive framework, others may be more difficult to combine, because they may be based on opposing theoretical assumptions and rivaling explanations that cannot be reconciled. Thus, some caution is warranted to avoid matching together approaches that depart from opposing premises and basic assumptions. Nonetheless, comprehensive heuristic frameworks within transition studies can be helpful in fostering an integrated perspective across different academic disciplines, which is important for addressing complex sustainability problems. Thus, instead of avoiding integration altogether, the diversity of ontological backgrounds and theoretical ambiguities should be made explicit and welcomed by reflecting on inherent pluralities and broadening perspectives (Stirling, 2011, p. 84 f.). Therefore, the basic concepts in the field of transition studies, their definitions and their ontological backgrounds will be spelled out in the following.

3.1.1 Central Concepts and their Origins

The notion of **transition** is the central concept around which a distinct field of research has emerged. The term is defined broadly as a process of fundamental change in a **socio-technical system**, which provides a specific function or service for society as a whole, e.g. energy, mobility, food or water and sanitation. Substantial change within these systems is necessarily radical or of a fundamental nature, because these systems are complex as regards their actor constellations, including governmental actors, industry and firms, civil society organizations and individuals, they are built around large infrastructures and specific technologies and their system boundaries do not coincide with typical disciplinary, sectoral or institutional boundaries. Rather, a socio-technical system is delineated based on the specific network of actors, technological infrastructure and institutions (formal, such as regulations, and informal ones, such as guiding principles and norms) that together fulfill a specific societal function in a characteristic way. In this way, the concept of socio-technical system in transition studies can be distinguished from the way it is used in organization studies, where it originated (cf. Trist & Bamforth, 1951; Trist, 1981), not with regard to its basic principles though, but with regard to scope and field of application. A full-fledged **transition** in such a socio-technical system thus means structural change in various societal domains and it can be expected to span at least one generation, thus a period of 25 to 30 years. The long-term and complex nature of transitions implies a process of multiple decisions in different arenas across an extended period of time, thus including feedback loops and constantly changing circumstances. In the end, new actors and networks, new business models and consumption patterns will have emerged. The role of specific technologies changes as well as basic institutional structures and societal perspectives on the way that, for instance, energy or mobility are provided in general (Hoogma et al., 2002, p. 198; Markard et al., 2012, p. 956; Nilsson et al., 2012, p. 52 f.).

The notion of 'transition' has prominently emerged in current discourses on future sustainable development – however, any meaningful empirical observation of a transition as an actual phenomenon can be made only with a view to past transitions, e.g. fundamental changes in transport systems at the turn of the 20th century, the industrial revolution or other major historical transformation processes. These transitions were emergent, as opposed to current efforts of transforming modern societies, with concrete initiatives and strategies being politically negotiated and decided, planned and mapped out where possible, in order to facilitate future sustainable development. Furthermore, the term transition is used as a guiding vision, while, strictly speaking, it is only possible to talk about a transition, once it has been 'completed' and an ex-post perspective allows the observer to assess whether fundamental change has actually taken place. Thus, shifting the focus from transitions in general to **sustainability transitions**, means that the direction of an open-ended change process becomes a central element. In contrast to emergent transformation processes, sustainability transitions have an inherently normative component, insofar as they are focused on change towards more sustainable production and consumption patterns in modern societies. What sustainability means in concrete cases is certainly ambiguous and contested, thus generally subject to debate and conflict, and, what is more, concrete case-specific sustainability criteria may also change over time. Consequently, an important element in sustainability transitions is the way that these are guided and directed proactively (which is different from emergent transitions, not following an overarching agenda). Often, political actors and governmental regulation play an important role because sustainable development has become an important part of political strategies and agendas at different levels. However, since transitions of socio-technical systems extend over different societal domains, other actors need to be involved, too, such as industry representatives, firms, consumers, researchers and civil society organizations, and they should cooperate in coordinated ways. This is particularly important in the case of sustainability transitions, because in most cases more 'sustainable' solutions cannot compete on established markets and, as in any case related to public goods, offer benefits to society as a whole but not directly to individual firms or consumers. Thus, sustainability transitions rarely emerge smoothly from current system structures and usually depend on facilitating changes in political and economic framework conditions. This leads to another central element in sustainability transitions: the role of vested interests and power struggles. Actors with a vested interest in the status quo will utilize the ambiguous nature of sustainability and try to influence the debate in such a way that fundamental change is hampered or precluded altogether. A particularly important role is played by large incumbent firms that dominate socio-technical fields, such as transport or energy systems. Due to their influence and resources they could be important for fostering the breakthrough and acceleration of change and alternative solutions. However, since fundamental change to current systems threatens their vested interests, they usually use their power to prevent change and secure their current positions (Geels, 2011, p. 25; Markard et al., 2012, p. 956 f.).

Both transitions and sustainability transitions focus on change in socio-technical systems, defined by their provision of a basic service for society such as mobility or energy. Especially when interested in transitions to sustainability, defining the object of study in this way can help to analyze and address the fundamental causes of unsustainability. As already mentioned, sustainability problems can be characterized as persistent, because they are so tightly interlinked with evolved societal structures and thus the way societies fulfill their various specific functions and purposes. Transitions in socio-technical systems directly address these basic societal functions and purposes, thus the root causes of sustainability problems, rather than more isolated aspects such as, for instance, green innovation, environmental policy or sustainable consumption patterns. As a consequence, in transition studies, the unit of analysis is not clear-cut in empirical terms: important delineation criteria for a socio-technical system as object of study are motivated based on sustainability concerns and revolve around the concept of a generic societal function. Relevant systems can then range from national energy systems to healthcare systems, to regional entities such as cities or ecological systems, or more abstract units of analysis, such as political systems or financial systems (de Haan & Rotmans, 2011, p. 92). This means that typical units of analysis from a wide range of disciplines can be studied from a transitions perspective while the common denominator is the orientation along functions and real-world problems, which is decisive for dealing with sustainability problems adequately and require defining system boundaries that often deviate from disciplinary-based definitions in academia. It should be noted that such an approach requires the researcher to be explicit about the object of study and to clearly delineate the respective unit of analysis.

A similar emphasis on generic functions and underlying structures is captured in the concept of **system innovation**, which is a dominant concept especially in earlier transition studies. The basic definition has already been introduced in chapter 3, laying out the three aspects of a system innovation:

(1) technological substitution,
(2) socio-technical co-evolution, and
(3) the emergence of new functionalities (Geels, 2004a, p. 19 f.).

Much like the term ‘transition’, a system innovation is used to describe fundamental changes in a socio-technical system. The emergence of new functionalities that results from co-evolutionary developments is the end-state of a transition where dynamics have interlinked across different levels and between societal domains, resulting in a new and different system configuration. The term ‘new functionality’ is used to describe how a system innovation (or transition) leads to a qualitative change in the way that a specific socio-technical system fulfills its particular function. While providing mobility or energy are basic functions that any modern society will have to fulfill, a sustainability transition in these fields might lead to fundamental changes in how this is done (e.g. energy provision in a central or decentralized energy system), what performance or quality criteria are applied (e.g. access to mobility vs. ownership of a car), and regarding the actor structure and dominant technologies. In contrast to the term transition, the notion of system innovation considers more explicitly the role of technologies (which are central elements in many sustainability-related problems and their potential solutions), while it also emphasizes that substantial change is not purely technological, or triggered uni-directionally by technological innovation, but rather the result of socio-technical co-evolution (Kemp & Rotmans, 2005, p. 34).

The term transition has gained prominence in comparison to system innovation and it has been argued that especially in the context of sustainability-oriented change and its proactive management, the term transition is to be preferred, because it is more process-oriented. The notion of transition draws more attention to a desired end state and the long and complex change process leading there. The explicit focus on the process of change also directs attention to the concrete barriers for transitions and the various interlinked dynamics within and outside a socio-technical system that shape the process as a whole (Kemp & Rotmans, 2005, p. 36). So, transition and system innovation are used synonymously, yet they emphasize slightly different aspects or perspectives of the same kind of phenomenon.

For the purpose of this thesis, both terms will also be used as synonyms, but the term system innovation is more central in the light of the research question and field of application. Since the potential of e-mobility developing as a sustainable system innovation – or the question of whether a transition may be emerging from developments in the field of e-mobility – depends on a specific core technology and the way it evolves with other non-technical elements from the social environment in which it is embedded, the term system innovation seems more suitable. It takes the technology as a starting point and “forces one to think about the long-term consequences of innovations: whether they give rise to or contribute to system innovation or do not alter the current path of development” (Kemp & Rotmans, 2005, p. 35). Looking at e-mobility as a potential system innovation can thus help to distinguish in what ways the electric vehicle is not just another ‘normal’ technological innovation and in how far e-mobility means a qualitative change in the deep structures of current mobility systems. Furthermore, the notion of system innovation facilitates a clearer focus on socio-technical co-evolution, rather than a purely macro-level focus on overall system levels, and it allows for focusing on the current state of an ongoing transition and analyzing its potential – in the light of a wider and long-term future perspective.

Apart from these basic notions that are the core or starting point of sustainability transitions as a distinct research field, other central concepts and propositions can be found in the different theoretical approaches and frameworks that are used to study transitions. Within the field of transition studies four to five different approaches of studying transitions have been identified. In their overview of the field, Markard et al. (2012, p. 955) identify four key frameworks in transition studies: the multi-level perspective on socio-technical transitions (MLP), technological innovation systems (TIS), transition management (TM), and strategic niche management (SNM). In their introduction to the journal “Environmental Innovation and Societal Transitions” and the field in general, van den Bergh et al. (2011, p. 9) identify four approaches as well, with a minor difference however: SNM is grouped together with the MLP and the fourth approach is suggested to be evolutionary economics with a focus on multi-agent modeling.

The **multi-level perspective (MLP)** on socio-technical transitions conceptualizes change in socio-technical systems as a process across three levels. The **regime** embodies the deep structure of a socio-technical system and contains its basic logic of functioning, while radical novelty emerges in **niches** that challenge the established regime structures. Regime and niches are embedded in a broader **landscape** level, i.e. the level of external influencing factors that shape overall developments. The MLP will be discussed in more detail in ch. 3.1.3.

Strategic Niche Management (SNM) is closely related to the MLP and focuses specifically on processes within niches and conditions for their successful development. Since transitions in the MLP are seen as processes of change, where innovation and novelty originally emerge in niches, SNM focuses on these seeds of change and on ways of fostering their development.

Transition Management (TM) is closely related to the Dutch policy context as a term and a concept with a particular focus on theory as well as practice. TM focuses on the process of steering and guiding desired transitions towards a sustainable future. It is in this way similar to SNM, but goes beyond this approach by focusing on a cyclical process of managing transitions that concentrates not only on experimentation in niches, but also on creating shared visions and problem perceptions across a broad range of actors, and on up-scaling niche experiments and constant monitoring of the process as a whole. TM and SNM are discussed in more detail in chapter 3.2.

The approach of **Technological Innovation Systems (TIS)** focuses on the relationship between technologies, or technological innovations, and the actors and institutions in a socio-technical system, analyzing how these elements influence each other and co-evolve. Within transition studies, the focus is on contributions of specific technologies or technological innovation systems to sustainability transitions and the functions and processes characterizing successful technological innovation systems. The TIS approach will be discussed in more detailed in the following chapter 3.1.2.

Finally, **multi-agent modeling approaches** based on **evolutionary economics** are not featured prominently in the field of transition studies. However, it has been proposed that a more explicit engagement with evolutionary theory (which provides many basic concepts on which transition studies do build already) could add to conceptual and empirical approaches within transition studies as well as overall scientific rigor, and that modeling could be an important addition to the currently dominant focus on case studies and qualitative analysis (Markard et al., 2012, p. 964). For a more comprehensive overview of this particular stream currently emerging within transition studies, see van den Bergh et al. (2011, p. 11 f.) and Safarzynska et al. (2011).

These different approaches of studying sustainability transitions have emerged from different disciplinary backgrounds, theoretical traditions and a plethora of combinations of different core concepts. These backgrounds and the key concepts, important for understanding the basic assumptions and premises guiding transition studies as well as those distinguishing the individual approaches presented above, will be introduced and discussed briefly in the following.

In general, transition studies with a focus on socio-technical systems have emerged from innovation studies, and especially those streams of innovation studies that have been influenced by evolutionary thinking that emerged from the crossovers between Darwinian biology and economics and that focus on industrial transformation and the development of technology, drawing also on the sociology of technology and, more recently, science and technology studies (Garud & Gehman, 2012, p. 981; Geerlings et al., 2009, p. 410; Stirling, 2011, p. 83). An early influence on transition studies is the work by scholars such as Nelson & Winter (1977, 1982) and Dosi (1982), who coined many of the terms and concepts dominating the field of transition studies today. As economists and innovation scholars they studied processes of technological development and the diffusion of innovations, and their particular scientific contribution was to introduce elements from evolutionary thinking into their field of study. For instance, technological development and the diffusion of innovations were explained in terms of variation and selection processes.

Such basic elements of evolutionary thinking helped to make sense of typical phenomena of inertia and long phases of stability in processes of technological development. The concept of technological paradigm or regime was introduced, which denotes a structural element in shaping technological development, or, in evolutionary terms, the selection environment for new technological solutions or innovations. A technological regime has been defined to include the shared (e.g. among engineers or specific scientific communities) guiding principles, search heuristics, and cognitive routines, which shape processes and outcomes of technology development processes. It explains how some technological problems come to be recognized as such, how the options for solving them are selected, what is included in the potential 'solution space' at all, and how the problem-solving process is being structured and carried out. The major achievement by scholars such as Dosi or Nelson and Winter is that they managed to show that these processes can (and need to) be explained if one wants to understand processes of technological change, because they are not 'given' or determined by technology itself – they rather emerge or evolve from specific cultures and rules among those developing technology. A technological regime can thus change over time, the state of knowledge and skills as well as cultural predispositions and perceptions of rational problem-solving approaches evolve as well (Garud & Gehman, 2012, p. 981; Geerlings et al., 2009, p. 406 f.).

However, it can be shown that, due to these technological regimes exerting selection pressure, technological development is relatively stable over long periods. This is expressed in terms of path-dependency (Arthur, 1989; Basalla, 1988; David, 1985; Sydow et al., 2009) and development following technological trajectories (Dosi, 1982). Similar to biological processes of mutation and variation, real novelty and radical innovations will from time to time, and basically by chance, originate as "hopeful monstrosities" (Mokyr, 1990, p. 291). In most cases, these will not manage to diffuse widely, because selection pressure exerted by established regimes will lead to their eventual disappearance. Nonetheless, sometimes there is fundamental technological change, usually triggered by external shocks or because a particular technological innovation manages to break through, either building on existing knowledge and skill or by destroying existing competencies and replacing them by new knowledge and skills. Any of these events can be the beginning of an "era of ferment" (Anderson & Tushman, 1990, p. 606) where the so far stable dynamics are disrupted, where numerous innovations emerge and compete for 'being selected' and different possible future trajectories begin to take shape. In the ensuing variation and selection process, one technological option will emerge as the 'winner', and around this winner will emerge the next dominant design (Abernathy & Utterback, 1978; Arthur, 1989). Another relatively stable trajectory will form and the era of ferment is followed by a phase of incremental innovation, where the new dominant design is further stabilized by, for instance, improving efficiency and reliability of a specific technology, by working towards economies of scale and capturing large market segments (Garud & Gehman, 2012, p. 981; Sierzchula et al., 2012, p. 52).

Such basic evolutionary conceptualizations of stability and disruptive change in technological development can still be found in more recent approaches in innovation studies. For instance, in his seminal paper on 'carbon lock-in', which is a central reference in transition studies, Unruh (2000, p. 820) builds on the concept of a dominant design and its evolution, in order to explain the emergence of specific technical systems, e.g. related to transport or energy supply, which cause today's severe environmental problems. An important insight is made here, which results from a critical perspective on evolutionary thinking: it is not automatically the 'best' or (if possible to define this in any objective sense) 'superior' technology that emerges as the winner from variation and selection processes and becomes the core of a new dominant design. Rather, it is a combination of technological characteristics, timing and framework conditions as well as strategic behavior that leads to a lock-in of new technological trajectories (David, 1985). This is an important insight with regard to the broadness of perspective on technological development and has consequences with regard to the role of involved actors and power constellations as well as the general economic and political framework conditions. It also shifts the focus when looking at concrete processes of transitions and disruptive technological change. For instance, another basic concept in transition studies is the “S-curve” model developed in innovation studies (Rogers, 1962), which captures change processes along different phases, building on a predevelopment phase where niche actors, or in innovation studies terms “early adopters”, begin to develop innovative practices, followed by increasingly steep take-off and acceleration phases, evolving into a phase of stabilization where a new system configuration has emerged and the curve indicating dynamics and change flattens out again. While traditional economic approaches tend to focus on the second half of this curve and the long-run equilibria, insights from evolutionary thinking in innovation studies have shown that the earlier phases are decisive, in order to understand dynamics in an era of ferment and a situation where old trajectories are disrupted and a new dominant design begins to emerge through a complex variation and selection process (Hoogma et al., 2002, p. 198; Nilsson et al., 2012, p. 52 f.; Unruh, 2000, p. 820).

Evolutionary thinking has not only contributed to the conceptualization of overall change processes in technology and innovation studies, it has also been used to develop a perspective on the many, not only technological, and interlinked drivers of innovation journeys. The concept of technological paradigms or regimes has already pointed to the interlinkages of technological innovations and institutions, i.e. guiding principles and cognitive routines, shaping technological trajectories. While in the beginning these regimes were mostly understood to be relevant within engineering or scientific communities, increasingly broader conceptualizations of technological development have included the overall societal context in which these processes are embedded. Thus, specific socio-technical configurations emerge from co-evolutionary processes including technical knowledge and technological innovation as well as political and economic circumstances, societal norms and values, individual behavior and use patterns (Stirling, 2011, p. 83; Unruh, 2000, p. 817 f.). Such a broader, co-evolutionary, understanding can for instance be seen in conceptualizations of long-wave theory on techno-economic paradigm shifts (Freeman & Perez, 1988). While in the beginning such shifts were explained as paradigmatic change in entire economies and societal institutions caused uni-directionally by technological innovation and economic forces, later work focused on mutual interrelations between different domains. Dynamic interdependencies between the societal dimensions of science, technology, economy, politics and culture were traced, in order to explain their alignment and inherent tensions causing shifts in techno-economic paradigms (Geels, 2011, p. 26).

In transition studies, especially the multi-level perspective (MLP) on socio-technical transitions, and the related approach of strategic niche management (SNM), draw heavily on basic concepts from this evolutionary perspective in innovation studies. The basic concepts of socio-technical regime and the derived niche and landscape levels have clearly been developed based on earlier versions of technological regimes or paradigms. Also, the MLP assumes path dependency and locked-in trajectories and conceptualizes transitions (to sustainability) as disruptive change – at least in early versions of the MLP. As in evolutionary innovation theory, change is initiated by external shocks (in the MLP: developments at the landscape level) or radical innovations (in the MLP: at the niche level). Alternating phases of instability and change, as described by the notion of an era of ferment, and more stable phases where socio-technical regimes persist and innovations remain mostly incremental are also envisioned in the MLP (Garud & Gehman, 2012, p. 981). Co-evolutionary dynamics also play a central role in the MLP, first, across the three levels of niche, regime and landscape, and second, between different societal domains, similar to those identified in the literature on techno-economic paradigms, i.e. technological, economic, political, cultural, and scientific sub-systems (Grin et al., 2010, p. 4). A major difference when comparing the MLP and shifts in techno-economic paradigms is that the latter focuses on economies as a whole, while the MLP limits its scope to transport, energy, food or water systems (Geels, 2011, p. 26; van den Bergh et al., 2011, p. 8). A focus on socio-technical systems defined by the specific function they fulfill is characteristic of transition studies and is a way of dealing with the specific challenges of sustainable development, which go beyond individual technologies but can only be shaped in meaningful ways at a level below macro-level processes affecting entire economies and societies. The MLP has further been refined by integrating concepts from the sociology of technology and sociological literatures, referring especially to the work of Anthony Giddens. Based on these literatures, a distinction is made in MLP studies between socio-technical systems, containing the material elements such as technological artifacts and infrastructures, actors and actor networks, and regimes in terms of rule systems that actors refer to (Geels & Kemp, 2007, p. 442). This will be elaborated further in chapter 4.3.1.

While the approach of technological innovation systems has emerged from the same as well as newer, parallel streams within evolutionary innovation studies as the MLP and SNM, the Transition Management (TM) approach in addition draws on complex systems theory and concepts of resilience and adaptation. Based on an understanding of persistent problems precluding more sustainable development and a motivation to actively steer transitions towards sustainability, TM focuses on complex societal systems, governance approaches and principles of integrated assessment (de Haan & Rotmans, 2011, p. 90). Since concepts from these theories are combined with evolutionary approaches from innovation studies there are sometimes inconsistencies in the systems perspective in TM (van den Bergh et al., 2011, p. 10). The notion of co-evolution is also referred to in TM, in the sense that managing transitions is a process where experimenting and learning are co-evolving elements in a cyclical process (Grin et al., 2010, p. 4). In short, in TM a comprehensive systems perspective is combined with reflexive governance approaches and principles of action research, resulting in a practice-oriented model for fostering and managing transition processes (Markard et al., 2012, p. 958 f.).

Shortly summarizing this section, it can be said that – apart from slightly deviating emphases e.g. in transition management – in transition studies a socio-technical system is delineated according to the generic societal function it fulfills, e.g. mobility, energy provision or food production. A socio-technical system is further defined as "a configuration of elements that include technology, policy, markets, consumer practices, infrastructure, cultural meaning and scientific knowledge" (Geels & Kemp, 2012, p. 49). In this context, a system innovation refers to a long-term and co-evolutionary process of change, where all of these elements mutually influence each other, amounting to major shifts in the overall system configuration, i.e. a transition. Since this process includes not only physical changes in infrastructures or organizations, but also a redefinition of norms and values, new perspectives on how certain problems are framed and eventually acted upon, a transition can be defined as a substantial shift in the deep and underlying structure of a system (Elzen & Wieczorek, 2005, p. 651; Geels & Kemp, 2012, p. 49; Grin et al., 2010, p. 2 f.; Kemp & Loorbach, 2006, p. 105; Meadowcroft, 2009, p. 324; Rotmans & Loorbach, 2010, p. 108 f.; Shove & Walker, 2007, p. 2).

3.1.2 The Role of Technology and Innovation

Since the role of a specific technological innovation, the electric vehicle, is central in this thesis, some explicit attention is given to the role of technology and innovation in transition studies and the theories on which this field of study is built. The preceding section has provided a brief overview of evolutionary thinking in innovation studies during the mid- to late 20th century and many scholars of that time have again looked back to older theories of technological innovation and economic development. The most prominent sources for them have been the work of Kondratieff and Schumpeter.

Kondratieff (1926) studied the interlinkages between technological and economic development and discovered that in the long term waves of development could be identified, spanning roughly 50 years. At the beginning of such a wave a groundbreaking technological innovation can be found and when such a wave begins to decline, new inventions are stimulated and will eventually trigger the next long wave. Schumpeter (1939) built on Kondratieff's work and further elaborated the interlinkages between technological innovation and economic development. He explicitly focused on the link between a technological innovation and its impact on the beginning of a new period of economic upturn. The role of entrepreneurs in this process is emphasized by Schumpeter, because even though firms are willing to invest and take risks during an economic crisis, it takes proactive entrepreneurs who in a process of creative destruction turn the inventions of scientists and engineers into marketable innovations and foster their diffusion, which, in the case of radical innovations, can be the beginning of a new long economic wave (Dijk & Yarime, 2010, p. 1371; Geerlings et al., 2009, p. 404 f.).

Building on Schumpeter's differentiation between an invention and an innovation, the role of specific types of technological innovations and development and diffusion processes have further been discussed in the field of innovation studies. As has already been mentioned, it is not always an obviously superior technology that successfully comes out of a diffusion process as the new dominant design. Radical innovations are thus not always the technologically most advanced or most sophisticated version of a specific technological artifact or machine, the more relevant question is whether a technological innovation manages to break through in a complex process of interlinking dynamics in a specific social context (Unruh, 2000, p. 820). Innovations can further be differentiated based on whether they build on and emerge from established trajectories and know-how, becoming disruptive only in the course of their further development, or whether they can be characterized as radical from the beginning, because they are making existing competences obsolete and require new rules and routines (Sierzchula et al., 2012, p. 52). For instance, Freeman & Perez (1988) distinguish incremental and radical innovations as well as changes of technology systems and changes in techno-economic paradigms. This systematization represents a distinction by scope of a specific innovation's impact: while incremental innovations are a minor technological change, radical innovations can have an impact on firms and industry structures. System innovations go beyond this level and affect also other societal domains, such as politics, culture and science. Finally, techno-economic paradigms shape entire economies or societies (Geels & Schot, 2007, p. 402).

The approach of technological innovation systems (TIS) is making up a large part of transition studies and is the one approach that is most closely related to the shared origins of transition research in innovation studies. It focuses on the emergence of technological innovations and specifically studies processes of socio-technical co-evolution, e.g. the interlinkages between technological development and related processes of institutional and organizational change. Innovation systems have been studied at different levels, i.e. sectoral, national, regional or technology-specific innovation systems. The notion of technological innovation systems (TIS), which is dominant in transition studies, goes back to Carlsson & Stankiewicz (1991). National innovation systems have been studied by some of the evolutionary innovation scholars mentioned earlier as basic references of transition studies as a whole, such as Dosi et al. (1988). A specific focus on sectoral innovation systems has been propagated by Malerba (2002), which aims at understanding sector-specific framework conditions, such as actor networks, institutions and knowledge base and how they shape technological innovation processes. Similar to other closely related approaches, such as social construction of technology (Bijker et al., 1987), or concepts such as large technical systems (Hughes, 1987), the basic assumption is that any socio-technical system, independent of its specific scale and scope, is characterized by technological and social or institutional elements that are mutually interdependent (Dolata, 2011, p. 19; Markard et al., 2012, p. 959; van den Bergh et al., 2011, p. 9 f.).

In the context of sustainability transitions research, TIS studies are focusing on the emergence of radical innovations that contribute to sustainability-oriented change in socio-technical systems, and consequently development processes of 'green' technologies are researched in this field. This is a specific deviation from more traditional innovation system research, which tends to focus more on generic technologies, which may contribute to overall economic growth and development of national (or regional) economies. Conceptually, the focus of TIS studies has shifted from basic structures of an innovation system to specific functions that explain successful performance or failure of a specific innovation system, respectively. Based on case studies and historical event analyses, it has been studied what kinds of functions are important in technological change processes, where they worked well and how different functions are interrelated (Kern, 2012, p. 300; Markard et al., 2012, p. 959; Markard & Truffer, 2008, p. 597; van den Bergh et al., 2011, p. 9 f.).

Usually, the implicit or explicit goal of TIS studies is to arrive at policy recommendations for supporting specific technologies, in transition studies recommendations are derived for supporting specific environmental innovations or 'green' technologies. Often drivers and barriers for innovation, related to how well a specific TIS performs the relevant functions, are identified and based on this analysis, and sometimes in comparison with other TIS, recommendations are developed on how to improve performance or remove barriers for innovation. Thus, the TIS approach is in most cases used to inform technology-specific policies (Markard et al., 2012, p. 959; Markard & Truffer, 2008, p. 601). However, it has also been discussed critically whether TIS approaches can really provide meaningful policy advice, when aiming at sustainability transitions. The focus on functions of innovation systems runs the risk of unduly neglecting factors and dynamics in the wider societal context. Similarly, the focus on one specific technology in a TIS study may lead to ignorance with regard to other technological developments that have an impact on the TIS under study, or maybe even compete with it. Finally, more emphasis should be put on explaining exactly why specific functions are not fulfilled in a TIS. In order to deal with these shortcomings of the TIS approach, it has for instance been recommended to find ways of integrating TIS and MLP perspectives (Kern, 2012, p. 300; Markard & Truffer, 2008, p. 610).

To sum up this section on the role of innovations in transition studies, it has been shown that a focus on technological innovations and their development is dominant in TIS approaches, but also a basic element in other transition approaches. Radical innovations play a role because they may trigger changes in other system elements. However, the focus is on system innovations that may arise from such processes of socio-technical change. The scope of an innovation is also an important criterion. Since transition studies focus on socio-technical systems, such as energy or transport systems, the scope is much smaller than for instance that of techno-economic paradigms, which shape entire economies, but broader than that of typical radical innovations in business and innovation studies, where the focus is on firms or industrial sectors. It is important to distinguish between different types of innovation, in order to avoid a perspective on transitions as deterministic and overly progress-optimistic technology-oriented projects. For the purpose of this thesis, a focus on TIS approaches has been discarded, because the electric vehicle is a good example for a radical technology that does not necessarily lead to a sustainability transitions. Since this is already obvious, it is not particularly useful to focus on conditions and functions of innovation systems for e-mobility (even if they included a focus on social innovation), because a broader conceptualization is needed.

3.1.3 The Multi-Level Perspective on Sustainability Transitions (MLP)

A central theoretical approach in sustainability transitions research is the Multi-Level Perspective (MLP), which conceptualizes transitions in socio-technical systems as a dynamic interplay of processes across three levels – landscape, regime, and niches – that interact and reinforce each other (see Fig. 8). These do not refer to specific spatial or organizational locations, but rather to a more theoretical idea of levels within functional space embodying different relationships between the respective actors, different dynamics and structures. The MLP framework draws on concepts from co-evolutionary innovation studies, science and technology studies, neo-institutional theory and social theory, in particular Giddens' theory of structuration (1984). It allows for identifying characteristic patterns and mechanisms playing out in transition processes (Geels, 2011, p. 26; Geels & Kemp, 2012, p. 74; Grin, 2010, p. 4; Rotmans & Loorbach, 2010, p. 131).

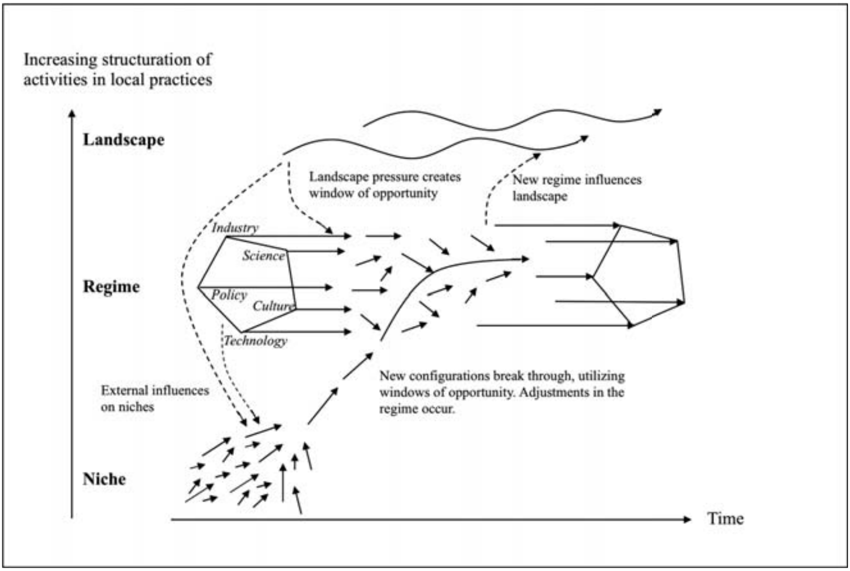

Fig. 8: Multi-level perspective on transitions (based on Geels & Schot, 2010, p. 25)

In the MLP framework, the landscape provides a relatively stable environment characterized by large-scale developments and long-term trends, which can hardly be influenced by individuals or specific groups of actors. A regime is defined as a set of structure, culture and practices that is shared by a specific group of actors. The regime guides the behavior and actions of its members by shaping their perceptions of problems as well as the range of possible solutions. Overall, it conceptualizes a dynamic social structure that is firmly established because it is constantly reproduced – yet, it also leaves room for a limited degree of variance. For new rules and routines to become part of a regime, individual and social learning processes are essential and issues of (normative) power need to be considered

(Shove & Walker, 2007, p. 4). Niches can develop where small groups of actors engage in new practices and behave in ways that do not conform to the general regime (Geels & Schot, 2010, p. 22; Kemp & Loorbach, 2006, p. 108; Nykvist & Whitmarsh, 2008, p. 1374; Rotmans & Loorbach, 2010, p. 108, 131 f.; Rotmans et al., 2001, p. 19 f.).

Based on the idea that fundamental change has shaped the past and the present and that past experiences provide valuable lessons (de Haan & Rotmans, 2011, p. 90), the MLP has been applied to the study of historical cases, gaining a better understanding of fundamental change processes in retrospect, for instance in transport, shipping, aviation, water management and industrial production (e.g. Geels, 2002, 2005b, 2006a, 2006b). The second major field of application is the study of sustainability transitions currently underway or in the future, especially in the fields of energy, mobility and agri-food (cf. Geels, 2011, p. 29). Apart from that, there have been numerous research articles dealing with the conceptual and theoretical development of the MLP and the regime notion more specifically (e.g. Geels, 2010, 2011; Genus & Coles, 2008; Holtz et al., 2008; Markard & Truffer, 2008). Basic concepts and notions of transitions in the MLP framework will be discussed in more detail in the following.

3.1.3.1 The Concept of Regime – Structuration and the Potential for Change

The concept of regime is central to the MLP framework and will therefore be elaborated in some more detail. The regime might be seen as the core concept of the MLP because a transition (or a system innovation) is defined as regime change. Apart from this, the regime is the conceptual core of the MLP, in so far as 'landscape' and 'niche' may be viewed as derived concepts that are defined in relation to a specific regime (Geels, 2011, p. 26; van den Bergh et al., 2011, p. 10).

As already mentioned, the earliest origins of the regime concept can be found in evolutionary economics and innovation studies, where the notion of technological regime was used to explain shared beliefs and common design heuristics among engineers and the emergence of technological trajectories. These approaches were further developed in the field of history and sociology of technology, studying how these technological developments are socially embedded, in so far as users, policy makers, existing infrastructures and institutions also shape paths of technological development (Dijk & Yarime, 2010, p. 1372; Geels & Schot, 2007, p. 399 f.; Genus & Coles, 2008, p. 4; Markard et al., 2012, p. 957). The concept of technological regime was then picked up within innovation studies and Science and Technology Studies, where the embeddedness of technology in society was further emphasized. Schot (1998), Rip and Kemp (1998) refined the understanding of regimes and further developed the regime notion in the context of socio-technical systems. Geels (2002, 2004b) thus introduces the notion of socio-technical regimes and further develops its sociological basis, especially its foundations with regard to Giddens' (1984) structuration theory. Regimes are conceptualized as rule sets that guide technology development at the micro-level, which is embedded in a context of macro- and meso-level developments of markets, infrastructures, regulations and culture. Introducing these different levels forms the basis of the MLP approach in current transition studies (Geels, 2010, p. 504; Geels & Kemp, 2012, p. 54 f.; Genus & Coles, 2008, p. 4; Smith et al., 2010, p. 436).

Overall, it can be shown that across transition studies there is a common understanding with regard to the basic logic of the regime concept and the defining characteristics of a regime. In early conceptualizations of technological regimes in engineering communities as well as in the notion of regimes within socio-technical systems, the term regime is a helpful category for grasping stability and path-dependency explained as an inherent logic or direction underlying development paths. What is also similar throughout the development of the regime concept and throughout the transitions literature is a constant effort to better understand the sources for persistence and inertia – in order to determine factors that explain regime change. However, there is also a major fault line separating two strands within transition literature, based on two different regime conceptualizations[3]. They differ with regard to a more concrete understanding of what a regime actually is. First, there is a narrow conceptualization that defines regimes as rule sets. Second, there is a broad conceptualization that includes not only rules but also other elements, such as actors, infrastructures and technological artifacts, in the definition of a regime (Markard & Truffer, 2008, p. 605; Markard et al., 2012, p. 957).

According to a broad conceptualization, a regime consists of actors and social networks, rules and institutions, technological artifacts and infrastructures. All of these regime elements are interrelated and emerge as a relatively stable semi-coherent configuration. Stability and path-dependency are created because the various processes within such a configuration of regime elements are interlinked and reinforce each other (Holtz et al., 2008, p. 626 ff.; Raven, 2007, p. 2198; Smith et al., 2005, p. 1493; Smith et al., 2010, p. 441; van den Bergh et al., 2011, p. 10; Verbong & Geels, 2007, p. 1026).

[3] A similar argument has been developed in a co-authored conference paper: Best, Prantner & Augenstein (2012).

According to a narrow conceptualization, a regime consists of rule sets. A distinction can then be made between regulative, normative and cognitive rules. Different social groups (e.g. in the spheres of science, technology, politics, markets) have different rule sets and these rules guide the behavior of actors who reproduce the elements of a socio-technical system. In a regime, various semi-coherent rule sets are linked together and mutually influence each other. In this way, a regime is understood as the deep structure that lies behind the stability and path-dependency of socio-technical systems (Geels, 2002, p. 1260; 2004b, p. 904 f.; 2006b, p. 1071; 2011, p. 27).

The rationale for a 'broad' approach is to provide an all-encompassing view on all the material and immaterial elements related to fulfilling societal functions in an appropriate way (Markard & Truffer, 2008, p. 607). However, one might also argue that especially with regard to this complexity, the interpretive strength of a narrow definition of regime lies in the fact that it allows for a more profound understanding of the deep structure that lies underneath the activities of actors who reproduce system elements – thus, structuring complexity (Geels, 2011, p. 31). In the end, the two conceptualizations may not be completely irreconcilable, since in practice it "is difficult to conceive a pattern of socio-technical practices reproducing without the presence of institutions, just as it is difficult to see how institutions can persist without their re-enactment through networks of actors engaged in material practices" – as was pointed out by Smith et al. (2010, p. 442). From an analytical point of view, however, the difference between the two conceptualizations does matter and the choice depends on the research question as well as basic theoretical assumptions.

A major difference between a broad and narrow regime conceptualization is the differentiation between the regime and the socio-technical system. In the narrow conceptualization of regimes as rule sets they are clearly separated. According to this view, a socio-technical system consists of material and measurable elements, thus, obviously, technologies and infrastructures, but also for instance regulations, consumption patterns and market relations. The regime as deep structure is then a more abstract category entailing the underlying rules that make sense of the basic logic of functioning of a specific socio-technical system (Geels, 2011, p. 31; Geels & Kemp, 2012, p. 56 f.).

What both regime conceptualizations have in common, however, is their relation to a 'generic societal function' as boundary criterion. This refers to very basic functions that are socially valued, such as energy provision, mobility or housing. The boundaries of a socio-technical system or a regime, respectively, are drawn according to such a specific function. All the elements that are involved in the complex process of fulfilling such a particular function are included (Markard & Truffer, 2008, p. 607; Holtz et al., 2008, p. 626 ff.; Smith et al., 2005, p. 1493; Smith et al., 2010, p. 436 ff.).

Especially when referring to the narrow regime concept, it is important to note that the regime concept is based on Giddens' theory of structuration (Giddens, 1984). Therefore the rule sets making up a specific regime represent Giddens' notion of the duality of structure, in so far as these rule sets are drawn upon by actors in their decisions and actions (thus, shaping action), while at the same time actors reproduce those rules by way of their actions (thus, being an outcome of action). The basic contribution of Giddens' approach is this very idea of duality, which is possible because structure and agency, or social practices, are sharply separated analytical concepts. Specific patterns of social practices are not themselves structure, structure is the more abstract principle behind concrete human action – it only has a 'virtual' existence (Giddens, 1984, p. 304). However, Giddens has been criticized for a lack of clarity and robustness when it comes to spelling out these abstract theoretical ideas in practice. For instance, structure is defined to consist of rules and resources, and when thinking about formalized rules or resources that provide agents with actual power over things or people, it can indeed be tricky to uphold the virtual nature of structure. An attempt has been made by Sewell (1992), arguing that structure as a virtual unit can be defended or re-formulated by explaining the 'virtual' interrelatedness between rules and resources: "Schemas [i.e. rules] not empowered or regenerated by resources would eventually be abandoned and forgotten, just as resources without cultural schemas to direct their use would eventually dissipate and decay. Sets of schemas and resources may properly be said to constitute structures only when they mutually imply and sustain each other over time" (Sewell, 1992, p. 13). Thus, the virtual nature of structure lies in the abstract principles and interrelations that help making sense of everyday objects and action. This type of ordering and clearly differentiating between tangible and intangible elements is similar to the separation in the MLP of a regime and a corresponding socio-technical system: the separation is analytical in nature and not valid in practice. Such an approach is useful when studying transitions because it shifts the analytical focus to underlying principles and explanations, however without resorting to structuralistic and deterministic models, but rather with a view to deeper meaning and explaining developments at a level that does not take observations at face value and forces the analyst to reflect on what is being observed and how one makes sense of it. Furthermore, it highlights the 'enabling' aspect of structure, which is central when interested in the role of agency and questions of shaping future transitions. In essence, the duality of structure explains how, on the one hand, a system is constantly reproduced by actors, while on the other hand, there is room for change because actors can reflect on the rules they draw upon. The three levels in the MLP are characterized by different degrees of such structuration (Geels & Schot, 2010, p. 18 f.).

The landscape is characterized by the highest degree of structuration, i.e. absolute stability, because it represents a 'given' environment, without a scope of action for individual actors aiming at changing landscape factors. Niches are characterized by the lowest degree of structuration in the MLP, they are highly unstable and they are the locus where truly new and different ideas that deviate from broadly shared frames of reference are being tested. Thus, niche actors actively create a space where their scope of action is as large as possible (Geels & Kemp, 2012, p. 52 f.). The regime is characterized by a relatively high degree of structuration: there is always some dynamic because actors can reflect on guiding rules and will introduce incremental changes in order to preserve and improve a socio-technical system; however, the basic rules are usually reproduced and attempts of developing a socio-technical system further generally remain within 'regime boundaries'. Thus, the overall stability of a particular socio-technical system can be explained in terms of an existing 'deep structure' or a regime. The landscape and niches can then be interpreted as derived concepts, which are defined in relation to a specific regime via their function as an external environment to it and as elements substantially different from it, respectively (Geels, 2011, p. 26 f.).

Even though the regime concept is not applied coherently across different fields of transition studies, some general findings have been made. Various studies of either historical transition processes or of current transition processes have shown that established socio-technical systems are relatively stable over long periods because they have emerged as specific configurations of technological, infrastructural and institutional elements that foster the development of incremental innovations rather than profound change that questions the underlying regime of a system (Markard & Truffer, 2008, p. 605; van den Bergh et al., 2011).

So, how can change be explained in the MLP and what are basic theoretical assumptions regarding the potential for change in general? It has been shown that transition studies as a whole and also the MLP as one concrete approach draw on various theoretical traditions with different implicit assumptions as regards the potential for fundamental change. The MLP has, for instance, been criticized for being overly structuralistic with too little room for assessing the role and impact of actors and concrete agency in actual processes of change. This can be explained by the fact that the MLP is, amongst others, based on concepts such as techno-economic paradigms, which focuses on technological development of entire economies and studies such processes in terms of macro-level structural change. Furthermore, socio-technical systems are defined according to the specific function they fulfill, which implies parallels with theories of structural functionalism (e.g. Parsons, 1951 or Luhmann, 1984), which have been discussed critically as regards their ability to explain phenomena of societal change (de Haan & Rotmans, 2011, p. 92). Simultaneously, however, the MLP is also firmly based on Giddens' theory of structuration, and while this is indeed also one of the more structuralist approaches within sociology (Loyal & Barnes, 2011), building among others on Parson's work, its core focus is on the interrelations between structural elements and agency in concrete social practices. Giddens departs from Parson, arguing that "there is no doubt that in his [Parson's] theoretical scheme the object (society) predominates over the subject (the knowledgeable human agent)" (Giddens, 1984, p. XX). Giddens' idea of the duality of structure and agency is emphasized here as a central tenet in the MLP and can thus help to distinguish it from more deterministic, structural perspectives on transitions as macro-level processes. It is used as an analytical perspective on currently on-going, highly uncertain processes and dynamics, as in the case of developing e-mobility, that helps understanding the role of involved actors, power constellations and concrete strategies. This is important for the question addressed here, namely understanding what the potential of current dynamics is, playing out in bounded time and space, to contribute to larger societal change processes.

A closer look at Giddens' theory of structuration and what it implies for questions of social change is needed, because at first glance the "problem with the notion of structure is that it makes dealing with change awkward" (Sewell, 1992, p. 2). The theory of structuration, similar to other grand social theories, e.g. that of Bordieu (1977) for instance, originally have been developed in order to explain the stability of a specific social order and the way that institutions are reproduced and societies persist. Phenomena of major change or transformation are thus usually explained as something exceptional and their causes are located outside the 'normal' (Sewell, 1992, p. 3). That is also what the MLP is sometimes criticized for, being overly structuralistic, relying on landscape pressure, or disruptive niche innovations that fall outside the scope of what is normal, to explain change. This observation is accurate when taking the MLP for its face value, based on a superficial glance at the basic graph (see Fig. 8) illustrating multi-level dynamics. However, it will be shown that this is not the case when considering the theoretical foundations of the MLP rooted in Giddens' structuration theory more clearly.

Even though Giddens has not very explicitly dealt with phenomena of change or the conditions and processes of societal transformation, structuration also does not deny change altogether or is seen as a phenomenon of stability and persistence of concrete social conditions. It captures the relation between agency and structure (which is persistent as an abstract process, not with regard to its consequences in practice) in everyday social practices, while these practices can result in a reproduction of current circumstances, or in a transformation of them just as well. “Social reproduction must not be equated with the consolidation of social cohesion” (Giddens, 1984, p. 24), which means that “the ordinary operations of structures can generate transformations” (Sewell, 1992, p. 16). Based on a critique of Giddens, Sewell argues that this is possible, if it can be assumed that structures exist at multiple societal levels; that actors can creatively apply rules and resources in different, sometimes unknown circumstances; that due to such creative application, the consequences for shifts in the allocation of resources, and thus power, is often unpredictable; that there are always multiple interpretations of the meaning of certain rules and resources, thus leaving leeway for creative actors to actively shape concrete social circumstances; and finally, if it can be assumed that different types of structures at different levels overlap or intersect, thus creating tensions and dynamic (Sewell, 1992, p. 16 ff.).

Such a conceptualization is coherent with basic outlines in the MLP, where different levels are characterized by different degrees of structuration and tensions emerge between different sub-regimes or even between entirely different regimes (see ch. 3.1.3.4). It is also coherent with Giddens who assumes that social processes are in principle open-ended with regard to concrete outcomes. One explanation is the fact that actors are conceptualized as knowledgeable and purposive agents with the capacity to reflect on their motivations and action. At the same time, it is important to note that they are situated in a specific social context and that actors are not ‘black boxes’, but that their behavior can be explained by the interplay of structural conditions for action and the way that individuals deal with these conditions. Thus, structure is both constraining and enabling actors (Giddens, 1984, p. 26 f., 169; Schiller-Merkens, 2008, p. 192). Together with the fact that structural framework conditions may vary in time and space, that unintended effects occur, and considering the knowledgeability of actors who are able to consciously decide whether to conform or deviate from ‘normal’ routines, change in societal systems is, in principle, possible and not necessarily dependent on external shocks or disruptions (Schiller-Merkens, 2008, p. 181).

However, even though social change or transformation is possible through intended or unintended action by knowledgeable agents, it is not possible to identify specific generalizable causalities or factors that influence structuration processes and lead to societal change. Such general theoretical propositions are not feasible because structuration processes are contingent and only become meaningful in concrete social practices and situations.

Similar to basic understandings of transitions, Giddens conceptualizes social change as a multi-causal phenomenon that can only be identified in retrospect by identifying start- and end-points, by some type of context-specific indicators, in an ex post analysis. It is further argued that due to the decisive role played by knowledgeable agents, transformation processes can only be understood by studying not only changing social structures but particularly strategic behavior by involved actors and the way that they refer to and position themselves with regard to structural framework conditions (Schiller-Merkens, 2008, p. 183 ff.). Understood in this way, structure is not a deterministic concept explaining first and foremost stability and reproduction processes, and much less a teleological idea assuming simple causalities for explaining complex transformations – rather, the concept of structuration can be particularly helpful in any "critical analysis of the dialectical interactions through which humans shape their history" (Sewell, 1992, p. 27). Since transition studies, and especially MLP analyses, are sometimes criticized for neglecting the role of concrete actors, this reconsideration of and explicit reference to Giddens is helpful and the case study on e-mobility will explicitly focus on strategic behavior by the involved actors.

3.1.3.2 Transition Patterns and Pathways

More structural, basic dynamics of transition processes have been developed in MLP studies (while the role of specific actors is implicitly assumed as integral part of structuration processes). Most prominently, Geels and Schot (2007) aim at refining the MLP by introducing more differentiated transition patterns and pathways, in order to deal with weaknesses and simplifications the original or basic version of the MLP has been criticized for. A major criticism has been that the MLP embodies an overly simplistic understanding of change processes where niche innovations emerge and subsequently become dominant, eventually overthrowing an existing regime. This basic conceptualization has led to a large array of transition case studies, which mainly focus on specific, presumably 'green', innovations and the way that they struggle against established regimes, with regimes being treated as monolithic, undifferentiated barriers or prohibiting structural conditions. In order to overcome this so-called 'bottom-up bias' and illustrate the complexity of transitions, the MLP has been enriched by focusing on transition patterns and characteristic pathways, emerging from varying dynamics in nature and time throughout transition processes (Geels & Schot, 2007, p. 405; Geels, 2011, p. 32).

A basic differentiation of change processes has been introduced by Geels and Kemp (2007). They distinguish reproduction, transformation and transition processes. First, reproduction processes characterize stable regimes where incremental innovations contribute to dynamic stability and regime preservation by actors continuously reproducing established regime rules. Second, transformation processes occur when there is regime change, enacted from within the regime but influenced by landscape pressure. Finally, transition processes occur when there are dynamics across all three levels leading to a new socio-technical system through landscape pressure, weakening of the established regime and the diffusion of radical innovations emerging at the niche level. Differentiating between these types of processes reflects some of the basic difficulties when dealing with structuration and change as discussed in the previous chapter. The three processes are differentiated according to structure-agency interrelations, i.e. the type of structural conditions and dynamics on the one hand, and the way that actors get engaged on the other hand. Furthermore, a balanced view on influential factors and causes for systemic change is developed, arguing that transition as well as transformation processes are predominantly emerging from inside a socio-technical system, while external developments need to be considered as important influencing factors as well. Thus, this approach illustrates a specific way of dealing with problems of structuralistic approaches, i.e. by stressing the interlinkages between actors and structure, and system-internal as well as external causes in processes of change (Geels & Kemp, 2007, p. 453 f.).

A typology of **transition pathways** has been developed by Geels and Schot (2007), further differentiating variations of timing and nature of multi-level dynamics in transitions. Based on historical case studies, four basic transition pathways are identified. They show differences in timing of interactions between niche, regime and landscape levels, the nature of these interactions ranging from symbiotic to disrupting, and the combination of timing and nature of specific dynamics (Geels & Schot, 2007, p. 405 f.). Table 2 provides an overview of the four basic transition pathways. It should be noted that these pathways may overlap or emerge in combinations in actual cases in practice.

These pathways are ideal-types, derived from basic theoretical propositions and illustrated with specific historical cases (see for instance Geels, 2002, 2005b, 2006a, 2006b, 2007). However, they will rarely occur in practice in such ideal-typical fashion, there may be variations and, with a view to ongoing transitions, it will not be possible to determine whether a full-blown transition will unfold or predict future dynamics. Therefore, the pathways can guide empirical analyses but have to be applied carefully, focusing on the different dynamics and mechanisms at play as well as the particular internal logic emerging in actual pathways (Geels & Schot, 2007, p. 415 f.).

Transformation pathway	Moderate landscape pressure occurs (*nature*) while niche innovations are still premature (*timing*); ➔ Regime actors modify regime rules and overall trajectory.
De-alignment and re-alignment pathway	Landscape pressure has a disruptive effect on the regime (*nature*), multiple premature niche-innovations emerge and compete (*timing*); ➔ Successful niche-innovation becomes central in a new regime.
Technological substitution pathway	Landscape pressure has a disruptive effect on the regime (*nature*), a niche-innovation has already been developed sufficiently (*timing*); ➔ A pre-existing niche-innovation becomes central in a new regime.
Reconfiguration pathway	Symbiotic innovations are developed in niches and are adopted by regime actors to optimize the existing regime (*nature & timing*); ➔ Subsequent accumulation of innovations results in regime change.

Tbl. 2: Typology of transition pathways, based on: Geels & Schot, 2007, p. 406 ff.

Apart from such broad transition pathways, more specific transition patterns have also been identified. First, an add-on and hybridization pattern can be observed where niche innovations are step-wise integrated in regime configurations and lead to the emergence of new combinations, e.g. the integration of battery technology in cars, ranging initially from starter batteries, to a combination of battery and internal combustion engine in hybrid cars, to pure battery-electric vehicles. Second, knock-on effects and innovation cascades an be observed where a technological innovation triggers change in related technological fields or leads to increasingly radical changes through interlinkages with other social phenomena, e.g. in the case of e-mobility, renewed interest was caused by developments in battery technology in non-automotive applications as well as its interrelatedness with energy transition issues and efforts towards more livable cities. Third, a fit-stretch pattern emerges where an innovation that was developed as a technological substitute able to ‘fit’ in current system configurations over time turns out to be a radical innovation, e.g. a stretch may occur from developing electric vehicles to broader conceptualizations of e-mobility as part of a fundamentally different transport regime. Fourth, hype-disappointment cycles are common phenomena, especially in the field of alternative vehicles where in the beginning expectations are high, causing a hype around the new technology, often resulting in disappointment when it cannot meet all those expectations. This pattern illustrates for instance the alternating phases of interest that can be observed for electric vehicles and fuel-cell vehicles. Finally, a niche-accumulation pattern can be observed where a niche innovation subsequently moves from its initial small technological niche (R&D or demonstration projects) to ever larger market niches, which is for instance also envisaged for electric vehicles being developed and tested in different fields of applications across various market niches, ranging from pilot projects to fleet applications in specific market niches (Geels & Kemp, 2012, p. 61 ff.).

A similar approach, focusing on the individual event sequences and generalizable, shorter-term mechanisms against the background of a broader transition dynamic, has been proposed by de Haan and Rotmans (2011) based on the assumption that any transition pathway consists of distinguishable patterns. This approach is explicitly distinguished from Geels and Schot (2007), because it is related to transitions thinking based on complex adaptive systems and classic systems theory, which is a source of transition management rather than the MLP. Furthermore, the focus is on individual patterns, rather than transitions as a whole. However, the basic approach of deducing basic propositions from theory is similar, and even though the approach is different from Geels and Schot, it is argued that basic transition thinking is similar and that "since a transition pathway also is a transition tale it ought to be possible to retell it with the patterns proposed in this article" (de Haan & Rotmans, 2011, p. 91).

Three patterns are identified – reconstellation, empowerment, adaptation – which are basically distinguishing top-down, bottom-up or system-internal impulses for change. Such a systematization is clearly derived from a conceptualization of societal systems as complex adaptive systems. According to classical system theory, change is caused by factors outside the system and by dynamics that are not 'normal'. Since the system in question is a societal system, external influencing factors can be characterized to work either from top-down or bottom-up. The conceptualization as a complex adaptive system allows for a third classification, i.e. change induced from within the system via e.g. feedback loops and gradual evolution as a 'normal' process. So, first, a reconstellation pattern describes a top-down pressure for change, from outside a specific societal sub-system or by government. Second, an empowerment pattern describes the processes where niche-innovations rapidly break through and become viable alternatives for an existing regime. Third, an adaptation pattern occurs when the system is changed from within, in order to secure its persistence or optimize the way it functions. This may sometimes require quite fundamental re-structuration or innovation processes, in the case of adaptation they are initiated from within established regimes (de Haan & Rotmans, 2011, p. 96).

Even though these patterns are different from the work of Geels and Schot (2007) with regard to conceptual background and analytical focus, they can indeed be found within the more elaborate transition pathways as well. Also, both approaches may seem to oversimplify transition dynamics in the real world (especially the very basic patterns identified by de Haan & Rotmans (2011)) and may be criticized for simultaneously explaining “everything and nothing”, due to their very general and abstract nature. However, this type of conceptualization can make sense, when considering the basic aim and explanatory style of transition studies in general, and MLP analyses in particular. When studying long-term complex phenomena, such as transitions, a broad heuristic framework, such as the MLP, is suitable. However, in order to arrive at generalizable and valid results when studying such phenomena, heuristic and process-oriented approaches need to produce patterns or mechanisms, i.e. repeatedly and typically occurring, causally linked event sequences. This is also important for systematization and comparability across qualitative case studies or narratives and may pave “an epistemological middle way” (Geels, 2011, p. 35 f.) between quantitative and variable-oriented research on the one hand, and more constructivist methodologies on the other (de Haan & Rotmans, 2011, p. 96, 100; Geels, 2011, p. 35 f.).

3.1.3.3 Niche-Regime Dynamics

The discussion of transition patterns and pathways, which have been developed to refine the MLP and explain typical dynamics of change in more detail, shows that, in principle, the various types of interactions between niche-, regime-, and landscape-levels are decisive for understanding transitions. However, the concrete patterns and pathways also imply that interactions between niches and a regime are of particular relevance, because a transition is, in essence, a change of regime, and the specific type of change, the nature of the new regime depends on the specific kind of ‘variation’ emerging in niches, from which new components can be ‘selected’. Niches thus provide the seeds for change; they determine the range of alternatives that have been nurtured in protected spaces, which are ‘available’ for new trajectories to develop at all (Smith, 2007, p. 429). While landscape developments can be both disruptive or stabilizing, the interactions between niche and regime can be much more varied and determine in a more qualitative fashion what exactly changes and how. In transitions, a niche-innovation (which can be anything, ranging from a specific technology, to an alternative social practice, new rules or guiding principles, or even changing societal norms) has to replace an existing regime. It does so either by overthrowing it in a disruptive change process, or in a more step-wise incremental way, sometimes even actively enacted from within the regime, e.g. by slowly adjusting established rules, or optimizing a regime continuously or only in some places, which in the end accumulates and amounts to more fundamental change. Without a doubt, the landscape is important as well – historically, factors such as macroeconomic crises, environmental catastrophes or global cultural development trends have always been important for triggering societal change. However, if one wants to understand especially shorter-term phenomena and ongoing developments that might only someday turn out to have been part of a broader transition, niche-regime dynamics are of particular relevance for a number of reasons:

First, a focus on niche-regime dynamics means a focus on concrete actors and their strategies. While the landscape level contains broader trends or disruptive crises that cannot be influenced directly by actors and which are emergent (social or ecological) phenomena, actual strategies and practices that shape concrete systems and room for actively guided change or persistence exists only at the niche and regime level – because they describe degrees of structuration in the social practices carried out by actual people. The landscape which is a bit clumsily conceptualized as the level with the highest degree of structuration, thus containing no scope for direct human action at all, is in fact different in nature and indeed external to processes of social change: "While niches and regimes work through sociological structuration, sociotechnical landscapes influence action differently. Sociotechnical landscapes do not determine, but provide deep-structural 'gradients of force' that make some actions easier than others" (Geels & Schot, 2007, p. 403). Thus, when interested in shaping transition dynamics or the socio-political processes involved, the more agency-prone categories of niche and regime are particularly relevant and helpful in guiding empirical analyses.

Second, especially when focusing on (potential) transitions in the making, a focus on niche-regime dynamics is important. A transition can only be identified in retrospect and with landscape developments it is clear that these macro-level phenomena and their actual impact will only be observable in retrospect. This can be illustrated by a relatively recent example: Whether the nuclear catastrophe at Fukushima will have had a role to paly in a broader energy transition can only be determined in retrospect – while the fact that the German government has politically decided that an energy transition is to be carried out is a much more relevant and observable phenomenon, which can be analyzed in its concrete form or choice of instruments, allowing for a discussion of the suitability of concrete policies and potential alternatives.

Third, the example of the German energy transition and Fukushima also highlights another aspect in favor of focusing on niche-regime dynamics: landscape developments or concrete events, such as the Fukushima incident, have no independent meaning of their own. Whether they exert pressure on existing regimes or stabilize established development paths depends on how they are perceived by concrete actors and what they make of it regarding their strategies and social practices. Landscape developments may come to be seen as something that confirms established strategies, thus contributing to regime stabilization and persistence, or they may make established strategies or guiding principles seem to have lost their effectiveness and raise questions about adapting behavior or thinking about radically new ways of doing things, thus contribute to the emergence of niches. Whether a landscape event or trend is seen as an indicator for a weakening regime and, what is more, as a concrete pressure for change, depends on perceptions and interpretations, e.g. in the form of policy formulation (Smith, 2007, p. 430). In the case of Fukushima it can be argued that even though it is used as legitimization for a government-induced energy transition project focused on renewable energies, it could in theory have just as well been used as an argument for increased efforts in nuclear R&D or a political focus on technologies improving safety and reducing risks.

Finally, it should be noted that some caution is warranted when studying niche-regime dynamics in concrete empirical cases, especially with regard to the definition of what exactly constitutes a niche or a regime. When interested in actors and strategies in transition processes and applying a multi-level perspective, one tends to group actors as 'regime actors' or 'niche actors'. This is problematic because this is often done in transition studies, and it is done without explicitly laying out the reasons for assigning a 'niche'- or 'regime'-affiliation. However, this has consequences for the subsequent analysis and it also contains implicit assumptions regarding problems and research questions as well as judgments about barriers and drivers for change (Pel & Boons, 2010, p. 1251). Furthermore, it is problematic from a conceptual point of view to describe specific actors as niche- or regime-actors. Levels in the MLP describe degrees of structuration and thus the deep structure that can, as a metaphor, help to better understand the basic principles explaining specific routines, strategies or social practices. It is thus important to differentiate between concrete actors and a regime embodying established structures or deviating activities that can be characterized as niches. The example of e-mobility clearly shows that the delineation of niche and regime is not clear-cut, neither in terms of actors nor in terms of structure. For instance, e-mobility can in practice be part of established regimes of car-dependency and private car ownership, or an element of sustainable urban mobility based on carsharing and intermodality, or the central technology functioning as the interface of a completely new system linking mobility and energy systems. Similarly, large car manufacturers are involved in developing electric vehicles and thus contributing to an emerging e-mobility niche, while they predominantly reproduce regime structures in their day-to-day business. So, even though delineations are often overlapping or fuzzy, also in this thesis it will be referred to niche- or regime-actors, in order to express basic power relations or strategic orientation. Nonetheless, it should be noted that niches or regimes do not describe, in theory, concrete places or people. Of course, a strict separation of structure and agency in practice is not possible and only makes sense for analytical clarity. For instance, differentiating between different groups of actors and degrees of structuration at niche or regime levels may help avoid a 'bottom-up niche bias' (discussed in ch. 4.3.2) where, in some cases unduly oversimplified, the focus is on 'green' niche innovations struggling against regimes as monolithic barriers for change.

It is therefore important to focus on the concrete and case-specific interactions between the levels of niche and regime. Some basic concepts and relevant processes have been identified in transition studies, focusing more in detail on the way that niches gain momentum and in what ways niche and regime dynamics are mutually interlinked – instead of simply being opposed and struggling against each other. For instance, the concept of 'niche-regimes' is used to describe a situation where a specific niche has grown into a visible alternative being in actual competition with regime structures, while not (yet) replacing an established regime as a whole. This conceptualization highlights the fact that there are intermediate dynamics or stages and that there are varying degrees of tension between niche and regime. A conceptualization of niche-regimes may also help to focus on the 'radical' innovations and alternatives that emerge from smaller niches, which are clearly opposed to the established regime, and the viable competing options to established regimes – instead of the more symbiotic innovations or smooth change processes that are part of normal regime adaptation and optimization processes (de Haan & Rotmans, 2011, p. 93).

This juxtaposition of radical and more symbiotic niches also highlights the basic dilemma in niche-regime interrelations. The chances for a niche to diffuse widely are highest when there is some degree of fit with established regime structures. While in some cases a smooth and step-wise integration of niche-innovations into an established regime may over time and in the course of learning processes lead to regime change, it is more likely that the result is an incremental adaptation of the regime without the more fundamental kind of change characterizing a full-blown transition. In contrast, a more radical niche that questions and opposes basic regime structures will rarely manage to break through and diffuse widely, especially when the regime is stable and not, for instance, weakened by landscape pressure. This type of niche contains the potential for fundamental change envisioned in transitions, but it will often disappear, because it finds no way of linking itself to the regime and growing into more dominant structures (Smith, 2007, p. 430). Zooming in on concrete niche-regime dynamics, variations and cases 'in between' these two extremes or ideal-types can be identified. One approach of studying the concrete dynamics involved in niche-regime relations is to focus on processes of translation between niches and regimes and how these mutually influence developments in niches and regimes (Smith, 2007). Three basic forms of translation have been identified: First, second-order learning processes lead to the identification of (sustainability) problems that are rooted in the deep structure of a regime and this informs the process of niche-building. In this way, regime structures are translated into a different frame of reference with different problem perceptions that form the core of an emerging niche (Smith, 2007, p. 443, 446). Second, the radically different visions emerging in niches are in some cases translated back into 'regime language'. The niche has shown that alternatives to an established regime are possible, or can at last be imagined, and the subsequent task then is to convey this to the regime level. Usually this means that elements within a niche are sought that are flexible enough to be interpreted in regime terms as well. For instance, if e-mobility is reduced to an issue of drive technology, it can simultaneously be part of a more alternative niche and the established regime. However, this example shows that "[u]nder this kind of translation, there is wider diffusion of a more shallow sustainability" (Smith, 2007, p. 446). Third, there are processes of mutual translation where regime incumbents and niche actors are more directly involved with each other, e.g. in large demonstration projects, real-world experiments or transition management projects. Ideally, in these settings processes of second-order learning are facilitated and a mutual understanding of the different basic assumptions and guiding principles can be reached. Eventually this may lead to a growing niche-regime, increasing the potential for a wider transition (ibid.).

Like 'translations', expectations and future images can play an important role, especially when niche-regime dynamics concerning a specific technology are concerned, as in the case of e-mobility. Some lessons have been learned with regard to images of the future role of new technologies, which can be used to argue that a cautious analysis of ongoing dynamics between niche and regime is important. Similar to the translation process from the regime to the niche level, future images of technologies are in the beginning shaped by established regime structures: current cultural norms and values shape expectations and new technologies are envisioned as substitutions of existing technologies serving unchanging needs. The possibility of completely new social practices emerging around different needs in the future or a new combination of old and new technologies is often ignored. At the same time, niche actors typically engage in translation processes that focus on promoting the specific technology, around which the niche is formed. Since they aim at fostering diffusion, they usually exaggerate the advantages of a new technology, and this may be successful for a while, especially when a new technology is suddenly appearing or experiencing development leaps and thus triggers fundamental shifts in visions of the future. When high expectations eventually cannot be met, which is likely for radical innovations that cannot easily be integrated in an established socio-technical system, disappointment and disillusionment can weaken the niche substantially (Alkemade & Suurs, 2012, p. 450; Budde et al., 2012, p. 1074). This basic discrepancy in future visions and in the related niche-regime dynamics, is also expressed by the fact that processes of diffusion and societal embedding of a new technology are usually not problematized to a sufficient degree (Geels & Smit, 2000, p. 877 ff.).

Thus, images of the future may vary within and between niches and the regime, which may lead to an eventual weakening of the niche, or possibly also to these images serving as boundary objects of translations between niche and regime levels. This type of dynamic also implies that the boundaries between niche and regime can become blurred or shifting. This is highlighted by the example of large car manufacturers investing in R&D for e-mobility while at the same time there are visions of future e-mobility that is more sustainable also in terms of more intermodal transport or carsharing, which threatens the basic business models of the automotive industry. Even in such a case, which at first glance amounts to not much more than technological development and diffusion of electric vehicles, various socio-technical configurations are emerging and these cannot always clearly be assigned to the regime or a specific niche. It also stresses the point that specific actors cannot easily be classified as regime- or niche-actors, not only due to conceptual considerations, but also because a strict delineation of niche and regime is not always feasible. For empirical analyses it is thus important to focus on the way that specific actors position themselves, e.g. in translation processes, and on actors that move between niche and regime levels, e.g. termed “pragmatic system builders” (Smith, 2007, p. 447), facilitating social learning.

3.1.3.4 Multi-Regime Dynamics

Apart from sometimes fuzzy boundaries between niche and regime in transition studies in general, the specific case of e-mobility furthermore cuts across multiple socio-technical systems and the associated regimes. Multi-regime interactions have been identified as an understudied, but promising field within transition studies, because a number of environmental innovations have emerged that cut across regime boundaries, such as the electric vehicle but also biofuels, combined heat and power (CHP), or using biomass from waste for generating electricity (Geels, 2011, p. 32; Konrad et al., 2008, p. 1191; Nilsson et al., 2012, p. 57). Developing e-mobility as a new drive technology and form of personal mobility affects first and foremost established transport or mobility regimes. Apart from that, the energy system plays a central role as a newly emerging actor in the field of mobility, providing electricity for powering electric vehicles. Especially when considering the potential of electric vehicles providing storage capacity in the context of an energy transition based on renewable energy sources, the energy regime is itself affected by developments in the field of e-mobility. Integrating electric vehicles in energy infrastructures will most likely require new mobility and energy services that go beyond traditional business models in energy provision, thus affecting energy system regimes. Finally, information and communication technologies (ICT) will become more important with regard to linking vehicles and energy infrastructures as well as different modes of transport and facilitating mobility services, which is relevant where developing e-mobility includes intermodal transport and carsharing services.

Apart from cases such as e-mobility, where a central technology creates new links and is located at the intersection of otherwise unrelated regimes, there are other cases where, for instance, two separated regimes are linked by a third regime (Konrad et al., 2008, p. 1197). One might also argue that e-mobility is such a case, in so far as ICT functions as an enabler of e-mobility by providing the possibility to link electric vehicles and energy infrastructures. Distinct regimes may also be identified, which fulfill a similar societal function and thus directly compete with each other. An example in the field of mobility is when a distinction is made between public and private transport regimes, or between separate regimes related to the different modes of transportation. Less competitive multi-regime dynamics may be observed where different regimes are exhibiting similar structures. In such a case there may be learning processes or synergy effects resulting from multi-regime dynamics (Konrad et al., 2008, p. 1198). In the case of e-mobility, it can be argued that transport and energy regimes are currently struggling with similar structural challenges. Both sectors are faced with increasing competitive pressure and concentration processes: in the energy sector due to deregulation and liberalization of energy markets and in the automotive sector due to saturated markets, at least in industrialized countries, and overcapacity. Developments in the field of e-mobility may thus either lead to symbiotic developments towards sector convergence, or to a situation where they enter into competition for market shares in a newly emerging e-mobility regime (Rammler, 2011, p. 19).

A systematic typology of multi-regime dynamics has been developed by Raven & Verbong (2007). They differentiate between four basic types of multi-regime interactions. First, there may be a competitive relation where two or more regimes fulfill a similar societal function. Second, there may be a symbiotic relation where regimes are closely connected and depend on each other or mutually benefit from each other in fulfilling their specific societal function. Third, there can be integration of formerly separated regimes, or parts of regimes, into a single new regime. Finally, there can be spillovers from one regime to another, e.g. when they are structurally similar, linking them together by learning and adaptation processes (Raven, 2007, p. 2199).

The examples related to the case of e-mobility highlight that the regime concept can be applied to various empirical objects of study and levels of analysis – always depending on the research question. For the purpose of this thesis, the role of the electric vehicle as a 'new' technology is central and it is asked whether socio-technical change patterns evolving around this technology can lead to more sustainable forms of mobility. This includes a view on the energy system, thus the focus is on multi-regime dynamics emerging around a radical innovation connecting different regimes – rather than an enabling regime (e.g. ICT) linking two otherwise unrelated regimes (e.g. energy and transport). Furthermore, the focus on sustainable mobility in a broader sense leads to a definition of an overall mobility regime, rather than a very detailed assessment of different transport sub-regimes (e.g. car-based, public, walking and cycling) and their basic rules of functioning. In this thesis, societal function is defined more generically, as 'providing mobility' and the different transport modes are understood to be different elements of an overarching mobility regime, which of course includes various sub-regimes, not only related to different modes of transport, but also the political and regulatory framework conditions, market and industry dynamics, science and R&D, and user behavior in the field of mobility.

A similar case where a specific technology has played a central role in emerging multi-regime dynamics is that of biomass from waste used as a source for electricity generation in the Netherlands. The formerly separated waste and electricity regimes began to interact when new ways of incinerating waste became interesting for energy companies looking for green energy technologies. A symbiotic relationship began to develop where waste companies also become electricity producers and energy companies also collect and process waste as a renewable energy source. A decisive aspect in this process was that the basic idea of 'waste' has been reframed and the new "concept of 'biomass' has emerged as the binding element in the interaction process" (Raven, 2007, p. 2206). Such a fundamental change in what waste is understood to mean, turning it into a valuable resource in an emerging energy system based on renewable resources, also means that the involved actors, in this case waste processing companies and energy producers, re-defined their roles and re-organized part of their business models and strategies. Thus, basic frames of reference that in the past separated two different regimes co-evolved and changed into a new and more symbiotic relationship between those regimes (ibid.).

It is proposed that a similar situation can be expected for the case of e-mobility, because the electric car as a technological artifact is a factual link between energy and transport regimes and, what is more, a broader understanding of e-mobility may evolve as a new concept, similar to that of 'biomass', that implies also deeper changes as regards role perceptions and basic functions. Again, there is a major difference between a situation where electric vehicles diffuse and substitute for conventional cars with the new 'fuel' provided by energy companies rather than the oil industry or, in contrast, a situation where e-mobility emerges as a system innovation with fundamentally different mobility patterns, business models, technological infrastructures and socio-political implications. Why should multi-regime dynamics be considered as a potentially important element in the emergence of system innovations (in the case of e-mobility, or also the presented biomass case)? Referring back to Giddens and its central tenets in the context of the MLP, it is argued here that the emergence of a technological artifact such as the electric vehicle that creates linkages between formerly separated regimes can have a potential for inducing second-order learning and structural change. In a setting where multi-regime dynamics unfold, actors are confronted with the diverging logic of another regime, its modes of signification and legitimation, its established patterns of resource allocation and accepted power constellations, and they are thus in a way forced to reflect on their own premises and guiding principles, in order to be able to make sense of the new situation (Schneidewind, 1998, p. 318; Schneidewind & Petersen, 1998). At least in principle there is a chance for opening up creative space, where tensions and processes of reframing basic rule systems and frames of reference lead to a greater potential for the emergence of a system innovation.

If such potential came to be realized and a system innovation were to emerge, it is hardly possible to predict or assess ex ante what the new socio-technical system and regime would be like as regards its concrete shape and basic structure. This is another aspect that makes a focus on multi-regime dynamics essential for the case of e-mobility and, in fact, any future oriented analysis of potential system innovations. Looking at historical cases of transitions or system innovations it is possible to, ex post, identify a specific regime that has emerged and trace the way it has developed, identify patterns of change that have played out over the course of history, and in this way also observe how boundaries of previously separated regimes may have become blurred or integrated into a new regime (as in the case of biomass, for instance). This is much less possible when one is to carry out an ex ante analysis of a potential future transition. Since it is not clear what a future regime may look like, and its emergence will result from a contingent process, one has to be careful to broaden the analysis beyond the regime in question (in this case the mobility regime) and also take account of other regimes that may have an impact on it or newly emerging interrelations with it (in this case the energy regime, for instance) (Konrad et al., 2008, p. 1191, 1197).

In sum, e-mobility is a challenging but also promising case from a multi-level perspective. It highlights the difficulties in delineating niche and regime, since national governments and large car manufacturers are involved in developing the e-mobility niche. In addition, it is a case where multi-regime dynamics have an important role to play, due to the new linkages created. It is thus important to focus on e-mobility as a field of innovation that cannot meaningfully be analyzed by a traditional focus on sectors or a specific regime. Especially regarding its potential for a future system innovation, it is imperative to pay attention to the many interlinkages e-mobility creates between, first and foremost, energy and mobility regimes, and also the factors fostering or hampering the development of e-mobility, which may be found across different regimes.

3.1.4 Critical Reflection: Shortcomings and Limitations

Criticism of two sorts should be discussed here: First, a critical perspective will be presented on the theoretical foundations of the MLP and its value in conceptualizing and explaining transformation processes. Second, criticism relating to applications of the MLP in transition studies as an emerging field of research will be discussed. These two different dimensions sometimes get mixed up and may in some cases lead to an unduly harsh critique or rejection of the MLP. In order to understand the basic theoretical value, and the limitations, of the MLP on the one hand, and to provide a critical perspective on the way that the MLP has been applied on the other hand, these two aspects should be treated separately. Even though a clear separation is not always possible, a distinction in principle is important, because the first type of criticism relates to conceptual difficulties and limitations, while the latter basically has to do with weak application.

In sum, the previous chapters have shown that the MLP provides an overarching heuristic framework that has a particular strength in analyzing transition processes in socio-technical systems defined by their specific societal function. The regime concept is thus a helpful analytical category in cases where the research question is concerned with "future more sustainable alternatives to fulfill these functions and not primarily in the fate of a specific technological configuration" (Konrad et al., 2008, p. 1192). Despite this broad aspiration, one weakness of the MLP approach is its view on co-evolutionary processes of change. In many transition studies it is analyzed how green niche innovations struggle against established regimes and the focus seems to be on the necessary changes at the level of regimes that would allow a transformation built around the specific niche innovation – rather than a clearly focused analysis of co-evolution of technological and social elements across niches and regimes. In that sense, van den Bergh et al. have quite insightfully characterized the MLP approach regarding transitions as "a co-evolutionary (or, more accurately, co-dynamic) interplay between processes functioning at the different levels of landscapes, regimes and niches" (van den Bergh et al., 2011, p. 10).

It can be argued that evolutionary approaches and innovation studies as dominant theoretical background have introduced a bias towards the role of technological innovation, i.e. a focus on niche innovations and the way that they get selected through evolutionary processes and overturn a regime. This critique is not to say that technology as a factor is to be ignored, which would be a wrong conclusion. Technology can be very powerful indeed, but it is not independent of its social surroundings. It is important to understand the interrelations and co-evolutionary dynamics, because neither will technology emerge as a savior in relation to any of the severe sustainability challenges of today, nor will it be possible to ignore technological innovation or will it make sense to neglect technology as an instrument to improve socio-technical systems (e.g. renewable energy technologies, more efficient fuels and drive technologies in the transport sector etc.).

The evolutionary perspective on which the MLP is based has also been criticized at a more fundamental ontological level. Concepts of variation and selection are criticized for unduly simplifying the basic mechanisms involved in social processes of change. Selection is treated as a process that functions independent of deliberate human action and thus the conditions for change are conceptualized as a factor that is external to the actual process of transformation. Actors are relatively passive, reacting to system shocks or crises. The resulting transformation processes are further conceptualized as shifts between phases of equilibrium and it is assumed that the different phases of stability and radical change can be clearly separated. Proponents of relational approaches based on 'flat ontologies' (Geels, 2010, p.507), e.g. Actor Network Theory (cf. Latour, 1987) or Social Construction of Technology approaches (Bijker et al., 1987), argue that the focus on external factors and selection environments is overly structural and denies the role of agency in transformation processes. It is assumed that actors and technological artifacts and infrastructures are interrelated in 'flat' networks – rather than structural hierarchies – and that actors are engaged in processes of negotiation and deliberation. Transitions are then conceptualized and studied as outcomes of such deliberative processes rather than macro-level phenomena of shifting equilibria (Cooke, 2011, p. 109; Garud & Gehman, 2012, p. 983 f.; Geels, 2010, p. 502; Geerlings et al., 2009, p. 410).

Such a fundamental critique of evolutionary approaches is important, in order to raise awareness for the basic assumptions inherent in evolutionary thinking, especially when applied in the study of socio-technical sustainability transitions: "From an evolutionary perspective, the image of a journey is one of making 'progress' through technological disruptions – of moving forward – while battling the remnants of the past" (Garud & Gehmann, 2012, p. 986). In view of current sustainability challenges, traditional concepts of progress, achieved through technological innovation and economic growth, may be counterproductive. It is therefore important in the analysis of sustainability transitions to recognize and be explicit about the normative diversity involved – and its theoretical as well as practical implications. For theoretical analyses this means that frameworks should rather be open with regard to complexity and diversity in transition processes, "embracing evaluative diversity and recognizing divergent normative vectors"(Stirling, 2011, p. 84). This means a partial deviation from innovation theory, as regards some of its basic premises of one-dimensional economic and technological progress, and instead awarding a more prominent role to agency and societal deliberation processes as well as social innovations or social practices that do not fit a primarily technological logic of innovation as progress (Garud & Gehmann, 2012, p. 986; Koch & Grünhagen, 2010, p. 234; Stirling, 2011, p. 83 f.; Volkmann & Tokarski, 2010, p. 154).

A weak perspective on agency and the politics of transitions is a general criticism of the MLP and it has been shown that this can, at least partly, be explained by the basic assumptions of evolutionary thinking inherent in innovation studies. However, when reflecting on the sociological concepts that also feed into the MLP and the normative diversities inherent in almost any theoretical approach, it can be argued that this conceptual weakness is just as much a problem of operationalization and application. Despite the seemingly 'structuralist' MLP graph (see Fig. 8), the role of human agency in transitions is explicitly addressed by referring to structuration theory and the role of knowledgeable actors as well as a focus on niche-regime dynamics with a view to power constellations among concrete actors and by clearly distinguishing levels of structuration in social practices, rather than grouping actors in fixed niche or regime categories.

In transition studies in general, a tendency can be observed to foreground the role of technology as the central element around which transitions evolve more or less mechanically and where the complex dynamics involved are unduly simplified, e.g. by applying the MLP in a rather superficial way (de Haan & Rotmans, 2011, p. 91). Especially for the purpose of this thesis, studying e-mobility as a potential system innovation – rather than diffusion processes of electric vehicles – such an oversimplification needs to be avoided. It is therefore important to be clear about what the MLP is, and is not, in terms of its specific explanatory style and research approach. The MLP can be grouped among middle-range theories that offer heuristic frameworks rather than precise models, which aim at explaining causal links between pre-defined variables. The MLP instead focuses on processes, complex dynamics and contingency, in order to explain transitions (Geels, 2011, p. 34 f.). It is thus well suited for approaching research questions such as the one posed in this thesis. The potential for e-mobility to develop as a sustainable system innovation depends on various influencing factors that will become relevant only in mutual types of interactions and in the context of emergent process sequences, which makes it hardly possible to identify a manageable selection of independent variables and clearly hypothesize what their relation is to a narrowly defined dependent variable. The concept of system innovation or transition captures complex and structural change across different societal domains, which makes it difficult to carry out a variable-oriented analysis in any meaningful way. Due to this empirical complexity, an open framework like the MLP may be better suited, with the consequence though that “the MLP is not a ‘truth machine’ that automatically produces the ‘right’ answers when the analyst enters the data” (Geels, 2012, p. 474). Furthermore, this means that, as regards methods, narrative explanations play an important role. Since these always include elements of interpretation by the analyst, they have to be carried out in a transparent and detailed way, in order to ensure scientific rigor. The difficulties involved in applying such methods should not lead to their outright rejection, since they can contribute to a more profound understanding of complex phenomena such as transitions (Geels & Schot, 2010, p. 101).

However, these types of overarching frameworks are generally difficult to operationalize and apply to empirical cases in meaningful ways. No straightforward hypotheses can be built and delineating the object of study as well as tracing influencing factors and multi-level dynamics is rather part of the research question, than premise on which the research is built. The strength of the MLP lies thus in identifying the relevant questions and opening up new perspectives, rather than prescribing a model explaining concrete transition dynamics for specific empirical cases. The MLP has been developed as a sort of boundary object where many disciplines can relate to each other and communicate their different understandings and concepts of transformation processes (Grin et al., 2010, p. 4). It functions as a broad heuristic aiming at a comprehensive understanding and exploring of transitions as a whole. This explains why the MLP is crafted as a 'macro-level' framework but it also shows that using it as a mechanistic and structuralistic theory is a misuse. It serves as a guiding basic framework, which allows, and requires, the analyst to "zoom in on actors" (Geels & Schot, 2007, p. 414) at the micro-level and in concrete empirical cases. Even though the MLP graph depicts structural levels and basic dynamics, these are the outcome of social practices, deliberation processes and power struggles among actor groups (ibid.).

Thus, the usefulness of an MLP analysis will in the end have to be determined empirically. Despite a continuously growing body of case studies and similar applications of the MLP, issues of operationalization and empirical validation of the regime concept are widely debated. General insights are that the MLP's central concept of regime does not per se prescribe a specific scope or unit of analysis. Drawing the boundaries of a specific regime or socio-technical system will have to be determined in relation to the societal function that is in the focus of the respective study and in relation to the specific research question. However, this should be done in a clear and explicit fashion and by pointing out the analytical strength of the regime concept for a specific case. Such methodological openness and clarity is lacking in many empirical case studies so far (Geels, 2011, p. 31; Holtz et al., 2008, p. 624 ff.; Markard & Truffer, 2008, p. 606 f.).

Apart from defining the 'correct' way of applying different conceptual levels empirically, it seems important to keep in mind that transition studies are essentially part of a critical social science tradition and aim at "[engaging] subjects in processes of reflection in ways that feed back into their practices, contributing to a re-orientation towards sustainable development" (Smith et al., 2010, p. 445). Thus, with regard to empirical operationalization it may also make sense to focus on regimes not only as a specific conceptual level in the MLP, but also as a relevant notion regarding the structuration of local practices (Shove & Walker, 2010, p. 474; Geels, 2011, p. 37). Reflexivity with regard to theoretical concepts and sensitivity with regard to the respective empirical case is needed, in order to "question the meaning and significance to action of levels on the ground, from the perspective of subjects" (Genus & Coles, 2008, p. 17). Transition studies are thus faced with tensions between aiming at becoming established as a field of research by the standards of the science system (publications, citations, quantitative methods, scientific rigor based on traditional standards) and its inherent desire to have practical implications, to act as ‘transformative science’ (cf. Schneidewind et al., 2015 forthcoming; Schneidewind & Singer-Brodowski, 2013; Schneidewind & Augenstein, 2012).

A related difficulty is that the MLP is mainly applied ‘ex-post’, explaining historical cases of transitions. In these cases, starting and end points of transitions can be identified and the dynamics and patterns emerging in the process can be traced. Ongoing transitions, or desired transitions towards sustainability are thus much more difficult to be studied. The following chapter therefore deals with the question of whether and how it is possible to apply the MLP not only ‘ex-post’ but also in a (potential) ‘ex-ante’ situation. Two related frameworks, transition management and strategic niche management, will be discussed as examples of more future-oriented approaches with a focus on shaping and steering transition processes. And it will be asked whether the MLP-framework can be adapted in such a way that it fosters a better understanding of current dynamics – whether or not these amount to an actual, full-blown transition eventually.

3.2 Analyzing “Transitions in the Making”

Transition studies are motivated by a concern for sustainable development and are thus inherently future-oriented. The underlying research question from which this field of research emerged is, basically, how to facilitate transitions towards future sustainability? It has been recognized that sustainability challenges in fields such as energy, transport, water or food can only be met by achieving structural transformation processes in complex societal systems. These challenges are approached scientifically by referring to established theories and fields of study, e.g. evolutionary economics, science and technology studies, complex systems theory or sociological grand theories, in order to learn about the phenomenon of transformation in general. The MLP has emerged as an overarching heuristic for analyzing past transitions, identifying general patterns and mechanisms of change in socio-technical systems. Based on the MLP, orientation towards the future comes in the form of a focus on “transitions in the making” and is spelled out in two prominent approaches in the field of transition studies, namely Strategic Niche Management (SNM) and Transition Management (TM).

Strategic Niche Management is an approach that focuses on fostering niches as the central nucleus for radical novelty from which transitions evolve, while Transition Management entails a broader perspective on the governance of transition processes across the different levels and phases of the MLP. Governance for sustainability transitions is conceptualized as a complex and long-term process. Assuming this type of complexity, and despite the fact that the term 'management' in SNM and TM suggests otherwise, it is argued that transitions cannot be managed in any straightforward manner, or stimulated by traditional command-and-control policies – at least "not in a simple way" and so "all one can do and hope for is to exercise some influence, or leverage, to modulate ongoing dynamics" (Hoogma et al., 2002, p. 198). Strategic Niche Management and Transition Management are therefore not straightforward management tools, but rather approaches that are based on the premise of such complexity and which can serve to guide interventions in a dynamic context. In that sense, "transition management and strategic niche management are portrayed as governance in themselves" (Nilsson et al., 2012, p. 52 f.).

So, even though research on technological innovations, innovation systems, and science and technology studies have been a major influence on transition studies, policy and political processes have become central issues, especially when the focus is on envisaged future transitions to more sustainable energy or transport systems. The broad definition of socio-technical systems as the basic unit of analysis of transition studies necessarily includes policy regimes as a central type of sub-regime characterizing the overall configuration of any specific socio-technical system. The central delineation criterion of such a system, i.e. the fulfilling of a generic societal function, also points to the central role of the political sphere, because this is where societal needs, problem agendas and preferences as well as instruments for achieving societal goals are negotiated and implemented (Kern & Howlett, 2009, p. 392). Thus, public policy has been identified as a key factor for influencing transitions and therefore SNM and TM have been developed as policy approaches suitable for dealing with complex issues of sustainable development.

The basic challenge that policy in this field is faced with is uncertainty – with regard to the complexity of sustainability challenges, the long-term and dynamic nature of change processes, and the resulting array of questions emerging from these framework conditions when aspiring to design policies and policy instruments for shaping the future. The basic premise from which SNM and TM have been developed is to deal with this type of uncertainty. Therefore, both concepts include a focus on a desired future, while keeping concrete instruments adaptable and open to reflexive processes of re-adjustment.

Another challenge that SNM and TM aim to address is to deal with conflicts emerging between bottom-up initiatives and radical novelty and established actors representing vested interests and using their power to hamper efforts towards sustainability transitions (Voß et al., 2009, p. 281). Referring back to the MLP, the central rationale of TM and SNM as future-oriented approaches for fostering sustainability transitions is to facilitate “niche-regime dynamics”. It is assumed that the seed for change emerges in niches and that transformative dynamics need to move to the regime level, because, from a ‘pessimistic’ point of view, they aim at changing currently unsustainable regimes that are categorically and fiercely opposed to any kind of change, and, from an ‘optimistic’ point of view, only powerful and resourceful regime actors have the capacity to up-scale niche innovations and to significantly contribute to systemic change. As shown by the different transition patterns, in reality there will be variations with regard to the relations between actors within and across niches and (sub-)regimes. SNM and TM deal with these processes, in practice and in theory, by identifying niches with a potential for influencing regime structures, studying ways of improving niche development and fostering processes of up-scaling.

With regard to the overall question of this chapter – how to deal with transitions in the making? – SNM and TM both depart from the premise that the potential for system innovations depends on well-developed niches and the way that they successfully manage to influence regime structures[4]. The basic aim is to analyze and understand such processes and, based on this, to develop suggestions and instruments for improving up-scaling in practice.

3.2.1 Strategic Niche Management (SNM)

Strategic Niche Management is an approach that aims at developing and nurturing protected environments, i.e. niches, in which new technologies and alternative social practices can flourish and grow, eventually serving as the starting point for regime change. This type of protection is needed, because radical technological or social innovations can hardly emerge when they are from the beginning subject to adversary selection pressures by the established regime, i.e. if they are in sharp contrast to dominant rules and guiding principles. Niches are therefore needed as a protected space in which radical alternatives can mature and eventually expand to replace the existing regime (Markard et al, 2012, p. 957 f.; Wells & Nieuwenhuis, 2012, p. 1683). In view of this intended expansion, it is also important not to over-protect, but

[4] A similar discussion of the concepts of SNM and TM has been published in a co-authored conference paper: Sterk, Augenstein & Wehnert (2014).

to open up the niche step-wise. This can be termed "selective exposure" and illustrates the interrelations between niche and regime: "Strategic niche management is a process in which a new technology and the existing environment can adjust to each other, because the creation of the niche changes the selection environment" (Schot et al., 1994, p. 1073).

Three distinct processes have been identified in the literature that characterize well-functioning niches and thus are important elements addressed by SNM. First, social learning processes are taking place in a niche, e.g. regarding the application of a specific technology in real-life circumstances, changes in user behavior, the necessary framework conditions, useful policy instruments, or the shaping of symbolic meaning of specific technologies or practices. Second, expectations and visions are developed in a niche. This serves two purposes, namely providing guidance for niche-internal processes, and attracting niche-external interest and support. Third, heterogeneous networks are built within and around a niche. These can be important for the envisaged expansion of a niche into a regime, if the network includes also regime actors and provides access to resources (Kemp et al., 1998, p. 190 f.; Hoogma et al. 2002, p. 28 f.; Geels, 2012, p. 472; Markard et al., 2012, p. 957 f.).

Overall, SNM can be characterized as a bottom-up approach and in practice often takes the form of pilot or demonstration projects. Proponents of SNM argue that niches should from the beginning rather be conceptualized as experiments instead, because SNM is less about testing technologies and user acceptance, but rather focuses on broader learning processes, where pre-existing user behavior, the way technologies are used and how they are embedded in their social context may be challenged and maybe even change (Hoogma et al., 2002, p. 5; Markard et al., 2012, p. 957 f.). Thus, SNM as an approach aims at developing niches in such a way that learning at this deeper, more structural level becomes feasible. The basic rationale for such an approach is based on the assumption that transitions are processes of socio-technical co-evolution, which are not a pre-determined outcome of the diffusion of any specific technology and socially more complex than market mechanisms. Therefore, experiments in niches should be designed as open-ended search and learning processes (Hoogma et al., 2002, p. 4).

In this respect, SNM is understood to be a new governance approach that goes beyond focusing on specific policy instruments aimed at achieving clear-cut goals or fostering specific 'green' technologies. It stimulates interaction between different actor groups and is intended as a way to proactively deal with conflicts and dilemmas emerging in striving for sustainable development. Thus it can basically be understood as an approach of reflexive governance where the involved actors learn to deal with complex change processes in a step-wise, deliberative and experimental way. This will allow for fundamentally new socio-technical system configurations to be tried out in niches and, by including as many of the relevant actors as possible, for finding ways of up-scaling these niche innovations to the regime level (Hoogma et al., 2002, p. 181 f.; van den Bergh et al., 2011, p. 13).

Practical experience based on projects that have from the beginning been designed on principles of SNM so far remain limited, because the concept is still relatively young. However, Hoogma et al. (2002) have analyzed e-mobility projects carried out throughout Europe during the 1990s based on criteria of SNM. These cases have shown that a number of aspects are of crucial importance for successful SNM.

First, it is important to clarify from the start the experimental nature of projects. They should be designed in such a way that underlying assumptions, e.g. regarding suitable technological options, the ‚right' strategies for diffusion and implementation, and ‚normal' user behavior, can be questioned and challenged. In practice this can be achieved by defining the concrete goals of projects in suitable ways. They should be formulated in terms of qualitative learning goals, rather than quantitative goals of diffusion rates or market shares. Furthermore, specifying goals should be done in a reflexive way, i.e. re-adjusting concrete goals throughout the process. Second, since SNM entails deliberation and navigating conflicts across a wide range of actor groups, setting up the niche with regard to the involved partners needs to be done carefully. In order to secure the necessary commitment and willingness to cooperate of all partners, it is suggested that expectations should be articulated openly and repeatedly throughout the course of a project. Finally, with regard to the up-scaling of niche innovations, a cautious and foresighted attitude is imperative. Barriers and opposition at the regime level should be anticipated and assessed realistically, in order to deal with them proactively and choose a suitable, often gradual, up-scaling strategy (Hoogma et al., 2002, p. 197).

Apart from the practical implementation of SNM, the conceptual approach itself has also been criticized. One major point of critique, which applies to other approaches in transition studies as well, is the often limited focus on future change (Wells & Nieuwenhuis, 2012, p. 1683). Such a focus remains limited when it fails to simultaneously take sufficient account of the barriers precluding this envisaged future change, while instead focusing, for instance, exclusively on managing processes within niches. Furthermore, the concept of SNM sometimes tends to be "power-blind". It explicitly advocates including a broad range of actors, where useful also industry actors with vested interests in preserving the dominant regime. This may lead to challenges in practice, when powerful incumbents dominate concrete projects. Especially in the context of sustainability transitions, the aim is radical change and this requires a careful balance of resourceful incumbents and niche actors with new ideas and alternative approaches (Hoogma et al., 2002, p. 201).

A major challenge, in theory and in practice, is thus to place SNM in the wider context of governance for sustainable development. SNM is based on a policy approach that, against the background of uncertainty involved in achieving sustainability goals, focuses on "modulating" on-going dynamics and utilizing windows of opportunity (Hoogma et al., 2002, p. 200). However, this type of policy approach cannot replace more traditional policy approaches and instruments, e.g. those that control pollution, set concrete boundaries and incentives, and thus translate and transfer sustainability objectives into established policy-making structures, which often follow an economic or market logic. SNM is neither a useful substitute for these kinds of policies, nor a way to improve them, but rather an addition that helps to deal with underlying questions and produces a broader range of alternative (technological) options (Hoogma et al., 2002, p. 200).

3.2.2 Transition Management (TM)

Transition Management is another central approach that has emerged from the search for new forms of policy design that are more reflexive, embedded in complex system realities and geared towards a long-term future (Voß et al., 2009, p. 276). Similar to SNM, the aim is not to replace existing policies, but to add new elements that are better able to deal with the uncertainties inherent in the process of fostering sustainable development in key societal domains. In contrast to SNM, the approach of Transition Management is more comprehensive and has a broader focus on transition processes as a whole.

TM has been developed together with politicians and scientists and was adopted by the Dutch Ministry of Economic Affairs as an overall policy framework in 2001. It proceeds along five cyclical steps: First, a transition arena is established, involving all relevant stakeholders for a specific policy problem. The aim of bringing those actors together is to induce processes of second-order learning by facilitating a common understanding of the underlying problem, the different perspectives held by others and the resulting interests and strategies. Second, this should form the basis for developing a shared vision among the involved actors. In a deliberative process, the basic goal of achieving, for instance, a more sustainable energy or transport system, is spelled out more clearly. The resulting vision should ideally be shared by all involved actors and serves as an orientation for the following steps. Third, and based on the particular vision that has been developed, possible pathways that might lead towards this envisaged future are being developed. Fourth, concrete experiments are designed and carried out in practice, in order to test options that have been identified to be promising. These experiments can and should be ambitious, in terms of going beyond established routines and policy instruments. They can be first steps on the pathways developed at earlier stages of the TM process. As a final step, the experiments should be monitored and evaluated, in order to facilitate a thorough learning process. This should result in continuous re-adjustment and re-evaluation of experiments, in order to find ways of up-scaling these experiments to the regime level. The different phases of TM are not clearly separated in practice, there are often feedback-loops and interlinkages across the different steps. For instance, experiments can induce a process of going back to earlier stages of TM, because insights that have been gained in practice may facilitate re-adjustments of future visions or potential pathways. It may also show that other actors should be included that were not considered relevant in the beginning. This shows that, similar to SNM, the basic aim is to establish processes and settings that facilitate learning processes and reflexivity in the design of concrete experiments, rather than implementing clear-cut instruments for achieving pre-determined quantitative goals (Loorbach, 2010, p. 171 ff.; van den Bergh et al., 2011, p. 13; Voß et al., 2009, p. 284 f.).

TM can thus be characterized as a new form of reflexive long-term policy. The way TM is conceptualized expresses skepticism with regard to older planning approaches and naïve ideas of controlling and 'managing' (in the narrow sense of the word) processes of change. Instead, the TM approach "combines an orientation toward a long-term vision of 'sustainable development' with short-term experimental learning to probe options and find pathways to realize the vision" (Voß et al., 2009. p. 277). This is done in a cyclical and recursive process, where the vision and the experiments are continuously reflected upon and if necessary re-adjusted. This requires a certain open-mindedness with regard to the definition of concrete aims and policy instruments, in order to be able to change them throughout the process (Voß et al., 2009, p. 277). Similar to SNM, the basic rationale behind this approach is the idea to modulate, rather than interfere in, dynamics that are already shaping a socio-technical system, because "[t]he complexity of the system is at odds with the formulation of specific, quantitative objectives" (Voß et al., 2009, p. 284). Accordingly, TM rather aims at facilitating the context in which this becomes feasible, instead of focusing on fixed goals and rigid strategies.

In the TM approach and the way it has evolved, struggles of dealing with the niche-regime interface and up-scaling of experiments are apparent as well. The rationale for setting up transition arenas is to provide a space for developing alternative ideas and practices and shielding them from regime pressure. Therefore, regime actors were intentionally excluded in early versions of the TM concept. In subsequent steps of refining the TM approach, it was argued that regime actors should indeed be included in transition arenas, because their financial and non-financial resources, e.g. societal legitimacy and political standing, could aid the process. This makes sense, if the eventual goal is to achieve a broader up-scaling of niche experiments. At the same time, this poses a threat of niches being captured by regime actors and experiments being steered in ways that impede the original goals of radical change. Ideally, there should be pressure on existing regimes, e.g. in the form of environmental laws or taxes, and against this background diverse niche developments would be granted the chance to flourish and compete with each other, in the end resulting in an evolutionary process of successful niches transforming regime structures (Kern & Smith, 2008, p. 4094).

However, despite the fact that transition management has been developed in a practical policy context in the Netherlands, it has so far remained predominantly an academic approach. It can be shown that on a conceptual level, issues of power in political processes and institutions tend to be ignored, or at least are not considered sufficiently. This theoretical "blind spot" leads to weaknesses and unintended outcomes in the implementation of TM processes. A number of studies show that in some cases incumbent actors have managed to capture TM projects and sustainability discourses, in order to hamper the achievement of substantial sustainability-oriented goals (Avelino, 2009, p. 381; Meadowcroft, 2009, p. 336; Voß et al., 2009, p. 277 ff.). Thus, problems with the implementation of TM in practice often have to do with a failure to account for political realities. Since TM is designed as a very open framework for deliberating and exploring options with large stakeholder constituencies, there is a threat that the process is captured by powerful regime incumbents defending their vested interests. The fact that these actors are usually more experienced and resourceful as compared to other interest groups, e.g. civil society organizations, is often not accounted for by the process design of TM. Similarly, by focusing on TM as a way of facilitating open-ended learning processes, the focus on concrete sustainability challenges and an awareness of the political struggles involved are sometimes lost (Avelino 2009, p. 381 ff.; Voß et al., 2009, p. 286 f.).

Another major challenge is the establishment of TM as a new policy approach itself. As is the case with SNM, TM is understood to be not a substitute or element of existing policy instruments, but rather as an additional or cross-cutting policy approach. However, this means that TM needs to be established within the context of existing and long-established political processes and routines. TM is a reflexive approach oriented towards the long term and this can be in conflict with existing patterns of policy-making, which may in turn lead to unintended effects when it comes to implementing TM. For instance, in the implementation process it can be observed how substantial sustainability-oriented goals are being reduced to more conventional measures of technological development and fostering economic competitiveness (Avelino 2009, p. 388; Heiskanen et al. 2009, p. 424 f.; Meadowcroft 2009, p. 329 f.). Since these "[c]ontextual dynamics feed back into the design process" (Voß et al., 2009, p. 289), TM itself can be seen as an experiment that needs to be constantly and critically evaluated and re-adjusted.

3.2.3 Fostering Transitions in the Making through SNM and TM?

Both SNM and TM have been developed out of a concern for designing policies that are better able to foster sustainable development. Dealing with sustainability challenges requires a perspective on the long term, an integrated perspective on interlinked societal domains, and on system innovations, i.e. the emerging interactions between technological innovations and social practices. Thus, the policy agenda for sustainable development basically aims at structural change in and of societies. Established political processes, such as electoral cycles spanning four or five years, political institutions, such as the traditions and culture passed on across generations of civil servants, or conventional policy instruments, which are focused on specific sectors and shorter time spans, are hampering the development of policies that can meaningfully address sustainability problems.

SNM and TM are approaches that are specifically designed with the aim of fostering structural change, for instance by focusing on socio-technical systems fulfilling generic societal functions, rather than on specific sectors or technologies. This integrated perspective is supplemented by a long-term orientation, assuming that transitions generally take 25 to 30 years. Recognizing that sustainability problems are complex and intertwined with change processes unfolding over substantial periods of time, leads to a substantially different approach when it comes to designing policy. It can be compared to the shifting focus within political sciences from "government" to "governance", because SNM and TM are process-oriented with a focus on a diverse set of relevant actors and their interlinkages. Potential for triggering structural change is not seen in specific policy instruments, but rather in the way that ongoing dynamics are utilized by a reflexive governance approach, where specific instruments are constantly evaluated and adjusted in flexible ways. SNM, and especially TM, rely on a mix of bottom-up and top-down approaches, i.e. weakening established structures where possible and creating spaces where alternatives can develop. In essence, SNM and TM are providing frameworks for reflexive social learning processes, in order to deal with the difficulty of aligning long-term visions of sustainability with the need for concrete action in the short term (van den Bergh et al., 2011, p. 13; Voß et al., 2009, p. 278, 281).

However, despite these noble aspirations, SNM and TM are faced with some major challenges conceptually and in practice. Most importantly, it is ignored that the political sphere is itself part of the dominant regimes in unsustainable socio-technical systems and that public policy is not an exogenous element that can introduce drivers for change from a neutral position. It is thus not sufficient to develop new concepts for more sustainability-oriented policy-making. A thorough analysis of the political domain itself and of the way that problems inherent in processes of policy-making can be addressed by concepts such as SNM and TM, is needed (Kern, 2012, p. 300; van den Bergh et al., 2011, p. 13 f.).

A related challenge has to do with the process-orientation of SNM and TM. While this is important, considering the complexity and duration of the envisaged change processes, it also entails the danger of losing direction. Achieving sustainability goals is the basic motivation, which should not get lost by focusing solely on process design. Concrete targets and suitable instruments to reach them should in some way be defined and guide the process (Voß et al., 2009, p. 298 f.). This is important especially because the very open processes in SNM and TM in combination with the principle of including regime actors in transition arenas, in order to eventually cross the boundary between niche and regime, may lead to unintended outcomes. Powerful regime actors may capture niches and actively prevent system innovation by using their influence and resources to shape them as market niches where technologies or business models are developed that follow established regime logics or guiding principles such as immediate economic feasibility and market success (Voß et al., 2009, p. 286 ff.). Experiences with the Dutch energy transition, where TM has been developed, have shown that even in a situation where transition arenas had been set up, ambitious goals had been agreed on and the process was initiated in a generally open atmosphere with regard to innovative policy approaches, the expected outcomes did not materialize. Established political institutions and processes could not simply be overridden or bypassed and presented formidable barriers precluding the emergence of system innovations. This implies that in the field of transition studies, and SNM and TM in particular, "analysis for policy needs to be complemented by analysis of transition policies and their politics" (Kern & Smith, 2008, p. 4101).

3.2.4 "Transitions in the Making": How to Analyze the Potential for System Innovation ex ante?

Approaches such as SNM and TM are important for inducing open-ended social learning processes, relying on reflexivity and adaptability as operational principles in view of a long-term orientation, in order to facilitate sustainability transitions. However, the critique of SNM and TM has also shown that they need to be accompanied by an analysis or monitoring of the actual potential for transformative change to emerge at different stages of "transitions in the making". This cannot be achieved by focusing on principles of SNM and TM as sole analytical concepts, because they focus on procedures and design of processes for new forms of policy. Apart from that, not all developments or policies that may have a potential for system innovation are from the outset designed as SNM or TM processes, as e.g. in the context of the Dutch energy transition. An assessment of potential in an ex ante situation, i.e. in the case of a presumed transition currently in the making, requires a broader perspective on systemic change that goes beyond a focus on process and looks at niche-regime dynamics with a view to the involved power struggles and political processes.

This is important because an analysis of a specific niche carried out along the principles of SNM, such as the emergence of shared visions and broad network-building, may result in findings of potential for system innovation that turns out to be at least questionable. For instance, Geels (2012, p. 472 f.) argues that the development of alternative vehicles, battery-electric as well as fuel cell vehicles, presents a case of successful SNM. These technologies have been developed in niches, visions, in terms of expectations related to these technologies, have become broadly shared, and eventually broad networks have emerged where car manufacturers have bought or formed alliances with smaller companies active in the field of alternative drive technologies. According to the process-oriented principles of SNM this may indeed be a successful case. However, from a broader transition perspective, this may only be true at first glance. It is at least doubtful whether this is a case of structural change with a potential for system innovation that radically alters established regime structures. Much rather, this seems to be a case of a niche being captured by regime actors. Even if alternative drive technologies have been developed in niches guided by a broader vision of sustainable mobility and radical change, car manufacturers are stepping in and taking over these new technologies to integrate them in their 'normal' activities of producing and selling cars without major changes to their basic strategies or business models. They have vested interests in preserving the current transport system and by entering the niche of alternative drive technologies and vehicles, they have found a way to steer developments in directions that do not threaten these interests.

At the same time, the development of alternative drive technologies at a larger scale only becomes possible with the help of these large car manufacturers' expertise and financial resources in the field of R&D. This is the very basic dilemma with regard to the niche-regime interface, that on the one hand, resourceful regime incumbents are needed for a broad up-scaling of experiments, while on the other hand, their involvement usually precludes the emergence of radical system innovations.

In contrast to this being presented as a questionable example of successful SNM, there are indeed some valuable lessons to be learned from SNM and TM with regard to the potential for system innovations emerging from transitions in the making. As argued by Hoogma et al. (2002, p. 181 f.), SNM does not aim primarily at the development of specific technologies or network-building per se. It is in essence about learning processes at the level of rules and guiding principles, questioning 'normal' behavior and routines. For the case of electric vehicle development, successful SNM would induce this type of learning, rather than technology diffusion (which is part of the process but not the central 'outcome'). In the beginning, an 'electric vehicle niche' would most likely be characterized by established rules and guiding principles. In practice this could mean that electric vehicles are expected to function much like conventional cars and they would be assessed and tested against the familiar concept of personal automobility with ICE cars. The learning processes envisioned in SNM would then lead to a stepwise departure from these structures, for instance, when users begin questioning their mobility behavior and possibly develop new routines, or car manufacturers considering new business models in cooperation with energy providers, who may start thinking about new forms of energy services. Thus, the learning processes relevant for successful SNM are broad, covering many issues and actors, and deep, going beyond established routines and guiding principles (Schot et al., 1994, p. 1072 f.).

Fundamentally, SNM is about the co-evolution of a technology and its environment at a deep-structural level. This has consequences for the evaluation of whether or not an SNM project has been successful. Success does not so much depend on direct economic success or the emergence of marketable products – as is well illustrated by the example of new drive technologies taken up by large car manufacturers, which is most likely not contributing directly to the emergence of a system innovation. The outcome of social learning processes are a more relevant success in this regard, but also much harder to measure. It has been proposed to focus on expectations and visions of the future that are developed in the context of an SNM project. Changes in images of a desired future and new guiding principles emerging from this can influence decision-makers in politics and industry based on what has been learned in niche experiments. This may eventually have a 'real' and visible effect, when it translates into concrete strategies and behavior (Hoogma et al., 2002, p. 195 f.).

Following from this, it is important to note that therefore also failures and problems emerging in the context of such experiments can amount to valuable lessons. During early phases of transitions or experimenting with alternative practices there will inevitably be failed attempts and approaches that turn out to be unsuccessful. This may not necessarily cast doubt on the experiment in general, but could just as well be an indicator for the premature state of a niche (Hoogma et al., 2002, p. 196). In order to learn about the potential for a system innovation to emerge, it is thus all the more important to also analyze cases of unsuccessful niches or experiments, which is often neglected in transition studies. Especially because efforts of fostering transitions take place in established policy contexts and against the background of dominant regime structures and this entails a danger of poor implementation and outcomes (as discussed earlier), it is important to identify and analyze cases of failed efforts and the barriers impeding system innovation (Kern & Howlett, 2009, p. 392 f.).

So, how can cases with a potential for emerging system innovations be analyzed? Principles of SNM and TM alone will not suffice, because they primarily focus on process design. What can be learned from these concepts is that the analysis should not focus on 'superficial' criteria, e.g. diffusion rates or economic success of a new technology, but rather on deep-structural learning effects relating to dominant rules and resources. An important aspect is also the niche-regime- interface, especially a cautious view to power relations, the politics involved and possible dynamics of 'niche capture'. These aspects are central in the MLP (which has of course also been the basis for developing concepts of SNM and TM) and recently, approaches have emerged that use the MLP as an analytical tool for assessing, for instance, policies that are aimed at fostering transitions.

A prominent example of such an approach has recently been presented in a paper by Kern (2012) where the MLP is explored as a framework for evaluating a UK policy initiative ("Carbon Trust") that aims at a transition to a low carbon economy. This policy initiative has been selected as a case study applying the MLP as a tool in the analysis *of* policy, rather than *for* policy. Applying the MLP as an analytical framework for ex ante assessment of policy builds on the insight that governments and public policy play a major role in transition studies, while it is often unclear what this means in terms of concrete instruments and processes, especially when considering that 'transition policies' are not developing in a void but in the context of established political structures. Therefore, the MLP is used here as a framework for analyzing in how far existing policies may or may not stimulate transitions. This approach departs from 'traditional' applications of the MLP to historic cases of transitions and turns towards envisioned transitions of the future by ex ante analyzing the policies that might contribute to realizing these future visions (Kern, 2012, p. 299). Similar to the focus on learning in SNM, here the focus ought to be on the 'deep-structural' impact of policy, rather than a quantitative assessment of short-term, direct and easily measurable outcomes of a specific policy.

Consequently, the basic concepts of the MLP are operationalized in a rather general fashion, focusing on learning processes at the niche level, changes in rules at the regime level, and on macro-economic trends representing the landscape. It is then analyzed in how far the selected example of a low carbon policy initiative contributes to the development of a well-functioning niche, in terms of improving specific low carbon technologies but also broader capacity building in networks, and changes at the regime level, again looking at diffusion of technologies but also social learning processes in established networks. The landscape level cannot be influenced by a single national policy initiative, the analysis here focuses on the exogenous drivers and barriers for policies aiming at transitions. Landscape trends are thus analyzed in terms of their impact on the specific policy being studied and it is shown how policy interacts with broader macro-economic trends and, for instance, is related to cultural values or philosophies of policy-making (Kern, 2012, p. 300 ff.).

Nonetheless, it will not be possible to predict the outcome of a specific policy, simply due to the complexity involved in envisioned low carbon transitions, even when the ambition is narrowed down to 'only' focus on energy or transport systems – which are still highly complex in themselves, including many actor groups, political domains, technologies and infrastructures. Adding a long-term perspective, complexity increases even more. This real-world complexity is reflected in the MLP, which refrains from explaining transitions as phenomena of direct, linear causalities with clearly identifiable variables driving the process independently. Rather, it is acknowledged that transitions are always an outcome of contingent dynamics and interlinkages of a multitude of variables and processes (Geels, 2012, p. 474; Meadowcroft, 2009, p. 328 f.). To get a grip on this complexity, historical cases have been studied, in order to identify characteristic patterns and mechanisms playing out in transitions (Geels & Schot 2007, as discussed in ch. 4.1.2). While it has been criticized that this type of reconstruction is not scientifically sound enough in terms of validity (see Dolata 2013, p. 27), it has produced insights in past events that do pass a plausibility-check –

assuming that due to the inherent contingency and highly complex nature of transition processes a greater degree of validity is possibly not feasible at all, this has been an effective way of scientifically reducing complexity. Even if this approach is useful for understanding past transitions, and maybe produces knowledge for the present with regard to specific patterns or mechanisms observable over limited time frames, scale and scope, it still does in no way allow for predicting the future: “Looking back from a vantage point in 2100, analysts may be able to discern the start and end of each distinct transition and identify the abortive efforts and reversals that characterize the overall movement. But for those living through these processes, it will be much more difficult to understand what is really going on” (Meadowcroft, 2009, p. 329).

Nonetheless, as shown by Kern (2012), generic patterns of niche-regime dynamics or the impact of landscape factors can help inform ex ante analyses of policies intended to stimulate transitions. The aim of such an analysis is certainly not to predict the future, as for instance compared to scenario methods, but it can provide insights into whether or not efforts are actually facilitating dynamics in the desired direction, which is an aspect sometimes not reflected enough in SNM or TM. Thus, the paper by Kern makes a valuable contribution by showing how “the MLP is used in a novel way: as a heuristic to ex ante assess policies (…) [and] their likely impact against the background of theorizing about patterns of large scale, socio-technical change” (Kern, 2012, p. 298). Assuming that it is not possible to precisely predict policy outcomes, and acknowledging that even ex-post policy analysis can sometimes hardly identify outcomes and unavoidably remains limited to outputs (again due to real-world complexity and non-linear causalities), an MLP-based ex ante analysis can still be useful. Policies can be evaluated against the background of ideal-typical multi-level dynamics leading to transitions in theory, e.g. regimes need to be destabilized, niches nurtured and landscape factors need to be taken into account. This will lead to an assessment of the degree to which a policy initiative contributes to such dynamics, thus an analysis of a policy initiative’s contribution to the potential for a transition to emerge: how well is the particular policy initiative suited to stimulate structural change, while always keeping in mind that the eventual outcome with regard to an overall transition of a socio-technical system as a whole depends on a plethora of other factors as well. Even in the face of such complexity and uncertainty, this type of ex ante assessment has advantages as compared to more classic evaluation methods based on quantitative cost effectiveness assessments or measuring reduced emissions (Kern, 2012, p. 308).

This is particularly relevant for a case such as e-mobility. A quantitative assessment of diffusion rates or reduced emissions would not say anything about the "system-innovative" potential inherent in the development of e-mobility. What is more, it would most likely not produce positive results and could even trigger efforts going in a completely 'wrong' direction, from a sustainability point of view at least. Looking at the slow diffusion of electric vehicles and their inability to compete with conventional cars, which would be important indicators in a quantitative assessment of policies fostering e-mobility, the consequence could be either discontinuing e-mobility efforts altogether or a re-adjusted focus of policy solely on technological improvement. This would from the start preclude the chances for e-mobility to develop as a system innovation, which has to do with a general problem of new technologies (and is an argument in favor of an MLP-based ex ante analysis that looks at underlying structural change and social learning, rather than numbers): new technologies are usually expected to substitute for existing technologies fulfilling the same functions in similar ways. The frames of reference against which technologies are assessed are established use patterns, business models, market mechanisms, and cultural values, thus the social system in which technologies are embedded. This may change, because while in the beginning "all the potentials, properties and new meanings of the emerging technology are still to be found out" (Geels & Smit, 2000, p. 878), processes of socio-technical co-evolution can over time lead to social learning processes and a re-framing of the new technology and its social context (ibid.).

It is therefore important to find a way of assessing the developments and policy initiatives in the field of e-mobility that are currently ongoing. From a sustainability point of view, such an assessment should focus on the potential of these developments to foster the emergence of e-mobility as a sustainable system innovation. As has been discussed throughout this chapter, the relevant elements of such an analysis should be social learning processes facilitating structural change and multi-level processes of socio-technical co-evolution. Such an assessment is difficult and can never result in precise predictions of the future, but as shown by Kern (2012) valuable lessons about the direction of change induced by specific policy initiatives can be learned. And, as emphasized earlier in ch. 2.4, in these cases "making an assessment, for each specific technology, of the likelihood that it could lead to co-evolutionary dynamics" (Hoogma et al., 2002, p. 36) is important, despite the methodological difficulties this entails. Based on these considerations, in the following chapters a theoretical framework will be developed to analyze the potential, or reasons for a lack thereof, for e-mobility emerging as a system innovation.

3.3 Developing a Theoretical Framework for Analyzing System Innovations

In this section, an analytical framework for studying system innovations will be developed. It will be tailored to the specific research question of this thesis regarding the potential of e-mobility emerging as a sustainable system innovation – while insights may be valuable for similar cases of 'transitions in the making' in other fields as well. It has been shown that from a sustainability perspective, the car-based transport system is faced with challenges that can hardly be met by way of purely technological solutions (such as the introduction of electric cars). Rather, a system innovation around, or including, a technological innovation such as the electric car is needed, if sustainability challenges are to be addressed in a systematic and comprehensive way. Understanding e-mobility as a system innovation thus refers to the diffusion of a new drive technology as well as fundamental changes in infrastructures, regulation, business models and user practices.

How can such a complex and certainly long-term process of widespread transformation be grasped analytically? The MLP has been introduced as a framework that provides a useful heuristic for analyzing long-term and radical change. However, a number of weaknesses and difficulties in applying the MLP have been discussed in previous sections that need to be addressed, in order to approach the research question of this thesis. For instance, the macro-level perspective on transitions focusing on structural dynamics playing out over a period of 20 or more years makes it difficult to analyze transitions that are still in the making. It has been shown that in order to assess the potential of e-mobility amounting to a sustainable system innovation, it is crucial to observe and understand currently emerging patterns of socio-technical co-evolution on a micro-level. This type of analysis can shed light on the inherent potential for system innovation, the major barriers impeding structural change, and the role of actors and strategies in a concrete empirical case of such emergent processes.

For developing this framework, elements will be introduced as auxiliary concepts into the broader framework of the multi-level perspective, which is a common way to utilize such heuristic frameworks in optimal ways and improve the analysis of concrete empirical cases. It has become clear that while the MLP has proven helpful in offering a comprehensive heuristic for complex transition dynamics, the downside is that due to this broad perspective, it cannot meaningfully address micro-level processes of socio-technical co-evolution at the same time. However, this is a crucial aspect when studying the potential inherent in 'transitions in the making'. Thus, for the purpose of this thesis, some basic concepts from theory on technology-based sector transformations developed by Ulrich Dolata (2009, 2011, 2013) will be introduced throughout the following sections, and a brief overview of this specific approach is presented in the following.

In his framework for analyzing technology-based sector transformations, Dolata has developed an explicit focus on the co-evolutionary dimension in processes of socio-technical change. Basically, Dolata argues that such a framework is needed because the various approaches used to study the interrelations between technology and society focus primarily on phenomena of technological change and on how these are embedded in societal structures. What is lacking in these approaches is a focus on the way that technologies themselves shape their social surrounding and how this influences processes of technology-based transformation. It is further argued that most of these approaches remain rather abstract because their unit of analysis is an economic system or society as a whole and at this level it is hardly possible to trace the concrete patterns of co-evolutionary dynamics (Dolata, 2013, p. 25). These are in fact the specific weaknesses identified for many MLP-analyses. Dolata deals with issues of explaining the interplay of technological innovation and social change, where the focus is not merely on tracing either how technologies have changed in a social context, or on the societal framework conditions enabling technological change. He addresses the question of how technology itself shapes and changes social structures, without however adopting a deterministic perspective on technology that leaves no role for the social dimension in socio-technical transformation processes (Dolata, 2011, p. 12 f.). In order to analyze socio-technical change, Dolata develops an analytical framework that focuses on the level of concrete industrial sectors and the way that technological innovations trigger socio-economic and institutional change processes within sectors. For instance, the emergence of advanced information and communication technologies as well as modern biotechnologies can be shown to have had an impact on various economic sectors and their political and social surroundings. In these cases, a new technology created new opportunities as well as constraints that were experienced differently in different sectors (Dolata 2009, p. 1066). Technology-based sectoral change is further explained as a function of two interrelated influencing factors (see Fig. 9). First, there is the transformative capacity of a new technology. For a specific technology, the transformative capacity may be either high, exerting direct and disruptive pressure, or low, having an indirect impact and leaving the basic sectoral structures intact (e.g. in the case of incremental innovations fulfilling subsidiary or supporting functions). Introducing transformative capacity as a distinct influencing factor allows for analyzing the impact on socio-economic and institutional structures of a technology in its own right. At the same time, transformative capacity is an inherently relational category, because it depends not only on the specific characteristics of a technology but also on the respective sector on which it has an impact (Dolata, 2009, p. 1068 f.). A second influencing factor is therefore introduced: sectoral adaptability. It describes how established sectoral structures, institutions and actors react to a new technology. Sectors characterized by low adaptability lack elements or mechanisms that allow for anticipating or proactively fostering substantial change. In these sectors, socio-technical change is disruptive and focal actors react to (rather than direct) change as an unsettling crisis. Sectors characterized by high adaptability are endowed with institutional mechanisms and actors that anticipate and actively deal with technological innovations and change. The overall sector structure is typically competitive and innovative, thus facilitating experimentation and directing structural change around a new technology in a proactive way (Dolata, 2009, p. 1070 f.).

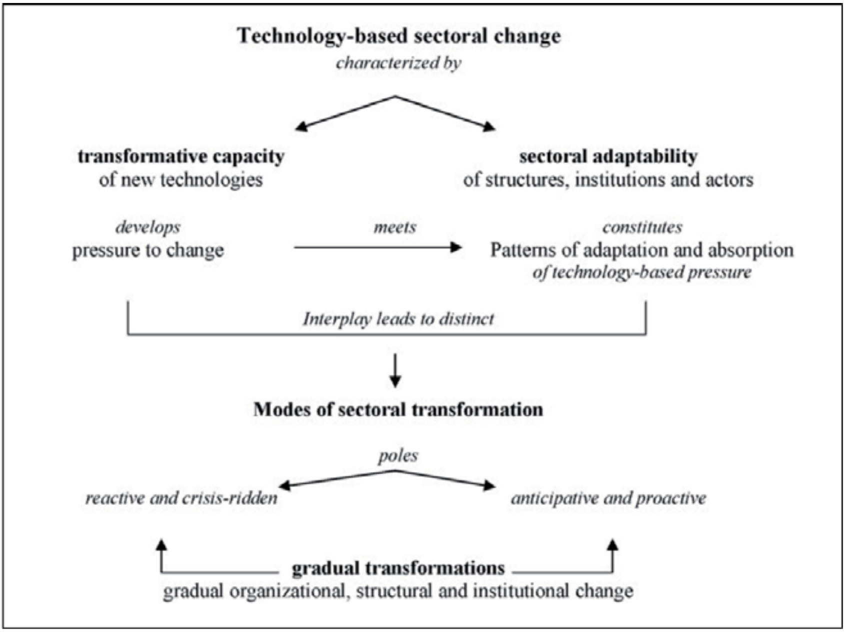

Fig. 9: Technology-based sectoral change: basic categories (Dolata, 2009, p. 1067).

The interplay of a technological innovation and the social processes within the sector, in which it is embedded, leads to sectoral change, which is conceptualized as a long-term process featuring phases with varying degrees of institutional and structural transformation, ranging from path-dependent continuities to radical breaks. Looking for dynamics of gradual transformation makes it feasible to identify concrete patterns of sectoral transformation, thus tracing the complex mechanisms of stepwise institutional renewal, its interplay with constantly new opportunities and challenges presented by technological developments and the role of different actors in these processes (Dolata, 2009, p. 1073).

In the following, a conceptual framework will be developed for addressing the specific research question of this thesis, i.e. how can the potential for the emergence of a sustainable system innovation in the case of e-mobility be analyzed? Based on the theoretical background discussed in previous sections and integrating auxiliary concepts from Dolata's approach of studying sector transformations, the framework developed here focuses on the following aspects:

- What is the relevant unit of analysis for studying system innovations? (Ch. 3.3.1)
- How can the relation and interplay between incremental innovation and radical system change be conceptualized? (Ch. 3.3.2)
- How do technological and social elements co-evolve? (Ch. 3.3.3 and 3.3.4)
- How to deal with the fact that the envisaged system innovation exists only potentially and in the future? (Synthesis in ch. 3.3.5)

3.3.1 Unit of Analysis: Socio-technical System and Regime

The MLP focuses on transitions in socio-technical systems, which are defined based on the generic societal function they fulfill. This refers to very basic functions that are socially valued, such as energy provision, mobility or housing. The boundaries of a socio-technical system are drawn in relation to such a general function. Accordingly, system boundaries can be relatively wide including all the elements and actors that are involved in the complex process of fulfilling such a particular function. This includes actors from all relevant societal domains, such as politics, business, science, civil society and the way that they shape the different system elements, such as technology and infrastructures, policy, markets, consumption patterns, culture and social practices. All those elements form a specific configuration in relation to the respective societal function, e.g. provision of energy or mobility. In terms of the MLP, there are more dominant actors within the established configuration and more peripheral niche actors (Markard & Truffer, 2008, p. 607; Holtz et al., 2008, p. 626 ff.; Smith et al., 2005, p. 1493; Smith et al., 2010, p. 436 ff.).

The 'meta-coordination' of the various system elements can be captured in terms of a socio-technical regime. Adopting a narrow conceptualization, regimes as rule sets or institutions are clearly separated from the socio-technical system. According to this view, a socio-technical system consists of material and measurable elements, thus, obviously, technologies and infrastructures, but also for instance regulations, consumption patterns and market relations. The regime as deep structure is then a more abstract category entailing the underlying rules that make sense of the basic logic of functioning of a specific socio-technical system (Geels, 2011, p. 31; Geels & Kemp, 2012, p. 56 f.). From an analytical point of view it is important to differentiate between the regime as the 'deep structure', the structure or rules that actors draw upon in their concrete action and the outcome of their action which becomes manifest in the socio-technical system configuration. This analytical separation allows for tracing structuration processes – even though it is clear that structure only has a virtual existence and materializes in the concrete actions and behavior of actors and eventually also the physical consequences of them (What types of technologies are produced? What types of infrastructures are being built?). However, as an interpretive approach the differentiation of structure and agency (in Giddens' terms) allows for a more structured analysis and explanation of processes of reproduction as well as change in socio-technical systems.

Thus, according to a narrow conceptualization, a regime consists of rule sets. Different social groups (e.g. in the spheres of science, technology, politics, markets) have different rule sets and these rules guide the behavior of actors who reproduce the elements of a socio-technical system. In a regime various semi-coherent rule sets are linked together and mutually influence each other. In this way, a regime is understood as the deep structure that lies behind the stability and path-dependency of socio-technical systems (Geels, 2002, p. 1260; 2004b, p. 904 f.; 2006b, p. 1071; 2011, p. 27).

A distinction can be made between different types of rules that play a role here. Geels distinguishes three types of rules: formal, normative and cognitive rules (2004b, p. 904). First, formal rules or institutions are the most obvious and explicit types of rules, they can be laws and regulations issued by governmental entities, or codes of conduct of other, non-governmental organizations. They usually exist in an official or written form and they always include measures of sanctioning or punishing non-compliant behavior. Second, normative rules comprise the shared set of norms and values of a specific social group or society as a whole. They are usually implicit rules that are expressed in a more or less common understanding of what is 'right' or 'wrong', what can be expected from people, what are their roles and responsibilities. Normative rules may be characterized as a 'softer' type of institution, in the sense that they usually do not exist in a coded form and do not include a system of formal sanctions. However, the existence of normative rules may be less explicit but is nonetheless very real. They are transported and learned via socialization processes and behavior that deviates from broadly shared normative rules will be met by sanctions in the form of irritation by other members of the relevant social group or even exclusion from it. Third, cognitive rules are the very basic belief systems, mindsets, interpretive schemes, which structure the way that actors perceive their environment, give meaning to it and process information. Cognitive rules are important for constructing meaning and making sense of experiences, thus enabling actors to interact with others and their general surrounding, while at the same time they also constrain their perception and scope of action because there is necessarily a limited amount of interpretations of the world. Cognitive rules are the most implicit type of rules or institutions; they exist largely unconsciously in peoples' minds and are reflected in a social group's shared symbols or myths, their routines and common interpretive frames (Geels, 2004b, p. 904).

These different types of rules or institutions can be related to Giddens' modalities of structuration. The modalities are elements that actors draw upon in the reproduction of systems and thus also leading to the reproduction of structure. There are three types of modalities: interpretative schemes that actors draw upon; facility, i.e. allocative and authoritative resources that actors draw upon; and norms. These modalities provide the link between the concrete interaction in which actors engage, which can be analyzed in terms of communication, power and sanction, and the more abstract structural features, which can be analyzed in terms of signification, domination and legitimation. Giddens emphasizes that the three types of modalities can be separated only analytically and are closely interlinked in actual social practices (Giddens, 1984, p. 28 ff.).

The same is true for the rules making up a socio-technical regime. The different types of rules are interlinked and together form a rule set. Such a rule set is relatively stable because the different rules build a more or less coherent whole, where they relate to each other and where changes in one rule affect others as well. Therefore, regimes can be described as semi-coherent rule sets (Geels, 2004b, p. 904). Furthermore, different actor groups share their individual rule sets, which provide them with orientation and coordination. It is therefore possible to distinguish between, for instance, policy regimes, technological regimes, science regimes or consumer regimes. In a specific socio-technical system, these then form sub-regimes that together evolve as a socio-technical regime. The socio-technical regime thus describes the 'meta-coordination' between the different sub-regimes, which in turn can be seen as form of meta-coordination of rules in a rule system. The overall socio-technical regime usually does not encompass all the relevant sub-regimes in their entirety. Since a socio-technical system is defined in relation to a specific societal function, the socio-technical regime includes those rules that interlink the different sub-regimes in relation to that function. This explains that the individual sub-regimes making up a socio-technical regime are autonomous to some degree and at the same time also dependent on the other sub-regimes (Geels & Kemp, 2012, p. 55).

The focus on socio-technical systems and underlying socio-technical regimes as the relevant unit of analysis in the MLP is a major difference as compared to similar approaches explaining socio-technical change. One example of such approaches that has been discussed here is Dolata's framework for studying technology-based sector transformation. Apart from similar theoretical assumptions regarding processes of change and similar research questions being addressed, they differ significantly with regard to the relevant unit of analysis. Since the aim here is to develop an integrated framework and refining the MLP, the unit of analysis addressed in Dolata's approach will be outlined in the following.

In contrast to the decidedly systemic perspective of the MLP, Dolata argues that a sectoral approach is needed, in order to study the concrete patterns of socio-technical change and avoid overly general analyses that result from focusing on abstract economic or societal systems (Dolata, 2013, p. 25). However, the approach for studying sector transformations developed by Dolata adopts a relatively broad perspective on sectors. A sector has a relatively clearly demarcated economic core defined by the sector's main industrial or economic activity (e.g. producing cars). The way this activity is carried out, is mainly shaped by the core economic actors and structures but is at the same time also influenced by non-economic actors and institutions. A sector is therefore understood to include not only its economic core but also its societal environment, i.e. political actors, media, science and social movements, all of which have an impact on sector structures (Dolata, 2011, p. 18). Apart from a specific constellation of actors and the role of institutions, a sector is also characterized by its technological profile. The techno-structure and the institutional structure are interrelated and form a coherent 'match'. Therefore, sectors are conceptualized as socio-technical fields that go beyond the sector's economic core and that are constituted by a technological profile, socio-economic structures and institutions, and actors and their relations and interactions (Dolata, 2011, p. 18 f., p. 33).

According to this approach, the fact that a sector is relatively stable with regard to its typical characteristics and actor constellations can be described in terms of a sectoral regulation pattern. This refers to a structuration process evolving from the interrelations between technology and socio-economic institutions: typical socio-technical constellations, structures and institutions provide a framework that guides the behavior of actors and shapes their interaction. It is important to note that in a sector, defined as a socio-technical field, there is a wide array of actors involved. There are the economic core actors, such as the established producers, service providers, suppliers and consumers, as well as more peripheral economic actors, such as developers of new technologies, and also non-economic actors, such as politicians, scientists and civil society actors. These are related in different and sector-specific ways. Their relations and thus also the overall configuration of a sector tend to be relatively stable over long periods of time, but they are never static. The different actors have different interests and power resources, and they interpret given rules and social institutions differently. This leads to continuous incremental changes and in some instances also to radical change. The impetus for radical change often develops in the periphery of a sector and then challenges the established core actors that have long been dominating sectoral structures (Dolata, 2011, p. 29 ff.).

The elements of a socio-technical field – a specific technological configuration, the types of relevant actors and the role of institutions – could also be part of a corresponding socio-technical system according to the MLP approach. Also, the differentiation of core and peripheral actors within a sector as a socio-technical field bears similarity with the relation of niche and regime level in the MLP. However, the decisive difference is the basic logic of delineation, which in Dolata's approach refers to the economic core of a sector. For instance, the automotive sector is defined around its economic core of producing cars (Dolata, 2011, p. 18) and it is characterized as being overall proactive and open towards new technological developments, due to technology-based competitive pressure (Dolata, 2011, p. 96). This is a valid result when considering the automotive sector per se, because there is price competition and manufacturers compete via technological innovations. However, innovations here refer to incremental innovations that remain within 'regime limits'. From the point of view of sustainability transitions research, the car-based mobility regime is highly stable and characterized by inertia (Geels et al., 2012, p. 351). In the MLP approach, the socio-technical system with its underlying regime as the relevant unit of analysis is delineated in relation to the societal function it fulfills. Therefore, niche and regime levels are differentiated according to the degree to which established structures of fulfilling this function are being reproduced, or whether alternative practices are being sought that might fulfill this function in a different way. The differentiation of core and peripheral actors in Dolata's sector transformation approach is in contrast based on the importance that different actors have for a very specific economic activity.

Both, technology-based sector transformation and the MLP focus on socio-technical change – albeit motivated differently. Dolata's sector transformation approach focuses on the impact of new technologies, how they induce change, and how change can look very differently in different sectors, thus tracing the interrelated, socio-technical nature of such change. It is recognized that this type of change can only be grasped fully when sectors are understood to be socio-technical fields, because technologies and individual firms (as core economic actors in a sector) are embedded in wider social structures. So, the empirical elements in technology-based sector transformations are similar to those relevant as elements of a socio-technical system in the MLP approach. Here, it has also been recognized that socio-technical change is a multi-dimensional phenomenon that can only be understood when looking beyond isolated technology developments or firm strategies. The difference in perspective, however, is that the focus is on the function that a specific socio-technical constellation fulfills within a society and change of the socio-technical constellation is analyzed in relation to the respective function (Smith et al., 2005, p. 1491 f.). So, Dolata's approach of sector transformation aims at analyzing the impact of new technologies on specific socio-technical configurations, while the MLP analyzes change in socio-technical configurations with a view to the overall function a socio-technical system fulfills. This explains the relevance of the MLP for studies on sustainability transitions: It is especially suitable in cases where the research question is about sustainable ways of fulfilling a societal need, such as mobility, energy and water provision or housing (Konrad et al., 2008, p. 1192). A sectoral approach is too limited for these types of questions because it focuses on the impact of a given technology on a given configuration and even though the concept of sectors as socio-technical fields is similar to a socio-technical system in the MLP, the analytical focus is on the core economic structure and activities, which is fundamentally different from the more systemic perspective on general functions fulfilled by a socio-technical system. Similarly, the technological innovation systems (TIS) approach in transition studies focuses on green innovations and conditions for their development and is thus also less suitable when interested in the overall sustainability of a socio-technical field.

Choosing a suitable unit of analysis thus depends on the research question. When one is interested in the fate of a specific technology or the effects it has on specific actors and structures, a sectoral approach is useful. When studying sustainable system innovations this focus is too narrow. This type of question is concerned with fulfilling societal needs in radically different ways and thus cannot meaningfully be limited to a specific industrial sector or set of established actors (or even a specific technology, in the sense that its characteristics and specific way of functioning and non-technological consequences are 'fixed' in its design). In this respect, the concept of regime, which is central to the MLP, can be helpful. The fact that a regime is generally defined in relation to a generic societal function represents a central analytical strength for transition studies. It allows for introducing an analytical focus on sustainability-oriented ways of fulfilling societal functions, which is an advantage as compared to many more 'traditional' approaches that focus on transformations around specific green technologies or the impact of green innovations on a given technological configuration. Furthermore, the regime concept is, on the one hand, relatively open in so far as it does not prescribe a specific unit of analysis; rather, it can be applied to different types of physical system configurations, depending on the respective subject of study. On the other hand, it is analytically precise in so far as it refers to the basic rule sets that explain a particular system's configuration and logic of functioning.

In sum, when studying a sustainable system innovation, the suitable unit of analysis is a socio-technical system, which can be delineated along the generic societal function it fulfills (e.g. 'providing mobility'), and which is characterized by a specific regime, thus the rule systems or the deep structure that explain the specific way of functioning and the physical configuration of the socio-technical system. A system innovation can be defined as regime change.

A major challenge in transition studies is the delineation of concrete socio-technical systems and regimes for specific cases, thus the basis for empirical operationalization. Across transition studies, conceptual papers as well as case studies, the concept of regime has been applied very differently. This has been criticized as a weakness of the MLP framework in general by several transition scholars (Holtz et al., 2008, p. 625; Markard & Truffer, 2008, p. 605; Smith et al., 2005, p. 1492). For instance, it has been argued, that the regime concept is used as a synonym for sectors or various kinds of 'systems' without actually specifying the concrete unit of analysis (Markard & Truffer, 2008a, p. 607). This critique has been discussed by Geels (2011, p. 31), basically arguing that the incoherent application of the regime concept is not a theory-inherent problem, but rather the result of the normal difficulty of delineating the scope of an empirical case (see also chapter 3.1.4). An important aspect for delineating regimes in a clear and coherent way is to distinguish between the socio-technical system, i.e.

the involved tangible elements such as technologies, infrastructures and market transactions, and the socio-technical regime as the underlying deep structure, i.e. the formal, normative and cognitive rules. This distinction allows for utilizing the interpretive potential of the regime concept, which aims at gaining a better understanding of the structuration process where actors reproduce system elements by focusing on the underlying deep structures. This focus is inherent to the MLP and the regime concept and resulting from its theoretical background in Giddens' sociological theory of the duality of agency and structure. Therefore, applying the regime concept to cases where the focus is on overall transition patterns (and not as much on structure-agency dynamics) often leads to a vague and imprecise use of the regime concept as another term for system or sector. In many cases this goes hand in hand with an inappropriate characterization of regimes as systems with an inherent intention or directional dynamic of their own, because the micro-sociological perspective on knowledgeable agents reproducing and modifying structure is lost when looking only at the macro-dynamics of transitions (ibid.).

Nonetheless, delineating a regime in a concrete case is not trivial or self-evident. Drawing boundaries of a socio-technical system and defining the relevant regime for an empirical case depends on the research question. Based on the respective research question, the scope of the analysis has to be determined and then the definition of the relevant regime is the result of a deliberation process of framing the research question. For instance, in energy transition studies, the regime concept can be used to focus on centralized power generation regimes or on regimes of different energy sources, or even on regimes of different conversion technologies. In each of these cases different structures, actors and practices would play a role. This shows that defining a specific regime depends not only on the suitable aggregation level, but also on the perspective of the research interest. As a consequence, it is important to deal explicitly with the question of why and how the regime concept is applied in empirical research (Holtz et al., 2008, p. 624; Markard & Truffer, 2008a, p. 606 f.).

The starting point for defining a regime is the societal function to which it is related. This focus is suitable when studying sustainability transitions or sustainable system innovations and it has implications for the definition of a regime. It spans the production, consumption and governance perspective in relation to the specific function and it looks beyond specific technologies. Therefore, the regime cannot be determined around the functioning of a specific technology or in relation to a specific policy or group of actors. All actors and elements that are relevant for fulfilling a societal function need to be considered. The regime then captures the institutions, power relations and value systems expressed in the (re-)production of structure by actors, which materializes in the way that different actor groups interact and (re-)produce physical system elements in relation to the societal function (Holtz et al., 2008, p. 626; Konrad et al., 2008, p. 1192).

Following on from the orientation along a societal function, Holtz et al. (2008) propose a definition of regimes based on five characteristics. The first characteristic of a regime is that it has a **'purpose'**, thus is delineated according to a societal function. Here, the regime is understood to be a system including the technologies, institutions and power constellations that determine the way that a societal function is being fulfilled.

Second, a regime is characterized by **'coherence'**. This means that the different elements are interdependent. Technologies, infrastructures, institutions, actors and their strategies mutually adapt to each other and evolve as an interrelated and coherent whole.

Third, a regime is characterized by **'stability'**. Innovations do occur, but they are incremental in the sense that they originate from established search heuristics and stay within established (technological) paradigms. As a consequence, they also do not alter established structures. In this way, the regime presents a selection environment that prevents radical innovations that might question the basic logic of a regime's functioning. More precisely, a regime is dynamically stable, allowing for incremental changes following along a trajectory with relatively clearly delimited boundaries.

Fourth, a regime is characterized by **'non-guidance'**. This means that there is not one central actor steering a regime and thus the way that a societal function is fulfilled. It also means that there is no common strategy or action by all relevant actors to fulfill a specific societal function in a shared effort. Rather, the specific trajectory of a given regime is the result of the interrelated actions of different actor groups, having varying intentions and pursuing different strategies and interests. The societal function is an abstract category that provides an analytical perspective on the interrelated and interdependent actions of different actor groups in a field delineated by the researcher. The regime concept is a tool for interpreting the basic features and logic of functioning of a system, which emerges from the alignment of actors and their strategies and other system elements.

Finally, a regime is characterized by **'autonomy'** in the sense that its basic characteristics and dynamics are determined by internal factors. This is not to say that a regime is not shaped or influenced by external factors, such as macro-economic or overall political trends, thus the landscape in terms of the MLP. A regime may also be affected by other socio-technical or ecological systems. However, the specific trajectory of a regime is not mainly the result external forces, but rather develops from the alignment of regime-internal actors and other system elements (Holtz et al., 2008, p. 626 ff.).

Based on these five characteristics, Holtz et al. have adopted the following definition:

"A regime comprises a coherent configuration of technological, institutional, economic, social, cognitive and physical elements and actors with individual goals, values and beliefs. A regime relates to one or several particular societal functions bearing on basic human needs. The expression, shaping and meeting of needs is an emergent feature of the interaction of many actors in the regime. The specific form of the regime is dynamically stable and not prescribed by external constraints but mainly shaped and maintained through the mutual adaptation and co-evolution of its actors and elements" (Holtz et al., 2008, p. 629).

The definition by Holtz et al. (2008) is useful because it departs from a technology-centered perspective on regimes and utilizes the specific analytical power of the regime concept that sets it apart from other approaches. According to Markard and Truffer (2008, p. 607), the key conceptual strengths of the regime concept are that it can facilitate a better understanding of the stability of socio-technical configurations through the interlinkages between various system elements, of the many dimensions involved in fulfilling a societal function, and of innovation processes that usually produce incremental innovations that stabilize trajectories of socio-technological systems. These aspects basically focus on explanations of the dynamic stability of socio-technical systems delineated in relation to a societal function, which is also the core of the definition developed by Holtz et al. (2008). A similar approach is chosen by Konrad et al. (2008). They also define a regime in relation to a societal function and propose to identify a specific regime in cases where "couplings between constituting elements (actor networks, technologies, institutions) are stronger (e.g. if they are regularly enacted or difficult to substitute) within a specific regime than outside" (Konrad et al., 2008, p. 1193). This definition based on 'couplings' also focuses on the regime-internal dynamics as an explanation for dynamic stability in the way a societal function is being fulfilled.

However, in all of these definitions there is no clear differentiation between socio-technical system (the tangible elements involved in fulfilling a societal function) and the regime (defined as the deep structure, or rule sets, underlying the physical system configuration). For instance, Holtz et al. (2008) do make reference to structuration theory, arguing that they adapt the concept of the duality of structure, in order to focus on "actions executed by the actors influenced by the structural elements and structural elements reproduced and changed by the action of actors" (Holtz et al., 2008, p. 631). By including both tangible system elements and intangible structural elements in the regime concept, Holtz et al. aim at capturing structuration processes as a whole. They are in fact 'integrated' in this way in reality, since structure has only a 'virtual' existence (Giddens, 1984, p. 17; Sewell, 1992, p. 6) and manifests itself in the concrete action of actors and thus eventually also in the material system elements.

However, it is argued here that for analytical clarity it makes sense to differentiate between agency and structure. Therefore, a 'narrow' regime definition is adopted of regimes as the deep structure that should be viewed separately from concrete agency in socio-technical systems. This separation is only valid for interpretative purposes, arguing that "[t]he crucial determining factor in the effective operation and development of the regime lies not simply in the agency of individual core members, but in the norms and procedures governing their structured relationships and interdependencies" (Smith et al., 2005, p. 1505). The basic rationale of this approach is to improve the understanding of the dynamic stability in concrete configurations of socio-technical systems and their trajectories by focusing the analysis on the underlying structuration processes. In order to clearly conceptualize these processes, a separation of structure and agency as analytical categories is advocated here.

The definition developed by Holtz et al. (2008) is therefore adapted in the following way:

A regime comprises a coherent configuration of technological, economic and social rule systems, including formal, normative and cognitive rules, extending over different groups of actors with individual goals, values and beliefs. A regime relates to one or several particular societal functions bearing on basic human needs. The expression, shaping and meeting of needs is an emergent feature of the interaction of many actors in a socio-technical system, where interaction reflects structuration processes related to a regime. The specific form of a socio-technical system and its underlying regime is dynamically stable and not prescribed by external constraints but mainly shaped and maintained through the mutual adaptation and co-evolution of its actors and elements.

Accordingly, the five characteristics of a regime are defined as structural properties. For instance, the purpose of a regime refers to the rule systems related to the way a societal function is fulfilled. These include the different rule systems of the various dimensions involved in fulfilling the societal function (technology, industry, markets, policy, culture). Coherence then captures the interdependence and mutual adaptations that have evolved across these different rule systems forming a coherent overall regime. Stability can be interpreted in terms of the simultaneously constraining and enabling character of structure. Thus, regime structures do enable the development of innovations and at the same time have a constraining effect because they produce mostly incremental innovations. Non-guidance means that there is not one dominant rule system imposed on all relevant actors in a socio-technical system, clearly steering it in a particular direction. Non-guidance describes a situation where different rule systems, i.e. different sub-regimes, are interrelated and become aligned and how an overall regime emerges from this dynamic constellation. Autonomy means that the regime as a rule system is not merely a result of external forces. In the logic of structuration theory, actors are knowledgeable and actively create structure, they are not simply reproducing a given structure. The way that regimes are shaped can therefore not be explained as a reactive or predetermined process. There is room for creativity and alternatives for action and so regimes can be described as autonomous because their specific form evolves from the concrete actions of knowledgeable actors. To some degree, regimes are shaped by external conditions and environmental constraints; however, the concrete shape that a regime takes within such broader contexts depends significantly on the interpretations of actors. So, the stability of regimes as well as their specific development paths should be seen in a wider context, however they cannot be explained by external factors only. The development of a regime is the outcome of processes of mutual adaptation and alignment of interrelated sub-regimes.

In sum, the starting point of the analysis of a system innovation should be an orientation along the particular societal function that is in question. This requires a careful definition, since the notion of a societal function is broad and can be ambiguous, too. As a second step, the relevant socio-technical system and underlying regime by which the societal function is fulfilled should be identified and differentiated. This is important in order to analyze structuration processes, which requires a clear analytical separation of structure, or in this case regimes, on the one hand, and agency, in this case interaction in socio-technical systems, on the other. Even though this separation is only an interpretative approach and only useful for analytical purposes (in practice such a separation does not exist), it is nonetheless decisive. The reason is that a specific physical system configuration can in principle express very different underlying structural principles or logics of functioning. If the aim is to really understand the basic logic of a socio-technical system and its trajectories, in order to identify the potential for substantial change, it is necessary to gain a profound understanding of its dominating structures and underlying guiding principles.

3.3.2 Socio-technical Change and the Concept of System Innovation

A next step is then to understand how socio-technical systems and regimes change. What type of change is involved and what concrete processes play a role? The concept of system innovation needs to be defined and characterized more clearly as a process of co-evolutionary socio-technical change. According to the definition adopted in this thesis, the co-evolution of technological and social dimensions is the second major characteristic of a system innovation. Such co-evolution may be understood as the central 'bridge' leading from technological substitution (first characteristic of a system innovation) to the emergence of new functionalities in a socio-technical system (third characteristic of a system innovation).

In the MLP approach, the usage of the concept of 'co-evolution' can be characterized as an implicit or underlying basic idea, which is expressed by focusing on *socio-technical* systems and regimes in the first place. As has been described earlier, a regime comprises various sub-regimes and together these form the semi-coherent 'deep structure' of a socio-technical system. The concept of co-evolution is used in this context to capture the complex process where each of these sub-regimes have their own specific characteristics and follow their specific development paths, while at the same time they are mutually dependent and together shape the overall trajectory and stability of a socio-technical regime. Thus, in the MLP, co-evolution describes the alignment processes and interlinkages within regimes, and dynamics across niche and regime levels (Geels & Schot, 2010, p. 21).

It has been argued that a result of this analytical perspective is a lack of agency and understanding its role in multi-level transition processes (Genus & Coles, 2008, p. 1441; Smith et al., 2005, p. 1492). Even though the MLP has a view on agency, due to its roots in Giddens' structuration theory and thus the basic understanding that structure or regimes as rule sets are always enacted by specific actors (Geels, 2011, p. 29), it produces explanations that are generally of a more structural nature (Foxon, 2010, p. 8). This relatively broad focus on the interplay of structuration processes within and across the three levels does indeed abstract from micro-level dynamics, such as the development of specific technologies, strategies of individual actors or actor groups and how such processes are interrelated.

However, this critique refers to the application of the MLP to specific case studies and is not an inherent shortcoming of this approach in general. The way that co-evolution is understood in the MLP allows for analyzing the dynamics within and between different rule systems of the various technological and social dimensions involved in a socio-technical system and forming a specific alignment and trajectory. It is therefore important to consider that regimes are not homogeneous entities but rather dynamically stable configurations of semi-coherent rule sets. This means that there is neither complete inertia within a regime, nor can specific technologies be assumed as 'givens' because they are shaped by structural dynamics and at the same time can themselves have varying impacts, i.e. it is not fixed in their design how they shape their environment in detail. Geels argues accordingly that such a detailed understanding of regimes "would make the strength, homogeneity and internal alignment of regimes an empirical question rather than an assumption" (Geels, 2011, p. 31). Even though a regime may appear as a coherent and homogeneous unit from the outside, and even though it is possible to determine basic structural principles of a regime as a whole, a second and more rigorous glance will show that there are almost always internal dynamics and tensions.

Such internal dynamics are the inevitable consequence of the fact that a regime comprises various sub-regimes. There are typically technological regimes as well as policy, science, market and cultural regimes, each characterized by their own structural dynamics. It seems quite likely that not all of the rules constituting these different rule systems 'match' each other and that there will be tensions, expressed in debates or conflicting interests of the different actor groups. The overall regime remains stable when there are basic rules or guiding principles prevailing across the different sub-regimes and when they are aligned in such a way that dynamics in one sub-regime are curbed by the interlinkages with other sub-regimes. However, there may be situations where tensions or deviating dynamics between specific types of rules or even between entire sub-regimes de-stabilize a regime as a whole. At this point, a window of opportunity emerges for a substantial change of the regime, and thus a transition (Geels, 2011, p. 31; Geels & Schot, 2010, p. 44). Due to the complexity of regime internal dynamics, "radical changes are likely to proceed through a complex and unique history of interrelated events" (Smith et al., 2005, p. 1494).

With regard to the type of change depicted in the MLP, a transition or a system innovation is not a linear process, where clear causal relationships between a limited number of influencing variables can be identified. In that way, it deviates from classical concepts of the diffusion of innovations, conceptualizing change as a sequence of typical phases of an S-shaped curve (cf. Rogers, 1962). The MLP also is not a technology-centered approach, even though technologies are a central element of the focal unit of analysis, namely socio-technical systems. The emphasis of the MLP is on structural conditions, because change is perceived to be a systemic and social phenomenon and not mainly the result of technology-push. While classical innovation approaches focus on the development and diffusion of specific technologies in a wider societal context, the MLP focuses explicitly on this context, because systemic change (a transition or system innovation) cannot be explained adequately by limiting the analysis to the emergence of a new technology (Geels & Schot, 2010, p. 27).

The concept of co-evolution can be seen to work twofold in the MLP. First, from an overall perspective it is the co-evolution of the three levels of the MLP – niches, regime and landscape – that may lead to a transition in a socio-technical system. A transition is defined as a change of the regime, which may come about when an established regime is weakened, for instance due to landscape pressure, and a window of opportunity emerges for a niche innovation to diffuse and become dominant, which then leads to a new regime developing around this niche innovation. Radical change is thus conceptualized as the result of co-evolution, in so far as the dynamics within and between the three levels are interlinked and eventually reinforce each other amounting to a full-fledged transition of the socio-technical system. Second, the concept of co-evolution plays an important role in the conceptualization of regimes. Since a transition or a system innovation is defined as regime change, it is important to understand the processes within a regime. It comprises different sub-regimes and the way that these sub-regimes are mutually dependent and together develop within a relatively stable trajectory is explained as a co-evolutionary process. Since the sub-regimes are interlinked and evolve together, they either stabilize a certain development path, or if diverging tendencies in one sub-regime become strong enough, they may mutually reinforce overall regime de-stabilization.

Even though the MLP is often characterized as a co-evolutionary approach, the closer look adopted here shows that the explanations offered by the MLP to deal with radical change may more accurately be described in terms of interlinkages and alignments within and between the levels of a socio-technical system (Foxon, 2010, p. 8). It may thus be argued that in the MLP "a constructivist explanation of technology's generation on the local level is combined with a social evolutionary approach of structural selection on the global level" (Geels & Schot, 2012, p. 30).

In sum, when trying to characterize the type of change depicted by the MLP and the way that the concept of co-evolution is understood and applied, it becomes clear that the MLP is a heuristic analytical tool with a focus on the macro-level processes of transitions. At the micro-level, the development and diffusion of technology is viewed as an outcome of multi-level structuration processes. These structuration processes are of central interest and their complex interrelatedness is described in terms of co-evolution. However, there is no explicit focus on concrete co-evolutionary dynamics at a micro-level, for instance between specific elements of a socio-technical system, between specific groups of actors or between specific sub-regimes. This is due to the heuristic character of the MLP, which aims at offering a comprehensive picture of the long-term and dynamic macro developments of transitions. In order to make the MLP fruitful for empirical studies and concrete cases, it should be complemented with other theoretical approaches and a suitable scale and scope need to be chosen. This is also the reason why in this thesis the notion of system innovation (even though often used synonymously) is preferred to the notion of transition, in order to be able to focus also on the local or micro-level of more direct and concrete socio-technical co-evolution in socio-technical systems.

With regard to the overall research question of this thesis, the point is not to focus on innovation processes as regards the way that technologies are being developed and how this development is shaped by wider socio-economic processes, because the electric car as a technological innovation does already exist and its diffusion is supported in different ways. However, the central question is whether it has the potential to develop as a radical and systemic innovation – thus, looking at how this technology shapes its socio-economic environment and understanding how its usage or role is in turn shaped in the context of a broader socio-technical system. Thus, there is a need to understand and conceptualize co-evolutionary change, where co-evolution means something in between the MLP's sociological/structural co-evolution of aligned sub-systems and more classical (co-)evolutionary approaches focusing on variation, retention and selection mechanisms in innovation processes.

The latter understanding of co-evolution has its origins in biology and refers to the way that two populations, species or organisms evolve and mutually influence each other. Concepts of evolution and co-evolution have, however, also been applied in the social sciences, focusing on organizations, institutions or technologies as (co-)evolving systems. Important categories are variation, retention and selection, which are the basic processes of evolution, explaining how novelties emerge (mutation of genes in the biological context, or the development of innovations in social systems), how advantageous characteristics of a population or a social system are retained or preserved over the long term, and how the process of selecting favorable characteristics works ('by accident' in the biological world or in an often partly guided way in social systems, such as markets or political arenas) (Foxon, 2010, p. 12). One may speak of co-evolution when there are two evolving systems, i.e. characterized by processes of variation, retention and selection, which have a direct and causal impact on each other. The type of impact they have on each other may vary, because co-evolutionary relationships can be anything from cooperative to predatory in character.

Kallis and Norgaard explicitly emphasize that "[c]oevolution is different than mere co-dynamic change although they are often misused synonymously" (Kallis & Norgaard, 2010, p. 690).

Concepts of evolution and co-evolution have been adapted from their origins in biology to the field of Science and Technology Studies, in order to explain technological change. Technologies or technological systems have been conceptualized as evolving systems, explaining their often path-dependent development characterized by specific technological trajectories or paradigms (as discussed in ch. 3.1.1 and 3.1.2). It has also been recognized that technological development or change cannot be adequately understood when observed in isolation, i.e. as a purely technological phenomenon. The concept of co-evolution is used to understand how technologies are shaped by their socio-economic environments and how, in turn, technologies shape economic and other social systems. Each of these systems is viewed as an evolving system and the way that they influence each other, thus their co-evolution, leads to dynamic and uncertain technological development paths. It is thus also emphasized that no specific technological development is the inevitable outcome of a particular technology-inherent logic. There is thus also rarely the possibility to predict socio-technical developments and there are always potential alternatives (Foxon, 2010, p. 8; Geels & Schot, 2010, p. 32).

However, it has already been pointed out that the concept of co-evolution, in its many adaptations in the field of the social sciences, is not used in a coherent way and, what is more, is often used imprecisely. Especially in transition studies, what is termed 'co-evolution' can in many cases be described much more accurately as 'co-dynamic' development. The basic idea here is generally to show that socio-technical transitions can be understood only from an overall systems perspective, and that various technical and social elements are interlinked and mutually influence each other. This may be characterized as an overall co-evolutionary perspective, but it falls short of tracing the concrete causal links between two evolving systems and identifying the concrete mechanisms and dynamics of such co-evolutionary processes. In order to improve the analytical rigor of transition studies, the "understanding that 'everything' might be coevolving with everything else needs to be complemented with the identification of what is coevolving with what and how in specific conditions or contexts and as relevant to specific analytical and policy purposes" (Kallis & Norgaard, 2010, p. 691). Analytically separating the particular elements that are co-evolving (against the background of a systemic perspective, where all those elements are aligned in various ways) may improve understanding of the concrete micro-level processes relevant in transition processes and thus may also cast new light on the roles of actors, strategies or policies in these processes (Foxon, 2010, p. 13).

Compared to the MLP, Dolata's concept of technology-based sector transformation proves to be of greater strength with regard to this aspect. In this approach, the transformative capacity of new technologies and sectoral adaptability are analytically separated, in order to focus on the direct interrelation between technological and social elements. New technologies are shown to have a transformative capacity and thus a direct impact on a sector's socio-economic and institutional structure. At the same time, the degree to which a sector is adaptable determines the actual impact a new technology can have. So, co-evolution is conceptualized here as a direct interrelation between changes in technology and changes in other elements of a sector.

Before focusing on this interplay between the transformative capacity of new technologies and sectoral adaptability in more detail, the type of change and basic dynamics that Dolata's sector transformation approach entails will be discussed in the following. It has already been noted in ch. 3.3.1 that in contrast to the MLP, the focus is on change in industrial or economic sectors. Nonetheless, sectors are defined rather broadly as socio-technical fields, including not only the economic core of a sector but also other socio-economic structures, institutions and actors that are related to it. In that way, the research questions and basic problem frames of the MLP and of the sector transformation approach differ substantially, while their empirical object of study can be relatively similar. This applies not only to the elements of a socio-technical field as defined by Dolata or a socio-technical system in the MLP, but also to the basic dynamics within these fields or systems and thus also the basic understanding of fundamental change within them.

For instance, similar to the conceptualization of socio-technical systems and regimes, sectors as socio-technical fields are not to be seen as completely homogeneous entities made up of actors that share the same set of rules and apply the same strategies in aiming to achieve a certain goal in unison. A sector is rather characterized by the interplay of heterogeneous groups of actors with different interests and different degrees of power to influence others. This results in continuous processes of structuration, of de- and re-institutionalization that eventually shape the configuration of a specific sector. The overall outcome may be more or less coherent when looking at a specific sector as a whole, but underneath this there are power struggles, conflicts and differing interpretations (Dolata, 2011, p. 26).

It is argued that fundamental change in a sector is often triggered by the emergence of new technologies. The potential of new technologies is in many cases hampered by the established institutional structures of their socio-economic context, which then act as a barrier to the further development of new technologies and inhibits reaping their potential benefits. In this way, new technologies can trigger processes of searching for new arrangements within organizations and established institutions because they cast doubt on whether established socio-economic structures are still fulfilling specific functions adequately. Since sectors as socio-technical fields consist of heterogeneous actors, those search processes or early phases of change are characterized by a high degree of uncertainty. There are different interpretations of the problem at hand, different strategies being pursued and different goals or orientations being referred to by different actors. These different points of view are competing in this phase and there are power struggles and open conflict between different actor groups. It can also be observed that these search processes are often initiated by relatively marginal actors that are part of the socio-technical field but do not belong to its economic core. The result of search processes developing around new technologies may in some cases result in fundamental changes in a sector, i.e. changes in its basic socio-economic structure, its institutions and organizational arrangements. This means that there may in the end be new actor configurations and new power constellations, new patterns of market relations, new demands on the relationship with science or on policies and regulation as well as new boundaries being drawn of a specific sector and re-adjusting its relations with other sectors (Dolata, 2011, p. 26 f.).

The type of change in this concept is similar to the conceptualization in the MLP. Both approaches view change as a gradual and multidimensional process that unfolds in a heterogeneous and dynamically stable system. Both refer to structuration processes and view change as a non-deterministic, open-ended process characterized by uncertainty and conflicting dynamics. Fundamental change is conceptualized as a deep and structural type of change at the level of institutions, rules and guiding principles of a socio-technical system or a sector as a socio-technical field, respectively. Both approaches also emphasize the role of marginal or 'new' actors in initiating change – niche actors in the MLP and actors at the fringes of a sector in Dolata's approach.

Also, both approaches refer to the concept of co-evolution, whereas it is applied differently. In the MLP, co-evolution is used as a notion that describes the alignment and interlinked development of the different dimensions of a socio-technical system across the levels of niche, regime and landscape. Co-evolution also captures the coordination between the different sub-regimes making up an overall socio-technical regime. Thus, co-evolution in the MLP could rather be understood as the co-dynamic development characterizing macro-level transition processes. In the sector transformation approach, co-evolution is applied on a micro-level, focusing on the direct impact technology has on socio-economic sector structures and vice versa. Sector transformation is explained as a function of two interrelated influencing factors, namely the transformative capacity of a new technology on the one hand, and of sectoral adaptability on the other. By analytically separating technology and the socio-economic system of a sector, this approach aims at tracing the direct and causal links between these two influencing factors and thus explaining the resulting socio-technical change on a micro-level.

Dolata explicitly criticizes the MLP for a lack of analytical rigor and accuracy at the micro-level. He argues that the basic idea of the MLP is useful, since it depicts socio-technical change as a process where pressure for change is exerted on regimes as selection environments and where this pressure is perceived and acted upon in specific ways. The interplay of selection pressure and the capacity to adapt may then result in a transition. However, he criticizes that it is not explained sufficiently how selection pressures emerge and what exactly determines the degree of adaptive capacity of a regime. Furthermore, the types of regime change discussed in transition studies are not systematically developed and derived from theoretical insights on the interplay of selection pressures and adaptive capacities. Therefore, he argues, that many transition studies are limited to providing plausible explanations that lack the necessary theoretical rigor and empirical basis (Dolata, 2013, p. 27; Dolata, 2011, p. 40). Consequently, in his approach Dolata focuses on the direct causal links between the transformative capacity of new technologies and sectoral adaptability.

However, even though technology-based sector transformation provides an approach that allows for producing explanations on the direct and causal influences of technologies on socio-economic sector structures and vice versa, it still falls short in terms of a truly co-evolutionary explanation. Neither technology, nor the sector is conceptualized as an evolving system per se. This aspect is much more explicit in the MLP. The different dimensions or regime elements in a socio-technical system (technology, markets, policy, culture) are conceptualized as rule systems that follow trajectories and their development can be explained by taking recourse to evolutionary mechanisms of variation, retention and selection. What is then missing is a micro-level focus on co-evolution, i.e. the causal impacts that two or more of those evolving sub-systems directly have on each other, as developed in Dolata's sector transformation approach.

With regard to the research question of this thesis, Dolata's approach is problematic because it is a sectoral approach. When one is interested in the fate of a specific technology or the effects it has on specific actors and structures, a sectoral approach is useful. However, as has already been pointed out in ch. 3.3.1, when studying sustainable system innovations this focus is too narrow. This type of question is concerned with fulfilling societal needs in radically different ways and thus cannot meaningfully be limited to a specific industrial sector or set of established actors. Therefore, when studying a sustainable system innovation, the suitable unit of analysis is a socio-technical system, which can be delineated along the generic societal function it fulfills (e.g. ‘providing mobility’), and which is characterized by a specific regime, thus the rule systems or the deep structure that explain the specific way of functioning and the physical configuration of the socio-technical system. Therefore, the type of change that is in the focus is a system innovation defined as regime change.

An important aspect of a system innovation is socio-technical co-evolution and it has been shown that in the MLP, the various social and technological dimensions or sub-regimes are well described in terms of evolving systems. With the notion of co-evolution, the MLP rather describes co-dynamic alignment processes capturing the ‘bigger picture’ of mutually dependent developments across niche, regime and landscape levels. What is lacking is a clear view on the direct and causal influences that social and technological elements have on each other, i.e. actual co-evolutionary mechanisms on a micro-level. Such a perspective is necessary for dealing with cases such as e-mobility, where a technology is emerging and it is important to understand what its impact is on social system elements and how concrete co-evolutionary dynamics shape the way the technology is used in (potentially) new system configurations. If a transition or a system innovation will develop around such a technology, the configuration of the resulting socio-technical system and the way it fulfills a specific function, can be explained by the very concrete and direct interactions of a socio-technical co-evolution process. In order to be able to adapt such a perspective, the concepts of transformative capacity of new technologies and sector adaptability will be adapted, where necessary, and integrated as complementary concepts within the wider MLP-framework. The analytical separation of a new technology and of the relevant social elements will help to better trace direct and micro-level co-evolutionary processes. It is argued that such an integration is possible because basic premises of the two approaches, MLP and sector transformation, are similar. Their general view on change as a gradual and complex process corresponds, as well as the way that socio-technical systems or socio-technical fields are conceptualized as dynamically stable configurations characterized by structuration processes. A major difference, however, is the central boundary criterion for delineating the relevant unit of analysis. In the MLP it is the societal function that a socio-technical system can be said to fulfill, while Dolata focuses on sectors as socio-technical fields defined around an economic core. Since the focus of this thesis is on sustainable system innovations, which requires a view on fulfilling societal functions in socio-technical systems, the next step in developing a theoretical framework is to adapt the concepts of transformative capacity of new technologies and of sectoral adaptability in such a way that they can be incorporated in an MLP-framework and still retain their analytical strength.

3.3.3 The Transformative Capacity of New Technologies

In order to analyze and better understand technology-based transformations of industrial or economic sectors, Dolata introduces the concept of transformative capacity of new technologies as one decisive influencing factor. The point is to conceptualize technology as an independent influencing factor as a first step, in order to be able then to grasp its interplay with the 'social' elements, eventually resulting in sectoral transformation. Nonetheless, it is clear that this separation is analytical in nature and that the transformative capacity of new technologies is an inherently relational concept. It can only be determined based on the possibilities to use and further develop a new technology in a specific sectoral context and based on the institutional and structural conditions which a new technology meets in a specific sector. Technologies can have an impact on sectors only because applying or using them usually requires some degree of change in socio-economic institutional structures. It is the mis-match between the potential of a new technology and the feasible possibilities of using it under given circumstances which can be characterized as the transformative capacity inherent in a new technology. The more a new technology becomes relevant for a sector and the less it can be embedded in existing sectoral structures, the larger is its transformative capacity and thus the pressure for change it exerts on established sectoral organizations, institutions and behavioral patterns (Dolata, 2011, p. 68 f.).

Considering these qualifications regarding the transformative capacity of new technologies as a relational category, while at the same time analytically isolating technology as an influencing factor in its own right, two general characteristics of a new technology are introduced by Dolata. First, it has to be distinguished whether a technology can be characterized as exogenous or endogenous, i.e. is it developed within the sector that is to be studied, or outside? This is an important differentiation because it allows for locating where the pressure for change is coming from. It can make a difference whether a new technology has been developed within a sector and thus has already been shaped by sectoral structures in its early development, or whether it comes from outside and has been developed under substantially different circumstances. In both cases, the transformative capacity can be either high or low. A technology may require enormous structural adaptations even though it has been developed within a sector. At the same time, the transformative capacity of an exogenous technology can be low because it may only have a subsidiary function not affecting the technological core of a sector. So, determining whether a technology can be characterized as endogenous or exogenous is helpful for understanding where the pressure for change originates but it says nothing about the degree or strength of this pressure (Dolata, 2009, p. 1068 f.). Second, it has to be distinguished what type of effect a new technology has on a specific sector. Effects may range from being only indirect or even supportive of established sectoral functionalities to being much more direct and disruptive with regard to the established structures of a sector. Based on these effects, a new technology can be characterized as having a low or high transformative capacity, respectively (Dolata, 2009, p. 1068). So, in order to get a grip on the transformative capacity of a new technology, it should be considered where it originates, i.e. whether potential pressure for change is exerted from within a sector or from outside its boundaries, and it should be assessed whether it has a direct and disruptive impact on established actors, institutions and structures of a sector or whether its effects are more indirect and complementary, thus leaving the established sector configuration largely intact (Dolata, 2009, p. 1069).

Based on these two characteristics it can then be determined whether the transformative capacity of a specific new technology is either high or low in the context of a specific sector that is confronted with the emergence of this technology. It should be noted explicitly at this point that transformative capacity cannot be measured quantitatively in any meaningful way. It is hardly possible to identify unambiguous and universally valid indicators for such an undertaking. This is partly due to the fact that transformative capacity remains a relational category and that it cannot be determined based on characteristics or features of a specific technology in its own right and independent of its sectoral context of application. However, a number of qualitative criteria have been identified according to which the transformative capacity of a new technology can be captured in a way that is precise enough to serve as a useful heuristic for developing scenarios or reconstructing specific cases. These criteria assess the characteristics of a new technology with regard to the specific configuration of the sector that is to be studied (Dolata, 2011, p. 70 f.).

The criteria, as presented in the following, aim at grasping "the extent to which new technological opportunities and their attributed peculiarities

- alter the technological profile of the sector and enhance or destroy the existing knowledge base and competencies;
- affect the existing patterns of research and development, production, distribution, products, and market relations;
- facilitate or enforce new patterns of cooperative and competitive interaction;
- initiate institutional readjustments (e.g. new regulative and legal frameworks or modified guiding principles, norms, and beliefs);
- open up or widen the existing borders of the sector, thereby provoking a more intense interpenetration of different sectors (e.g. by the migration of powerful external actors into the sector)" (Dolata, 2009, p. 1070).

The basic idea of the concept of transformative capacity as reflected in these criteria is that a new technology may have the potential to shed new light on the established mechanisms and basic logic of functioning of a given sector. The emergence of a new technology may give rise to a situation where the existing technological basis of a sector, its institutional and organizational structure as well as its guiding principles are increasingly being questioned. Put differently, new technologies may raise doubts about an established and to date unquestioned sectoral configuration because they "challenge the existing match between technology, structures, and institutions in the course of their formation and adoption" (Dolata, 2009, p. 1070). In such a situation, a new technology causes pressure for change and it may trigger processes of searching for new sectoral configurations. However, the fact that a new technology possesses a high transformative capacity does not necessarily have consequences in practice. Whether or not the emergence of such a technology leads to processes of sectoral transformation depends significantly on the way that this is perceived and acted upon by sectoral actors. Transformative capacity merely points to the inherent potential of a technology in relation to given sectoral structures, thus as a concept it captures the virtual range of possibilities or alternatives that become feasible with this technology. Actual change results from the interplay that unfolds within the social configuration and dynamics of a sector (Dolata, 2011, p. 73 f.).

In order to study system innovations, the concept of transformative capacity, which has been developed in the context of sectoral studies, needs to be adapted to the context of socio-technical systems. It has already been pointed out that according to Dolata sectors can be defined as socio-technical fields around an economic core. The elements included in such a socio-technical field are similar to those in socio-technical systems as the focal unit of analysis in the MLP. The major difference is that socio-technical systems in the MLP are delineated according to the societal function they fulfill. Therefore, the relevant economic core activity is not as central as in the sector transformation approach; rather, it is one element making up the socio-technical system in concert with politics, technology, infrastructure and culture.

Following this, the criteria for assessing the transformative capacity of a new technology as developed by Dolata need to be slightly adapted, in order to fit with the perspective on the function fulfilled by a socio-technical system. Again, since the definition of a sector as a socio-technical field is similar to that of a socio-technical system, most of the relevant aspects are included in the existing criteria. Thus, following the original systematization by Dolata:

In order to assess the transformative capacity of new technologies it needs to be analyzed to what extent the new technological opportunities and their attributed peculiarities

- alter the technological profile of the socio-technical system and enhance or destroy the existing knowledge base and competencies;
- affect the existing patterns with regard to market relations, research and development, policy making and user behavior;
- facilitate or enforce new patterns of interaction between different actor groups of the socio-technical system;
- initiate institutional readjustments (e.g. new regulative and legal frameworks as well as modified guiding principles, norms, and beliefs within different sub-regimes);
- open up or widen the existing borders of the socio-technical system.

Adapting the criteria in this way is possible because the basic idea they reflect of the concept of transformative capacity is that of a technology emerging as a challenge to existing structures and pointing towards alternative ways of organizing these established structures. This idea is central both for understanding co-evolutionary processes of change in sectors as socio-technical fields as well as in function-oriented socio-technical systems. The difference in perspective when focusing on the function fulfilled in a socio-technical system has been introduced in the criteria by including, apart from the economic dimension, the political and cultural or user dimension more explicitly (these elements also play a role in the sector transformation approach but are viewed as a field forming around the economic core). So, even though the criteria can be kept similar and the basic idea of the approach remains the same, the empirical consequences and the outcomes with regard to the types of answers may differ more fundamentally. The change in perspective from focusing on a sector and its economic core activity to a socio-technical system that fulfills a societal function in a specific problem field (e.g. sustainable mobility) may not alter the focus being set on a specific technology (e.g. electric cars) and it may in both cases be useful to apply the concept of transformative capacity, in order to understand the challenges and potentials inherent in this technology. However, with regard to the implications that this type of research can have, it is a major difference whether the transformative capacity of electric cars is analyzed in relation to a sector (possibly changing the way that cars are produced) or in relation to a function-oriented socio-technical system (possibly changing the way that mobility is provided).

Assessing the transformative capacity of a new technology along the criteria developed here can be shortly summarized as an approach that identifies the mis-matches of a new technology with the established elements of a socio-technical system (e.g. its technological profile, patterns of interaction, or even its boundaries) and thus also with the underlying regime (e.g. the guiding principles within different sub-regimes). Since all the physical elements and interactions of actors within a socio-technical system can be understood as an expression of the dominant regime, it is important to trace how a new technology affects this underlying deep structure. Empirically, the focus obviously has to be on the tangible system elements, in order to trace the implications of a new technology. However, a regime perspective will allow for a more systematic analysis of the most important and fundamental mis-matches related to the very basic logic of functioning of an established system. Another empirical consequence is a research approach that focuses on the technological shortcomings that are attributed to a new technology. Technological shortcomings understood as mis-fits of a new technology with an established system are, in principle, shortcomings only with respect to the existing conditions and thus may in some cases very clearly point to the new technology's transformative capacity.

3.3.4 System Adaptability

In Dolata's technology-based sector transformation approach, sectoral change is explained as a result of the interplay between the transformative capacity of new technologies and the adaptability of the sector. The concept of sectoral adaptability is introduced as an analytical tool to capture the way that newly emerging technological opportunities are perceived and dealt with in a given sector. Adaptability in this context means more than a passive reaction to changing conditions, as in the common sense of the word. Since new technologies are seldom emerging as a 'given' with clear implications on ensuing consequences, adaptability here refers to a more active way of dealing with the uncertainties and ambiguities involved in technological change processes. New technologies often remain in an immature and developing phase for quite a while. At this early point they do cause pressure for change on sectors because it is already clear that there are mismatches with existing structures. However, it is much less clear how exactly a new technology can and will be used in the future, how significant its role will be and thus, how sectoral structures will change exactly. As a result, new technologies first and foremost trigger search and selection processes in a sector, where different expectations are formulated, discussed, revised and refined in an often controversial and non-linear fashion. The concept of sectoral adaptability captures the way that a sector is able to deal with such search and selection processes in situations where the established organizational and institutional structures seem to function less well than they did before and where well-tried strategies and guiding principles fail to deliver solutions to new problems (Dolata, 2009, p. 1070; Dolata, 2011, p. 76).

In order to assess the adaptability of a sector, it is not sufficient to focus on the way that already mature technologies have eventually been adopted. At this point the critical phases of sectoral change have already been overcome. Sectoral adaptability can only be grasped when looking at the process as a whole and especially focusing on the early phases of (potential) change. Whether a sector is characterized by high or low adaptability depends on how the potential of immature technologies as well as the related organizational and institutional effects it might have are perceived and dealt with. Thus, sectoral adaptability describes the degree to which a sector is prepared to deal with insecurities and ambiguities concerning its future development (Dolata, 2011, p. 76 f.).

Dolata identifies three levels on which "sectoral adaptability can be identified:

- on the organizational level the ability to identify, communicate, and adopt the challenges of new technologies in a timely manner and to renew established routines and strategies;
- on the institutional level the openness and flexibility to change and readjust […] the regulations, norms and shared beliefs guiding and structuring the activities of the actors involved;

- on the structural level the permeability of research, production, market, and demand conditions in supporting discontinuous innovations, developing new products, constituting new markets, and facilitating the entry of new actors" (Dolata, 2009, p. 1070).

Based on this more general separation of levels of a sector, Dolata identifies a number of factors that are relevant for determining the adaptability of a sector. These are (1) the ability of key actors to adapt as well as the institutional and structural conditions for overall sectoral adaptation; (2) the role of the fringes of the sector and the relations between the sectoral core and its periphery; (3) organizational, institutional and structural mechanisms fostering or impeding change; and (4) power relations within the sector based on social or technological sources of power (Dolata, 2011, p. 118 ff.). Characterizing a sector according to these criteria and analyzing how these factors are interrelated in the specific sector allows for identifying its specific degree of sectoral adaptability. Generally, this may range from low to high adaptability.

Low adaptability can be found in sectors that have been stable and successful over long periods of time without having had to adjust substantially their market relations, industry structures, regulations and overall guiding principles along the way. These sectors are often highly vulnerable with regard to technological changes and at the same time are lacking mechanisms or anticipatory strategies for dealing with uncertainties and prospective change. The emergence of new technologies is mainly perceived as a risk threatening established and successful economic performance. As a consequence, these sectors typically react to the emergence of potentially disruptive new technologies by increasing their efforts of preserving the established sectoral structures and technological profile. A transformation of these types of sectors usually is a crisis-ridden process where the impetus for change comes from actors at the fringes of a sector or from external actors. These actors perceive the emergence of new technologies as an opportunity to gain importance and possibly even replace the established core actors, who are trying to preserve the existing structure to their advantage. So, essentially processes of change in these cases can often be characterized as power games (Dolata, 2009, p. 1071).

In contrast, there are sectors characterized by high adaptability, in the sense that they are more anticipative of novel technological developments and actively deal with radical technological innovations. This is possible in cases where a sector possesses established institutionalized mechanisms for anticipating and adapting to changing circumstances or new influencing factors. Usually this can be found in sectors that are characterized by fierce competition and where innovation and experimentation are important and highly-valued elements. Such general conditions allow for a proactive attitude of actors and structural flexibility to deal with emerging technologies already at an early stage (Dolata, 2009, p. 1071).

As regards the criteria that have been developed for assessing the transformative capacity of new technologies, it is obvious that also sectoral adaptability cannot be approached by any clearly delineated quantitative measure. The aim of the criteria for sectoral adaptability developed by Dolata is to provide a heuristic to assess sectoral adaptability in a systematic way, while being aware of the fact that there may be a multitude of relevant factors and interlinked dynamics playing a role. Furthermore, this approach is a way to deal with the fact that causes for inertia and structural path dependency have been relatively well explored, whereas high adaptability and its causes are much less clear (Dolata, 2009, p. 1072). This may in fact simply be due to the nature of the matter at hand, namely that sectors as well as socio-technical systems generally develop in such a way that stability and continuity can be preserved as much as possible.

The MLP departs from exactly this insight and “provides a way of addressing the core analytical puzzle of transitions, namely stability and change” in socio-technical systems (Geels & Kemp, 2012, p. 50). Overall system stability is explained as a result of path-dependent development and lock-ins of different types, for instance “shared beliefs that make actors blind for developments outside their scope; consumer lifestyles, regulations and laws that create market entry barriers; sunk investments in machines, people and infrastructure; resistance from vested interests; low costs because of economies of scale” (Geels & Kemp, 2012, p. 50 f.). These mechanisms correspond to the factors that Dolata discusses as an explanation of low sectoral adaptability, whereas the focus of the MLP is broader, in order to capture the function-oriented socio-technical system, which goes beyond Dolata’s focus on the core economic activity determining a sectoral socio-technical field. Also, similar to Dolata’s approach, where external actors and actors at the fringes of a sector play an important role with regard to introducing radical novelties, the MLP emphasizes the role of niche-actors[5]. They are important advocates of change, since established actors and structures

[5] The discussion of the role of fringe or niche actors points to the importance of entrepreneurs and an overall entrepreneurial culture. Fostering the potential of emerging system innovations in the field of mobility as well as other crucial societal sub-systems therefore depends on more profound approaches of entrepreneurship education

are threatened by innovations that are radical in so far as they imply a different system configuration (Geels & Kemp, 2012, p. 50 f.)

Rather than systematizing varying degrees of adaptability, in the MLP it is assumed that socio-technical systems are in principle characterized by overall dynamic stability. Nonetheless, fundamental change is possible and has occurred throughout history. Such fundamental changes, i.e. transitions or system innovations, are conceptualized as regime change. A recent approach introduced by Kemp et al. (2012) for studying ongoing or even just potential future transitions, is to investigate 'cracks' (p. 3) in established regimes. It is argued that regimes as the deep structure of socio-technical systems shape and stabilize path-dependent trajectories, while at the same time there are always regime-internal dynamics due to the fact that a regime consists of various sub-regimes. A potential for substantial change is emerging when tensions are developing within the regime, i.e. when cracks in the thus far well-aligned regime configuration threaten overall stability. Such a situation presents a window of opportunity for radical innovations to diffuse and trigger wider socio-technical change (Geels et al., 2012, p. 355 f.; Nykvist & Whitmarsh, 2008, p. 1385). Similar to Dolata's concept of sectoral adaptability, in the MLP it is the appearance of cracks in the regime that increase the possibility for a more proactive perception and dealing with novelty, a larger scope for institutional readjustment and thus eventually the prospect for a transition or system innovation.

In order to improve the analysis of system innovations in terms of co-evolutionary socio-technical change, it is proposed here to adapt the concept of sectoral adaptability to the study of socio-technical systems. Since both the MLP and the sector transformation approach emphasize the importance of structuration processes, where technological innovations may trigger new practices and institutional readjustments, it is possible to integrate the concept of adaptability in the MLP. Since the focus of the MLP is on socio-technical systems, the notion of system adaptability is introduced and will be spelled out more clearly in the following. The aim is to develop criteria of system adaptability (similar to what Dolata has done for the study of sector transformations), in order to enrich the MLP with a more systematic approach for analyzing co-evolutionary processes of socio-technical change.

In the MLP framework, a system innovation can be defined as regime change. Therefore, system adaptability, analogous to the concept of sectoral adaptability, describes the

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in schools and universities but also in professional contexts in practice and in individual companies. These issues are elaborated in: Braukmann et al. (2012), Braukmann & Schneider (2008).

way that a technological innovation is perceived and dealt with in the context of established regimes. Since regimes are defined as rule sets, system adaptability depends on the stability or instability of the regime and thus the way that rule systems can be readjusted. Regimes are conceptualized as rule systems based on Giddens' theory of structuration and the basic idea of the duality of structure. In the context of socio-technical systems this means that a 'material' change in such a system is always interrelated with changes in structures or, more accurately, it is the outcome of a structuration process where actors (re-)produce structures. In that sense, system adaptability increases, when a regime as the established, and so far persistently reproduced, set of rules is destabilized.

Since both the sector transformation approach and the MLP assume structuration processes as the basis for the development of specific system configurations and their stability, a closer look should be taken at how change can be explained by drawing on Giddens' theory of structuration. The basic idea of the duality of structure is implicit in the sector transformation approach and more explicitly used in the MLP in distinguishing different levels according to their varying degree of structuration. However, even in the MLP the reference to Giddens' concept remains relatively superficial. Stability and change are interpreted in terms of actors reproducing established structures or actively introducing novelty by deviating from established structures. This does result in a useful heuristic for understanding the scope of action that different actor groups perceive for themselves and make use of. However, what is needed is a more in-depth understanding and an actual explanation of how structuration processes may produce change (see also ch. 3.1.3.1). This may then shed light on the concrete factors influencing system adaptability.

In this respect, it is important to reflect on the underlying question that Giddens' structuration theory deals with. The concept of the duality of structure explains how large parts of everyday social practices are characterized by routinized behavior and how this contributes to the overall stability and cohesion of social systems. However, this does not mean that structuration theory first and foremost explains social order or the continuous reproduction of the very same social practices over and over. Rather, structuration theory is about stability in the sense that social practices are conceptualized as a continuous phenomenon, while within these continued social practices there is room for change as regards the concrete shape and form of these practices (Schiller-Merkens, 2008, p. 180). This is reflected in the MLP in so far as regimes are described as 'dynamically' stable. Based on this, the question is how can a change in structure, i.e. in institutions or basic rule sets, be explained?

As a starting point for approaching this question, it is important to note that Giddens distinguishes three dimensions of the duality of structure, along which different types of institutions can be grouped. These three dimensions are signification, domination and legitimation and their specific properties are reflected in different types of interaction in social systems, namely in communication, in the way that power is exercised and sanctions are enforced. Giddens then introduces the modalities of structuration, in order to clarify what the specific types of institutions are that actors draw upon in their social practices and in what way this leads to the (re)production of overall structural properties. The modalities of structuration include (1) interpretative schemes that actors draw upon when they communicate and which reflect structural properties with regard to signification, (2) facility, i.e. the allocative and authoritative resources decisive for the execution of power and reflecting structures of domination, and (3) norms which imply different types of sanctions and reflect structures of legitimation (Giddens, 1984, p. 28 ff.). Institutions, or rule sets in terms of the MLP, can be grouped along these modalities. Institutionalized forms of symbolic meaning and discourses can be analyzed in terms of interpretative schemes, political and economic institutions reflect the allocation of resources (and thus power relations) and moral or legal institutions express what is perceived to be legitimate behavior and are connected with sanctions. Grouping and systematizing institutions in this way allows for analyzing and explaining the specific configuration of a social system, for instance by identifying the role of different types of resources or by studying the way that symbolic meaning or legitimized traditions have an impact on social practices and what types of sanctions they produce (Lamla, 2003, p. 58 f.).

Based on this general conceptualization, possibilities for structural change can be identified when there are tensions or contradictions emerging in the way that the modalities of structuration are drawn upon. The conditions for structural change are thus favorable when there is heterogeneity or even contradictions among the rules in a social system. Since rules according to Giddens refer to structures of signification and legitimation this means that within a social system interpretive schemata and expectations regarding appropriate behavior would vary. With regard to authoritative and allocative resources, the conditions for structural change are favorable when the distribution of these resources is unequal and there are large disparities in the distribution of power (Schiller-Merkens, 2008, p. 198).

The analysis of system adaptability should thus focus on the interrelations and dynamics between the different sub-regimes, i.e. the interlinked rule sets that together constitute an overall regime. The key elements determining whether overall system adaptability is high or low are reflected in regime configurations that are either well-aligned or characterized by internal tensions.

Much like transitions and regime change in general, system adaptability can ultimately be determined only in retrospect. However, it is possible to identify landscape factors that have an impact on established regimes as well as dynamics between niches and a dominant regime. This latter aspect of niche-regime dynamics is important because even if there is substantial landscape pressure and a niche with transformative capacity, the potential for a transition depends on the way that incumbent regime actors deal with this situation. In some cases, 'cracks' in the regime may induce regime incumbents to take up niche-innovations. This can play out favorably, because regime actors are in a more powerful position than niche actors and have the resources to introduce novelty at a larger scale (Nykvist & Whitmarsh, 2008, p. 1385). An example from the field of mobility could in this respect be the recent efforts of large OEMs to develop carsharing services, thus promoting and developing this niche. However, studies of transition management policies have also shown that in many cases incumbent regime actors manage to capture green niches, such as for instance carsharing, and sustainability discourses, in order to fit them into current regime structures as a way to preserve the status quo (Avelino, 2009, p. 381; Meadowcroft, 2009, p. 336; Voß et al., 2009, p. 289). It is thus important to identify not only the cracks in the regime, but also the way that these are dealt with, i.e. how adaptable the socio-technical system actually is. The key elements determining whether overall system adaptability is high or low are reflected in regime configurations that are either well-aligned or characterized by internal tensions:

- Rules: What are the dominant interpretive schemes and norms in a socio-technical system? Are they coherent across the regime as a whole or can tensions and conflicts be identified?
- Resources: How are resources distributed in a socio-technical system? Can conflicts or tensions with regard to the distribution of power be identified?

Assessing system adaptability should thus focus on constellations of power between actors and the guiding principles or frames of reference they draw on. System adaptability increases with emerging conflicts regarding the distribution of power among groups of actors and incoherence and emerging uncertainty with regard to established norms and values.

3.3.5 An Integrated Analytical Framework: Synthesis and Discussion

Integrating elements from Dolata's concept of technology-based sector transformation in the Multi-Level Perspective is possible because both approaches emanate from a similar conceptualization of change in general. Both go beyond more traditional and simpler approaches of looking for alternating phases of system inertia interrupted by short periods of radical system shift. Transitions as well as sector transformations are conceptualized as continuous and ongoing processes, determined by the constant interplay of stability and varying degrees of change. The basic aim of both approaches is to identify concrete patterns that may help structuring and better understanding overall complexity. By integrating their particular strengths in an adapted analytical framework, research on sustainability-oriented system innovations, such as e-mobility, can be structured in a more profound and theoretically grounded way (cf. also Augenstein, 2014 forthcoming, 2012a, 2012b).

The different elements that have been discussed in the preceding sections – the relevant unit of analysis, conceptualizations of socio-technical co-evolution and system innovation – will now be integrated in an adapted analytical framework (see Fig. 10). The core of the analytical framework is the system innovation, defined as regime change. Since the regime refers to the deep structure that lies beneath the physical, i.e. measurable, configuration of the socio-technical system elements, the analysis will empirically have to focus on those elements, such as technologies, infrastructure, formal and informal institutions as well as actor strategies and behavior. This is how the two influencing factors from the concept of technology-based sector transformation – the transformative capacity of new technologies and sectoral adaptability – can be integrated. They are assessed according to a number of qualitative criteria and at different levels, respectively (Dolata, 2009). These are corresponding to the 'measurable' elements of socio-technical systems according to the MLP. However, their analysis in terms of factors influencing a system innovation requires a broader focus transcending sector and current regime boundaries, investigating the potential for radical system shift. Therefore, it is referred to system adaptability, instead of sectoral adaptability, because a system innovation implies that a societal function may eventually be fulfilled in substantially different ways, with a different technology and possibly also by different actors.

The analytical separation of transformative capacity of new technologies and of system adaptability allows for tracing concrete patterns of co-evolutionary transformation. Dolata has criticized the MLP approach for identifying transition patterns and pathways that have been derived in an interpretative fashion that is not adequately systematic and thus lacking validity. At the same time, Dolata's approach remains limited, due to its sectoral focus – at least when system innovations are concerned. Thus, integrating an analytical separation of transformative capacity of new technologies and system adaptability, on the one hand, and the MLP concept of a wider socio-technical system for fulfilling a specific societal function as the relevant unit of analysis can improve the analysis of system innovations.

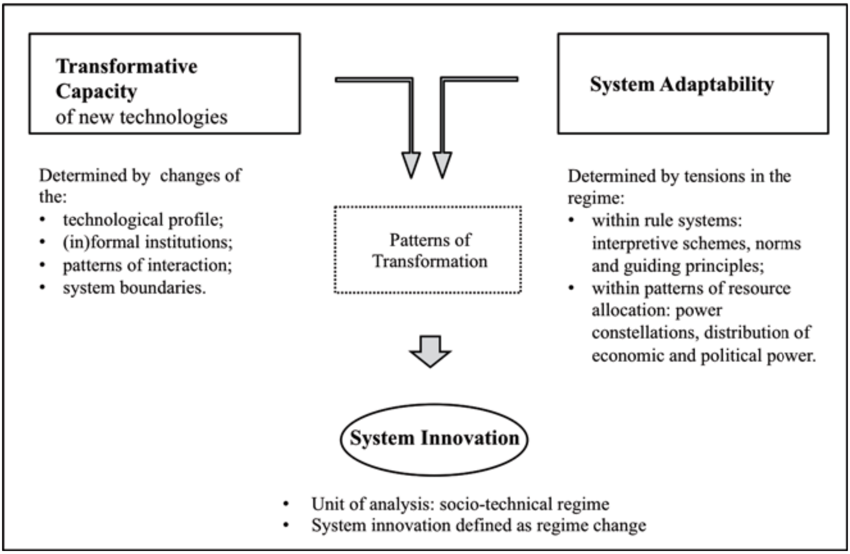

Fig. 10: An integrated framework for analyzing system innovations.

Introducing the concepts of transformative capacity and system adaptability can shed light on the co-evolutionary dynamics emerging between a specific technology and relevant actors. It is argued that this can add to MLP analyses by focusing on the role and strategies of concrete actors in dealing with technological innovation, and by offering a perspective on technology as an influencing factor in its own right. Tracing the case-specific interplay of a technology with specific characteristics and actors in more or less stable system configurations provides a way of assessing the potential emergence of a system innovation. The potential for a system innovation thus depends on the interplay of the transformative capacity of a new technology and the adaptability of the socio-technical system in question. In each specific case, it needs to be determined whether the transformative capacity and system adaptability are (relatively) high or low, respectively. In principle, four types of situations are possible regarding this interplay, as shown in Tbl. 3.

This table shows that in the case of a new technology characterized by low transformative capacity, diffusion is feasible no matter how adaptable the socio-technical system is. This is obviously the case, since low transformative capacity means that the technology can be characterized as an incremental innovation that fits within the current structures and 'simple' market-based diffusion is likely. However, in this situation there is no potential or need for a system innovation, or at least none that builds around the technology in question. In the case of a new technology characterized by high transformative capacity, the potential for a system innovation depends on the degree to which the socio-technical system is adaptable. Where system adaptability is low, even the diffusion of the new technology, let alone the emergence of new functionalities, is not feasible at all. This describes the ideal-typical situation where a technology does not fit the existing structures, which in turn are stable and hardly able to adapt. If, however, system adaptability is high, there is a high potential for a system innovation to emerge, because in order to deal with the 'mis-fits' of the new technology, the system necessarily has to adapt (in terms of developing new functionalities).

	Low System Adaptability	**High System Adaptability**
Low Transformative Capacity	Diffusion	Incremental Innovation
High Transformative Capacity	No Diffusion	System Innovation

Tbl. 3: The potential for system innovation: transformative capacity and system adaptability.

This type of classification can help to clarify a few aspects in the debate about the momentum of the developments around the electrification of the car and it helps to shed light on the question whether there is a potential for sustainable system innovation. A 'simple' diffusion process of electric vehicles seems unlikely, because it can be assumed that the transformative capacity of electric vehicles is high, in so far as they do not fit the current mobility system and cannot compete with conventional cars on the established system's terms (e.g. regarding range and price). If the transformative capacity of the electric vehicle (which will be assessed in more detail in ch. 4.3) is to unfold, thus if its system-innovative potential can be realized, this will crucially depend on the degree to which current mobility systems can be characterized as adaptable, i.e. in terms of regime 'cracks' and the specific ways these are dealt with by actors in concrete situations. And, finally, even if patterns of socio-technical co-evolution and signs of the emergence of new functionalities can be observed, this does not necessarily mean that a new system configuration is automatically more sustainable than the current system. Thus, criteria for assessing the contribution of emerging developments or trends to more sustainable mobility patterns need to be added to the analysis. Referring back to the three traps for sustainable system innovation, it can be shown that the 'quantitative' and the 'qualitative' trap are closely interlinked when it comes to radical innovations with high transformative capacity: a quantitative diffusion of electric vehicles will not be sufficient to address complex sustainability challenges, and at the same time qualitative change in terms of new functionalities is not only relevant from a sustainability perspective, but also if a radical innovation that does not fit seamlessly in an established system is to diffuse at all. In short, if e-mobility is to be developed successfully and if it can be shown that electric vehicles have a high transformative capacity, then this is only feasible in terms of a system innovation. While such a process of socio-technical co-evolution is a precondition for developing more sustainable system configurations, this is not automatically the case and not every kind of new functionality is necessarily producing more sustainable outcomes.

Especially this latter aspect leads to a brief reflection on the strengths and also the limitations of the framework developed here: In sum, this integrated framework for analyzing system innovations aims at emphasizing the specific strengths of the MLP and addresses its weaknesses by refining it based on insights from the concept of technology-based sector transformation: focusing on socio-technical systems and regimes as the relevant unit of analysis when interested in sustainable system innovations, and a clear conceptualization of socio-technical co-evolution in the context of sustainable system innovations. It will not be feasible, with the help of this framework, to determine with certainty whether e-mobility will eventually emerge as a sustainable system innovation and what type of transition pathway will unfold. As already discussed in earlier chapters, a transition or system innovation can only be identified in retrospect and the dynamics in transitions are characterized by uncertainty and contingency. However, the framework allows for an assessment of potential by characterizing the potential inherent in a new technology, in this case the electric vehicle, determined by its transformative capacity, the potential inherent in current system dynamics, i.e. its adaptability, and at least early signs of co-evolutionary patterns. If the basic uncertainty and contingency involved in transition processes are taken serious, and considering the history of the electric vehicles and its past failures, early signs of emerging system-innovative trends should be treated with caution. A focus not only on ‘positive signs’ but just as much on the barriers and obstacles for system innovation seems appropriate because “the collective research focus on change has tended to obscure a potentially more important reality, both in theoretical and empirical terms – there is not enough attention paid to understanding, confronting and ultimately resolving the tendency for change not to happen” (Wells & Nieuwenhuis, 2012, p. 1682). In the following empirical analysis, the framework developed here will be used to identify episodes where system-innovative dynamics begin to emerge, but its explanatory value will be more pronounced when it comes to assessing the barriers and obstacles impeding their further development.

4 E-MOBILITY AS A SUSTAINABLE SYSTEM INNOVATION – THE CASE OF GERMANY

When interested in the potential for further momentum of developments in e-mobility, Germany is an interesting case at the moment because it has launched one of the largest national initiatives for fostering e-mobility. The aim of Pt. III is to explore the theoretical framework and the concepts of transformative capacity and system adaptability by tracing the dynamics of the German innovation system for e-mobility, focusing especially on the 'automotive state' of Baden-Württemberg. Insights will be gained regarding the conditions for increasing system adaptability or barriers impeding it – as a way of estimating the potential of this particular niche and its chances for future up-scaling.

The results of the analysis are directly relevant for the empirical case, due to the critical situation of Germany with a nation-wide energy transition project underway and an important automotive sector, and with e-mobility linking these two fields that are of major relevance economically and with regard to sustainable development goals. The results will also contribute to a better understanding of transition processes that are 'in the making' and that require conceptual approaches that are able to deal with ex ante assessments of the potential for emerging system innovations. Advancing theory in this field of transition studies is relevant for a number of fields, including but not limited to energy and transport, where technologies are central, but co-evolutionary socio-technical transformation will be imperative when aiming at more sustainable societies or societal subsystems.

4.1 Methodology

The empirical analysis of the development of e-mobility in Germany will be structured along the main theoretical concepts developed in chapter 3, thus system innovation, transformative capacity and system adaptability. The aim is to trace how the transformative capacity of the BEV is adapted to, or fail to be adapted by the socio-technical system in which it emerges and thus, indicating the potential for e-mobility to develop as a sustainable system innovation.

The first step is therefore to capture the abstract notion of a sustainable system innovation for the concrete empirical case of e-mobility. Developing an idea of what this would entail in practice, is an important framework for guiding the overall analysis. This will be done in chapter 4.2. Since it is not clear whether a system innovation will occur at all and even if so, what the future socio-technical system would look like specifically, the approach chosen here is to define a basic ideal-type. Defining such a basic ideal-type is sufficient for this specific analysis, because the aim is not to conduct a full-fledged sustainability assessment of different forms of e-mobility, or a life-cycle assessment of the environmental impact certain vehicle technologies have. Rather, at this early stage of development the goal is to gain a robust idea of the direction in which things are moving. Since the potential transition is an open-ended and long-term process, a more precise approach is simply not feasible, because a sustainable mobility system may take different forms with regard to infrastructure, business models or behavioral patterns. At the same time, it is imperative to include some form of sustainability assessment to ensure that what is actually analyzed is the potential for achieving some variant of sustainable e-mobility. Therefore, literatures on sustainable mobility in general are drawn upon to identify the relevant basic criteria, such as renewable energy sources for powering vehicles, integrated and intermodal mobility patterns that do not solely rely on privately owned cars. Such elements of an envisioned sustainable mobility system of the future and, based on the theoretical framework, the concept of regime change that these elements amount to, provide an ideal-typical orientation for the analysis. Consequences for the concrete empirical design are, for instance, that basic criteria of sustainable forms of e-mobility will be deducted that serve as an orientation for identifying concrete examples, e.g. e-mobility projects with small-scale 'system-innovative' potential, in the subsequent case study.

Second, the transformative capacity of the BEV will be discussed in chapter 4.3. Based on the criteria developed in the theoretical framework, it will be analyzed in what ways the BEV (1) alters the technological profile of the socio-technical system; (2) affects established patterns within the socio-technical system (market relations, R&D, policy making, user behavior); (3) facilitates new patterns of interaction between actors; (4) initiates institutional readjustments; (5) opens up or widens existing borders of the socio-technical system. The transformative capacity will be analyzed based on a review of the relevant literatures. These include basic handbooks on the BEV or e-mobility as a new technology, studies on the potential and challenges of e-mobility in Germany that focus on technological and market-related aspects. This approach relying on secondary sources is feasible because the electric vehicle has been 'invented' already more than 100 years ago and its basic functioning is well-known. The implications of this technology and its new role in visions of future mobility are widely discussed in the context of the German innovation system and, more generally, in public discourses on transport policy and developments in the automotive sector. Since these debates are dominated by established regime structures (rules, norms, guiding principles involved in the way that mobility is perceived, organized and envisioned), they offer a good insight in the technological shortcomings identified in relation to this regime, thus further highlighting the basic tenets characterizing this specific regime and simultaneously offering a glimpse at the transformative capacity inherent in the 'new' technology (whether or not this materializes eventually, or not).

Third, the concept of system adaptability will be explored in a specific case within the German innovation system: the region of Baden-Württemberg. The rationale for choosing to do a case study is that this method is most suitable for studying "a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009, p. 18). This type of complexity is characteristic of most social phenomena, where multiple variables with different degrees of influence and their specific interrelations play a role. Causal explanations are thus rarely at the same time necessary and sufficient, but rather depending on complex causal chains and contingent dynamics (Mayntz, 2009, p.21). The case of e-mobility as an evolving phenomenon of socio-technical co-evolution is no exception in this respect. In addition to overall complexity in a real-world setting that cannot be manipulated like a laboratory experiment and fuzzy boundaries between the object of study and its context, case studies are also suitable when the research question and design are exploratory in nature (Baxter & Jack, 2008, p. 545). This criterion applies as well, since the aim is to explore the potential of e-mobility as a sustainable system innovation in a concrete situation, where neither the empirical basis nor the existing literature provide enough substance for identifying all relevant variables or testing pre-formulated hypotheses. Nonetheless, it is emphasized that basic theoretical propositions that guide the case study analysis are important. The concepts developed in the theoretical framework will serve as such guide for the analysis, as is laid out in this section. With regard to the concrete case study design, dealing with complexity requires multiple sources of evidence, which are then converged by means of triangulation (Yin, 2009, p. 18). The detailed design of the case study on Baden-Württemberg, including the mix of sources and methods of analysis, will be explained in chapter 4.4.1.

Baden-Württemberg has been chosen as a single case study, because it is a critical "most likely" case, which is one rationale for choosing a single case study design, even though this is often viewed as not sufficient for generalizing from empirical findings. It can however be argued that a single case study "is ideal for generalizing using the type of test that Karl Popper called 'falsification'" (Flyvbjerg, 2006, p. 227).

"Popper himself used the now famous example 'all swans are white' and proposed that just one observation of a single black swan would falsify this proposition and in this way have general significance and stimulate further investigations and theory building. The case study is well suited for identifying 'black swans' because of its in-depth approach: What appears to be 'white' often turns out on closer examination to be 'black.'" (Flyvbjerg, 2006, p. 228)

What does this imply for the case of e-mobility in Germany and Baden-Württemberg specifically? Based on the theoretical framework, it can be assumed that the interplay of a technology with transformative capacity and a system characterized by tensions or crisis, thus to at least some extent adaptable, would result in a system innovation, or at least the potential for a system innovation should be observable at an early stage, as is the case here. Overall, existing literature and public debate rather indicate that the prospects for e-mobility developing as a sustainable form of mobility are bleak. So, the question is, what is the actual potential for a system innovation? The case of Baden-Württemberg is suitable to explore this, because it is a critical case, which can in general be "defined as having strategic importance in relation to the general problem" (Flyvbjerg, 2006, p. 229).

For one thing, the case of Baden-Württemberg as an innovation system for developing e-mobility is not a typical small-scale niche. It has been initiated by the federal government, is well-funded and involves incumbent actors – this may imply possibilities for change at a larger scale, or illustrate why change is impeded from the beginning. It also shows characteristics that according to the theoretical framework may be signs of relatively high system adaptability: an automotive industry that is acting on global markets, thus facing global trends that turn out to threaten established industry structures and market dynamics; the participation of incumbents from the automotive industry, the energy sector and ICT companies, thus a situation where actors from different regimes cooperate and it can be assumed that tensions between different rule systems, power struggles regarding the allocation of resources and a process of reflecting on and refining different frames of reference may emerge. This makes it a critical case, selected carefully based on these characteristics, which is preferable to an average or random case here. It is also a "most likely" case: If it can be shown that even in this case, exhibiting relatively advantageous conditions, the potential for a system innovation remains limited, it can be generalized that this is valid also for most other cases (Flyvbjerg, 2006, p. 230 f.).

Thus, the rationale for choosing a single case is that, with respect to generalization of findings, one case is sufficient to falsify a theoretical proposition. However, the basic aim is not to simply reject the theoretical framework that has been developed in its entirety, but to refine general propositions with regard to the emergence of system innovations or transitions. Also, a flat-out rejection is not feasible, because the theoretical framework developed here is a relatively broad heuristic, which does not contain explanations of linear causality between concrete variables and thus, the case study aims at identifying the critical factors and can aid the development of more concrete hypotheses. The case is used as an in-depth exploration, analyzing where exactly the barriers for system innovation can be found and how developments are hampered. Apart from refinements of theory, this can provide insights into what may be drivers for system innovation, or at least starting points for improving the prospects for sustainability transitions in the field of transport.

The three chapters on system innovation (ch. 4.2), transformative capacity (ch. 4.3) and the case study focusing on system adaptability (ch. 4.4) are not isolated, much like the theoretical concepts on which they are built represent an analytical separation rather than isolated elements that are in fact clearly distinguishable in practice, and therefore there are several interlinkages between the chapters. For instance, the ideal-type definition of a system innovation will guide the analysis by providing selection criteria for e-mobility projects that the case study is built around (the detailed case study design is layed out in chapter 4.4.1) and it will be the basis for a critical reflection of the case study findings. Furthermore, since transformative capacity and system adaptability are interrelated categories, which only have meaning when considered together, the respective findings have to be integrated as well. The findings of chapter 4.3 show to what degree the BEV can be said to have an inherent transformative capacity in the face of current regime structures. For a more detailed assessment, in chapter 4.4 the case study provides a more in-depth perspective on how this technology is actually dealt with in a specific innovation system by different groups of actors. Thus, chapters 4.3 and 4.4 are basically a shift in perspective, looking at the phenomenon of socio-technical co-evolution from both sides, the “technical” in chapter 4.3 and the “socio-“ in chapter 4.4. This analytical separation will not be clear-cut throughout the entire analysis, because the two elements are co-evolving; however, the emphasis is different – depending on which side of the coin we look at. In chapter 4.5, the results of the empirical section will be drawn together and reflected upon in an integrated fashion. Implications for the case of e-mobility in Germany and for the theoretical framework will be discussed.

4.2 Delineating the System Innovation as an Ideal-Type

In order to deal with the question of whether co-evolutionary dynamics and the emergence of new functionalities actually contribute to a more sustainable system configuration, a sustainability assessment has to be included. Due to the complexity of the issue, this can only be done in a qualitative fashion and depends on the specific case. Transitions to sustainability are characterized by uncertainty and ambivalence, i.e. one cannot determine with certainty whether ongoing dynamics will eventually result in a transition and one can rarely define unambiguous sustainability criteria – especially in cases of 'transitions in the making' (Konrad et al., 2008, p. 1192). It is therefore proposed here that when analyzing 'ex-ante' cases, such as the electrification of the car, a first step would be to delineate the envisaged system innovation for the specific case. Since it is not clear whether a system innovation will occur at all and even if so, what the future socio-technical system would look like specifically, the approach chosen here is to define a basic ideal-type. In order to do so, the concept of e-mobility as a system innovation needs to be connected with general criteria of sustainable mobility. Departing from current sustainability challenges, some basic criteria a sustainable mobility system would have to fulfill can be defined. It has been argued in chapter 2.2 that sustainable mobility requires a paradigmatic change including not only efficiency increases in vehicle technology and fuels but also an overall reduction in the volume of travel, reduction of trip lengths and substitution of individual car use by intermodal transport and carsharing. Following from this, some basic criteria for assessing developments around the electrification of the car can be defined. Criteria for sustainable forms of e-mobility include:

- more integrated and intermodal forms of mobility,
- concepts of collective ownership of cars or carsharing,
- and renewable energies as the basic electricity source.

It is of course less clear what exactly the corresponding socio-technical system would look like, because there may be different types of infrastructure, business models or behavioral patterns that could make up such a sustainable mobility system. However, the concept of regime change – in this case a break with the currently dominant car-centered outlook on mobility – and the basic criteria required for sustainable mobility provide an ideal-typical orientation for the analysis.

The aim of the following sub-sections (4.2.1 – 4.2.4) is to link these general principles of sustainable mobility with e-mobility. This is important because in current discourses it is often taken for granted that e-mobility, in terms of the electrification of the car, is automatically contributing to a reduction of the environmental burden caused by the transport sector. However, this causality is not as straightforward when considering that there is a global increase in the volume of traffic and thus an increase in absolute levels of resource use in production of vehicles and emissions, especially when considering current electricity mixes. Thus, technological improvement and efficiency gains will be compensated for by the sheer force of increasing absolute numbers. Approaching e-mobility as a project of technological substitution becomes even more inadequate when looked at from a broad sustainability perspective, including issues of social justice in terms of access to mobility and livable cities. The literature on sustainable mobility shows that the dominance of the car as the central technological artifact and the lock-in that has evolved around it, in terms of infrastructures, business models, use patterns and symbolic meaning, are at the heart of current problems. A transition towards more sustainable forms of mobility would thus include that the role of the car in society is at least questioned and possibly even redefined. The central question of this thesis is whether developments in the field of e-mobility link up with such more basic debates on modern transport systems and may even contribute to a situation where it becomes possible to question fundamental and long-established 'truths' in mobility.

Therefore, ideal-typical – from a broadly defined sustainability perspective – elements of sustainable forms of e-mobility are outlined in the following. It is shown how new linkages are beginning to show between e-mobility and the broader context of an energy transition to renewable energies (ch. 4.2.1), e-mobility and less car-dependent forms of mobility in fleet applications (ch. 4.2.2) and intermodal transport concepts (ch. 4.2.3), as well as between e-mobility and innovative business models in the field of carsharing (ch. 4.2.4). These aspects have been chosen because they are potentially contributing to more sustainable forms of mobility in principle (reducing and substituting for conventional car use) and they show the specific potential of e-mobility going beyond technological improvement. They will later on serve as indicators or basic criteria for identifying "system-innovative" e-mobility projects and initiatives in the case study (ch. 4.4.3).

The purely technological issues and efficiency-related benefits in the process of electrifying the car are not dealt with in detail, since they are a minor aspect in the context of a broader sustainability perspective. Also, the reduction of the overall volume of travel and trip lengths is not considered explicitly, because this has mainly to do with substituting mobility with virtual forms of communication and with city and land use planning. These can be considered as framework conditions within which mobility patterns unfold and thus fall outside the scope of this thesis.

4.2.1 E-mobility and Renewable Energy

The first characteristic of sustainable forms of e-mobility seems to be relatively straightforward and obvious. If electrifying transport is to contribute to reducing negative environmental effects, it is not enough to reduce local emissions, which is already the case when electric vehicles are used, even in the context of an energy system where a large share of generated electricity is produced from fossil sources. A truly sustainable form of e-mobility should guarantee that the electricity used to power electric vehicles is produced from renewable sources. The specific way that the energy and the mobility transitions are interlinked and may create synergies for achieving more sustainable outcomes in both fields has been laid out in chapter 2.3 and it has also been highlighted that there are some basic challenges. This is important when looking at the envisaged transition towards sustainable e-mobility in practice. Even though there is such a large potential of electric vehicles fostering the transition to renewable energies by providing short-term storing capacity on the one hand, and the energy transition fostering sustainable forms of e-mobility by providing clean energy sources on the other, ways still have to be found for realizing this potential in practice. With current use patterns of cars and current business models of energy utilities this will not be feasible. For instance, from the point of view of energy utilities it is important that a significant number of electric vehicles is available at regular times and with a reliable storage capacity, which is difficult to organize in a system of predominantly private car ownership (Canzler & Knie, 2011, p. 113 f.). For car owners, on the other hand, it is important to have an adequately developed recharging infrastructure, which however is too expensive for energy utilities to set up, as long as it is just another sales channel for electricity (ibid.). One possible starting point for dealing with these issues is to focus on vehicle fleets (operated by companies, municipalities or other public bodies) rather than private car owners, at least at this early stage of developing e-mobility.

4.2.2 E-mobility in Fleets

Fleet operators are used to managing relatively large numbers of vehicles in the most efficient way. They also have a history with electric vehicles, because early delivery services, e.g. postal or dairy products, were once preferably operated with electric vehicles. Even today, many services, delivery or other, offered by fleet operators typically remain within distances that would be within the range of an electric vehicle. Furthermore, integrating controlled charging systems into the normal business of a fleet operator seams feasible and it would provide them with a new source of income via offering battery reserves in addition to mobility services. This would allow for a more reliable and predictable use of electric vehicles as storage capacity and even as part of bidirectional vehicle-to-grid (V2G) concepts (Canzler & Knie, 2011, p. 50; Dijk et al., 2013, p. 139).

Fleets could also be an important starting point for introducing significant numbers of electric vehicles. Since in fleets the maximum capacity of vehicles is utilized and they are used in standard ways and similar use patterns, learning effects with regard to their optimal use can be realized relatively quickly. Once the fleet is put to optimal use, the electric vehicles can demonstrate their specific qualities. Furthermore, cost savings and scale effects can be reached relatively quickly in fleets, so that in this case, as opposed to the case of private car owners, both the fleet operators and the energy utilities would more easily find business models that are beneficial to both parties (Hein et al., 2013, p. 1655; Vallée et al., 2013, p. 63). For instance, in this case the charging infrastructure could more realistically be not just a charging spot but just as much an infrastructural element for guaranteeing grid stability – thus, an actual connecting hub from which both sides can profit. This could also allow for developing business models that are more profitable than building up charging points for merely selling electricity (Canzler & Knie, 2011, p. 67).

The fact that the prospect for electric vehicles used in fleets is much better than for ‘normal’ private cars, does not necessarily mean that they will forever be confined to this particular niche. From a sustainability perspective it would be beneficial if more mobility uses or trips were organized by vehicles operated in fleets (thus reducing private car ownership and use). Especially with the electric vehicle that can be utilized as a means of transport and an infrastructural element in the energy systems, new options for business models may emerge that could trigger new, profitable forms of carsharing and intermodal mobility concepts (Canzler & Knie, 2011, p. 46 f.; Tran et al., 2012, p. 332).

4.2.3 E-mobility and Intermodality

Since sustainable mobility in general would require a reduction and substitution of car use with a shift to other modes, such as public transport, walking or cycling, sustainable e-mobility would ideally combine the introduction of electric vehicles with the development of intermodal transport concepts. E-mobility can in this case be understood as a holistic transport concept including various (electrified) modes of transport that are interlinked in a mobility service scheme. Especially in cities there is a large potential for such concepts, because many younger people already rely on a combination of different modes of transport and do not own a car (Newman & Kenworthy, 2011). Problems of congestion and lacking parking spaces can also be addressed by a shift to intermodal mobility in cities. Furthermore, if electric vehicles are integrated in intermodal transport chains their disadvantages as compared to conventional cars, especially concerning range, do not play a significant role anymore.

Even though forms of intermodal mobility can already be observed in practice, it is still a challenge to further establish marketable concepts that can compete with so far dominant modes of private car use for most trips. Successful concepts need to be reliable, easily accessible and intuitively usable, in order to be an attractive alternative to the privately owned car (Canzler & Knie, 2011, p. 38). Ideally, an intermodal mobility service would include the existing public transport system (trams, metros, local trains etc.) as well as carsharing services, rental cars, taxis and rental systems for bikes and pedelecs. All of these transport modes should be integrated in a comprehensive infrastructure of central transfer points between modes, charging and parking stations. In order to guarantee user-friendliness, a guidance and information system needs to be in place as well as a ticketing system that allows for 'one-stop-shop' solutions, i.e. buying tickets for an entire trip using different combinations of transport modes. Therefore, a central mobility service provider is needed that can bundle and integrate activities and serves as contact point for users (Kemp & Rotmans, 2005, p. 34; Vallée et al., 2013, p. 75).

A seemingly obvious type of actor that could function as a comprehensive mobility service provider are public transport operators. They already have ticketing services in place and operate mobility chains, combining for instance trams and busses on different lines. However, in Germany, public transport operators are providers of public service tasks, whereas strategically planning and financing these service tasks is in the hands of public authorities. This structure hampers entrepreneurial activities on the part of public transport operators and denies them the legal and financial means to integrate bike and car rental or sharing concepts in their services (Canzler & Knie, 2011, p. 82 f.). Similar to the situation regarding the integration of e-mobility in the energy system, here the synergies that the development of e-mobility and intermodal transport concepts could produce are so far not really utilized because the existing actor structure, business models and use patterns impede innovative approaches.

4.2.4 E-mobility and Carsharing

As already mentioned, carsharing can become a central element of an intermodal transport system. However, it will be treated here also as a separate element of sustainable e-mobility because it represents a very specific form of reducing the burden of transport that cannot be substituted by a non-travel activity. In this case, an environmental benefit does not result from a reduction of the volume of transport or trips lengths, or from a shift to other modes, it rather increases efficiency by increasing the average occupancy of existing (shared) cars and it questions the deeply embedded and dominant pattern of the privately owned car as the most common means of transport (Bongardt & Wilke, 2008, p. 66; cf. Wilke, 2009a, 2009b). Even if carsharing does not represent a shift towards fundamentally different, e.g. intermodal, forms of transport and rather a tendency to move away from car ownership to car services, there can still be substantial sustainability benefits. In a service-oriented scheme it is likely that the symbolic value of the car, which is central when it is owned and in this way connected to an individual personality, becomes less relevant and criteria of efficiency and operability gain importance (Nykvist & Whitmarsh, 2008, p. 1382).

In Germany, the earliest carsharing systems have been established already in 1988 and today a number of different forms of carsharing exist. There are smaller-scale concepts where privately owned cars are shared among a group of people, e.g. in a neighborhood, or can be rented via a private online exchange platform. More common are carsharing services offered by professional providers. The various professional services differ with regard to the range of vehicle types that is on offer, the modalities of registration as a user and of booking a car, the billing system (paying either by kilometers driven or by time of use), and whether or not the cars have to be returned to specific pooling stations (Vallée et al., 2013, p. 72 f.).

Carsharing systems have increasingly emerged over the past few years, with also large automotive companies (Daimler and “car2go”) and public transport actors (Deutsche Bahn and “DB Flinkster”) founding their own services. A reason is that especially younger people living in cities do not buy as many cars as they used to – or buy them at an older age – and that, in general, European markets for cars are increasingly saturated (Infas, 2011). Realizing that many people do in fact rely on a combination of transport modes, an opportunity is seen to profit from these newly emerging social practices by offering short-time rental services that fit within intermodal mobility patterns (Canzler & Knie, 2011, p. 59).

This general trend can play an important role for the successful introduction of electric vehicles, and it contributes to more sustainable forms of transport. A major obstacle for the diffusion of electric vehicles on mass markets is that battery costs are so high that they cannot compete with the cost of a conventional car. If electric vehicles are operated as shared cars, users are not faced with the high initial purchase costs and carsharing operators can much better realize cost and scale effects via their fleet management systems and by operating their BEVs also as means of electricity storage – which might be an additional source of income, for instance through feed-in tariffs or reduced electricity prices (Dijk et al., 2013, p. 139; Vallée et al., 2013, p. 63). Depending on the success of carsharing services, in the end depending on whether there is a change in overall mobility patterns and the dominance of the privately owned car, the environmental benefits can be large, since it is estimated that one shared car substitutes for roughly 16 private cars (Canzler & Knie, 2011, p. 115 f.).

4.3 The Transformative Capacity of the Electric Vehicle

Based on the ideal-type vision of e-mobility as a radically different sustainable form of future mobility, the question is – how can this desired future be achieved? Throughout chapter 3 it has been shown that there is no straightforward way of managing transitions and that current developments and potential for system innovations need to be analyzed, in order to find ways of steering and modulating ongoing dynamics in desired directions. In a technological field such as e-mobility, processes of socio-technical co-evolution are at the heart of a wider transition. For a better understanding of socio-technical co-evolution it has been proposed to analytically separate the transformative capacity of new technologies and system adaptability.

A new technology may have a high transformative capacity, exerting direct and disruptive pressure on its social environment, or a low transformative capacity, having only an indirect impact and leaving basic structures of a socio-technical system intact. Thus, a technology can either amount to a radical innovation inducing substantial change or an incremental innovation fulfilling subsidiary or additional functions. The transformative capacity may depend on whether an endogenous technology (i.e. a technology developed within an established field), or an exogenous technology (i.e. a technology developed outside its eventual field of application), is concerned. Transformative capacity is an inherently relational category, because it depends not only on the specific characteristics of a technology but also on the respective social structures on which it has an impact. So, new technologies can be shown to have a transformative capacity and thus a direct impact on socio-economic and institutional structures, while at the same time, the degree to which those social structures are adaptable determines the actual impact a new technology can have. Nonetheless, the central idea of introducing transformative capacity as an independent analytical category (where, clearly, separation is possible only theoretically) is to be able to analyze the impact on socio-economic and institutional structures of a technology in its own right (Dolata, 2011, p. 12).

In our case, the new technology is the battery-electric vehicle. This is not an unambiguous choice. One might argue that innovations in the field of ICT are much more relevant for 'triggering' advancements in e-mobility and enabling integrated and intermodal forms of e-mobility. Thus, it is indeed possible to argue that this is where the actual transformative capacity is located. Similarly, in e-mobility a wide range of vehicle types are being developed and especially pedelecs and e-scooters are much more successful than electric cars (e.g.in touristic applications in Germany or as increasingly popular means of every-day transportation in Asian mega-cities). Furthermore, these vehicles play an important role for more sustainable forms of mobility and multimodal individual transport. Nonetheless, the BEV has been chosen as the relevant 'new' technology – even though it is not new in terms of its technological innovation and development, but has newly gained prominence for a number of reasons. The car, the automobile, is the central technological and especially also culturally relevant artifact when talking about personal mobility. Consequently, the emergence and the potential of e-mobility are publicly and politically debated in terms of the electric car, while all other aspects, e.g. other types of vehicles, transport modes etc., are variants of or elements related to the BEV. Thus, the electric car is the 'boundary object' around which the field of e-mobility has evolved and which is central for all kinds of involved actors – either as a technological solution, the starting point or an element in a new system, or an evil that needs to disappear. Therefore, the BEV is, after all, the central technology in relation to which different actor groups position themselves, develop attitudes, reactions and strategies, eventually determining overall system adaptability.

So, how can the transformative capacity of the electric car – which currently has only a marginal real impact – be assessed? The approach chosen here is to identify the 'mis-fits' of the electric car with the existing system structure, thus what is discussed as the technological shortcomings of the electric car in current debates. It is the mismatch between the potential of a new technology and the feasible possibilities of using it under given circumstances which can be characterized as the transformative capacity inherent in a new technology. The more a new technology becomes relevant for a sector and the less it can be embedded in existing sectoral structures, the larger is its transformative capacity and thus the pressure for change it exerts on established sectoral organizations, institutions and behavioral patterns (Dolata, 2011, p. 68 f.). The empirical consequence is in this sense a research approach that focuses on the technological shortcomings that are attributed to a new technology. Technological shortcomings understood as mis-fits of a new technology with an established system are, in principle, shortcomings only with respect to the existing conditions and thus may in some cases very clearly point to the new technology's transformative capacity.

In the case of e-mobility, such an approach may help to overcome a perspective where the mis-fit between a new technology and the existing system structures is discussed in terms of necessary but lacking technological improvements only. What is perceived as a technological shortcoming from the point of view of the current mobility system may have completely different implications for a potential future system that functions based on different infrastructures, use patterns, business models and is operated by different actors.

Since it is hardly possible to identify unambiguous and universally valid indicators of transformative capacity, it cannot be measured quantitatively in any meaningful way. However, a number of qualitative criteria have been identified for assessing the characteristics of a new technology with regard to the specific configuration of the socio-technical system that is to be studied. As introduced in chapter 3.3.3, the transformative capacity of a new technology can be determined by analyzing in what ways it:

- alters the technological profile of a socio-technical system,
- affects established patterns within a socio-technical system (market relations, R&D, policy making, user behavior),
- facilitates new patterns of interaction between actors,
- initiates institutional readjustments,
- opens up or widens existing borders of the socio-technical system.

With regard to the **technological profile** of the socio-technical system that has evolved around the fulfilling of mobility needs, a widespread diffusion of the BEV would entail major changes. Especially since Germany has a large automotive industry with a focus on the premium segment and powerful internal combustion engines, the BEV means a severe turning point and a restructuring of the automotive sector across its entire value chain (Hüttl et al., 2010; Kampker et al., 2013a).

The modern automobile as the dominant means of transport has specific characteristics making up the basic features of its technological profile, such as being a multi-purpose vehicle, built from steel and powered by an internal combustion engine (Orsato & Wells, 2007, p. 995). OEMs and suppliers have developed competences accordingly and the introduction of BEVs would require completely different and new competences. Current activities in the fields of producing motors, gear units, exhaust systems and oil pumps become obsolete when the internal combustion engine is replaced by an electric motor and a battery. If OEMs want to retain their current value creation levels, large parts of battery production and production of components for electric motors need to be done by them directly, rather than sourced out or bought from suppliers (Gnann & Plötz, 2011, p. 38; Kasperk & Drauz, 2013b, p. 37 f.). Furthermore, these technologies are well-developed in other fields, but still have to be adapted to automotive applications. This is most obvious for the case of batteries. In general, electronic applications and nanotechnologies will play an increasingly important role, while mechanical and hydraulic components will disappear (Kampker et al., 2013b, p. 22f.; Kasperk & Drauz, 2013b, p. 37). These shifts in the technological profile also means that completely new resources are needed in the production process, especially rare earths, which have to be procured and processed differently (Rammler, 2011, p. 20).

Such a fundamental shift – which would be challenging for any industry – is especially severe for the automotive industry, because OEMs have focused on increasing the variety of their offer by developing more vehicle types and by differentiated models within a specific series. This has led to increasing costs, shorter model and development cycles, which forces OEMs to concentrate on core competences and a limited amount of elements of the entire value creation process (Kasperk & Drauz, 2013b, p. 37). Such a concentration process limits flexibility and the ability to adapt to fundamental technological changes.

Similarly, it is always difficult to fundamentally change elements that are closely related to the core of a specific brand. For the automotive industry as a whole, the core of a brand is the internal combustion engine, which is the distinguishing feature across the different car manufacturers and the central element in automotive value creation. Thus, the emergence of electric cars as the new core technological artifact would involve a fundamental re-structuration of the automotive industry in terms of re-defining core competences and the technological core of an automotive brand. Another fundamental uncertainty in such a transformation process relates to the question whether OEMs, suppliers or battery producers will develop the core competences for manufacturing electric drivetrains (Kasperk & Drauz, 2013a, p. 110 f.; Rammler, 2011, p. 20).

A brief look into the history of the automotive industry and its origins at the turn of the 20th century shows how path-dependencies have developed and led to a technological lock-in of the automobile powered by an internal combustion engine. Such a historical perspective also helps to understand how severe a transformation towards e-mobility would be on various, not only technological, levels. In their historical analysis of the automotive industry, Orsato and Wells (2007) explain how the industry ended up being “locked into a business model that gives primacy to high output, low unit market prices, and deriving revenues from the outright sale of new cars (including financing) rather than other income streams” (p. 996). A number of factors and processes contributed to this outcome, for instance the emergence of ‘Fordist’ production techniques and robust steel body-chassis technology, which together facilitated largely automated mass-production of cars. At the same time this increased capital intensity of automotive production and a focus on achieving economies of scale (Orsato & Wells, 2007, p. 995). This type of production optimally (and only) fits with a business model of selling large numbers of cars at generally affordable prices. The technological lock-in of the internal combustion engine was, in addition, partly resulting from efforts of oil companies, most prominently Rockefeller’s Standard Oil. After the diffusion of electric lighting had led to losses for the oil industry, they lobbied car manufacturers to develop internal combustion engines in such a way that they would run on hydrocarbon fuels. The oil industry had a strategic interest in establishing direct links with the automotive industry as a new business opportunity – and eventually succeeded in this endeavor (Orsato & Wells, 2007, p. 996 f.). All of these long-established principles and relationships would become obsolete, if the core of the automobile’s technological profile disappeared in the process of electrification.

This would also call for the development of new business models. Just like the ICE car, the electric car has its own technological specificities that will not fit with old principles of cheap mass production and realizing economies of scale (at least not in the beginning) and requires other strategic partners than the oil industry. Especially the high production costs and problems of range and charging time of electric vehicles – which are the basic differences with regard to the technological profile of ICE and electric cars – indicate that automotive value creation in an ‘electrified age’ would look very different from today. Due to its range limitations, the electric car is no longer a multi-purpose vehicle, which implies that the industry would shift its focus from vehicle sales and financing to offering mobility services (Canzler & Knie, 2011, p. 77; Kasperk & Drauz, 2013b, p. 35). This is a fundamental and serious challenge, not only for the automotive industry, but also for customers: while it is rationally possible to “question the reasons for consumers to keep buying over-dimensioned and over-specified cars” (Orsato & Wells, 2007, p. 997), it is also obvious that the technological profile that has become dominant in the field of automobility is the norm against which the electric vehicle and concepts of e-mobility are being compared.

The obvious and substantial 'mis-match' the electric car represents with regard to the established technological profile in the socio-technical system of automobility is reflected in the way that the automotive industry deals with the trend towards electrification. Great efforts are undertaken to develop electric cars that can compete with conventional cars in terms of price and range, and which are in essence and functionality not really different from the automobiles we have today (Wells & Nieuwenhuis, 2012, p. 1686). This strategy becomes obvious when looking at the principle of "conversion-design" which dominates the development of electric cars by established OEMs. The basic idea is to 'convert' a conventional car into an electric car by simply exchanging the drivetrain (Kampker et al., 2013b, p. 22). This can shortly be summarized as an attempt to "force this competing and quite different technology into the constraints of the existing regime to which it is not optimally adapted" (Wells & Nieuwenhuis, 2012, p. 1686).

Assuming that the automotive regime would be able to adapt to electric vehicles – instead of the other way around – the characteristics of the electric car could be the core of an overall fundamentally different technological profile of automobility. This would possibly lead to new business models as well. Some car manufacturers have already been experimenting with leasing concepts where batteries of electric cars are leased to customers, in order to lower the purchase price of the car (Wells & Nieuwenhuis, 2012, p. 1686). With regard to the electric vehicle itself, the approach of 'purpose design' – in contrast to conversion design – aims at developing new vehicle concepts that utilize the specific advantages of electric vehicles, instead of trying to imitate a traditional car, which will most likely result at best in a less good alternative (Kampker et al., 2013b, p. 22). So, when the electric car's mis-fits with the current system would turn into the corner stones of a new system of automobility, this process could be described in terms of a system innovation. The fact that the electric car presents a 'mis-fit' is alone an indication of its transformative capacity. The automotive industry is currently struggling with this situation. OEMs are hesitant to invest in the development of electric vehicles, because this is risky in a situation of uncertainty and where it is quite obvious that electric cars are not competitive on current markets. At the same time, political and economic pressure force OEMs to look for innovations and alternatives, with electric vehicles currently being presented as a promising option (Kasperk & Drauz, 2013a, p. 104 f.; Wells & Nieuwenhuis, 2012, p. 1688).

The basic dilemma for the automotive industry is the fact that multi-purpose cars powered by internal combustion engines have been perceived to be the core of the automobile system's technological profile. ICE technology is consequently viewed as the core competence of OEMs. The electric vehicle makes this core element obsolete and thus puts into question the actual role and function of those actors. The transformative capacity of the electric vehicle therefore does not ‘only’ relate to technological change, but to changing perceptions of the role of OEMs from manufacturers of propulsion system to a broader role of providers of mobility (Orsato & Wells, 2007, p. 1004).

Thus, the electric vehicle affects not only industry structures and the technological characteristics of the central product, the car, but also **patterns in markets, R&D, policy making and user behavior** (acatech, 2010). The envisaged diffusion of electric vehicles would not only produce technological mis-matches for the automotive industry, but all kinds of institutional and behavioral mis-matches in various dimensions affecting different groups of actors. A system of automobility has historically emerged where the car is the central technological artifact but where other elements, such as roads, gas stations and a fuel industry, user behavior, car-related services, regulation and policy etc., have together evolved into a working system. All of these elements and the patterns of interaction between them will be affected when the core product is attempted to be replaced by a, in many ways fundamentally different, new technological artifact (Geels, 2012, p. 473; Markard et al., 2012, p. 956).

Users are affected, because electric vehicles cannot be used in the same way as conventional cars. They perform much worse as regards range, price and charging (Vallée & Schnettler, 2013, p. 30; Kampker et al., 2013b, p. 20 f.). The charging infrastructure also has to be built up (Kampker et al., 2013b, p. 19). The service infrastructure around car use, e.g. garages, dealerships etc., is also not in place for electric vehicles, thus presenting another restriction for users (Vallée et al., 2013, p. 100). As already indicated, new business models are needed to deal with the high prices of batteries. New use patterns, such as carsharing and forms of intermodal mobility, could help dealing with the high selling price and limited range of BEVs as well as the lacking charging infrastructure (Kampker et al., 2013a, p. 1 f.; Kasperk & Drauz, 2013b, p. 39 f.).

R&D in the field of automobility would also have to re-focus, in order to accommodate new technological fields of research, such as chemical and electrical engineering. Typical marketing-oriented research focusing on user acceptance and diffusion patterns also will not be sufficient with regard to electric vehicles, as long as conventional cars and their characteristics are the standard frame of reference.

Finally, the electric vehicle as a technology at the interface of the automotive and energy sector cuts across political domains, e.g. energy and transport policies. Furthermore, the fact that a charging infrastructure for electric vehicles needs to be built up involves challenges for policies in the field of city planning and spatial management.

With regard to **institutional readjustments**, the electric vehicle in many ways does not fit the existing mobility system in terms of regulations and standards. While conventional cars can be re-filled at every gas station, the plugs and charging infrastructure for electric vehicles differ according to operators and in different countries. The operation of a public charging infrastructure also needs to be regulated with regard to parking spaces, reservations, and billing systems (Vallée & Schnettler, 2013, p. 32). Where innovative mobility concepts are developed for fostering e-mobility – e.g. urban intermodal mobility services integrating different modes of transport – infrastructures and management systems are needed for organizing user-friendly access (Vallée et al., 2013, p. 63).

The BEV also points towards **new patterns of interaction**, for instance, cooperation between OEMs and battery producers (Gnann & Plötz, 2011, p. 24 f.), or mobility providers and energy suppliers (Kasperk & Drauz, 2013a, p. 123 ff.). Especially the long-established networks of OEMs and automotive suppliers would have to be re-adjusted if the industrial core of producing ICE cars would shift to the production of electric cars, or even more fundamentally, if mobility services were to become central in combination with electric cars. Already today, it is normal for OEMs to build strategic alliances with other OEMs or large suppliers, in order to realize synergies and economies of scale, especially in the field of R&D. This pattern of interaction would have to be intensified and broadened, if it were to be adjusted to the electric vehicle. Many, also smaller, suppliers have competences in the fields of battery technology, electric motors and light-weight design. Thus, joint activities with these sometimes smaller and new partners would be advantageous, while a potential threat exists with regard to the delineation of boundaries in these forms of cooperation. Since they deal with the new technological core of electrified drive trains, they are of high strategic importance and require a high degree of integration (Kasperk & Drauz, 2013a, p. 123 f.). Similarly, large automotive suppliers can already be observed to adjust their regular patterns of interaction by cooperating with new partners that can provide them with new competences in the field of electronic applications and battery technology. The expected shift in the value creation process from traditional vehicle technology to the electric drivetrain is seen as a chance by larger suppliers to expand their position in the value chain, which may eventually lead to new patterns of interaction between OEMs and suppliers in general (Kasperk & Drauz, 2013a, p. 125; Kasperk & Drauz, 2013b, p. 38 ff.). Most likely, OEMs will try to position themselves as ‘system integrators’ being involved in all levels of value creation. This can be achieved by building a broad network and engaging in cooperation with key partners. Especially small and innovative firms in the field of e-mobility that are in need of financial resources will most likely be acquired by OEMs, in order to gain new resources and competences, and to keep potential competitors in check (Kasperk & Drauz, 2013a, p. 123 f.; p. 126).

Last but not least, completely new types of interaction will have to emerge, in order to deal with the most severe 'mis-fit' of the electric car. It is no longer powered by fossil fuels, but by electricity, thus requiring new suppliers and a completely new charging infrastructure. Furthermore, replacing the ICE by an electric motor and battery leads to a much more limited vehicle range and relatively long charging times. This means that new patterns of interaction with energy suppliers would have to be found, in order to guarantee a sufficient build-up and operation of charging infrastructure. For energy suppliers entering the 'mobility market' it is a challenge to find new patterns of interaction with their customers, because charging infrastructure operated by different energy companies and used by different types of private vehicle owners or service operators, e.g. carsharing firms, requires new offers and services, going beyond electricity being a relatively simple commodity supplied in one standard way. The integration of the vehicle and the charging infrastructure, the organization of charging and billing processes as well as the management of mobility services requires new patterns of interaction with the ICT sector as the third key industry linked with the automotive and energy sectors, in a new system that may evolve around the electric car (Kasperk & Drauz, 2013a, p. 126; Kasperk & Drauz, 2013b, p. 40).

These new forms of interaction show that the **borders of the socio-technical system** will be opened in the course of developing e-mobility, for instance, by sectors entering the mobility field that have not been part of it before, e.g. energy, battery producers and ICT companies. Electrifying the drivetrain will not only lead to changes in the interactions between OEMs and suppliers or changes in components of automotive production. Rather, this would mean the emergence of a fundamentally different industry structure, where new actors become central and relationships are being redefined. Obviously, battery producers would play a central role and could position themselves along the automotive value chain (Kasperk & Drauz, 2013b, p. 41). More fundamental change is also likely. For instance, e-mobility is a completely new field of business for energy suppliers, which does not only offer an additional opportunity to sell electricity, but could also induce the development of completely new business models, which may in the long term facilitate a central role for energy companies emerging as providers of mobility solutions (Kasperk & Drauz, 2013a, p.

110). As already mentioned, ICT companies would come to play a central role as providers of the connecting link between the electric vehicle and the energy infrastructure in which it needs to be embedded. These companies may become a central new actor in an e-mobility system, because apart from providing a key technology, they might even emerge as the providers of intermodal mobility services (e.g. integrated service offer including reservation, charging, billing as a one-stop-shop solution) and the primary contact point for customers via Smartphone applications (Kasperk & Drauz, 2013a, p. 117 f.). In addition, the established actors in the field, the OEMs, could redefine their role, looking into stationary applications of batteries or energy services (as for instance done by Volkswagen AG in cooperation with the energy supplier Lichtblick SE), or investing themselves in energy production and charging infrastructure. They might also cooperate with energy and ICT companies as providers of mobility services, utilizing their established after-sales and services infrastructure in innovative ways (Kasperk & Drauz, 2013b, p. 41 f.).

In general, the electric vehicle as the central technological artifact of a potential new e-mobility system questions the role and functions of established actors and of the potential newcomers. Depending on how the different actors position themselves in this new field, how they manage to demarcate their individual claims, and find ways of cooperating with each other, a fundamentally different socio-technical system might emerge around the electric vehicle (Kasperk & Drauz, 2013a, p. 115 f.; Kasperk & Drauz, 2013b, p. 45). The fact that a large number of non-automotive actors is from the beginning involved in or someway related to the development of e-mobility may open up new perspectives on (electric) cars, the way they are produced, designed and used (Vallèe et al., 2013, p. 90). In this way, the electric vehicle possesses an 'indirect' transformative capacity: by triggering shifting system boundaries and new forms of cooperation, the conditions for its own further development and the way it becomes embedded in its social environment are shaped by actors with a fresh perspective on mobility. New perspectives and the combination of different perspectives in a new field are potentially important for the development of e-mobility as a system innovation, because change in basic interpretive schemes, guiding principles and norms, requires processes of reflection and learning.

Tbl. 4 summarizes the findings regarding the transformative capacity of the battery-electric vehicle. This brief overview indicates that the transformative capacity of the BEV is high. While these criteria of transformative capacity need to be studied in more detail, in order to understand the concrete implications for industry, policy, markets, regulations etc., the point here is to show the very basic mis-fits of the BEV with the current mobility system.

BEVs cannot simply replace conventional cars without major changes in industrial production structures, business models, use patterns and political regulations. Whether these mis-fits with the current mobility system unfold a potential for more systemic types of change, depends on the degree to which the socio-technical system around it can be characterized as adaptable.

In what ways does the electric vehicle as a new technology...	
…alter the **technological profile** of the socio-technical system?	- Structural change in automotive industry: core competences become less important. - New technologies gain importance.
…affect established **patterns** in the socio-technical system?	- Electric vehicles are not competitive, new business models emerge. - Concept of the 'multi-purpose car' is challenged. - New fields of R&D gain importance. - New types of cross-sector policies are needed.
…initiate **institutional readjustments**?	- Regulation is needed for standardization. - Regulation is needed for integration with the energy system.
…facilitate new patterns of **interaction**?	- Established relationships are challenged between car manufacturers and suppliers; mobility providers and energy suppliers. - ICT companies link energy and automotive sector.
…open up or widen existing **borders** of the socio-technical system?	- Boundaries between the automotive sector and the energy sector become blurred. - ICT emerges as a new 'link'.

Tbl. 4: The transformative capacity of the battery-electric vehicle.

Some general observations can be made that indicate that the established socio-technical system revolving around automobility shows signs of growing system adaptability. In theory, the key elements determining whether overall system adaptability is low or high are reflected in regime configurations that are either well-aligned or characterized by internal tensions. Geels (2012) has identified four 'cracks' in the automobility regime that are indicators of destabilized regime structures and thus potentially factors increasing overall system adaptability. These are, first, increasing traffic-related problems in cities, such as congestion and local pollution, which decrease quality of life in cities at a time when increasing numbers of people live in urban areas. Second, the market for cars in most developed countries, especially in North America and Europe, are saturated as can be shown by decreasing volumes of car sales, indicating that "peak car" has been reached (Goodwin, 2012, p. 11; Newman & Kenworthy, 2011). This aspect is also discussed by Orsato and Wells (2007), arguing that "there are many reasons to believe that the foundations for this historic success [of the automotive industry] are fading away" (p. 998). It is shown that the automotive industry is in an overall difficult situation with saturated markets in developed countries, unexpected difficulties in entering emerging markets (e.g. due to price instabilities and lacking infrastructure), and a business model based on the need to realize economies of scale to deal with low profit margins, while customers demand a wide variety in products. In combination, these factors have at least increased the overall vulnerability of the historically successful automotive industry (Orsato & Wells, 2007, p. 999). Third, political pressure on the automotive industry and on unrestricted car use is slightly increasing. Some efforts are undertaken with regard to the regulation of CO_2-emissions, local traffic management and a broader orientation along the principle of sustainable mobility. This crack is to be treated cautiously because overall the automotive industry is not severely threatened by political regulation as has been shown by governmental support during the financial crisis or successful lobby efforts by the German automotive industry in EU negotiations on emission regulation. Fourth, there is an increasing awareness of environmental problems and resource scarcity. This crack also needs to be treated cautiously, because especially for OEMs this is not so much a 'direct' problem, but rather an indirect one, articulated by politicians and to a lesser degree by customers (Geels, 2012, p. 478 f.).

Departing from these 'cracks' as macro-level societal and economic trends, some early signs of minor change in the automobility world can be observed. An example is the (eventually failed) business model of Better Place, a mobility company, which focused on operating charging spots and battery exchange stations and leasing batteries to customers, thus reducing their initial purchase cost of a BEV (Christensen et al., 2012, p. 501 f.; Orsato et al., 2012, p. 214 f.). Thus, in this case some of the most prominent problems with BEVs, namely battery costs and recharging infrastructure, have been addressed in the form of an innovative business model. A second example is the problem of limited range of BEVs and planning challenges when BEVs are to be used for electricity storage. These technical problems can be dealt with much better by fleet operators or carsharing service providers than by individual car owners. Thus, carsharing companies and fleet operators may not only have an impact on the development of e-mobility as users but potentially also introduce new use patterns of mobility that are not centered around private car ownership (Orsato et al., 2012, p. 217 f.). Thus, referring to the basic category of transformative capacity of new technologies, it can be shown that the alleged technological shortcomings of battery technology are in some cases a trigger for change in social processes and thus open perspectives for a potential system innovation around e-mobility in the future.

However, despite a few innovative approaches and even though 'cracks' can be shown to have appeared, the overall automobility regime still seems to be relatively stable. The focus of OEMs is not so much on experimenting with innovative business models than it is on trying to develop electric vehicles that can be compared to and compete with conventional cars. The basic approach of industry R&D is geared toward a technological fix of environmental problems – possibly arriving at an economic and environmental win-win outcome. Dealing with the more fundamental, underlying challenges of a car-centered system is thus effectively being avoided (Nykvist & Whitmarsh, 2008, p. 1377; Wells & Nieuwenhuis, 2012, p. 1687).

Similarly, studies of user acceptance of electric cars show that in general people are interested in the new technology and in buying electric vehicles as long as they function basically like a ‘normal’ car. The conventional car is the commonly known standard and electric vehicles are evaluated by directly comparing them in the light of what is known. Then, obviously, the electric vehicle does not perform sufficiently with regard to range, price and charging time. Interestingly, the few aspects where the electric car performs better, e.g. offering the possibility for charging at home, a new type of driving experience and being locally emission-free, are seen as much less relevant (Schlager & Oltersdorf, 2011, p. 133). Comparing electric vehicles with conventional cars as the standard, especially in terms of range and price, is also the general pattern observed in political efforts and in the field of (publicly funded) R&D, where the majority of financial resources are dedicated to battery technology. The battery is perceived to be the basic technological weakness, because it is still too expensive and not performing well enough to allow for an acceptable vehicle range (Weider et al., 2011b, p. 105).

These examples show that system adaptability must be more than the existence of ‘cracks’ in a regime, which then serve as a window of opportunity for new technologies to emerge and diffuse, resulting almost automatically in an ensuing process of socio-technical co-evolution. System adaptability is an inherently agency-related category. Regime structures are more or less actively and consciously reproduced and drawn upon by actors in their real-world contexts. Thus, the emerging ‘cracks’ as an analytical category may give hints regarding instances for potential system adaptability at an aggregated level. However, whether or not a concrete system is adaptable depends critically on *the way* that actors perceive and deal with change, and not just the fact that on a macro-level things change, trends and crises occur. Similarly, the transformative capacity merely points to the inherent potential of a technology in relation to given regime structures, thus as a concept it captures the virtual range of possibilities or alternatives that become feasible with this technology.

Actual change results from the interplay that unfolds within the social configuration of a system and its constituting actors.

For the case of e-mobility this means that its potential can only show where it is applied in practice and where experimentation and learning can take place. Only when there is actual, micro-level socio-technical interaction, is it possible that the electric vehicle gains meaning and a symbolic value of its own, independent from the conventional car as standard frame of reference. This will then also prepare the ground for new mobility patterns, industry structures and business models (Weider et al., 2011b, p. 106 f.). The 'cracks' and macro-level perspective described briefly in this section do show that the automobility regime is facing severe problems and that there is a potential, or a threat for many, of structural change. At the same time, there is no convincing and completely spelled-out alternative waiting to replace elements of the old system. Most likely, a transitional phase is beginning to take shape, where it is still a major challenge to begin to re-think 'mobility' (Canzler & Knie, 2011, p. 31). Therefore, in the following, a more detailed look is taken at the German innovation system, where experimentation in the field of e-mobility is actually taking place. A focus on this lower level (as compared to macro trends in the automotive industry and society as a whole) allows for understanding 'micro-level' socio-technical co-evolution and behavior of actors involved in developing e-mobility. The aim of this endeavor is to better understand where the actual seeds for system adaptability may be found, or what the major barriers are, which hamper the development of e-mobility even in a situation where framework conditions are "favorable".

4.4 Case Study: E-mobility in Germany – Assessing System Adaptability

Since the new technology, in this case the electric car, can be assessed regarding its basic technological properties and its envisaged function in the context of the ideal-type system innovation, at this point the potential of such a system innovation actually evolving depends on system adaptability. In the following, a case study on the German innovation system for e-mobility will be presented that aims at shedding some light on the concept of system adaptability and what it entails in this specific case[6].

[6] Preliminary results of this case study have been published in Augenstein (2014, forthcoming).

4.4.1 Case Study Design

The aim of the case study is to analyze system adaptability in the field of e-mobility development specifically in the German state of Baden-Württemberg. Since system adaptability is characterized by changes in rules and resources and depends on actor and power constellations, the case study has to include a combination of methods that can grasp these different aspects. Before these concrete steps of data collection and analysis are layed out, the boundaries of the case have to be defined.

With regard to the period of investigation, the year 2009 has been selected as the starting point, since this was the start of the first major funding program "Model Regions for Electric Mobility", and the subsequent developments are followed up until the present. With regard to the spatial boundaries of the case, an embedded design has been chosen. The central unit of analysis is the German state of Baden-Württemberg, which as a federal state, i.e. one of the German 'Länder', has clear geographical and political boundaries. However, since the funding programs for e-mobility are launched by the federal government and the overall strategy for developing e-mobility is also shaped at the federal level, the case of Baden-Württemberg needs to be embedded in its broader German context. Therefore, chapter 4.4.2 will briefly describe the German innovation system for e-mobility as a whole, with a particular focus on political initiatives at the federal level, the development of funding programs and the actor structure determining the strategic perspective of the German government. Relevant data sources are official government documents and existing studies on the goals and actor structure of the German innovation system. These are screened, in order to identify power structures and the dominant rule systems influential actors refer to. In order to gain an in-depth insight on system adaptability, the analysis also needs to focus on concrete interactions of different groups of actors, which can best be observed in the context of concrete e-mobility projects carried out in Baden-Württemberg (chapter 4.4.3). Against the background of the overall actor structure, dominant rule systems and patterns of resource allocation in Baden-Württemberg as a whole, these individual projects can be understood as sub-cases embedded in the broader context of Baden-Württemberg's innovation system (which is in turn embedded in a broader German context). Collecting and analyzing data within these sub-units of analysis can help to illuminate the case as a whole (Baxter & Jack, 2008, p. 550), thus insights on system adaptability for e-mobility in Germany. This case study design entails thus a typical case-oriented, rather than variable-oriented, analysis where insights within the different sub-cases will be compared and related in the end, in order to identify general patterns or dynamics (Kohn, 1997, p. 5). The results of analyses at these different levels will be re-integrated in chapter 4.4.4.

Following the broad overview of the German innovation system in chapter 4.4.2, which will mainly be based on official government documents and secondary sources, e.g. the few existing studies on the German innovation system for e-mobility, the analysis for Baden-Württemberg will proceed as follows. First, a brief overview is given on the region of Baden-Württemberg in general and the e-mobility initiatives taking place during the period of investigation from 2009 until today (chapter 4.4.3.1).

Second, a network analysis will give an overview of the actor structure of Baden-Württemberg's innovation system (chapter 4.4.3.2). The method of network analysis is suitable for analyzing system adaptability, i.e. the degree to which a system is well-aligned or showing regime 'cracks' with regard to dominant rule systems and actor-/power-constellations: Basic premises of social network analysis are that actors in a specific network are interdependent and their relationships can be captured in terms of structural properties, which can be both constraining and enabling (Jansen, 2006, p. 18 f.; Wassermann & Faust, 1994, p.4). Thus, the basic conceptualizations on which network analysis builds is well in line with the concept of system adaptability in terms of regime structures. Social network analysis has a rich history, it is applied across different disciplines, it combines qualitative and quantitative approaches in widely varying degrees of sophistication (cf. Scott, 1991; Wassermann & Faust, 1994). For the purpose of this case study, where the relevant network is relatively small and the aim is to identify actor constellations in relation to their resourcefulness or influence on a regional innovation system and the basic rule systems (frames of reference and interpretive schemes in the context of e-mobility), a relatively simple network analysis will suffice. It will proceed as follows. As a starting point, relevant actors making up the innovation system are identified based on their participation in projects and receiving R&D funding in the context of the official governmental programs, or other forms of participation in institutionalized settings of the innovation system, e.g. specific sectoral or regional networks or associations. Relevant data sources are thus official documents, e.g. an overview of recipients of governmental funding published by the Federal Ministry for Education and Research (BMBF), or information brochures published by the Regional Project Coordination Agency (Regionale Projektleitstelle, PLS) in Baden-Württemberg. The identified actors are then clustered according to their respective affiliation with a specific industry or sector, the field of science and research, the public sphere or civil society organizations. An overview is thus gained on the basic actor structure of the network. In order to analyze dominant rule systems, including an assessment of who shapes them to significant degrees, and patterns of resource allocation, i.e. overall power relations, in a next step, the relations and power positions of actors within the network are studied. The actors are grouped according to the relative influence they have on the innovation system as a whole, which can be "low", "moderate" or "high". Indicators for influence are the amount of funding an actor receives, the number of projects in which an actor participates and whether or not an actor functions as project leader in larger project consortia. It is assumed that these criteria are appropriate, because receiving financial resources from the federal government signals an important role attributed to a specific actor group and their specific focus of activities, and thus dominant rule systems with regard to perceived key aspects of developing e-mobility. Being involved in one or more concrete projects, and especially leading a project, signals the availability of both authoritative and allocative resources, and it grants the respective actor the possibility to actively shape strategies of developing e-mobility. The broad categorization of levels of influence is thus determined by the relative position of actors compared to each other. Finally, the network analysis' focus shifts beyond the level of individual actors and includes a focus on the level of projects. Based on the relevant criteria for a sustainable system innovation developed in chapter 4.2, e-mobility projects carried out in Baden-Württemberg are clustered according to their specific focus, ranging from 'vehicle technology' to 'system-innovative' approaches. This overview provides insights on dominant rule systems and patterns of resource allocation, because it shows whether established power structures are reproduced in the form of 'conventional' project designs, or whether substantial material and immaterial resources go to 'system-innovative' projects. Finally, it will be analyzed what types of actors, with regard to affiliation and levels of influence, typically participate in what types of projects, in order to identify typical patterns of cooperation and respective outcomes relevant for the potential of a system innovation.

Third, discourses that reflect the basic frames of reference dominating the network are analyzed, in order to complement the insights on different levels of influence of specific actors with their respective views, guiding principles and resulting strategies (chapter 4.4.3.3). An overall assessment of system adaptability is then possible by identifying the dominant rule systems of different actor groups and the relative influence that these have, based on the power position of their respective proponents. Relevant data sources are official statements or position papers. A focus of the analysis will be on tensions or contradicting lines of argument and the relative position of varying frames of reference with regard to the influence of the actors that can be related to different positions.

Fourth, a closer look will be taken at projects that can be characterized as 'system-innovative' (chapter 4.4.3.4). These projects are selected based on the criteria identified with regard to an ideal-typical system innovation: project focus on intermodality, carsharing, integration with renewable energy, and, in general, a focus on mobility that is not car-centered, as e.g. in a project on e-mobility and housing. These projects are analyzed with regard to their specific focus and design. Based on the overview of the actor structure across all the projects in the previous section, a more in-depth analysis of the actors and cooperation patterns involved in these projects is carried out. In-depth interviews[7] have been carried out with actors responsible for managing these projects. These were the project managers of involved firms (in the fields of energy supply, public transport, ICT, housing) and researchers. Interviews have also been carried out with representatives of the Regional Project Coordination Agency (PLS), i.e. the public agency responsible for coordinating the different projects. The semi-structured interviews, ten in total with each lasting between 60 and 90 minutes, focus on general perceptions and visions of e-mobility as well as the concrete projects and the funding program in general, actor constellations and conflicts[8]. Thus, the role of the interviewed actors is twofold: On the one hand, as project partners involved in system-innovative projects they are part of the innovation system as the object of study; on the other hand, they are also experts with an insider perspective on the innovation system as a whole and treated simultaneously as sources of information about the object of study. This is accounted for by separating these two roles into different sets of question, either directly related to the specific projects and personal perceptions, or focusing on assessments of developments in the field of e-mobility in Baden-Württemberg and Germany. Obviously, there may still be issues of overlapping roles, for instance, assessments of the innovation system structure are influenced by personal experiences in a concrete project setting, or personal beliefs regarding the overall development of e-mobility have an impact on how the innovation system is assessed. This ambiguity is dealt with by carefully analyzing the interviews based on theory-informed categories of perception of and ways of dealing with e-mobility (system adaptability) along the criteria of transformative capacity.

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[7] To ensure openness during the interviews, anonymity has been guaranteed to the respondents and their names as well as those of their respective organizations are withheld in this thesis.

[8] The guiding questions used in the interviews have been developed based on the theoretical concepts developed in ch. 3.3.5 and the detailed questionnaire can be found in Appendix D.

Finally, the results of the case study of Baden-Württemberg are discussed and results are being presented in chapter 4.4.3.5, while chapter 4.4.4 discusses the findings in the context of the German innovation system as a whole.

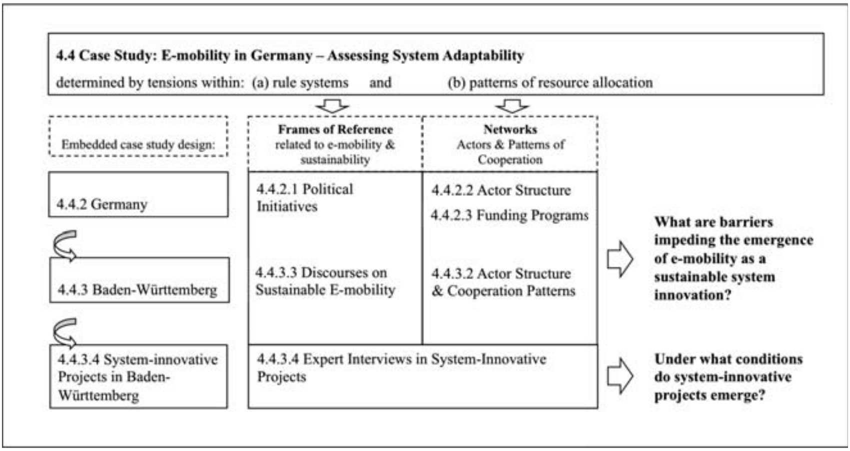

Fig. 11: Case study design.

4.4.2 The German Innovation System for E-mobility

As in many other countries, there has been more than one attempt to introduce electric vehicles and develop e-mobility in Germany. Some of the basic technological innovations, i.e. electrical motors and various types of batteries, date back to the early 20th century and in more recent history, the 1990s have been a major hype phase (Høyer, 2008, p. 70 f.). Before this more substantial hype, the increasing awareness for global environmental problems, local pollution caused by transport especially in large cities as well as the oil crisis during the 1960s and 1970s spurred a phase of intense research and development of electric vehicles. When the dependence on oil from OPEC countries emerged as a real threat and stricter environmental regulations were adopted – and against the background of decreasing growth rates in car production – two large German OEMs, Daimler-Benz AG and Volkswagen AG, bundled their efforts in developing electric cars. However, these efforts did not materialize and visions of electric mobility vanished again (Canzler & Knie, 2011, p. 102 f.; Høyer, 2008, p. 66).

More substantive action was taken during the 1990s. The general sustainability discourse had gained momentum and an important factor was the "Zero Emission Vehicle" regulation adopted by the California Air Resources Board (CARB) (Dijk et al., 2013, p. 136;

Sierzchula et al., 2012, p. 50). In Germany, a large-scale demonstration project was launched in 1992 by the German Federal Ministry of Education and Research (BMBF) and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). A fleet trial with 60 electric cars was carried out on the island of Rügen. Apart from that, a number of smaller pilot projects aimed at market introduction of electric vehicles in some of the German states ('Länder'). The results of these projects – which involved only the automotive sector as industrial partners – were discussed controversially, especially political actors voiced ecological concerns regarding significantly higher CO_2-emissions of electric vehicles as compared to conventional cars, due to the German electricity mix at that time. Also, in California the political regulation on zero emission vehicles was subsequently weakened and in the end basically nullified as a result of legal action initiated by different US car manufacturers. So, by the end of the 1990s, German activities in the field of electric mobility had come to a relatively abrupt halt (Canzler & Knie, 2011, p. 103; Schwedes, 2011, p. 12 f.; Weber & Hoogma, 1998, p. 558; Weider et al., 2011b, p. 108).

The most recent hype around electric mobility took off in 2007. A number of framework conditions have been relevant for this renewed interest: Climate change had resurfaced as an important issue on political agendas and gained prominence in public as well as scientific discourses. Especially in the fields of energy and transport the heavy dependence on oil and the threat of 'Peak Oil' have been increasingly perceived as a serious problem (Schwedes et al., 2013, p. 75). Furthermore, the global financial and economic crisis had negative impacts on the automotive industry, which already has to deal with saturated markets in most industrialized countries and is faced with a constant pressure to reduce costs due to its current system of production (Orsato and Wells, 2007, p. 998).

4.4.2.1 Political Initiatives by the Federal Government: Caught between Environmental and Economic Goals

Against this background, the German government stepped in to support the nationally important automotive industry (Schwedes et al., 2013, p. 75). The government's focus on e-mobility as the favored technological option can be explained by a number of aspects. With the German energy transition underway, BEVs were seen as important means of energy storage in a renewable energy system. Furthermore, advances in battery technology, concerns regarding the future of automobility in global mega-cities and especially the growing importance of the Chinese market for German OEMs and China's efforts of fostering the electrification of the car played an important role, too (Dijk et al., 2013, p. 141 ff.; Schwedes et al., 2013, p. 75 f.). The German government also has to deal with political pressure at the EU level to achieve the 20/20/20 goals of increasing energy efficiency and the share of renewable energy by 20% until 2020, to contribute to the general vision of sustainable transport development (EC 2001; EC 2011) and the focus on developing alternative vehicle technologies in the 7th Framework Program for Research (Dijk et al., 2013, p. 138; Köhler et al., 2009, p. 2985 f.).

The attitude of political actors had thus changed compared to the 1990s. In 2007, the German federal government adopted an "Integrated Energy and Climate Program" (IEKP), which contains measures and draft legislation for increasing energy efficiency and fostering the development of renewable energies. The development of electric mobility is included as one measure for reducing CO_2-emissions in the transport sector (BMWi & BMU, 2007, p. 89). For the first time, electric mobility has been taken up by political actors as an element of strategies for achieving a transition towards renewable energies and a contribution to climate change mitigation (Schwedes, 2011, p. 14). Electric mobility was also increasingly seen as an economically important field for technological innovation. The German government launched the Economic Stimulus Package II as a way to react to the economic and financial crisis in 2008/2009 and it contained, amongst others, measures for fostering research and development of electric mobility worth 500 million € (Schwedes, 2011, p. 14).

This combination of environmental and economic goals pursued by the German government in the field of electric mobility remains a central characteristic of the strategic initiatives taken in the following years. In 2009, the German government launched its „National Development Plan for Electric Mobility" (NEPE), which apart from setting goals of climate production and reducing dependency on oil, spells out the aim for Germany to become a „lead market for electric mobility" and to have „one million electric cars on Germany's roads" by 2020 (Bundesregierung, 2009, p. 46). To reach this goal, a comprehensive strategy ranging from basic research to market introduction is to be developed and actors from science, industry and politics are to be included in the strategy development process. Important elements would include not only the entire value chain around the electric car, but also its integration in the energy system and especially its potential contributions in the context of the transition to renewable energies (p. 4). The necessary R&D efforts in the fields of battery development, components and standardization, grid integration, battery recycling, information and communication technologies, education and competence building as well as preparing the technology and the market for commercialization are to be financed by the 500 million € of the Economic Stimulus Package II implemented to deal with the economic crisis in 2008/2009 (p. 24). In the context of the Economic Stimulus Package II, the Federal Ministry of Transport, Building and Urban Development has launched "Electric Mobility in Model Regions", where eight regions have been selected as model regions for the period from 2009 to 2011 (Tenkhoff et al., 2011, p. 11 f.).

The goals envisioned in the national development plan are specified further in the "Government Program Electric Mobility" launched in 2011 (Bundesregierung, 2011, p. 5). The government program is meant as the starting point for a new phase of launching a market for electric mobility, introducing concrete measures following the preparatory phase starting in 2009. This is seen as an important milestone on the way towards Germany becoming a lead market for electric mobility. The necessary measures are consequently embedded in a 'market logic' of supply and demand: R&D efforts should concentrate on drive technologies and components as well as the integration of vehicles in energy and transport systems – while it is emphasized that these efforts should be bundled in overarching thematic research projects. The basic rationale for this is to support relevant German industries and to be able to showcase the quality of German products in newly emerging systems for electric mobility. The demand side is addressed in a similar way. Research projects on the integration of electric vehicles in energy and transport systems are basically needed as a means of creating visibility and of demonstrating e-mobility to users (Bundesregierung, 2011, p. 7).

However, it is also emphasized that establishing Germany as a lead market for electric mobility implies more than developing new drive technologies, but rather aims at future more sustainable energy and transport systems. Special emphasis is therefore put on the changing relations between established industry sectors, changes in individual lifestyles and the role of cities and urban infrastructures. New forms of cooperation will be needed on the way towards the lead market; however, the cooperation viewed as central in the government program are industry coalitions along new value chains, which should create the market, while science and policy function as innovation support and framework provision (Bundesregierung, 2011, p. 15).

A number of concrete measures are envisaged in the government program. First, a joint R&D program is to be launched to speed up market breakthrough of electric mobility. There have already been the 500 million € from the Economic Stimulus Package II that have been invested during the period from 2009 to 2011. Following this, another billion € of governmental funding is made available until 2013. It will be used to finance large demonstration projects, the so-called "Technological Lighthouses for Electric Mobility" and "Electric Mobility Showcases". R&D efforts should concentrate on the identified key challenges with regard to battery technology, electric vehicle technology (focusing on materials, components and vehicle energy management, in order to realize cost effects), the charging infrastructure and grid integration. Furthermore, a coordination office, the Joint Agency for Electric Mobility of the Federal Government (GGEMO), is being set up to provide funding advice and coordinate the various R&D activities (Bundesregierung, 2011, p. 18 ff.).

Second, the large demonstration projects envisaged in the funding program are highlighted (Bundesregierung, 2011, p. 25 ff.). They play an important role as new and innovative R&D instruments that are introduced in terms of a systemic approach. The so-called "Electric Mobility Showcases" are large-scale regional demonstration projects where the different industrial sectors and the public sector, in this case the 'Länder', work together to make electric mobility accessible to the general population and to make visible the technological competence of the German industry in a limited number of major projects. Consequently, the characteristics (and thus also selection criteria) for showcase regions are a systemic approach (especially including the interfaces between the electric vehicle, the energy and the transport system), cooperation across value chains, testing regulatory frameworks, reaching a critical mass to assess everyday suitability of e-mobility solutions, involvement of the public, a focus on education and professional qualification, and (financial) commitment of involved industry and public partners (Bundesregierung, 2011, p. 26 f.). In addition to the showcase regions there will be "Technological Lighthouse" projects, which will focus on distinct technologies and specific fields of application. They are seen as a strategically important complement to the showcases by developing technologies that can quickly be used in practice and contribute to achieving cost effects (Bundesregierung, 2011, p. 29 f.). Both programs are envisaged to mutually profit from each others' experiences and results.

Since only a limited number of showcase regions have been envisaged, it was hoped that some of the already existing model regions for electric mobility can be continued as showcases. The remaining model regions should, where possible, be continued in the context of the normal funding programs of individual ministries – while the joint funding program focuses on the showcase regions (Bundesregierung, 2011, p. 28).

Third, roadmaps and various governmental initiatives, e.g. organizing stakeholder conferences or engaging in EU and international political arenas, are envisaged for the fields of education and professional qualification for electric mobility (Bundesregierung, 2011, p. 31), questions of certification and standardization of products and production processes

(Bundesregierung, 2011, p. 32 f.), as well as international cooperation (Bundesregierung, 2011, p. 56 f.).

Fourth, in the fields of charging infrastructure and energy provision (Bundesregierung, 2011, p. 34 ff.), and resources, materials and recycling (Bundesregierung, 2011, p. 41 ff.) as well as a number of legislative initiatives are planned and key challenges and open regulatory questions are identified. Furthermore, legal measures relating to road traffic law or emission and environmental law as well as (tax) incentives are laid out (Bundesregierung, 2011, p. 46 ff.).

In sum, it can be shown that there is, overall, strong political commitment to developing e-mobility in Germany. A broad range of measures and substantial amounts of financial resources are dedicated to the goal of developing a lead market. However, it can be shown that under the surface, tensions are emerging between environmental and economic goals of developing e-mobility, and between classic industry R&D and more 'system-innovative' approaches, for instance in the showcase region program.

4.4.2.2 Actor Structure in the German Innovation System for E-mobility: A Key Role for Regime Incumbents

Apart from setting strategic goals in the National Development Plan and providing governmental funding for R&D, the German innovation system for e-mobility has also been characterized by an institutionalization of organizational structures at the federal level. Early in 2010, the Federal Ministry of Economics and Technology (BMWi) and the former Federal Ministry of Transport, Building and Urban Development (BMVBS, re-structured in 2014 as Federal Ministry of Transport and Digital Infrastructures (BMVI)) set up the Joint Agency for Electric Mobility of the Federal Government (GGEMO), located at the BMWi. The GGEMO functions as a Secretariat which coordinates the activities of the federal government in the field of e-mobility, organizes official events and conferences, and provides support to another important body, the National Platform Electric Mobility (NPE). Based on the National Development Plan, the German government has invited representatives of industry, science, politics, labor unions and civil society to build this National Platform Electric Mobility in 2010.

The members of the NPE have decided to follow an approach that is systemic, market-oriented and technology-neutral (NPE, 2010, p. 5). They have committed themselves to the 2020-goal of establishing a lead market and having one million electric vehicles on the road by 2020. Within the NPE, activities are focused across seven working groups dealing with the following aspects: 1) power train technology; 2) battery technology; 3) charging infrastructure and grid integration; 4) standardization and certification; 5) materials and recycling; 6) education and qualification; 7) framework conditions. The NPE as well as the individual working groups regularly report on the progress that has been made and provide the government with recommendations (NPE, 2010). An overarching steering group meets regularly to discuss the progress that has been made in the individual working groups. Members of the steering group are the state secretaries of the involved federal ministries, the Joint Agency for Electric Mobility of the Federal Government (GGEMO) and the chairpersons of the seven working groups (usually members of company boards). Steering group meetings are also attended by the "Industriekreis", a group consisting of representatives of industry associations (VDA, BDI) and labor unions (IG Metall). The official reports of the NPE are written by an editorial team, which consists of representatives from each of the working groups and the "Industriekreis" (Canzler & Knie, 2011, p. 88).

The main topical focus and activities of the seven working groups show that the NPE is guided by a 'traditional' approach where the problem is separated along disciplinary lines and is basically treated as a technological problem. It can be argued that this is the logical consequence of the member structure of the NPE. Representatives of the automotive and the energy sector have been dominating the working groups as well as formal and informal decision-making processes. Public transport actors were not represented at all and interests of civil society organizations and users in general remained underrepresented (Canzler & Knie, 2011, p. 11).

A study carried out by the Independent Institute for Environmental Issues and the Institute of Transportation Design, which has been conducted on behalf of the Federal Ministry of Transport, Building and Urban Development (BMVBS, now BMVI), finds that the composition of the NPE reflects the general actor structure of the innovation system as a whole (Zimmer & Rammler, 2011). The aim of this study was to provide an overview of the relevant actors in the German innovation system and assess their impact on future technological developments as well as their guiding visions and perceptions of e-mobility (Zimmer & Rammler, 2011, p. 186). The study shows that two-thirds of the actors making up the innovation system are business and industry representatives. The last third is made up of scientists and politicians, while consumers and civil society organizations hardly play a role. It can be shown that only one third of all those actors have a significant impact on the structure and developments within the innovation system. These are representatives of OEMs and their supplier networks, large energy suppliers and some actors from the chemical industry, electrical engineering and ICT and their respective industry associations. In the realm of politics, influential actors are the federal government and the involved ministries, and, in the field of science, a small number of universities and research institutes also have a significant impact. This actor constellation is in line with the innovation system's emphasis on building up the charging infrastructure and developing battery technologies (Zimmer & Rammler, 2011, p. 83 f.).

The network analysis carried out in this study also shows that by launching the NPE and giving it a central role, the German government has actively granted the established industrial actors the opportunity to dominate developments. The leading positions in the NPE are held by representatives of the automotive sector, battery technology and engineering as well as large energy suppliers – thus, actors subject to fundamental path dependencies and with a focus on product innovations. Consequently, the study also finds that those actors that could be expected to contribute to the development of system innovations (e.g. small firms in the fields of electric cars, charging infrastructure or renewable energies, actors at municipal levels) are lacking influence and the financial means to have an overall impact on the innovation system (Zimmer & Rammler, 2011, p. 84).

Even though the NPE is made up of established industry actors, it became nonetheless obvious that developing e-mobility would amount to a challenge that goes beyond sector-specific technological questions. Car manufacturers are aware of the fact that the global trend of growing mega-cities threatens their business model of selling cars and that they will have to find forms of cooperation with the public transport sector. Similarly, energy utilities have realized that e-mobility is not only about changes in the field of transport but that integrating electric vehicles and smart grids eventually implies a fundamentally different system of energy provision. Discussions in the NPE have shown that most of the involved actors have trouble coming to terms with redefining their established strategies, business models and patterns of cooperation, due to great uncertainties regarding future products, markets and power relations between the actors involved in developing e-mobility (Canzler & Knie, 2011, p. 11 f., 14).

Conflicts also loomed with regard to the allocation of governmental funding. Energy utilities claimed the need to have the charging infrastructure subsidized, car manufacturers were arguing for subsidizing electric vehicles in order to decrease their purchase price, and the science partners also voiced their demands. It became clear rather quickly that the sum of these individual claims would be far beyond any realistic government program and that compromises would have to be found. A pattern emerged in these negotiations that proved to be a successful way of avoiding dead-lock: when positions of different actors seemed irreconcilable, agreement was reached that with regard to a particular issue, there was a need for further research before definite decisions could be taken. This way a hopeless battle over who should get how much money in subsidies could be sidestepped (Canzler & Knie, 2011, p. 89 ff.). The need to find new ways of cooperating, in order to secure governmental support, further became clear to the members of the NPE when the government program for electric mobility was launched in 2011, because it did not hold out the prospect of funds for particular sectors and their individual interests but rather emphasized the need to strive for overarching goals (Canzler & Knie, 2011, p. 14).

Outside these official and highly institutionalized groups, such as the NPE, especially the environmental and consumer associations offered a more critical perspective on e-mobility. They emphasized the need for a more comprehensive view on sustainability, thus broadening the dominant focus on electric vehicles to include issues of renewable energy sources for powering BEVs and visions of future more sustainable mobility in general. However, since they were not represented in the NPE their impact remained limited. Arguably, environmental associations, NGOs and independent environmental research institutes willingly positioned themselves outside the debate about e-mobility by taking an opposing stance – even though the basic critique is less about e-mobility in general, but rather about the car-centered perspective dominating the political debate and initiatives (Zimmer & Rammler, 2011, p. 183 f.).

In the overall political discourse, e-mobility appears as a promising option for mobility in the future that is currently struggling with technological problems such as limited range, long charging times and high costs, which are typical for an innovation in a premature state. These problems are to be overcome by fostering R&D and stimulating (technological) innovation. However, the fact that the problems dominating the debate are those that are most obvious when looking at the BEV in comparison to conventional cars (more expensive, smaller range, longer charging) – rather than problems related to alternative forms of future mobility (transition to renewable energies, social aspects going beyond vehicle technology) – shows that the current (auto)mobility regime remains the decisive frame of reference also with regard to visions of future mobility and the transformation process leading there. This is in line with the actor structure dominating the innovation system, i.e. representatives of OEMs, automotive suppliers and the energy sector, which make up the NPE and other influential bodies (Zimmer & Rammler, 2011, p. 184 f.).

4.4.2.3 Funding Programs: Trying to Achieve Systemic Change through Technological Innovation

The most visible efforts in fostering e-mobility so far have been the three major funding programs „Electric Mobility in Model Regions“, “Technological Lighthouses of Electric Mobility” and “Electric Mobility Showcases”.

The funding program “Electric Mobility in Model Regions” has been launched by the Federal Ministry of Transport, Building and Urban Development (BMVBS, now BMVI) and is coordinated by the National Organization for Hydrogen and Fuel Cell Technology (NOW GmbH). Eight regions have been selected as model regions for the period from 2009 to 2011. They were conceptualized as innovation clusters focusing on the following goals: technology-neutral R&D in the field of battery-electric vehicles, user-oriented demonstration, integration into transport, land use and urban planning and development, local integration of stakeholders and exchange of information across the model regions (Tenkhoff et al., 2011, p. 11). It can be shown how dominant rules and guiding principles manifest themselves in the way that financial resources have been allocated within the program.

The volume of funding made available in this program amounted to 130 million € from the Economic Stimulus Package II and thus made up a large part of the overall funding for electric mobility of 500 million € in total. Roughly 70% of the model region funds were allocated to private businesses and together with industry investments the total project volume amounted to roughly 300 million €. Across the model regions, 220 project partners were involved, 150 of which can be grouped among OEMs, component suppliers, energy suppliers and transport and logistics. In total, 70 individual demonstration projects focused on aspects of individual, commercial or public transport and in these projects approximately 2,500 electric vehicles (ranging from E-bikes to BEVs and commercial vehicles) were deployed and a charging infrastructure comprising roughly 1,000 charging stations was built up. Apart from technology-oriented research on vehicle technology, research was conducted on environmental effects, especially with regard to questions of available electricity sources, and on user acceptance of electric vehicles (Tenkhoff et al., 2011, p. 12).

Fig. 12: Electric Mobility in Model Regions – Overview (Sax-Mobility II, 2012).

The Federal Ministry of Education and Research (BMBF) has published a comprehensive overview of the government's funding activities in the field of e-mobility (BMBF, 2011). This overview contains lists of each individual amount that has been spent in the context of the Economic Stimulus Package II, in order to foster e-mobility. Based on this overview and the official evaluation report of the model regions (Tenkhoff et al., 2011), an overview has been gained on the number of individual projects within each of the eight model regions and the amount of money that has been allocated to these projects from the governmental funds. Then those projects have been selected that qualify as sustainable or system innovative according to the criteria deducted from sustainable mobility literatures (integration of renewable energy, fleet applications, intermodality, carsharing, see ch. 4.2). Any project that fulfills one or more of these criteria has been selected, based on the project description in the official evaluation report of the model region program. The share of funds that has been allocated to these projects has then been compared to the overall share a model region received for all projects.

In the model region Rhein-Ruhr, 2 out of 8 projects focus on system-innovative elements, such as fleet applications and carsharing. In Stuttgart, 2 out of 7 projects focused on fleet applications and (car-)sharing. In Bremen/Oldenburg, 3 out of 10 projects focused on carsharing. In Munich, 2 out of 4 projects focused on fleet applications and carsharing. In Saxony, 1 out of 3 projects focused on fleet applications. In Rhein-Main, 3 out of 16 projects focused on intermodality and carsharing. In Berlin/Potsdam, 2 out of 4 projects focused on intermodality and carsharing and on environmental effects of BEVs. In Hamburg, 1 out of 4 projects focused on the integration of renewable energies and fleet applications. The results of this quantitative comparison with regard to the share of funding allocated to these individual projects as related to the total amount of funding that a respective model region received is presented in Tbl. 5.

Model region	Total amount of funding	Share of funding for ‚system-innovative' projects
Rhein-Ruhr	19.5 Mio. €	45.9%
Stuttgart	14 Mio. €	21.8%
Bremen-Oldenburg	11 Mio. €	32%
München	9.5 Mio. €	59.8%
Sachsen	9 Mio. €	18.6%
Rhein-Main	7.2 Mio. €	10.6%
Berlin-Potsdam	6.5 Mio. €	74.7%
Hamburg	6 Mio. €	45.7%

Tbl. 5: Project funding in model regions and share of funding for 'system-innovative' projects (data based on BMBF 2011, Tenkhoff et al., 2011).

This overview shows that the amount of funding that goes to projects, which focus on system-innovative aspects, is in most cases low to moderate. In two model regions, the share of funding allocated to 'system-innovative' projects is higher than 50%: in Munich, it is 59.8% and in Berlin/Potsdam, it is 74.7%. In the case of Munich, a closer look at the individual projects shows that the 59.8% identified as funding for system-innovative projects, contain 54.5% going directly to Audi, a dominant regime actor. In the case of Berlin, 74.7% of the funding going to projects focusing on system-innovative aspects can be explained by the fact that in Berlin none of the large German car manufacturers are situated and as the capital it is a typical urban environment where public transport plays an important role. This is also the reason why for the case study Baden-Württemberg/Stuttgart have been chosen, because it is a more traditional automotive location with a large OEM, as well as a large energy supplier, while system-innovative approaches do still emerge to a relevant degree (apart from that efforts are continued in the follow-up showcase region program and a broad network of initiatives is developed, in contrast to some of the other model regions). In sum, this overview shows that there is a willingness to invest large sums in e-mobility, while the projects that are chosen as eligible for funding remain largely within ‘regime limits’.

However, according to the official evaluation report, the model regions have been successful and achieved the envisaged goals. Consequently, the Federal Ministry of Transport, Building and Urban Development (BMVBS, now BMVI) continues to follow this type of funding strategy, which centers around user-oriented demonstration within regional clusters, high industry participation and a technology-neutral approach (Tenkhoff et al., 2011, p. 31). This means that some of the model region projects are funded beyond the end of the official program in 2011 and a new follow-up funding program has been launched in 2012: the “Electric Mobility Showcases” (Bundesregierung, 2011, p. 28). In the description of the showcase program, signs can be found that there is more ‘system-innovative’ potential: a “systemic approach across the interface of the electric vehicle with the energy and the transport system” has been chosen and a critical mass of vehicles is to be achieved, in order to “learn about the suitability of electric mobility solutions” (Bundesregierung, 2011, p. 26 f.).

In April 2012, four showcase regions have been selected: Berlin/Brandenburg, Lower-Saxony, Baden-Württemberg and Bavaria/Saxony. The total volume of funding for the showcase region program is 180 million € and each showcase will approximately receive up to 50 million € in a period from 2013 to 2015.

Fig. 13: Showcase Regions for Electric Mobility – Overview (GGEMO, 2013).

Four ministries are funding this program, the Federal Ministry of Economic and Innovation (BMWi) and the former Federal Ministry of Transport, Building and Urban

Development (BMVBS, now BMVI), each with a share of 67.5 million €, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU, re-structured in 2014 as Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)) with a share of 25 million €, and the Federal Ministry of Education and Research (BMBF) with a share of 20 million € (Bundesfinanzministerium, 2013, p. 10 f.; Bundesregierung, 2012).

The showcase regions are accompanied by a parallel funding program on "Technological Lighthouses of Electric Mobility". In the government program of 2011, relevant subject areas have been identified for innovations leading to technological progress and cost reductions in the field of e-mobility. These are "Information and Communication Technologies", "Mobility Concepts", "Charging Infrastructure and Grid Integration", "Recycling and Resource Efficiency", "Energy Systems and Energy Storage", "Drive Technology and Lightweight Design" (BMWi, BMVBS, BMU & BMBF, 2012). Relatively large amounts of funding are allocated to the lighthouse program. For instance, the field of battery technology, as part of the lighthouse "Energy Systems and Energy Storage", is funded with 80 million € per year over a three-year period, thus more than the showcase region program as a whole. Assuming an average funding rate of 40% (scientific partners usually receive up to 100% funding, while firms usually receive less than 50%), the NPE has calculated that the other lighthouses receive similar amounts of funding. In the field of drive technologies more than 100 projects together have a total project volume (including governmental funding and private investments) of more than 850 million € (NPE, 2012, p. 20), 43 projects in the field of lightweight design have an overall project volume of 300 million € (p. 24), and in the field of ICT there are 15 projects with a total volume of more than 175 million €, and, at that time, 17 projects waiting for approval with an envisaged project volume of another 125 million € (p. 27). Individual lighthouse projects that are outstanding with regard to relevance and technological excellence are selected from within these fields. In 2012, the government has selected nine projects, and another 6 projects in 2013, which qualify as lighthouse projects (BMWi, BMVBS, BMU & BMBF, 2012; BMWi, BMVBS, BMU & BMBF, 2013; GGEMO, 2012).

A detailed analysis of the allocation of funding to individual projects, as has been carried out for the model regions, is not feasible for the showcase and lighthouse projects, since the relevant data is not available (also, many projects are still in an early phase and new projects are still being approved). Nonetheless, the relative magnitude of funding and project volumes has been illustrated based on some examples above. What is important to note is the specific interplay of the showcase region program and the lighthouse program. They illustrate the overall focus on systemic innovation in the second funding period after 2011, which is however internally split up into a technological and industrial field (the lighthouses) and a social field (showcases). While the pressing technological challenges, e.g. in the field of battery and drive technology, are addressed in lighthouse projects aiming at the development of groundbreaking technological innovations, the challenges of actually creating the „lead market“ are dealt with in showcase regions. Here, questions of user acceptance, new mobility patterns, intersectoral cooperation in the fields of energy and transport, and city planning are to be integrated in large-scale regional experiments. Despite this „experimental“ rhetoric, the basic aim is to „present“ e-mobility to a broader public and to demonstrate that it can work (Canzler & Knie, 2011, p. 90 f.).

This implies that the actual challenges, or problems to be solved, are of a technological nature, while the social process of embedding e-mobility seems to be more of a diffusion or societal acceptance challenge. This impression is reinforced when looking at the significantly higher amounts of governmental funding allocated to the lighthouse program. And even within the lighthouse program, the focus on industrialization for e-mobility becomes apparent, for instance in the field of battery technology. The largest amount of public and private financial resources is invested in manufacturing technologies for mass production of batteries, it makes up 417 million € of the total 601 million € invested in battery R&D over a three-year period (NPE, 2012, p. 15 f.).

4.4.3 Baden-Württemberg – The Automotive State

A closer look has been taken at Baden-Württemberg, the third-largest of the German states, or ‘Länder’, with a population of more than 10.5 million inhabitants (Statistische Ämter des Bundes und der Länder, 2014) and an important automotive region. Traditionally, the conservative party, the Christian Democrats, is strong, but since 2011 Baden-Württemberg is governed by the Green Party in a coalition with the Social Democrats. The largest and also the capital city is Stuttgart with more than 600.000 inhabitants, followed by Mannheim and Karlsruhe with each around 300.000 inhabitants. All of these cities are important locations for the automotive industry and science, i.e. universities as well as large non-university research institutes. Apart from these urban centers, Baden-Württemberg is a rural region characterized by agriculture and forestry with scattered communities, many of them with less than 5,000 inhabitants (BW, 2014).

Baden-Württemberg's automotive industry, including OEMs and suppliers, is the region's key industry with the highest turnover, e.g. 127.3 billion € in 2008, as compared to other regional sectors as well as other German automotive regions, and is thus often referred to as the „automotive state" of Germany (Hawlitschek, 2011, p. 31). Every 10th job in Baden-Württemberg is directly or indirectly related to the automotive industry, ranging from OEMs to suppliers and the related trade and service companies, in sum amounting to more than 400,000 employees in this field (MFW et al., 2011, p. 51). Two of the largest German OEMs, Daimler AG and Porsche AG, as well as important suppliers such as Bosch and approximately 600 small- and medium-sized component suppliers are located in Baden-Württemberg, especially concentrated in the Stuttgart region. Among them are nine of the world's 100 largest automotive suppliers. The important role of the supply industry also becomes apparent when looking at its growing share of the automotive industry's total turnover. It has grown from 13% in 1990 to almost 40% in 2005, indicating a trend among OEMs to buy more components, instead of producing them themselves, and that components are getting increasingly more complex and valuable (Hawlitschek, 2011, p. 34 f.; MFW et al., 2011, p. 48). The important role of the automotive industry was also apparent during the last recession in 2008/2009. While the automotive industry, and therefore also Baden-Württemberg as a whole, were severely hit by the economic crisis, it also contributed to a relatively quick recovery, in the course of the general economic recovery and due to the governmental economic stimulus packages largely tailored to the needs of the automotive industry. The long-established strength and broad positioning of the automotive industry in Baden-Württemberg is seen as a major success factor leading to the ability to offset and even exceed the losses in 2009 already one year later (Displan et al., 2009, p. 226 f.; Münzenmaier, 2013, p. 12).

Apart from the automotive industry, one of the four largest German energy suppliers, EnBW AG, as well as renowned universities and research institutes in the field of energy and automotive/transport research can be found in Baden-Württemberg. It is thus an exemplary case for the German innovation system for e-mobility, as regards the actor structure. Consequently, from 2009 to 2011 the capital region around Stuttgart has been one of the model regions, since 2008 Baden-Württemberg hosts the industry cluster "Electric Mobility South-West", and apart from this, there are a number of other smaller-scale federal and regionally funded R&D programs and projects in the field of e-mobility. In 2012, the so far largest initiative, the showcase region "LivingLab BW^{e} mobil" has been launched. An overview of the different e-mobility initiatives will be given in the following.

4.4.3.1 E-mobility Initiatives in Baden Württemberg

Developments in the field of e-mobility are perceived to be of major importance for a region such as Baden-Württemberg, which is economically dependent on its automotive industry (Displan et al., 2009, p. 209).

"To maintain its leading position in the future, the anticipated effects of electromobility on automobile value creation must be detected and the associated opportunities and risks for the state must be identified" (MFW et al., 2011, p. 6).

Early on, in 2009, the government of Baden-Württemberg launched its own state initiative for electric mobility ("Landesinitiative Elektromobilität"), worth roughly 30 million €, with the aim of developing an integrated transport system based on renewable energies. Building blocks of the initiative are developing Baden-Württemberg's research infrastructure, education and professional training, dealing with transport-related aspects, and funding concrete projects (Engel, 2011, p. 21). An important milestone was the founding of the "State Agency for Electric Mobility and Fuel Cell Technology e-mobil BW GmbH" (e-mobil BW), financed by 2 million € of the state initiative funds (MFW et al., 2011, p. 44 f.). The state agency e-mobil BW functions as a central platform for knowledge exchange and an umbrella organization, coordinating the different activities in the field of e-mobility and the involved actors, initiating projects, and promoting e-mobility to the public (MFW et al., 2011, p. 71). A follow-up initiative ("Landesinitiative Elektromobilität II") was subsequently launched in 2011 for another 4-year period providing an additional sum of 50 million € for the development of e-mobility, and, among other things, support the application for the federal showcase region program as a follow-up to the model region program, where Baden-Württemberg had already hosted the model region Stuttgart from 2009 to 2011 (Staatsministerium BW, 2011).

Based on these early efforts, a complex network of initiatives and projects has evolved, which as a whole constitutes the innovation system for e-mobility in Baden-Württemberg. As already mentioned, at the state level, Baden-Württemberg has launched two subsequent initiatives for developing e-mobility. Funding from these initiatives have been allocated to the state-level program "E-mobility in rural areas", which is coordinated by the Baden-Württemberg State Ministry for Rural Areas, Nutrition and Consumer Protection (MLR, 2013), and to the showcase region "LivingLab BW^{e} mobile", which is part of the federal showcase region program, jointly funded by the Federal Ministry of Economics and Technology (BMWi), the Federal Ministry of Education and Research (BMBF), the Federal Ministry of Transport, Building and Urban Development (BMVBS, now BMVI), and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU, now BMUB). The “LivingLab BW^{e} mobil” has been chosen (and is predominantly funded) at the federal level as one of the showcase regions for the period of 2012-2015. It is the successor of the model region “Region Stuttgart”, which had been funded from 2009 to 2011 by the BMVBS in the context of the Economic Stimulus Package II. Another large project is the “Leading-Edge Cluster Electric Mobility South-West”, which is also funded at the federal level by the BMBF. Apart from these larger projects – the model and showcase region, and the excellence cluster – there is a wide array of not only state-level projects, but also other projects funded in the context of R&D programs by the individual federal ministries (Loogen, 2013, p. 11).

This rather complex structure is coordinated by the state agency e-mobil BW, which has been founded for this particular task, and the Stuttgart Region Economic Development Corporation (Wirtschaftsförderung Region Stuttgart GmbH, WRS), which has long-standing experience in the coordination of regional R&D and innovation activities. The overall process of developing e-mobility, in which the various initiatives and projects are embedded, is envisioned to include four phases. Phase I, up until 2012, has concentrated on individual projects with specific topics and limited focus. Currently, Phase II aims at establishing a more integrated system and transfer of knowledge until 2015. Phases III and IV, until 2020 and after, are then subsequently focusing on increasingly interlinking regional e-mobility systems, eventually achieving a completely integrated “e-mobile” state Baden-Württemberg (Loogen, 2013, p. 11).

In sum, e-mobility initiatives have started to develop in Baden-Württemberg in 2009 in a relatively uncoordinated fashion across a broad number of federal and state-level funding programs. Up until 2012, there were various projects and initiatives all over Baden-Württemberg, funded by different agencies at different levels, and thus embedded in different R&D programs with varying overall strategic goals. Now, in the middle of Phase II, a more integrated approach seems to take shape, coordinated by e-mobil BW, together with the Stuttgart Region Economic Development Corporation (WRS). A major aim is to achieve a transfer of knowledge between the Living Lab BW^{e} mobil in the Stuttgart and Karlsruhe Region and the various research projects of Phase I (e-mobil BW, p. 15). A more systematic approach can also explain the focus on the “LivingLab BW^{e} mobil” and the “Leading-Edge

Cluster Electric Mobility South-West" as the two largest and most visible projects – and their specific combined role: While the cluster aims at an industrialization process, thus aiding structural change towards an e-mobility industry (e-mobil BW, 2013a, p. 4), the Living Lab functions as the testbed for day-to-day suitability and business models for electric mobility (Loogen, 2013, p. 10; e-mobil BW, p. 17). Thus, the basic idea is to solve technological problems and develop innovations, and then test them in practice with regard to user acceptance and potential for marketability and diffusion. These two processes are, however, clearly separated, also formally, i.e. into two different R&D programs, with room for mutual evaluation, but limited room for integrated perspectives or problem perceptions.

4.4.3.1.1 Model Region Stuttgart

The model region "Region Stuttgart" has been the first visible effort of Baden-Württemberg to position itself in the field of e-mobility. It has been funded by the BMVBS (now BMVI) with 16.2 million €, and including the investments by industrial partners, the total project volume amounted to 33.5 million € (MFW et al., 2011, p. 72). In the model region „Region Stuttgart" more than 800 different kinds of electric vehicles have been deployed: 700 two-wheeled vehicles (Pedelecs, electric bikes and scooters), 5 hybrid-electric busses, 54 commercial vehicles (electric and hybrid-electric vans and transporters), 50 passenger BEVs as well as some other alternative electric vehicles such as Segways. With regard to infrastructure, more than 130 public charging stations and 40 charging stations at company sites have been built up. 32 partners have been involved in eight projects. Overall tasks and goals of the model region have been defined as follows:

- Initiating and executing pilot projects
- Building up and integrating charging stations in public spaces
- Preparing urban and regional mobility concepts through pilot projects
- Creating and managing a network for e-mobility in the Stuttgart region
- Supporting industry and business in dealing with structural change

The focus of the projects has been on testing electric vehicles in commercial and municipal vehicle fleets, building up the charging infrastructure and developing urban and regional transport concepts for preparing the market introduction of electric vehicles. Research carried out in the model region has focused on the technological performance of electric vehicles in different applications and their acceptance by test users. Remaining issues are primarily seen in the context of lacking public charging stations, a need for overall regional mobility concepts and further network initiatives, in order to support industry and business in dealing with structural change (Tenkhoff et al., 2011, p. 195; WRS(a)). A more detailed overview of the different projects carried out in the model region "Region Stuttgart" can be found in Appendix A.1.

It can be shown that only two model region projects depart from a broader definition of ‚e-mobility' ("Elektromobilität vernetzt nachhaltig"/"E-mobility links sustainably", "Elektromobile Stadt"/"E-mobile City"): various types of electric vehicles (BEVs, electric bikes etc.) are used, the main actors are municipalities, cities, research institutes and universities, as well as a municipal utility company and a small logistics company. Two projects have a focus on renting or sharing electric vehicles, in this case pedelecs or e- bikes. One project ("500 Elmotos") is a fleet trial with electric bikes ("Elmotos") manufactured in the region. The large energy supplier EnBW AG is responsible for the charging infrastructure and also engaged with test users, monitoring and analyzing their mobility behavior and general user acceptance. The second project also focuses on renting Pedelecs in Deutsche Bahn AG's (German National Railways, DB) "Call-a-Bike" service. This project may amount to more than broadening DB's 'product portfolio', because the project leader is the city of Stuttgart and cooperating partners are the DB Rent GmbH and EnBW AG. Thus, there is a cooperation between different actors with very different goals, a city as the connecting link between public transport and energy infrastructures. The four remaining projects focus on purely technological aspects or applications, with no 'regime-transcending' cooperation, such as testing a hybrid bus in Stuttgart's public transport system as well as a number of electric vehicle prototypes and developing charging infrastructures.

Overall, the focus is on testing electric vehicle technologies for very general suitability in established daily practices, thus projects focus largely on commercial fleet applications and renting of e-bikes and e-scooters, rather than electric cars. The actor constellation in individual projects is not very diverse and remains mostly within sectoral boundaries. The charging infrastructure seems to be treated as a framework condition, within which different transport actors (ranging from OEMs, automotive suppliers and public transport companies) try out vehicles in field tests.

4.4.3.1.2 Leading-Edge Cluster Electric Mobility South-West

The „Leading-Edge Cluster Electric Mobility South-West“ has emerged as one of the winners of the nation-wide „Leading-Edge Cluster Competition“ initiated by the BMBF. This competition is part of the federal governments „High-Tech Strategy“, which aims at fostering R&D and strengthening the national economy by supporting cooperation between science and business, and especially SMEs. The aim is to generate innovations in networks and clusters that quickly achieve market breakthrough and contribute to global competitiveness (BMBF, 2013b). The Leading-Edge Cluster Competition is a central element for identifying the most promising networks and R&D partnerships that will, after several rounds of competition, receive public funding over a period of up to five years. The competition is not limited to specific sectors or technologies, it is open to all types of regional innovation networks that are perceived to have potential with a view to future markets in different industrial fields (BMBF, 2013c).

The regional network "Clusterinitiative Automotive South-West", which had already been founded in 2007 applied in the BMBF's Leading-Edge Cluster Competition and after three rounds of competition in 2007, 2009 and 2011 was selected as one of the so-called "excellence clusters" in January 2012. After its founding in 2010, the state agency e-mobil BW stepped in to fulfill the task of a more professional cluster management[9]. The "Cluster Electric Mobility South-West" will receive 40 million € from the BMBF over two funding periods until 2015, and subsequently until 2017 (BMBF, 2013a). Since only research projects are eligible for these federal funds, the state of Baden-Württemberg provides an additional sum of 5 million €, in order to finance projects with a focus on education and professional training, and to support internationalization efforts of involved SMEs[10].

The guiding strategic motto of the cluster is "road to global market", highlighting its focus on industrialization of e-mobility and overall aim of securing the position of the German automotive industry as a strong and competitive exporter. Roughly 80 partners, from science and different industry sectors, ranging from automotive to energy and ICT, make up the cluster that is located along Baden-Württemberg's automotive and research centers of Stuttgart, Ulm, Karlsruhe, and Mannheim. Cluster activities are structured along four fields of innovation that reflect the need for integrating developments in the automotive, energy, and ICT sectors: thus, fields of innovation are the "vehicle", "energy" with a focus on charging

[9] http://www.emobil-sw.de/de/ueber-uns/historie.html
[10] http://www.emobil-sw.de/de/ueber-uns/aufgaben.html

electric vehicles, "ICT" with a focus on intermodal mobility, fleet management and integration of electric vehicles with smart grids, and finally, the field of "production" with a focus on automatization and efficiency of manufacturing processes[11]. Improvements in these fields of innovation are hoped to facilitate market breakthrough of e-mobility, thus also contributing to the goal of establishing Germany as a lead market for e-mobility. It is argued that this can be achieved by reducing costs, better satisfying customer needs, and an intermodal electrified transport systems (MFW et al., 2011, p. 71).

In sum, the "Cluster Electric Mobility South-West" addresses the challenges for e-mobility developing a sustainable system innovation by clearly emphasizing the need for intersectoral cooperation and including intermodal transport as a central aspect. However, the structural layout of the cluster indicates that this potential will most likely remain limited, due to the sector-oriented separation of research questions in distinct innovation fields, and the dominant logic of industry-oriented R&D in the context of the federal government's High-Tech Strategy. A more detailed overview of the 13 individual cluster projects can be found in Appendix A.2.

4.4.3.1.3 Showcase Region LivingLab BW^e mobil

The showcase region "Living Lab BW^e mobil" is much larger than the preceding model region in terms of participating partners, number and scope of projects as well as the overall volume of funding. More than 100 partners from business, science and public authorities are involved and approximately 40 projects are carried out in the Stuttgart region and the city of Karlsruhe. The showcase projects are coordinated by the state agency e-mobil BW in cooperation with the Stuttgart Region Economic Development Corporation (WRS). Projects are financed by the federal government with roughly 45 million € and an additional 15 million € provided by the state government of Baden-Württemberg and the Stuttgart region municipality. The quantitative goal pursued in the showcase region is to have roughly 2.000 electric vehicles deployed and more than 1.000 charging stations installed by 2015. However, as proclaimed in image brochures and on official websites, the showcase region "LivingLab BW^e mobil" follows a systemic approach and aims at developing e-mobility as an integrated sustainable mobility system along nine key topics among which the individual projects are grouped. The key topics are 1) Intermodality; 2) Fleets and commercial transport; 3) Energy,

[11] http://www.emobil-sw.de/de/aktivitaeten.html

infrastructure and ICT; 4) Living and electric mobility; 5) Urban and traffic planning; 6) Vehicle technology; 7) Communication and participation; 8) Training and qualification; 9) Interdisciplinary research accompanying the showcase projects (GGEMO, 2013, p. 4 f.). This overall structure shows that the dominant focus on vehicle technology and infrastructure build-up that has dominated the preceding model region has to some degree been replaced by a focus on intermodality, fleet applications and questions of integrating e-mobility in housing and city planning as well as ICT-based connections with energy infrastructures. A more detailed overview of the individual showcase region projects can be found in Appendix A.3.

4.4.3.1.4 Other Initiatives

A variety of funding opportunities for e-mobility exist, apart from the major programs initiated by the federal government, such as the model region and showcase region programs. For instance, funding opportunities have also been realized in cases where programs are not exclusively dedicated to developing e-mobility – but are nonetheless open for this issue in their respective context, such as the already mentioned "Leading-Edge Cluster Competition", or the "Central Innovation Program – Medium-Sized Business" (MFW et al., 2011, p. 44). Many of the individual federal ministries also have their distinct funding programs in the field of e-mobility, where some project consortia from Baden-Württemberg have been successful.

The project MeRegioMobil[12] and its successor iZeus[13] are funded by the Federal Ministry of Economics and Technology (BMWi) in the context of its "ICT for Electric Mobility I and II" programs. Here, the focus is on integrating electric vehicles and the energy system via smart grids and ICT. The aim of MeRegioMobil has been to build up a charging infrastructure and carry out fleet trials, investigating innovative business models and ICT-applications. The project iZeus further develops these issues and includes a more explicit focus on intermodality, integrating renewable energies via electric vehicles and smart grids, charging and load management, and political framework conditions and regulations. Many of the partners in MeRegioMobil and iZeus are also involved in other projects in Baden-Württemberg in the context of the model and showcase regions or the e-mobility cluster. Also funded in the context of the BMWi's "ICT for Electric Mobility" program is the project CROME[14], short for "cross-border mobility for electric vehicles". It is a joint project carried out in cooperation with French ministries and project partners. The focus of this project is on

[12] http://meregiomobil.forschung.kit.edu/index.php
[13] http://www.izeus.de/
[14] http://crome-projekt.de/index.php?id=307

issues of standardization, e.g. of charging infrastructure, roaming and billing systems, which are even more challenging when involving cross-border mobility (MFW et al., 2011, p. 69, 73). Finally, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU, now BMUB) has funded the project "Future Fleet[15]", focusing on the integration of electric vehicles in company fleets and developing an innovative charging system, in the context of its program on "Smart Grids, Renewable Energies and Electric Mobility".

Apart from these initiatives at the federal level, the state of Baden-Württemberg has its own program on "Electric Mobility in Rural Areas[16]" in the context of its "Landesinitiative Elektromobilität". Starting in 2013, roughly 20 small-scale projects are funded that have been selected based on a set of criteria: the electricity used to power vehicles has to be produced from renewable sources, participation of citizens needs to be ensured, and local businesses are to be involved in the infrastructure build-up. The selected projects receive funding amounting to 100,000 € or a maximum of 150,000 € when they include more than one municipality (MLR, 2013). Another focus, related to the issue of mobility in rural areas, is tourism. For instance, the project "ZUMO – Future Mobility in the Black Forest Vacation Region" develops concepts of sustainable mobility for tourists and is also funded by the state of Baden-Württemberg (MFW et al., 2011, p. 73). Finally, state funds are also used to support the build-up of research infrastructure, for instance in the field of battery technology and battery production. More than 10 million € have been invested to develop Ulm as an important location for battery research, including the university, the Center for Solar Energy and Hydrogen Research (ZSW) and the Helmholtz Institute for Electrochemical Energy Storage (HIU) (MFW et al., 2011, p. 45).

4.4.3.2 Network Analysis – Dominant Actors and Cooperation Patterns for Developing E-mobility in Baden-Württemberg

A network analysis has been carried out, in order to identify the relevant and most influential actors making up the innovation system for e-mobility in Baden-Württemberg. With regard to method, a brief overview has been given in ch. 4.4.1, and the analysis will proceed as follows. In a first step (ch. 4.4.3.2.1), a comprehensive overview of involved actors and the basic

[15] http://www.isoe.de/en/projects/completed-projects/mobilitaet-und-urbane-raeume/future-fleet/

[16] http://www.mlr.baden-wuerttemberg.de/Minister_Bonde_E_Mobilitaet_ermoeglicht_nachhaltige_Verkehrskonzepte_fuer_einen_starken_Laendlichen_Raum/121351.html

structure of the innovation system's actor network has been gained. In a second step (ch. 4.4.3.2.2), the relations between these actors and their respective power positions and influence on innovation system dynamics have been analyzed. The third step (ch. 4.4.3.2.3) includes a focus on the level of projects – in the context of the model region (ch. 4.4.3.2.4), the showcase region (ch. 4.4.3.2.5), and the excellence cluster (ch. 4.4.3.2.6). In order to integrate actor and project perspectives, thus an integrated view on rules (topical focus in projects) and resources (power constellations in the actor network), patterns of cooperation across these projects are traced (ch. 4.4.3.2.7). In a final step, those projects are clustered according to degrees of (system-)innovativeness (ch. 4.4.3.2.8 – ch. 4.4.3.2.10), i.e. ranging from projects on vehicle technology to projects with an integrated perspective on sustainable e-mobility, and related to the identified cooperation patterns and respective actor structure.

4.4.3.2.1 Identifying Actors in the Network

In order to gain an overview of the innovation system as a whole and include all relevant actors of this network, actors have been identified based on the following criteria:

- Actors that are listed in the official sourcebook e-mobility for Baden-Württemberg, an overview of relevant actors in the field of e-mobility in Baden-Württemberg, published by the Stuttgart Region Economic Development Corporation (WRS) and the State Agency for Electric Mobility and Fuel Cell Technology Baden-Württemberg GmbH (e-mobil BW), i.e. the two organizations responsible for coordinating the regional innovation system for e-mobility.
- Actors that are listed as official project partners in e-mobility projects in the context of the model region Stuttgart, the showcase region LivingLab BW^{e} mobile, the Leading-Edge Cluster "Electric Mobility South-West", and other e-mobility projects in Baden-Württemberg funded by individual federal ministries.

Explicitly excluded are actors that only participate in smaller projects funded in the context of Baden-Württemberg's „Landesinitiative Elektromobilität I & II", because these local initiatives and actors would have significantly increased the number of included actors, while they individually have relatively little influence, due to their size. If they are, in some cases, of particular relevance they will be taken account of, because they are listed in the sourcebook e-mobility.

A very specific role is played by the two organizations forming the official Regional Project Coordination Agency (PLS), which has been established in the context of the model region. First, there is the Stuttgart Region Economic Development Corporation [17] (Wirtschaftsförderung Region Stuttgart GmbH, WRS), a regional business development company that has already been founded in 1995 as a subsidiary of different local authorities in the Stuttgart region with the aim of promoting economic development, coordinating activities and connecting companies, research institutes and public agencies. The Stuttgart Region Economic Development Corporation coordinated the application process for the model region program and then further coordinated activities within the model region Stuttgart. Second, the State Agency for Electric Mobility and Fuel Cell Technology Baden-Württemberg GmbH (Landesagentur für Elektromobilität und Brennstoffzellentechnologie e-mobil BW GmbH, e-mobil BW) has been newly founded in 2010 as a ministerial agency with the aim of functioning as the central contact and information point for all issues related to e-mobility. The central task of e-mobil BW is to support the transformation to e-mobility and support the regional industry in this change process by coordinating activities, such as the different funding programs, supporting transfer of knowledge, integrating SMEs, organizing cluster activities, and initiating large collaborative research projects (e-mobil BW, 2013b, p. 15 ff.).

The total number of actors included in the network analysis amounts to 239 organizations, including companies, associations, research institutes and universities, municipalities and cities. Actors have been clustered, as shown in Tbl. 6, according to the different sectors involved in developing e-mobility, i.e. automotive, energy, battery technology, ICT, as well as the relevant non-industry domains, i.e. science, public actors, and civil society. Clustering actors accordingly has produced the following results: 78 actors from the automotive industry are part of the network, 4 of which are OEMs and 56 belong to the supply industry. Additionally, there are 18 actors that focus on the production of electric vehicles or products and technologies serving as specific equipment for electric vehicles. The field of battery and fuel cell production and respective production technology is represented by 8 actors, and 26 actors from the field of ICT are part of the network. The energy sector is represented by one large energy supplier and 8 regional energy suppliers or municipal utility companies ('Stadtwerke'). 10 actors can be grouped among the category of 'mobility providers', 5 of which are public transport actors and 5 are carsharing or rental service providers. A diverse group of 35 "other" industry actors or companies can be identified,

[17] http://wrs.region-stuttgart.de/sixcms/wrs_en_aboutus/

including for instance consultancies, logistics companies, housing companies, standardization organizations, traffic and parking management organizations. These actors are involved in specific aspects of developing e-mobility in Baden-Württemberg and participate in concrete projects, even though they cannot be grouped among any of the more typical sectors or fields perceived to be relevant for developing e-mobility.

In the non-industrial or business domain, 7 public actors have been identified, including Baden-Württemberg's capital city of Stuttgart as well as smaller municipalities. 40 actors from the field of science are part of the network, including 16 universities and university institutes, 17 non-university research institutes and 7 organizations focusing solely on education and professional qualification. Finally, there are 26 associations involved in the network, 7 of which are traditional industry associations, 5 associations focus specifically on issues of e-mobility or renewable energies, and the remaining 14 are regional associations.

Actors (239)	Cluster	Cluster - differentiated
78	Automotive	OEMs (4), Suppliers (56), Electric vehicle and equipment producers (18)
8	Battery/ fuel cell production	
9	Energy	Large energy utilities (1), regional and municipal energy utilities (8)
26	ICT	
10	Mobility Providers	Public Transport (5), Carsharing/Rental (5)
35	Businesses/Industry - "OTHER"	Consultancies (13), Logistics (3), Standardization (3), Housing (4), Traffic Management/Parking (4), Other (8)
40	Research & Education	Universities (16), Non-university research institutes (17), Education and professional qualification (7)
7	Public	
26	Associations	Regional (14), Industry (7), E-mobility (5)

Tbl. 6: Overview of actors in the innovation system for e-mobility in Baden-Württemberg and their sectoral affiliations.

This quantitative overview provides only a first glance at the network structure, without any insights on the "quality" of this network or its topical focus and strategic agenda. As could have been expected, it does show that actors from the automotive industry are well represented and that, since the automotive supply industry plays an important role in Baden-Württemberg, a relatively large number of supplier companies is involved. Further, it can be shown that all relevant sectors that are generally assumed to be crucial for developing e-mobility are represented to a significant degree, with the automotive industry and ICT companies taking center stage (in terms of absolute numbers), and battery technology and the energy sector being represented as well. Apart from those established industrial actors, the importance of whom is emphasized strongly in public and political discourse, the network also includes a relatively large number of ‘alternative mobility’ actors, e.g. from the fields of public transport and carsharing, and actors not directly linked with the transport sector, e.g. housing, or, more specifically, not linked to the field of automobility and vehicle technology, e.g. traffic and parking management. Since the network has emerged in the context of political efforts of fostering e-mobility at the federal level and the resulting R&D programs, public actors and especially universities and research institutes play an important role. The representation of civil society is weak, except for a few associations that are not industrial in nature or installed by municipalities. Overall, it can thus be shown that industry or company representatives dominate the network with 166 actors in total, while the second largest group is formed by 40 actors from the field of science, and the remaining 33 actors are either public or associations.

4.4.3.2.2 Identifying Relations and Power Positions in the Network

In order to gain more qualitative insights on the structure of the network and the relations between actors within it, the level of influence and power of individual actors have been identified and they have been grouped according to their level of influence, which can range from high to moderate or low. Levels of influence have been determined based on actors’ participation in projects and whether they are leading project consortia, because the innovation system basically consists of R&D and demonstration projects and the central coordination activities across all projects. Being a project leader is thus a relevant criterion, because it does not only imply influence on project focus and choice of project partners, but it also entails involvement in meetings with the Regional Project Coordination Agency and other project leaders and the strategy development processes taking place in these contexts. Finally, influence levels have been based on whether and how much funding actors have received from the governmental funding for e-mobility in the context of the Economic Stimulus Package II. The BMBF has published a detailed list of the allocation of funds and recipients and the analysis of this funding structure provides insights on the power positions of actors with regard to their ability to mobilize financial resources and their standing in terms of not only economic, but also political power. The allocation of governmental funds may thus reflect not only the allocative resources an actor possesses (the higher the public funding, the higher is also the amount invested by the actors themselves), but also their authoritative resources, in terms of their reputation and influence in the political sphere. Unfortunately, this type of data does only exist for the model region funding in the context of the Economic

Stimulus Package II. For the showcase region and excellence cluster, only data on total project budgets is available, and no data on what share of the funds were received by each project partner.

In short, the following criteria have been applied:

- Participation in e-mobility projects
    - (1 project – low influence; 2-5 projects – moderate influence; > 5 projects – high influence)
- Project leadership in collaborative research projects
    - (none – low influence; once – moderate influence; more than once – high influence)
- Amount of funding from Economic Stimulus Package II
    - (0-500T € – low influence; 500T-5 million € – moderate influence; > 5 million € – high influence)

These three criteria have been aggregated for each actor to show whether the overall level of influence is high, moderate or low (see Tbl. 7).

Actors (239)	Cluster	Influence high	Influence moderate	Influence low
78	**Automotive**	1	4	73
8	**Battery/ fuel cell production**	-	1	7
9	**Energy**	1	1	7
26	**ICT**	-	3	23
10	**Mobility Providers**	-	2	8
35	**Businesses/Industry - "OTHER"**	-	1	34
40	**Research & Education**	2	5	33
7	**Public**	-	1	6
26	**Associations**	-	-	26

Tbl. 7: Levels of influence in the innovation system network: Concentrated power and dominant regime actors.

The analysis shows that only four actors in the network can be characterized as having a high level of influence. These are an OEM (Daimler AG), a large energy supplier (EnBW AG) and two non-university research institutes (Fraunhofer Institute for Labor Economics and Organization (IAO) and Karlsruhe Institute of Technology). 18 actors with moderate influence have been identified. These are four automotive suppliers, three ICT companies, three non-university research institutes, two universities, two public transport companies, a regional energy company, a battery producer, a consultancy, and the city of Stuttgart.

The largest share of 217 actors can be characterized to have a low level of influence on the overall dynamics of the innovation system. These are typically organizations or companies of a relatively small size that often lack experience with large R&D projects, or actors that are not typically involved with or new to the field of transport and energy. Actors that could contribute important perspectives on e-mobility as a sustainable system innovation also typically lack influence, such as for instance civil society organizations, local associations and carsharing service providers. A more detailed overview of the type of actors involved and their respective influence level can be found in Appendix B.1.

As already mentioned, the list of actors identified here is not comprehensive. For instance, there is also the regional “Landesinitiative Elektromobilität I & II”, the funding program for e-mobility launched by the Länder government of Baden-Württemberg. As part of this program a larger number of small, local projects is carried out, with small cities and municipalities. These projects and actors have been excluded, because the larger programs, i.e. the model and showcase regions and the excellence cluster, involve the major players in Baden-Württemberg, are more relevant in terms of size and budgets, and are more closely connected to the overall developments in Germany. It is also worth noting that some of the actors analyzed here do not participate in projects of the model or showcase regions or the excellence cluster. They are however listed in the sourcebook electric mobility for instance, because they are members of sectoral networks and associations, or because they supply vehicles or compartments employed in the projects (without being an official partner in these projects).

It should also be noted that the role of the Regional Project Coordination Agency as the central coordinating actor is not sufficiently reflected in this analysis and their influence is underrepresented by the overview presented above. Since the Stuttgart Region Economic Development Corporation and e-mobil BW do not directly participate in projects, they do not appear as influential actors according to the criteria applied here. However, they can indeed be characterized as actors with a high level of influence, because they are involved in the overall project structure of the innovation system and can particularly influence how the overall focus is set by developing the project portfolio, coordinating the application process, networking and connecting potential project partners.

The overall findings of the network analysis have been validated by including an assessment of the structure of Baden-Württemberg’s innovation system and of the roles and influence of (perceived to be) dominant actors in the interviews. In the interviews it was affirmed that the Stuttgart Region Economic Development Corporation and e-mobil BW in their coordinating function play an important role for facilitating exchange of information and cooperation in projects. They were referred to often and thus are indeed influential actors with a central position in the innovation system. Overall, the network is perceived to be relatively small with most actors being familiar with each other and characterized by pragmatic ways of working together, even when there may be potential conflicts, e.g. between the Green state government of Baden-Württemberg and industry representatives. What is special for the case of Baden-Württemberg, as compared to other German model or showcase regions for e-mobility, is the strong position of SMEs in the automotive supply industry, as is reflected by their strong representation in the network analysis. Furthermore, the local Stuttgart public transport company (Stuttgarter Straßenbahnen, SSB AG) plays a central strategic role and has actively promoted intermodality as a major focus of the showcase region. This is also reflected in the network analysis, with two public transport companies (SSB AG and Deutsche Bahn AG) characterized by moderate influence. In contrast to the situation in Baden-Württemberg, substantial efforts and an influential role of the public transport sector are not typical elsewhere, and, for instance, in the National Platform Electric Mobility at the federal level.

Since the focus is on concrete e-mobility projects and patterns of interaction between different actor groups in these projects, the next section will focus on those actors being involved in the official projects, the overall structure of the different projects making up the innovation system, their development over the period from 2009 until today and patterns of cooperation.

4.4.3.2.3 Identifying Patterns of Cooperation

Based on the overview of relevant actors and their relations with regard to power and influence, this section aims at identifying patterns of cooperation between those actors: which actors work together? Are there typical cooperation patterns with regard to relative influence or affiliation with sectors? Have cooperation patterns changed over time, e.g. from the model region to the showcase region? Are there different cooperation patterns in the different framework funding programs, e.g. when comparing showcase region projects and excellence cluster projects?

In order to answer these questions, in the following the individual projects within the model region, the showcase region, and the excellence cluster are compared with regard to the actor structure of each specific project. Based on the results of the network analysis so far, for each project, it will be analyzed what the affiliations of the cooperating project partners are, i.e. either 1) automotive, 2) battery technology, 3) energy, 4) ICT, 5) mobility services, 6) other, or 7) research; and whether their level of influence on the innovation system is low, moderate or high.

Excluded from this step of the analysis are those projects that solely focus on creating public awareness and providing information and projects in the field of education and professional qualification. They are excluded because they focus on dissemination and providing general information about e-mobility to the public, rather than developing and demonstrating or testing in practice different aspects of e-mobility, which is central to the questions addressed here.

4.4.3.2.4 Patterns of Cooperation in the Model Region "Region Stuttgart": Modest Attempts at Cross-Sector Cooperation in a Traditional R&D Setting

Table 8 provides an overview of the model region projects and the respective patterns of cooperation:

Projects model region	**Automotive**	**Battery technology**	**Energy**	**ICT**	**Mobility services**	**Other**	**Research**	*Low influence*	*Moderate influence*	*High influence*
Elektromobilität vernetzt nachhaltig ("E-mobility links sustainably")	X		X	X	X	X	X	6	2	
Elektromobile Stadt ("E-mobile city")	X		X	X		X	X	8	1	1
IKONE	X		X			X	X	1		3
ELENA	X			X		X	X	12	1	
500 Elmotos			X	X		X		2	2	1
PEDELEC			X		X	X			2	1
S-Hybus					X	X		2	1	
Boxster E	X							1		

Tbl. 8: Patterns of cooperation in the model region "Region Stuttgart" based on affiliation and influence of project partners.

This overview shows that actors from the automotive industries do not participate in projects that predominantly focus on vehicles other than cars, as in the "500 Elmotos" and

“PEDELEC” projects, which focus on e-bikes and e-scooters, or the “S-Hybus” project, where hybrid busses are tested. There is only one project, “E-mobility links sustainably”, where actors from the automotive industry and a carsharing service operator cooperate. Actors from the public transport sector, mobility service providers and ICT companies are comparably underrepresented. A striking result is that there are no actors from the field of battery or fuel cell production involved. Research institutions also participate only in four out of eight projects. Projects without scientific partners focus on testing specific vehicle technologies by their manufacturers (Porsche’s Boxster E) or operators (the Stuttgart regional public transport company SSB’s “S-Hybus” or German National Railway DB’s e-bikes in PEDELEC). Thus overall, the involvement of universities and research institutes in the larger projects – larger in terms of involved actors and actor groups – signals the traditional character of a publicly funded R&D program. With regard to the desired interlinkages between the energy, the automotive and the ICT sector, it can be shown that automotive and energy actors are cooperating in three projects, and in two of them ICT actors are involved as well.

The distribution of actors according to their relative influence in the innovation system, i.e. their power position, indicates a specific pattern. At one end of the scale, there are three actors characterized by a high level of influence cooperating directly, including only one other actor with low influence (“IKONE”). At the other end of the scale, highly influential actors typically work together in projects exclusively with partners that are characterized by low to moderate influence (“Elektromobile Stadt”, “500 Elmotos”, “PEDELEC”). Actors with a moderate level of influence can be found in all kinds of project-specific actor constellations, except for the one project where more than one actor with high levels of influence are involved (“IKONE”). Actors with low levels of influence typically cooperate with more influential actors (e.g. “IKONE”, “500 Elmotos”, “S-Hybus”), or form project consortia with a relatively large number of project partners (e.g. “ELENA”, “Elektromobile Stadt”, “Elektromobilität vernetzt nachhaltig”). An exception is the project “Porsche Boxster E”, which can be explained by the fact that Porsche is characterized as an actor with low influence, which is accurate when analyzing Porsche’s influence and proactive involvement in the model region, however does not correspond with Porsche’s general economic position. It can also be argued that the project “Porsche Boxster E” is only loosely integrated in the model region, since it is a fleet trial of one Porsche model and does not receive any governmental funding. Arguably, this is a way for Porsche to be involved at all and stay informed about developments at relatively low cost and effort.

4.4.3.2.5 Patterns of Cooperation in the Showcase Region "Living Lab BW^e mobil": New Actors in Diverse Cooperation Settings and Disillusioned Regime Incumbents

As a successor of the model region, in the showcase region the number of projects has increased significantly. While there have been 8 model region projects, the showcase region features 26 projects. An additional 4 projects focusing on communication with the public and education have been excluded here. A detailed overview of the showcase region projects and the respective patterns of cooperation are depicted in Appendix B.2.

The analysis shows that actors from the automotive industry are only involved in 8 projects, and in only two of those 8 projects an energy company is involved as well. The project consortia are typically not very diverse as regards the actor structure, with the notable exception of the "Stuttgart Services" project focusing on intermodality and comprising partners with diverse backgrounds. At the opposite end of the scale, two projects focus exclusively on testing vehicles and are carried out with no partner at all by an OEM (Daimler and Porsche). Typical cooperation partners in other projects led by an OEM are either universities and research institutes, or "other" actors depending on the specific field of application, in this case for instance taxi or airport operators.

A battery producer is now involved in one project, while actors from the field of ICT still seem to be underrepresented, participating in only four projects. Participation of actors from the public transport sector and mobility providers, especially carsharing services, has increased to five projects. Overall, it can be shown that intermodality has gained importance and takes center stage in terms of project volume and publicity.

Energy companies either work exclusively with an automotive actor in small project consortia, or in very large projects with ICT or public transport and research as well as "other" partners. There is however not a single project where the crucial combination of automotive-energy-ICT is put into practice as a concrete cooperation project, where actors from all three sectors are involved.

There are many projects carried out by "other" actors, sometimes together with scientific partners. These other actors, i.e. not typically associated with the field of mobility per se, include for instance actors from the fields of housing, facility management, non-profit organizations or public actors, such as cities or municipalities.

Universities and research institutes are involved in more than half of all projects (17 out of 26). They are not participating in projects that focus exclusively on testing vehicle technology, electrifying existing mobility services or municipal fleets, and some of the more unconventional projects by "other" actors, e.g. from the field of housing or the smaller municipalities. At the same time there are two purely scientific projects carried out by scientific actors without participation by external actors. This highlights the fact that the showcase region is overall a typical R&D funding program, with disciplinary research designs and a focus on clearly delineated fields of research that scientists are used to, e.g. questions of integrated e-mobility are split up into research questions on either mobility, energy, city planning, or user behavior.

A central observation is that there are indeed many more projects than in the model region, while at the same time there is a very small number of projects, where a broad range of actors from different sectors and fields cooperate directly. Noticeable exceptions are only two projects, focusing on intermodality and on fleet-charging. Similarly, there is a tendency to work in smaller project consortia. There are 10 projects that are carried by a single actor or include only one or two project partners. The patterns regarding power relations of cooperating actors are more varied as compared to the model region projects. Some project consortia are made up of homogeneous actors in terms of influence, i.e. actors with low influence cooperating, or actors with high influence cooperating. A relatively large number of projects are more heterogeneous. There are constellations where more than one actor with high influence work together and furthermore cooperate with actors with moderate influence and larger numbers of actors with low influence, most prominent in this respect is the intermodality-focused project "Stuttgart Services", but there are other projects with more varied project consortia as well.

4.4.3.2.6 Patterns of Cooperation in the Leading-Edge Cluster "Electric Mobility South-West": Focusing on Industrial R&D for E-mobility in the Automotive Sector

While the showcase region shows a more 'systemic' orientation, as compared to the preceding model region, with a focus on intermodality and demonstrating, or literally "showcasing", e-mobility to the public, the Leading-Edge Cluster "Electric Mobility South-West" is clearly a funding program aiming at industrialization for e-mobility. It is more directly addressing OEMs and especially the supply industry than the showcase region program. A detailed overview of the 13 individual cluster projects and the respective patterns of cooperation are depicted in Appendix B.3.

The analysis shows that the involvement of automotive actors in the excellence cluster is high, with an automotive partner participating in 10 out of 13 projects. In accordance with this being a very typical R&D funding program, a research partner is involved in all of the projects. It is noteworthy that also across the cluster projects, there are only two projects where actors from the automotive and the energy sector cooperate, one project where actors from the energy sector and ICT cooperate and one project where automotive and ICT are involved together. As in the showcase region, there is no project where actors from all three fields cooperate.

The dominant cooperation pattern observed is automotive and scientific partners forming a project consortium. There is only one project with a battery producer involved and also the energy and ICT sectors are underrepresented, participating only in three and four projects, respectively. Public transport actors and mobility service providers are only represented in two projects.

Overall, there are more actors with moderate to high influence involved in projects of the cluster, as compared to the model or showcase region. This can be explained by the fact that these projects are more explicitly focused on industrialization and it has been shown that particularly large OEMs and energy supply companies are characterized by relatively higher influence. These actors may also have less interest in demonstration projects and rather focus on technological development. Additionally, the funding rates applied by the government are higher for excellence cluster projects as compared to the model and showcase region.

4.4.3.2.7 Clustering Projects: Limited Potential of Multi-Regime Dynamics and Unexpected Seeds of System Innovation

It has been shown that there is a relatively high share of projects, where actors from different sectors and fields are involved. With regard to the analysis of system adaptability, cooperation crossing sectoral boundaries is important because it can be assumed that this contributes to the emergence of system innovation, due to the tensions emerging between rules and resources inherent in different regimes and the new perspectives and processes of reflecting on established strategies and behavioral patterns this may facilitate. Especially cooperation between the automotive, the energy and ICT sectors is emphasized, in the literature and public discourse, as the decisive interlinkage for developing e-mobility. With regard to this specific type of cooperation, the results of the network analysis so far are mixed. To gain a more profound insight on the consequences of the identified cooperation patterns, a closer look needs to be taken at the topical focus of the concrete forms of cooperation in projects. Considering the limited degree of cooperation between the decisive groups of actors (automotive, energy and ICT), do projects with a potential for system innovation still emerge? How can projects be classified with regard to their relevance for developing e-mobility as a sustainable system innovation? Since varied forms of cooperation have been identified, are there also patterns in the way that specific actor constellations produce typical outcomes in terms of project design and goals? The aim of this section is thus to focus on the design and aims of the projects carried out, in order to provide a more qualified and in-depth analysis of the various forms of cooperation and their potential as a seed for system innovation.

Based on their official project description in Tenkhoff (2011) and online, e.g. on the homepage of e-mobil BW or individual project homepages, the projects of the model region, showcase region, leading-edge cluster and projects funded by individual federal ministries have been grouped according to their basic focus and the degree to which the respective project can be characterized as 'system-innovative':

- Projects that are not system-innovative at all and primarily focus on electric vehicles, their technological development or optimization.
- Projects that have a systemic perspective on innovation and focus on the electric vehicle in its various contexts, e.g. dealing with charging infrastructure, without however questioning basic regime principles, e.g. private car ownership as the dominant pattern or a focus on market-based diffusion.
- Projects that are system-innovative and go beyond established regimes, e.g. by focusing primarily on new forms of mobility, e.g. intermodality and carsharing, or include a strong sustainability perspective, e.g. with regard to energy sources.

A detailed overview of the individual projects, the degree to which they can be characterized as 'system-innovative' and the respective patterns of cooperation in these projects are depicted in Appendix C.1 – C.3.

4.4.3.2.8 Projects focusing on vehicle technology: Cross-sectoral cooperation patterns without systemic perspectives

First, it can be shown that a relatively large share of projects considered here fall under the category of "vehicle"-focused projects, i.e. 15 out of 43. Most projects in this group are carried out in the context of the Leading-Edge Cluster, which makes sense, in so far as this is explicitly an R&D funding program for the industrialization of e-mobility. Half of the model region projects also fall within this group. This may indicate that these were the earliest attempts to develop e-mobility and the focus on vehicles was most obvious during this early stage. Consequently, in the showcase region where a systemic perspective and intermodality are emphasized as important aspects, only three projects can be characterized as focused purely on vehicle technology.

Obviously, all projects involve actors from the automotive industry, except for the two projects where busses are tested by a public transport company. The vehicle-oriented projects in the showcase region are the only ones (except the model region's "Boxster E" trial by Porsche) that are carried out by the respective OEM or transport operator alone. This may indicate the "exotic" status of these projects in the context of the showcase region program, which has overall set a more systemic and 'socio-technical' focus.

All the other projects of this group, carried out in the model region and the cluster, include at least a science partner or another industry partner. Only five projects are carried out by project consortia including partners from more than two fields. Typically included, apart from the obligatory science partner, are partners characterized as "other", e.g. the central German standardization organization for the field of transport and vehicle safety ("TÜV") or various types of consultancies. ICT companies are involved in two projects as well. It can be shown based on these examples that even in cases of intersectoral cooperation, e-mobility is not automatically looked at from a broad or systemic perspective – the focus may still be on the vehicle itself. For instance, a typical pattern is a cooperation between an OEM and an energy supplier, where the latter installs and operates charging points, while the actual project focus is predominantly on testing the operability of a specific electric vehicle. Similarly, the two projects where automotive actors cooperate with ICT companies are clearly 'vehicle-oriented', focusing on electrifying conventional cars, and on increasing the range of electric vehicles through ICT applications on-board or as car-to-car-communication systems.

4.4.3.2.9 Projects focusing on systemic e-mobility: Broadening perspectives outside cross-sectoral cooperation settings

The largest share of projects can be characterized as „systemic", i.e. 19 out of 43 (thus closely followed by the 15 'vehicle-projects'). It can be shown that three out of eight model region projects can be characterized as systemic, and 15 out of 25 showcase region projects, thus more than half. This highlights the emergence of an increasingly 'systemic' perspective on e-mobility during the development phase from the model region to the showcase region, while clearly e-mobility concepts and strategies still remain largely within regime limits, i.e. having a systemic focus, in terms of interlinkages between transport and energy systems, ICT applications as enablers of such interlinkages, without however amounting to a system innovation. This would include questioning basic premises of current transport systems and mobility patterns, relying predominantly on private car ownership, basically unlimited range of ICE vehicles, and clear separation of business models in the transport and energy sectors.

Only four of the 13 cluster projects can be characterized as systemic, highlighting the cluster's focus on industrialization processes. Additionally, there are two projects that are funded in the context of individual federal ministries' R&D programs for e-mobility, "MeRegioMobil" (funded by the BMWi) and "CROME" (funded by BMWi and BMVBS) with a broader regional focus, and in the case of "CROME", even an international perspective, since it is a cooperation project with French ministries and project partners focusing on cross-border e-mobility, including aspects of integrating energy systems and e-mobility (e.g. dealing with issues of standardization, roaming, billing etc.).

Cooperation including partners from the automotive, energy and ICT sectors can be found in only three projects, strikingly none of them part of the showcase region program. Two of them have been part of the model region and they may be seen as early attempts that obviously were for some reason not continued with a similar actor constellation, as could have been possible in the showcase region context. The third project including an automotive-energy-ICT cooperation pattern is "MeRegioMobil". This project is funded in the context of the BMWi's program "ICT for Electric Mobility", thus arguably, the fact that ICT as the decisive and enabling link between vehicles and energy infrastructure is central in this program, presents a favorable condition for this type of cooperation.

There are five projects that do not involve any form of intersectoral cooperation. These are either purely scientific research projects, as well as two fleet trials carried out by Audi, and by a Baden-Württemberg state ministry. These fleet trials qualify for being characterized as 'systemic', because they do not focus on testing a specific vehicle by employing them in a fleet, but on integrating electric vehicles in a municipal fleet and a city-specific delivery service fleet, respectively. Thus, the focus is less on the vehicle technology itself, but rather on embedding it in a specific 'social' or use context.

Among the 15 systemic showcase region projects, only six projects include participation by an automotive actor. Most of them cooperate exclusively with science partners. Only one project also includes an energy company and a few projects are based on cooperation with actors from "other" fields, especially specific fleet operators, e.g. taxi companies, or the Stuttgart airport.

In sum, it is striking that among the systemic projects there are barely any forms of cooperation including partners from the automotive, energy and ICT fields, all in one project. The importance of this type of intersectoral cooperation is time and again emphasized by politicians and actors involved in e-mobility projects and could have well been a more common phenomenon in projects oriented towards a more comprehensive system of e-mobility. The few examples here indicate that for such cooperation a focus on ICT as the central linchpin may be favorable (as e.g. in the case of the project "MeRegioMobil"). Also, one might assume that these forms of cooperation are despite all the hopeful rhetoric particularly difficult in practice, as indicated by the discontinuation of two model region projects that had included automotive, energy and ICT actors. Otherwise there are no clear patterns of cooperation detectable. There is a broad variety of a relatively large number of projects that can be characterized to have a focus on systemic e-mobility. This can be explained by the increasing awareness of the need for more comprehensive systemic approaches in the aftermath of the model region and of the early phases of e-mobility development. A situation characterized by such a great variety and flux is typical for a phase of experimentation and learning and will possibly lead to a consolidation process over time.

4.4.3.2.10 Projects focusing on system-innovative e-mobility: New impulses from ICT, mobility services and actors entering the field of e-mobility from outside transport or energy regimes

The remaining 11 projects, out of the total number of 43 projects considered here, can be characterized as system-innovative. This means they address aspects or deal with questions that question fundamental characteristics or basic rule systems making up the current (auto-) mobility regime, e.g. experimenting with carsharing systems, intermodal mobility, or integration of renewable energies. The majority of these, i.e. seven projects, are carried out in the context of the showcase region, strikingly with none of them including a partner from the automotive industry. Almost half of them do not include a scientific partner either. These projects are dominated by "other" actors, participating in five projects, and actors from the field of mobility services, participating in three projects. Energy and ICT actors are participating in three projects, directly cooperating only in one of them. This is the "Stuttgart Services" project focusing on intermodality, which is outstanding with regard to its broad inclusion of actors from all fields, except automotive and battery technology. Most of the other project constellations are much less diverse.

An exception is the project "iZeus", funded in the context of the BMWi's "ICT for Electric Mobility" program and the follow-up project "MeRegioMobil". This latter project focuses on a comprehensive concept of integrating e-mobility and energy systems via ICT applications with a clear focus on how to foster the development of renewable energies and the energy transition in this way. Furthermore, this is the only project including an automotive, energy and ICT actor (plus an actor from the field of battery technology and a science partner).

The remaining system-innovative projects are characterized by cooperation between ICT and energy companies, or ICT and a mobility service provider, and partners from the field of "other" actors (i.e. not from the automotive or energy sector) or science. The only system-innovative project that can be found in the model region, "PEDELEC", might be a particularly interesting case. Here an energy supplier cooperates with a public transport company and an e-bike manufacturer. Since this is the only system-innovative project in the model region context, this may indicate that in the early phases of experimenting with e-mobility, energy companies were hopeful of finding new and innovative business models, and were thus ready to experiment. Later on, this seems to have been followed by disillusionment and re-focusing on established business models. In turn, ICT companies seem to have gained a stronger position and perspective on possible new fields of activity in developing e-mobility as a system innovation.

Even though there are no very specific patterns of cooperation emerging in system-innovative projects, what can be shown is that intersectoral cooperation including actors from automotive, energy and ICT sectors is obviously not decisive. This type of cooperation barely exists at all, while system-innovative projects do emerge nonetheless. A relatively large share of those projects are not at all based on intersectoral cooperation, rather they are carried out by outsiders, such as a housing company, a regional association, mobility providers, or science partners.

4.4.3.3 Discourses and Dominant Frames of Reference: System Adaptability for Sustainable E-mobility

The network analysis has provided an overview of Baden-Württemberg's innovation system for e-mobility as regards the basic power structure and influence levels of specific actor groups. The network has also been analyzed in terms of the projects, in which these actors are involved. Thus the innovation system has been captured as an intertwined network of actors and of projects. The projects have been clustered with regard to their topical focus and degree of innovativeness as well. It has then been analyzed whether there are correlating links between specific types of projects and specific types of actor constellations. To go even more into depth, this section will now look at the specific positions of individual actors, in order to identify their respective topical and strategic focus in the field of e-mobility, their perceptions of innovativeness and relevant strategies (similar to the way that the different projects have been clustered based on criteria of focus and innovativeness).

The reason for including this step is that the concept of system adaptability includes a focus on changing rules (i.e. a "topical" component including frames of reference, guiding visions and symbolic meanings) and resources (i.e. power relations) across different groups of actors. While the network analysis has begun to capture the power relations between different actor groups, what is missing is an insight on the specific rule systems that the different groups of actors refer to. This is decisive when attempting to understand the potential for e-mobility developing as a sustainable system innovation: how is e-mobility perceived in general? Is it supported or rejected? What are the reasons for engaging in this field and what are concrete aims and strategies of different actors? Combining these detailed insights into frames of reference and rules that shape practices and routines of specific groups of actors with their respective position and influence in the network, can provide an overall insight into the adaptability of Baden-Württemberg's particular innovation system.

So, how can the position on e-mobility of different actors be identified? A common approach is to focus on their communication and analyze discourses emerging around new technologies. This makes sense for analyzing system adaptability as well, because system adaptability is determined by the attitude of relevant actors towards a new technology and the way they deal with it, eventually leading to a particular outcome (socio-technical change or disappearance of a technological option) that is uncertain and may take a wide variety of concrete forms. Such complexity and uncertainty results from the fact that no technology is unambiguous with regard to its diffusion or social embedding and therefore the meaning and deeper purpose attached to it will shape socio-technical co-evolution processes. Especially during early stages of technological development or diffusion, the attitudes towards a new technology often vary across different actor groups. Such discrepancies in the meaning attached to complex technological change processes shape the actual outcome of these processes – and they are reflected in the discourses evolving around a specific technology (Bakker et al., 2011, p. 153; Zimmer & Rammler, 2011, p. 62). Thus, identifying different streams or patterns in a technology-specific discourse and relating them to the respective actor groups and their relative influence can help to assess the degree to which a socio-technical system is adaptable and open to (what kind of) change.

Therefore, the positions of actors regarding e-mobility have been analyzed based on determinants of system adaptability, thus dominant rule systems, frames of reference and interpretive schemes that actors draw upon when describing e-mobility as a technological field, the context to which it belongs and the reasons why it is a legitimate field of activity for them. Relevant analytical categories can be identified as follows:

- Frames of reference in relation to e-mobility in general (e.g. how is it defined, what are legitimate reasons for engaging in this field, what kind of change or transformation processes are expected?)
- Changes in the technological profile of the socio-technical system (e.g. what are perceived to be risks and chances of e-mobility?)
- Drivers and barriers for e-mobility: Changes in established patterns (what needs to be done in different domains, e.g. markets, industry, R&D, policy, user behavior?)

An analysis of individual positions of actors has been carried out for all actors with high or moderate levels of influence, and also the Regional Project Coordination Agency (PLS) as the central coordinating actor in the overall innovation system. Thus, in total the positions of 22[18] actors have been analyzed, based on a total number of 31 documents. The way that actors position themselves in the field of e-mobility varies with regard to scope and form, some actors have official positions and detailed publications of different kind on the subject of e-mobility, others provide barely any information, e.g. only in the form of short notices on websites regarding participation in e-mobility projects or very short statements in annual reports or image brochures. Especially the analysis of positions of actors with moderate levels of influence has been differentiated with regard to the amount of information that is published at all.

Coordinating actors – high influence and "neutral" position

When the model region started in 2009, the **state agency e-mobil BW** had not yet been founded, and the regional project coordination was carried out by the **Stuttgart Region Economic Development Corporation (WRS)**. With regard to the central strategic purpose of the model region program, the WRS emphasized that the focus is on testing and

[18] The network analysis produces a result of 22 actors with high and moderate levels of influence (4 with high and 18 with moderate influence), plus 2 actors forming the PLS (e-mobil BW and WRS). Bosch GmbH and Bosch SI have been treated as one actor, the same is true for the university of Stuttgart and its Labor and Technology Management Institute (IAT). Therefore, the positions of 22 actors are analyzed here, instead of 24.

demonstrating e-mobility in public, in order to prepare market breakthrough. The basic rationale for engaging in the model region is to preserve the economic strength of Baden-Württemberg and provide support for the expected structural change:

"OEMs and automotive suppliers are aware of the fact that on the way to e-mobility, the vehicle has to be re-invented and they will face this challenge together." (WRS(a), p. 1)[19]

This quote shows that the focus is on the car as the central technology and product, which has to be re-invented, and on the industrial actors involved in car manufacturing. The central emphasis on this issue can be explained by the fact that the WRS has been founded as a regional agency with the basic aim of fostering economic development in the Stuttgart region. Their explicitly stated aim in the field of e-mobility is to prepare the region for the challenges ahead and ensure that economic value creation can be sustained (WRS(a), p. 9).

In a later publication by the WRS, which presents e-mobility projects in the context of the model region, the showcase region, and projects of the regional "Landesinitiative Elektromobilität", the title of the brochure – "Sustainable mobility" – already indicates a broadening of perspective. While the basic rationale still revolves around future economic perspectives for Baden-Württemberg's automotive industry, this view is broadened by a recognition of varied interests that have to be reconciled in modern industrial societies, e.g. environmental and economic, those of industry and people living in cities. Additionally, the goals of developing e-mobility now explicitly include intermodality and innovative mobility solutions (WRS(b), p. 1).

Based on experiences until the end of the model region program, a **"Structure Study BW^{e} mobile 2011. Baden-Württemberg on the way to electromobility"** has been published by some of the main actors or agencies in the regional innovation system, i.e. the state agency e-mobil BW, the Fraunhofer Institute for Industrial Engineering (IAO), the Ministry for Finance and Economics of Baden-Württemberg and the Stuttgart Region Economic Development Corporation (WRS). Analyzing the core findings and implications of developments around electric mobility that have been identified for Baden-Württemberg in this study, four overall themes are dominating the discourse: First, there is a theme of

[19] Original quote in German: *"Hersteller und Zulieferer der Fahrzeugindustrie sind sich bewusst, dass auf dem Weg zur Elektromobilität das Fahrzeug neu erfunden werden muss und stellen sich gemeinsam dieser Herausforderung."* (WRS(a), p. 1)

technology. The different kinds of drivetrains are discussed, the process of electrification via hybrid variants and the costs of components, especially the battery, and how to deal with this in the manufacturing process. Second, global markets and the potential for e-mobility exports (vehicles as well as other components such as power electronics, battery systems and chargers) are emphasized. Third, a topic of major importance is the national economy and the regional (Baden-Württemberg) industry. Important issues are how to create employment effects in a new and electrified automotive industry, where SMEs are of major importance. The transfer of knowledge gained by academic R&D to the industry and R&D cooperation as well as measures to qualify employees for the expected changes in products and manufacturing processes are highlighted as suitable means to support structural change in the region. Fourth, system innovation can also be identified as a theme, primarily in terms of an expected or desired convergence of the energy, automotive and ICT sectors. It is recognized that this also includes thinking about new business models and changes in use patterns. What is completely missing as a distinct theme is 'sustainability', i.e. any concrete emphasis on environmental goals in production, use, energy sources or overall system design of future e-mobility (MFW et al., 2011, p. 5).

These themes remain central, as can be shown by more recent official statements or positions published by **e-mobil BW** – with an added focus on sustainability. In its image brochure published in 2013 three major themes are highlighted. First, e-mobility is an important element of the energy transition and thus more than substituting a drive train: "it is not just the technology to satisfy our growing need for mobility that will be changed, but also the ways and means in which we are covering distances" (e-mobil BW, 2013a, p. 1). Concrete technological development should be open with regard to specific solutions and currently all options of drivetrains and vehicle technologies should be considered for further R&D (e-mobil BW, 2013a, p. 2). Second, the necessity of cooperation between the automotive industry, the energy sector and ICT is emphasized. Third, emphasis is put on including citizens in the transformation process and making e-mobility a reality in day-to-day practice (e-mobil BW, 2013a, p. 2). In the official strategy guiding the activities of e-mobil BW, the central elements are: industrialization for e-mobility, in order to preserve Baden-Württemberg as an important industrial location; a technology-neutral approach, including battery-electric and hybrid vehicles as well as hydrogen-powered fuel cell vehicles; and demonstration in practice and communication to the public (e-mobil BW). With regard to drivers and barriers for e-mobility, the emergence of business models and transferring results from R&D projects to concrete applications in practice is emphasized as an important element for establishing e-mobility (e-mobil BW, 2013a, p. 8).

Regarding future visions of e-mobility, important elements are new forms of mobility that are environmentally friendly, intermodal, economically viable, and socially just. E-mobility is thus increasingly perceived as a form of sustainable mobility, as expressed by the elements featured prominently in the future vision of e-mobility. Furthermore, the argument that e-mobility only makes sense when there are sufficient amounts of renewable energy to power vehicles seems to have gained prominence. For instance, it appears as a central argument in the already mentioned image brochure published in 2013 (e-mobil BW, 2013a, p. 7). Similarly, and as opposed to earlier years, potential conflicts between environmental and economic goals of developing e-mobility are slightly hinted at:

"Mobility of the future based on renewable energy sources is an essential part of the energy policy change. However, success in international markets also requires major progress in components and production costs, simple handling in everyday life and customer oriented connecting of various transport systems." (e-mobil BW, 2013a, p. 4)

This paragraph introducing the Leading-Edge Cluster "Electric Mobility South-West" in e-mobil BW's image brochure, at least hints at the fact that e-mobility as an element of the energy transition and e-mobility as a new German "export hit" may not necessarily be two sides of the same coin and that developing e-mobility is not automatically producing an economic and environmental win-win situation.

Actors with high influence

One of the actors identified to have a high influence on Baden-Württemberg's innovation system for e-mobility is, quite obviously, the Stuttgart-based OEM **Daimler AG**. Its position with regard to e-mobility is most clearly spelled out in the Sustainability Report and an official position on "Electrification of the Drivetrain". E-mobility is defined from a vehicle-centered, technological perspective, focusing on electric vehicles with battery and fuel cell drive (Daimler AG, 2012, p. 3). Clearly, the dominant frame of reference is the conventional ICE car and its characteristics, which is implied by the emphasis on batteries as the central technology field that needs to be further developed, in order to make e-mobility feasible (Daimler AG, 2012, p. 6). This focus on improving the battery, thus increasing the range of

BEVs and reducing cost, shows that ‘feasibility’ is understood to mean the ability for a BEV to compete with a conventional car.

Nonetheless, it seems certain that e-mobility will become a reality. The transformation process is seen as a step-wise path of technological development, leading from increasingly efficient ICE cars to hybrid vehicles to purely electric vehicles in the future (Daimler AG, 2012, p. 3, 10). Rationales for developing e-mobility are providing emission-free and quiet mobility in densely populated urban areas (Daimler AG, 2012, p. 19). In this context, Daimler’s car2go is presented as an innovative mobility solution for urban contexts (Daimler AG, 2012, p. 22). In contrast, especially fuel cell vehicles are advocated as a “convenient” alternative (Daimler AG, 2012, p. 29), due to their long range and short charging time that are “basically the same as for a conventional vehicle”, which makes them “also suitable for long-distance travel” (Daimler AG, 2012, p. 30). In this context, it is argued that cooperation with political actors and energy providers are important, because the hydrogen infrastructure is still lacking (Daimler AG, 2012, p. 30). The need for cooperation by everyone involved is also stressed in the sustainability report 2012 (Daimler AG, 2013, p. 25). Thus, political regulation and investment in infrastructure are seen as important drivers for e-mobility.

Sustainability is defined in terms of a “road to emission-free mobility” and e-mobility basically amounts to developing “locally emission-free electric vehicles” (Daimler AG, 2012, p. 2 f.). However, in its sustainability report, a broader vision is sketched of mobility concepts in a “new era of mobility”, which have to consider sustainable lifestyles in a “sharing society” with networked mobility services (Daimler AG, 2013, p. 19). Daimler’s car2go is presented as a prime example in this context, especially with prospects for further electrifying this carsharing service. The fact that from a sustainability point of view this requires renewable energy sources for powering vehicles is emphasized as a cautionary note (Daimler AG, 2013, p. 24). This is taken up by reporting about Daimler’s investment in a wind turbine generator system, which matches the energy consumption of all newly registered Smart fortwo electric drive models (Daimler AG, 2013, p. 47). E-mobility is dealt with under the heading of “Green electricity leads the way”, emphasizing that it is an option for the long-term future, while the next steps are improving the internal combustion engine and hybridization of power trains, and that e-mobility is one option, especially for urban contexts, and to be developed “along with the wider applications of the fuel cell-powered car” (Daimler AG, 2013, p. 48).

As can be expected, **EnBW AG** as a large energy supplier primarily refers to the on-going energy transition as the basic rationale for engaging in the field of e-mobility. Against this background, it is reasoned that in this way it is possible to simultaneously address problems of climate change and resource depletion as well as guarantee economic well-being for Baden-Württemberg. The future vision, as expressed by the project portfolio, revolves around BEVs as decentralized means of energy storage, intermodality and carsharing facilitated by ICT solutions, new forms of cross-sector cooperation and integration of mobility- and energy-related services. Strategic aims are defined in the field of energy provision, operating infrastructure, and offering mobility services for operators of electrified fleets. High costs and low range of electric vehicles are seen as the major barriers for e-mobility today, which should be addressed by building up charging infrastructure, improving EU-wide standardization (e.g. of charging plugs and cables), and by integrating different modes of transport (EnBW AG, 2014a, 2014b).

Daimler AG and EnBW AG, the two industry actors identified to have a high influence on the innovation system in Baden-Württemberg, can both be shown to picture a positive outlook for the future of e-mobility and they expect fundamental change with regard to the structural context, in which they are operating today. However, even though the need for cooperation across sectors and with political actors is emphasized, path dependencies with regard to established perspectives and concrete business models are obvious. The car manufacturer concentrates on vehicle technology and the energy supplier on energy infrastructures. It is, however, not clear how the link between the energy and the transport sector is to be facilitated and what concrete forms of cooperation would be needed – apart from stating that there will be convergence at some point. From a sustainability perspective, the issue of e-mobility and the integration of renewable resources is used as a strategic argument by Daimler, to put e-mobility and its potential for sustainability in a more critical perspective, while for EnBW this seems to be an aspect of the rather distant future when the system as a whole has evolved into a 'smart' one and when enough electric vehicles are available to fulfill their role as storing capacity for renewable energy.

Two research institutes have been identified as actors with high influence on the innovation system for e-mobility in Baden-Württemberg, the **Fraunhofer Institute for Labor Economics and Organization** (Arbeitswirtschaft und Organisation, IAO) and the **Karlsruhe Institute of Technology** (KIT). In their annual reports and information brochures, reasons for engaging in research on e-mobility are issues of resource scarcity and environmental pollution (Fraunhofer IAO, 2013, p. 19) and the energy transition (KIT, 2013, p. 9). The specific research focus of the Fraunhofer IAO is on e-mobility as a "driver of future economic growth" (Fraunhofer IAO, 2012, p. 106) and implications for the labor market in an industrial region, such as Baden-Württemberg, and Germany as a whole (Fraunhofer IAO, 2012, p. 85). The potential for technological innovation and creating interfaces between electric vehicles and energy infrastructures is another research focus (Fraunhofer IAO, 2012, p. 39). It is emphasized that e-mobility is to be developed in practice, e.g. in "living laboratories" (Fraunhofer IAO, 2012, p. 4), and that one objective of Fraunhofer is to create networks facilitating cooperation of the automotive industry, the energy sector and political actors, which is necessary in order to establish business models and infrastructure (Fraunhofer IAO, 2013, p. 19). The approach of the Karlsruhe Institute of Technology centers around challenges of achieving an energy transition, of which e-mobility is one element and which requires research designs that are interdisciplinary and integrate basic and applied research (KIT, 2013, p. 9).

Apart from those four actors that have been identified to have a high influence, actors with moderate influence on the innovation system and their positions have also been investigated in detail. Among these actors, five can be said to have an explicit position on e-mobility, e.g. in the form of specific publications, usually brochures on e-mobility, press releases, or a homepage dedicated to activities in the field of e-mobility. These are a large automotive supplier (Robert Bosch GmbH and Bosch Software Innovations GmbH), a regional energy supplier (MVV Energie AG), two actors from the field of ICT (SAP AG and PTV Group), and Deutsche Bahn AG (DB, German National Railways) as the largest German public transport company.

The positions of all these actors are based on a systemic perspective on e-mobility, against the background of the energy transition and intermodal transport systems, requiring a re-definition of the role of the car. Among these positions, **Bosch** as an automotive supplier has a still relatively limited perspective, in so far as the car is the central artifact around which systemic change is expected to evolve. Technological progress in battery development for increasing the range of electric vehicles is seen as a precondition for success (Robert Bosch GmbH, 2013), but following this, the infrastructure in which electric vehicles are embedded will be the actual innovation and foster their integration in energy and transport systems (Robert Bosch GmbH, 2013; Bosch SI, 2014, p. 3).

The important role of e-mobility as a critical economic success factor on global export markets and for the region of Baden-Württemberg is emphasized in the positions of Bosch (Robert Bosch GmbH, 2013) and MVV Energie (MVV Energie AG, 2011).

In the position of **MVV Energie**, e-mobility is further seen as an important element in the energy system of the future, which needs to be more environmentally friendly and based on renewable sources. It is emphasized that we are currently still at an early stage of development, but that environmental concerns and renewable energies will be the decisive drivers for technological development. The overall focus is future-oriented, concentrating on the role of electric vehicles as a means of energy storage in the long term (MVV Energie AG, 2011; 2014).

Questions of addressing climate change and resource scarcity, and securing individual mobility for a growing population are central in the position of the **Deutsche Bahn AG** as well. E-mobility is presented as a possible solution, however, only if there is enough electricity from renewable resources and the needed infrastructure can be built up (DB, 2012a). Related to their own activities in the field of bike- and carsharing, it is stressed that part of the solution for transport problems is the integration of e-mobility and public transport in intermodal mobility services. In the shorter term this is also advocated as a strategy for fostering market breakthrough of electric vehicles (DB, 2012b).

The positions of the two ICT companies, **SAP AG** and **PTV Group**, most clearly reflect a re-definition of the car in the context of e-mobility. For instance, the starting point for the software concepts and solutions developed by PTV Group is that the characteristics of electric vehicles are substantially different from those of conventional cars (PTV Group, 2013, p. 4). Therefore, new solutions are needed to realize the true environmental and economic potential of e-mobility. Similarly, in the position of SAP, it is argued that while current barriers for e-mobility are limited range and long charging times of electric vehicles, the basic challenge is not one of improving vehicle technology, but of a better integration of all elements, including vehicles, infrastructure and energy sources (SAP AG, 2011).

The remaining 11 actors that have been identified to have a moderate influence on the innovation system do not have explicit position statements on the issue of e-mobility. However, e-mobility is mentioned as a minor aspect, a specific field of activity or a topical issue in, for instance, annual reports, image brochures or press releases concerning participation in e-mobility projects. Still, the way that e-mobility is dealt with varies among this group.

For instance, the three automotive suppliers in this group, even though none of them has a detailed official position on e-mobility in general, provide very different amounts of information with regard to their engagement in the field of e-mobility. For instance, the supplier **Dürr AG** simply states on its website that the developments with regard to the electrification of drivetrains are relevant for their company as a leading expert in automotive manufacturing technologies and that therefore they are active in this field (Dürr AG, 2014). Some more detail is provided by **teamtechnik**, where the basic motivation for participating in a specific project is spelled out a little more clearly. It is argued that economically feasible manufacturing processes are a major challenge for the development of e-mobility and that teamtechnik is able to address this challenge based on their know-how in this field. The clear goal is to be able to produce marketable and competitive products (teamtechnik, 2012). The broadest perspective is offered by **ZF Friedrichshafen**. Reference is made to the potential of e-mobility as a quiet and locally emission-free transport alternative in cities. Compared to the other two this is the only explicit sustainability perspective, even though it remains limited to the direct potential of the electric vehicle: they can be an alternative for urban transport where distances are limited and vehicle range is not becoming a problem. Applications for e-mobility that go beyond urban contexts then clearly depend on developments in battery technology. Similar to the other two companies it is stated that existing competences in automotive manufacturing technologies will be used to further advance e-mobility development (ZF Friedrichshafen AG, 2014). This emphasis on own competences makes sense in a situation characterized by general awareness of structural change in the automotive industry and the need to preserve one's position on global markets.

Similar to the position of teamtechnik, the battery technology firm **ads-tec** also comments publicly on its involvement in an e-mobility project. Own competences in the field of battery technology are emphasized and a rationale why this field is of importance, in general, is also offered. It is argued that batteries and their handling is a key technological field and the major challenge for mobility and energy efficiency in the future (ads-tec, 2013).

The consultancy **RA Consulting** also makes just a short note on their website regarding their involvement in the Leading-Edge Cluster "Electric Mobility South-West". Promoting their specific know-how and competences as a consultancy is achieved here by highlighting that the consultancy's managing director has been part of Baden-Württemberg's official delegation to Berlin tasked with presenting the cluster's (successful) application to the BMBF in the Leading-Edge Cluster Competition. Consequently, the specific advantages of Baden-Württemberg and its innovation system for e-mobility are also stressed, implying the consultancy's knowledge of and involvement in the regional networks (RA Consulting, 2012).

Surprisingly, the **Stuttgarter Straßenbahnen AG** (SSB AG) despite their heavy involvement in the showcase region and leading the largest showcase region project "Stuttgart Services", do not have an official position on e-mobility. The project is mentioned in their annual report as an innovative approach within their sustainability-related activities. It aims at fostering sustainable intermodal mobility patterns and, in addition to that, offers growth potential for public transport and an opportunity to develop E-ticketing solutions (SSB AG, 2013, p. 7). Thus, e-mobility is approached from the public transport company's specific perspective and strategic goals. Rhetorically it is dealt with under the heading of "innovation and sustainability" in general, rather than being presented as a distinct field of activity of relevance for SSB AG.

Another central actor among the group of moderately influential actors in the innovation system, is the **capital city of Stuttgart**. Apart from its general political role as the seat of the Baden-Württemberg state government and the central location 'hosting' the model and showcase regions, it is also a municipal actor participating in e-mobility projects. In this function, it follows specific motivations and goals in the context of Stuttgart's local transport-related problems, i.e. congestion and local pollution. Electric vehicles are viewed as an element of sustainable mobility and therefore their diffusion is supported by the city, e.g. in the form of free parking arrangements. The perspective on sustainable mobility remains centered around the electric vehicle, its direct benefits with regard to local emissions, and its comparative disadvantages as opposed to conventional cars, thus requiring political support (Landeshauptstadt Stuttgart, 2012).

The remaining four actors with a moderate influence are universities or research institutes, namely the **University of Stuttgart**, the **German Centre for Aviation and Space Travel** (Deutsches Zentrum für Luft- und Raumfahrt, DLR), **Fraunhofer Institute for Production Technology and Automatisation** (Fraunhofer-Institut für Produktionstechnik und Automatisierung, IPA), and the **Center for Solar Energy and Hydrogen Research Baden-Württemberg** (Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg). They mention e-mobility as a field of research on websites or in image brochures and lay out the basic rationales why there is a need for research and what they focus on more specifically. Very briefly, the DLR states that e-mobility can play an important role for increasing vehicle efficiency and reducing emissions (DLR, 2012, p. 12). An even more explicit link to industrial R&D, which is highly relevant for Baden-Württemberg's automotive sector, is made by Fraunhofer IPA and ZSW. They emphasize their specific competences in the field of lightweight-design (Fraunhofer IPA, 2013, p. 10) and battery technology (ZSW, 2013, p. 11), and their applied-science contributions that are useful for OEMs and suppliers, and a central precondition for establishing a German lead market for e-mobility (Fraunhofer IPA, 2013, p. 10; ZSW, 2013, p. 11). The ZSW also argues in some more detail why e-mobility is a promising field of research – apart from developing technological applications for preserving the industrial location Baden-Württemberg. The basic reason why e-mobility is being developed is its potential role in fostering the development of renewable energies and increasing energy efficiency in the transport sector. In accordance with the ZSW's research focus, the central role of alternative drive technologies, battery or fuel cell, is stressed, especially because advances in these technologies will determine whether electric vehicles will be able to compete with conventional cars (ZSW, 2013, p. 29). A less technological perspective is offered by the University of Stuttgart. Here, the research focus is on business models and user acceptance of e-mobility and accordingly, e-mobility is portrayed as a more 'social' phenomenon of how to diffuse and employ electric vehicles in urban contexts. The basic rationale is to utilize e-mobility in the context of climate-related and city planning goals (Universität Stuttgart, 2013).

In sum, it can be observed that throughout the different positions the car as the central technological artifact is dominant in the discourse on e-mobility. Even though e-mobility implies something more comprehensive than the electrification of the car as we know it, the ICE car provides the central frame of reference based on which e-mobility as a concept is being defined or against which electric vehicles are compared. The automobile is also the historical core of Baden-Württemberg as an industrial site and whether it can persist depends on the region's ability to re-invent the car. It is striking that many positions also involve stories about future e-mobility where innovative mobility concepts are central (e.g. carsharing with Daimler's car2go or intermodal mobility patterns enabled by ICT-applications) and where these innovative solutions could basically solve problems of high purchase costs, limited range or long charging times of BEVs by using them in different ways than conventional cars – while nonetheless, these exact shortcomings of BEVs in direct comparison with conventional cars are mentioned as major barriers for future e-mobility.

4.4.3.3.1 Synthesis: Shared Hopes for the Future – Varied Perceptions of Current Problems and Suitable Strategies

Obviously, all of the analyzed actors are in some way active in the field of e-mobility and there seems to be a broad consensus that e-mobility is a growing field and will be successful in the long term. The basic frames of reference or contexts of e-mobility are summarized in the position of the Stuttgart Region Economic Development Corporation (WRS) and the state agency e-mobil BW in their function as regional project coordination. Three major themes can be identified, namely technology, economy and global markets, and industry convergence. E-mobility amounts to a project of technology-oriented structural change in the automotive industry. Since Baden-Württemberg has an important automotive sector, industry actors are of central importance and competent partners in the endeavor of establishing e-mobility. A technology-neutral approach (with regard to specific drive technologies and vehicle concepts) is followed by the industry and this is supported by public actors such as the two coordinating agencies e-mobil BW and WRS. The overall aim seems to be defined in economic terms, i.e. preserving Baden-Württemberg as an important industrial site and remaining competitive on global markets. A systemic perspective on e-mobility also comes to play a role, because it is argued that some form of industry convergence, including the automotive, energy, and ICT sector, is needed to make e-mobility feasible in the long term. While environmental and resource scarcity concerns are often mentioned as a general reason for developing e-mobility, the e-mobil BW over time increasingly adopts a broader perspective on sustainable mobility in the context of the energy transition. Since the e-mobil BW has been founded and is financed by the state government with a clear mandate of functioning as a politically neutral coordinator and facilitator, it can be assumed that the e-mobil BW represents an overarching discourse carried by relatively broad consent among the involved actors. This is a likely outcome of acting as a central information and connection hub and could be a combination of the position of the most influential actors or a lowest-common-denominator-position.

A possible result of such an overarching and consensual discourse is that some conflicts and tensions tend to be glossed over or ignored. One example in this case is the potential conflict between environmental goals and industry-related goals of developing e-mobility. In the communications by the e-mobil BW it is at most hinted at the fact that there may not always emerge an automatic "win-win" situation. This issue is also taken up in the position of Daimler AG, where it is strategically used to "play down" the role of e-mobility by emphasizing that it is only environmentally sensible when enough renewable energy is available. One may argue that this line of argument is used here as a way to shift the focus on problems that are not part of one's own responsibility.

Slight deviations from the overall discourse can be observed in most positions because e-mobility is always framed based on the specific actor's background and field of activity. For instance, for an OEM e-mobility has most importantly to do with vehicles that can locally be operated emission-free, an energy supplier is interested in the potential of e-mobility for the energy transition, and for a municipal actor, e-mobility is an element of city planning. Some actors do not have a very detailed or explicit position on e-mobility (at least not officially published). One example identified here are the automotive suppliers with moderate influence. They stress their competences, legitimizing their importance for the overall industrial structure. They possibly do not see themselves as highly important or responsible for the overall strategy of the automotive sector and thus do not publish detailed communications on e-mobility. Typically, suppliers in Baden-Württemberg are SMEs, which together make up a very important and influential group of actors, even though most of them are relatively small, as compared to the few large suppliers and the local OEMs. Obviously, their emphasis on own contributions can be explained by the fact that the analyzed documents are mostly forms of PR and general company information.

Deviating to a larger degree is the position of ICT and public transport companies. Due to their original fields of activity, they have a more systemic view on e-mobility and generally interpret it in terms of alternative forms of mobility including intermodal mobility and carsharing services. These are the new actors entering the field, who possibly see chances and potential for their business activities and strategic goals – rather than a threatening perspective of structural change and transformation. The central barriers for e-mobility are perceived to be external to their specific fields of activity (infrastructure, vehicle technology etc.), while they will contribute positively once the time is right and suitable framework conditions are in place. Among this group of actors, it is surprising that the SSB AG has not published an official position on e-mobility, even though it is such a central actor in the showcase region. However, this may also indicate that e-mobility per se is currently not a central issue with regard to the core business of the SSB AG, but that it is rather utilized as an opportunity to develop own interests and business activities.

Finally, it is also striking that the position of the involved scientific partners remains relatively close to the industry-dominated discourse. The focus of research is mostly technological, and in fewer cases interested in user acceptance and business models for e-mobility. The overall perspective is firmly centered on the conventional car as the basic frame of reference and standard comparison.

4.4.3.4 A Closer Look at System-Innovative E-mobility Projects in Baden-Württemberg

It has been shown that in principle the electric vehicle has the capacity to transform the established socio-technical system that has evolved around (auto)mobility, because in many ways it does not 'fit'. A transition involving the widespread diffusion of electric vehicles would have implications for the technological profile of the automotive industry (e.g. new vehicle components, production processes etc.) and new players would enter the field (energy sector, battery producers, ICT companies) and new forms of cooperation would be needed between the automotive and the energy sector, and, when including carsharing and intermodality, with public transport companies and mobility service providers. Since the electric vehicle is not well adapted to the current mobility regime, its diffusion would possibly also entail institutional change, with regard to formal institutions, such as laws and regulations, as well as with regard to informal institutions, such as cultural images and the role of the car.

Whether or not the potential inherent in this transformative capacity will actually unfold in a transition around e-mobility depends on the degree to which the current socio-technical system is adaptable. System adaptability increases when cracks appear in the regime. In the case of mobility, some cracks can currently be observed, such as resource scarcity, trends in the global automotive industry, local pollution and congestion in large cities. These have been discussed in chapter 4.3. in some more detail. Apart from the emergence of such broader trends and problems, the adaptability of a system is in the end determined by the way that actors deal with a new technology and react to these cracks in concrete situations. How, if at all, do they perceive these cracks and in what ways does the new technology come into play?

In the following, the analysis of the semi-structured expert interviews conducted with actors from the innovation system of Baden-Württemberg is presented. The interview partners were selected based on their involvement in e-mobility projects that can be characterized as ‘system-innovative’, i.e. going beyond purely technological R&D projects focusing on the diffusion of electric vehicles. A detailed overview of these projects is presented in Appendix C.4, and a brief description is given in the following, in order to provide some background for the analysis of the interviews.

The project **“Stuttgart Services”** aims at introducing an intermodal mobility service via a card that allows access to public transport, carsharing and a number of other services (e.g. access to public libraries and swimming pools). Consortium leader is the local public transport company Stuttgarter Straßenbahnen AG (SSB AG), and it is one of the largest projects, in total involving more than 20 project partners and associated project partners from a broad range of fields, including energy, ICT, public transport, carsharing, the city of Stuttgart and regional associations (Landeshauptstadt Stuttgart, 2012). The aim of the project is the introduction of the “Stuttgart Service Card”, an integrated mobility and service card that guarantees access to various mobility services, for instance public transport in the Stuttgart region (for users of yearly tickets), German National Railway’s mobility services, such as

“DB Flinkster” and “e-Flinkster”, “DB Call a Bike” and “e-Call a Bike”, and Daimler’s “car2go”. Over the course of the project (2013 – 2015), the aim is to establish a broader service platform, integrating not only mobility but also energy and other city services in this card and making it a city-wide means of payment. The aim is to increase the share of public transport, walking, cycling and electric vehicles. The project group is led by SSB AG and has developed the concept of Stuttgart Services, based on the idea that integrating various services in Stuttgart’s urban context will be the key for developing new forms of sustainable urban transport. Since the Stuttgart Service Card can be used for a wide array of services, new customers can be won and those that so far have not used public transport will be provided with an easy access (as a bonus that comes with the Stuttgart Service Card, which they have bought for other purposes).

The drivers for the Stuttgart Services Project are the growing awareness of interlinkages between e-mobility as an innovative issue that is high on the political agenda and public transport activities with regard to fostering multimodality and E-Ticketing. These are already prominent issues for a public transport company seeking to realize potential for market growth and better fulfilling actual customer needs. The opportunity to include a variety of other services in the Stuttgart Service Card is seen as a way to acquire new customers by providing easy access to public transport, and keeping existing customers by offering them additional services. Furthermore, various broader societal trends are taken as starting points and motivation for the project. These include increasing urbanization and political regulation with negative impacts on individual motorized transport (e.g. environmental regulation, vehicle-/city-toll, parking space management). Increasing costs of individual motorized transport (fuel, parking, tolls) and the ongoing energy transition are expected to create a further push-effect for e-mobility. Very generally, trends towards more networked societies and a “sharing economy” are expected to benefit developments of intermodal and integrated mobility services as the preferred option for customers. Together with technological progress in the field of ICT this is expected to lead to network effects and an increasing emergence of innovative services (SSB AG, 2013, p. 9 f.).

Stuttgart Services is a typical showcase region project, focusing on visibility and demonstration: It is open to ‘normal’ customers from the start, in contrast to more ‘scientific’ R&D or pilot projects with limited numbers of test users or research projects where virtual concepts are developed. Within the broader showcase context, Stuttgart Services is the lead project for the field of intermodality. It is connected with the other projects in the intermodality field in various ways, e.g. using shared infrastructure or integrating them through the Service Card.

For instance, the project **"e-Flinkster and e-Call a Bike"** is connected to Stuttgart Services via the Stuttgart Service Card. In this project, the German National Railways (Deutsche Bahn AG, DB) builds on its activities in the model region where pedelecs had been integrated in its "Call-a-Bike" rental service. The showcase region project further develops the electrification of DB's mobility services by integrating electric cars and bikes in its existing carsharing ("Flinkster") and "Call a bike" infrastructures. As an associated partner in the project Stuttgart Services, DB can offer their services also via the Stuttgart Service Card.

A more typical scientific R&D project on intermodality is the cluster project **"I-eMM – Intermodal E-Mobility Management"**. The project is led by the software firm PTV Group and, together with a consultancy and scientific partners from the Karlsruhe Institute of Technology, they develop an ICT concept for operating mobility services that integrate electric and conventional public transport and carsharing services. Both a carsharing operator and a public transport company are associated partners in the project. However, the project as a whole is less practice-oriented than the showcase region projects. The aim is to develop a concept that can eventually be applied by mobility service providers, but the project itself focuses on developing a conceptual prototype. The scientific approach is however quite comprehensive, using transport planning models and regional real data as the basis for potential business models for intermodal mobility services. These include a 'one-stop-shop' operating and management concept, including an integrated billing system, integrated fleet management of different operators and central information services for users. The basic rationale of this project is to utilize emerging trends in the field of mobility, in order to foster the development of e-mobility. It is argued that public transport mobility services or flexible sharing options are gaining importance, while car ownership is not as central anymore. As a reaction to this perceived societal trend, the project "I-eMM" aims at fostering intermodal mobility services and integrating electric vehicles in these innovative concepts (KIT, 2013, p. 1 f.).

Another project with a focus on ICT-applications for e-mobility is the project **"Future Fleet"**, which has been funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU, re-structured in 2014 as Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)) in the context of its own ministerial R&D program for e-mobility "Smart Grids, Renewable Energies and E-mobility". Electric cars have been integrated in the company fleet of SAP AG, which has also taken the lead in this project. In a cooperation with the regional energy company MVV Energie AG, the aim has been to build up the charging infrastructure at the SAP headquarters and to develop a software-solution for fleet and charging management. An important aspect of the project has also been that the vehicles are powered by renewable energies. Three scientific partners were also involved, the Hochschule Mannheim, the Institute for Social-Ecological Research and the Öko-Institute, doing accompanying research on issues such as environmental benefits and user acceptance. The project was carried out over a three-year period and was finally completed in 2011 (Deffner et al., 2012, p. 10; SAP AG, 2012, p. 5). The basic rationale for the project "Future Fleet" for SAP is the need to reduce CO_2-emissions in its company fleet and this may be achieved by introducing electric vehicles – with the additional potential for SAP to develop software solutions in the field of e-mobility: One important motivation for the project is the insight that e-mobility requires new forms of mobility and user behavior, and that therefore demonstration projects with active involvement of users are needed. Another aim was to show that software applications and intelligent management systems can be a solution to problems of limited range and long charging times of electric vehicles. It is argued that corporate fleets are an interesting field of application for e-mobility, because via fleet management systems the mobility needs of employees and distribution of charged vehicles can be coordinated. Thus, problems of privately owned and used electric vehicles – such as high costs, limited range and long charging times – are solved by an innovative use concept (SAP, 2012, p. 7).

Finally, one project has been selected that stands out with regard to focus and actor affiliation. The project **"Wohnen und Elektromobilität im Rosensteinviertel"** ("Living and e-mobility in the city quarter Rosenstein") is carried out by the housing company Siedlungswerk GmbH in the context of the showcase region. This project aims at developing an electric carsharing concept for an existing building project in Stuttgart's "Rosenstein"-Quarter. Based on an analysis of the mobility needs of future inhabitants of this housing project, a carsharing concept that can be integrated in the quarter's housing structure is being developed. An important focus is on an integrated on-site energy management, which includes opportunities for decentralized energy production, operating charging infrastructure and using electric vehicles as means of electricity storage. The basic aim of this project is to integrate 'housing' and 'mobility' via an integrated electric carsharing service as an important element in a comprehensive energy management concept (producing, storing and using electricity on-site) and as an opportunity to reduce the need for private car-ownership (e-mobil BW, 2013c). In this way the Rosenstein-project is at the same time one of the most system-innovative projects, including a comprehensive focus on renewable energies, mobility patterns and the role of the car in general, and one of the most unusual projects, because it is carried out by an actor that falls outside the typical range of automotive, energy or ICT affiliated actors.

These selected projects are small-scale examples of new forms of mobility evolving around the electric car. The respondents have been interviewed about these projects, the way that they have been developed and their role within the innovation system of Baden-Württemberg and its specific actor structure. The interviews thus provide more in-depth insights on how actors perceive developments of e-mobility, how they deal with it in a concrete setting and why. They can thus give hints on specific patterns and concrete forms of system adaptability (at this small scale).

The interviews have been analyzed along a number of categories that have been built based on the theoretical concepts of transformative capacity and system adaptability[20]. To gain insights on degrees of system adaptability, or elements that could play a role for wider system adaptability, the focus is on formal and informal rules that actors refer to and that shape their perceptions, as well as on economic and political resources, thus the power structure within which they perceive themselves to be acting. Since system adaptability is a relational category that can only be developed vis-à-vis a specific technology, thus in turn determining its actual transformative capacity, the categories for analyzing the interviews represent this interplay:

- Frames of reference in relation to e-mobility in general
    - How is 'e-mobility' defined?
    - What are motivations and goals of engaging in e-mobility projects?
    - What views are expressed on transformation processes and visions of the future?
    - Are tensions perceived to exist with regard to different goals of developing e-mobility (especially sustainability- vs. industry-related)?
- Changes in the technological profile of the socio-technical system
    - What are risks and chances of emerging e-mobility for the automotive industry?
    - What are risks and chances of emerging e-mobility for the energy sector?
    - What is the role of Information and Communication Technologies (ICT)?

[20] The questions guiding the semi-structured interviews have been developed based on these theoretical concepts as well and can be found in Appendix D.

- Drivers and barriers for e-mobility: Changes in established patterns
    - What is the role of business models for e-mobility?
    - What is the role of R&D and demonstration projects?
    - How are market dynamics perceived (supply- vs. demand-side mechanisms)?
    - What is the role of policy/politics?
    - What is the role of user behavior?
- New forms of cooperation for e-mobility
    - Does the emergence of e-mobility lead to new patterns of interaction?
    - How are patterns of cooperation and actor/power-structures in the innovation system of Baden-Württemberg perceived?
    - What is the role of the Regional Project Coordination Agency (PLS) as the central coordinating actor in the overall innovation system of Baden-Württemberg?
    - What conflicts are experienced or perceived to exist?
- New actors entering the field of e-mobility

4.4.3.4.1 Changing Frames of Reference: High Hopes for Future E-mobility based on Diverging Intentions and Problem Perceptions

How is 'e-mobility' defined?

When asked for their personal definitions, all of the respondents emphasized that the term 'e-mobility' includes not only the battery-electric vehicle, but rather a new concept of mobility in general that includes all kinds of electric propulsion systems (battery or fuel cell, including hybrid and plug-in hybrid versions) and vehicles (cars, busses, e-bikes and e-scooters)[21]. Some of the respondents explicitly included public transport and intermodality[22]. It was noted that the focus in current political discourses is primarily on the BEV[23] and that the role of public transport, where mobility is already in large parts 'electric', is often neglected[24]. While one of the respondents explained that the project focus on intermodality means "looking beyond the boundaries" of e-mobility[25], another respondent argued that this is "what e-mobility is actually about: thinking about completely new mobility chains, offering alternatives to customers on how to get from A to B"[26]. It is also a way to deal with the

[21] Interviews 1, 3, 4, 6
[22] Interviews 1, 2, 7, 8, 9, 10
[23] Interview 1
[24] Interviews 1, 8
[25] Interview 2
[26] Interview 7

shortcomings of BEVs and critique regarding their environmental performance: "it is not only about propulsion systems, that is where all the critical voices are correct, we have to integrate it in a larger system"[27].

In some of the interviews, ideas of e-mobility corresponded directly with a broader concept of sustainability, e.g. it was argued that since efficiency gains will not suffice for making transport more sustainable, issues such as fostering intermodality and carsharing need to be integrated in visions of e-mobility[28]. Some of the respondents expressed views of e-mobility as a holistic concept for urban mobility in livable cities[29]. Especially the interviewed representatives of the regional project coordination agency (PLS) see their role as facilitators of societal change and advocate e-mobility as a form of sustainable mobility[30]. It is seen as "the bridge towards sustainable mobility. It is slowly being realized that it is not a question of substituting a drive train but rather of how to integrate all the different elements"[31].

What views are expressed on transformation processes and visions of the future?

Consequently, visions of future mobility are revolving around ideas of more intelligent and networked mobility with a much smaller number of vehicles on the roads than today[32]. Positive hopes for the future of mobility are voiced: "imagine a city where we have dealt with all this and where we have an electrified transport system – it would be completely different, much quieter and with better air quality"[33]. New use patterns where people use a combination of transport means in mobility chains that can be organized via ICT and smartphones are perceived to be not very far away[34]. It is observed that "intermodal behavior" is becoming more and more common, that especially younger people use carsharing[35] and that overall "our society is changing constantly, sometimes rapidly without us realizing it. Who would have believed 10 years ago that the cross-linking of information devices or concepts like carsharing or multimodality would face such incredible growth rates"[36]. There seems to be the general perception of a change process being underway, which is somehow fuzzy and happens almost unnoticed: "People will at some point wonder where the BEVs in their garages have come

[27] Interview 9
[28] Interview 10
[29] Interviews 1, 5
[30] Interview 2
[31] Interview 4
[32] Interviews 2, 8
[33] Interview 5
[34] Interview 3
[35] Interviews 3, 6, 8
[36] Interview 6

from all of a sudden and what has happened to their ICE cars. It will be a slow and almost unnoticed process that we are now beginning to experience"[37].

At the same time, the development of e-mobility is perceived in terms of "transformation"[38], "societal change"[39] and questions of changing dominant mind sets, habits and thought patterns[40]. There are different perspectives on what this societal transformation includes, but all of them revolve around the conventional car, its image and role in everyday life. It is, for instance, argued that people are not ready to use or purchase BEVs, because they are not "real" cars, which, for instance, do not even sound like real cars[41]. Similarly, part of the explanation of the German automotive industry's success is believed to be due to the fact that people are emotional about the cars they produce and that this has an impact on quality. Such an emotional quality needs to develop around BEVs as well, because "if we as a society do not accept these vehicles as a part of future mobility, we will not be able to sell them elsewhere, because then they will not have the same product quality. (…) We as a society have to 'live' these products, if we still want to have this industry in the future"[42]. Structural change is perceived to be an important element also because e-mobility will only lead to ecological benefits when it is developed in intermodal transport and carsharing concepts, the success of which depends on whether the pattern of private car ownership remains dominant. Owning a car or not is a fundamental individual decision and it is a decisive one, because once an individual owns a car, it is used for most journeys, in order to be economical. Therefore, the success of alternative forms of e-mobility hinges on whether or not such a radical change in dominant use patterns is feasible[43]. Similarly, in the field of housing in the city of Stuttgart, there is not only a legal obligation but also a common understanding that an apartment is sold or rented together with a parking space for the car[44]. In some interviews, 'society' in general is being blamed for hampering the transformation[45]. It is for instance argued that there have been many successful R&D projects, but now the market does not follow developments quickly enough[46].

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[37] Interview 2
[38] Interview 10
[39] Interview 2
[40] Interview 10
[41] Interview 2
[42] Interview 2
[43] Interview 3
[44] Interview 5
[45] Interview 2
[46] Interview 6

Apart from these concrete aspects that hamper radical change, some more general remarks about designing or fostering a transformation and the way that society as a whole deals with such processes have been made. One impression is that the transformation process is not well-guided politically. A quantitative goal has been defined of having one million electric vehicles on the road by 2020 and R&D funding has been allocated, in order to reach this goal – however what is perceived to be lacking is a conceptual approach for achieving this goal, creativity in designing funding programs and a clear political strategy that amounts to more than a "hype" phase[47]. It is acknowledged that "a master plan is not feasible", but that nonetheless "we do not have any idea whatsoever of how the transition from a centralized to a decentralized energy and mobility system might work"[48]. Furthermore, it is criticized that (German) society is becoming increasingly risk-averse[49] and loses itself in debates about whether e-mobility is useful at all or whose fault it is that the transformation does not run smoothly[50]. The overall mentality is perceived to be hesitant and overly critical, because "when you establish a new system, everything has to work perfectly from day one"[51].

At the same time and in contrast to the system-innovative visions of future sustainable e-mobility, it can be shown that problem perceptions of developing e-mobility remain within the limits of current regimes. Despite the futuristic visions of future e-mobility, when asked for central barriers, most of the interviewed actors named problems such as limited range, high prices, long charging times and lacking infrastructure for BEVs[52]. These problems are particularly relevant when the diffusion of BEVs as a perfect substitute for ICE cars is the goal, thus it can be argued that while visions of the future are based on radically different forms of mobility, the current system determines problem perceptions. Focusing on problems in the light of the current system may limit visions, not of the future, but of the transformation process leading towards this alternative future and it may lead to problem-solving strategies that do not address the truly relevant challenges.

Nonetheless, the respondents were overall optimistic that e-mobility will eventually turn out to be a successful alternative and that transformation challenges can be met: "The problems that existed when the conventional car was introduced 100 years ago are not so

[47] Interview 1
[48] Interview 9
[49] For a discussion of entrepreneurial culture and public perceptions and images of „the entrepreneur" in Germany, see Braukmann et al. (2010).
[50] Interviews 1, 2
[51] Interview 8
[52] Interviews 10, 7, 5, 15

different from the problems today: there were no roads and not enough standardization, but the people still somehow managed to overcome these barriers"[53]. Furthermore, impressions are that even OEMs have begun to take the challenge seriously and see that new forms of mobility, as shown by car2go for the case of carsharing, can be successful[54]. Similarly, for the case of city planning, it is expected that the development of e-mobility can have a push-effect for creating more livable cities[55]. Apart from these positive expectations of eventual benefits, the respondents were more skeptical with regard to the pace of the transformation process: "I do see the potential, but to me things are not moving fast enough. Progress has slowed down over the last one or two years, there were lots of discussions, but little practical implementation. We can see it, the National Platform for Electric Mobility and their goal of having one million electric vehicles on the road – we are far away from that"[56]. However, even if "maybe it does take that long, 10 years, until business models are working"[57], it seems reasonable enough that "we have to be persistent and that e-mobility will definitely establish itself"[58]. The process of transformation is expected to be step-wise and resulting in a mix of different vehicles and technologies in different fields of application – rather than a radical break from the old system to a new completely electrified system[59].

Are tensions perceived to exist with regard to different goals of developing e-mobility (especially sustainability- vs. industry-related)?

When asked about whether conflicts exist between industry-related and environmental goals of developing e-mobility, assessments differed markedly, or, in some cases, such considerations seemed to never even have occurred to the respondents before. Some of them seemed to be ambivalent with regard to this issue: "This is hard to answer. There are different interests (…), but I think both goals lead in the same direction"[60]. Another respondent reported that at events promoting e-mobility projects, people want to know, for instance, where the electricity for powering the employed BEVs comes from and whether it is produced from renewable sources. Consequently, in the different projects "one tries to do it right and in

[53] Interview 4
[54] Interview 1
[55] Interview 5
[56] Interview 10
[57] Interview 6
[58] Interview 6
[59] Interviews 2, 5
[60] Interview 8

a sustainable way"[61]. However, the same respondent also admits: "Well, I do not know whether one can say that there is a real debate about these issues"[62].

Others see a clear "win-win" situation, for instance arguing that e-mobility is primarily developed for Asian markets, thus promising economic benefits as well as sustainability benefits of e-mobility for growing mega-cities[63]. It is emphasized that the showcase region is obviously a policy instrument fostering industrial R&D, while at the same time the largest project of the LivingLab BW^{e} mobil is Stuttgart Services, an intermodality project where "the car itself is not the central issue, it rather is a move away from the car, or it is at least of secondary interest"[64]. There is an awareness for critical ecological issues, for instance with regard to production processes and battery recycling, which need to be considered in this respect[65]. Another critical aspect is raised when one of the respondents suspects that the city of Hamburg has not been chosen as a showcase region, because there was no participation of an OEM[66], which indicates that political goals are focused around industry policy.

From the point of view of private companies involved in e-mobility projects, there are concrete conflicts or tensions between environmental and economic goals involved in developing e-mobility: "In our company, we have to deal with this conflict every time we start a new project. What can we do for the environment and how can we do it in an economically feasible way, because in the end we have to pay our employees and make a profit"[67]. The aim is to harmonize economic and environmental goals, asking "what is the business model, how does it become economically feasible for a company? Of course, not just in terms of Euros, but also in terms of our CO_2-balance, we will consider this, because in that area e-mobility will indeed produce benefits"[68].

Looking at the region of Baden-Württemberg as a whole, the question of integrating economic and environmental goals is of particular relevance: "Everything we do in Baden-Württemberg includes two aspects: on the one hand, the environment and sustainability, yes, but at the same time we have to focus on keeping our industrial basis. This is what is different when compared to Berlin for example: Berlin is trying to build something up, we already have

[61] Interview 4
[62] Interview 4
[63] Interview 2
[64] Interview 4
[65] Interview 10
[66] Interview 1
[67] Interview 5
[68] Interview 10

it and we try to keep it and complement it with new elements"[69]. Again, there is a tendency to 'blame' society as a whole for hampering, or at least not explicitly requiring, efforts in the direction of sustainability transformations. For instance, in the case of carsharing services or ecological housing projects, experiences are that customers are not willing to pay more, if the carsharing service is done with electric vehicles or if mobility services are included in housing projects[70].

What are motivations and goals of engaging in e-mobility projects?

Similarly, motivations for individual projects are rarely grounded in explicit concerns about sustainable mobility. Sustainability challenges are mentioned as the basic rationale for a society to engage in developing e-mobility at all, primarily for reasons of increasing oil scarcity, which will have negative effects on the automotive industry and the energy sector due to increasing oil prices[71]. Eventually this will also lead to increasing mobility costs for consumers, implying threats of social injustice[72]. E-mobility as a way to deal with CO_2-emissions and climate change is rarely referred to, one respondent explains that he even avoids climate-related arguments in favor of e-mobility because global warming is a contested issue in public discourse[73]. Economic arguments seem to take center stage instead, especially against the background of the importance of the automotive industry in Baden-Württemberg. There is a shared understanding that e-mobility will eventually play a major role in Asian mega-cities (including all kinds of vehicles and intermodal transport concepts) and that as a car exporting country Germany has to be able to serve these markets[74].

Apart from these more general concerns about global mega trends, the actual starting point for developing and initiating ideas for e-mobility projects was the "hype" around e-mobility that is perceived to have reached a peak around 2007 and 2008 – while it is not really clear what has caused this hype phase: "Nobody really knows why this issue sky-rocketed in such a way during 2007/2008 with everybody suddenly saying, yes, this could be the future"[75]. This hype was mentioned by most respondents as a phase where e-mobility as an issue suddenly surfaced and even though there was awareness of it before, this was the point

[69] Interview 4
[70] Interviews 3, 5
[71] Interviews 2, 6
[72] Interview 2
[73] Interview 2
[74] Interviews 2, 3, 5, 8, 9
[75] Interview 9

where actors began to consider it more seriously[76]. The economic crisis of this phase that especially hit the German automotive industry is mentioned as one factor explaining the emergence of that hype, because economic pressure triggered openness and willingness to consider alternatives and new ideas for the future of the automotive industry[77]. In some cases, there was direct political pressure to act, as reported by one respondent that the starting point for e-mobility initiatives in Stuttgart was "a hint given by a regional politician, who himself had received information from the federal government in Berlin, that there would be a call for applications for model regions for electric mobility and that it would be appreciated if Stuttgart applied"[78]. The political initiatives, such as the founding of the National Platform Electric Mobility (NPE), were also received favorably, for instance, by carsharing services because it increased acceptability for e-mobility by cities and thus opportunities to get access to free parking space or other types of support[79]. For many, the financial means made available through the Economic Stimulus Package II tipped the scales in favor of actually engaging in concrete R&D projects for e-mobility[80].

This availability of political support and program funding is seized as an opportunity to develop a number of specific interests: "Many issues are currently dealt with under the heading of e-mobility, such as ICT, car-to-car communication, car-to-infrastructure and intermodality. One could do all this with ICE vehicles just as well. E-mobility is used as a kind of 'surfboard' for developing these issues"[81]. One example is the development of carsharing concepts that have already existed for quite a while but have now become feasible against the background of the economic crisis and the opportunities emerging in demonstration projects, such as free parking and publicly supported infrastructure build-up[82]. Mobility service providers and ICT companies active in this field see a chance to advocate intermodality and develop specific services offering mobility chains[83], because "the concept of e-mobility makes it possible to again take up issues that would otherwise have been dropped and forgotten about"[84]. This even leads to situations where "it can be a balancing act

[76] Interviews 1, 4, 10
[77] Interview 3
[78] Interview 4
[79] Interview 3
[80] Interview 6
[81] Interview 2
[82] Interview 3
[83] Interview 8
[84] Interview 7

to justify to the funding agencies that what we are doing is an e-mobility project"[85]. Some actors strategically position themselves in the e-mobility debate, in order to "find ways of slowly changing our automobile society. You use every opportunity you get (…) because it will not be possible to abolish the car, but we have to domesticate, intermodalize it"[86]. Another example from the field of public transport is that fostering intermodality and developing e-tickets and smartphone applications has already been an issue for quite some time. Now, public funding for e-mobility provides a window of opportunity to receive not only financial support but also a network of potential cooperation partners[87].

This latter aspect is a central motivation for participating in e-mobility projects: building up networks, being informed about the activities of others and, last but not least, publicity, which is relevant especially for OEMs[88].

4.4.3.4.2 Changes in the Technological Profile of the Socio-technical System: Risk and Uncertainty in a Transitional Phase

Building up networks and exchange of information is highly valued because there is a general awareness of emerging global trends and developments that may threaten established industry structures. Addressing economic and environmental challenges by fostering e-mobility implies fundamental changes in the technological profile of the automotive industry and also the energy sector. Giving center stage to the electric vehicle as the central technological artifact potentially leads to manifold consequences of sector profiles, e.g. with regard to technological innovations and R&D, production processes, overall sector structures and business models.

Since most of the interviewed actors do not represent automotive or energy companies and only some of them ICT companies as a new central actor in this field, their statements do not represent the views or opinions of these industries themselves. Also, this has not been a central aspect in the interviews. Issues of industrial change induced by a potential transition to e-mobility have been discussed in more detail in chapter 4.3. However, the statements that have been made point to frames of reference with regard to the field in general and the (industrial) environment within which they perceive to act and how they deal with the overall situation. Furthermore, many of the respondents are involved in different settings of the

[85] Interview 1
[86] Interview 9
[87] Interviews 1, 8, 6, 7
[88] Interviews 2, 5, 6

overall innovation system (e.g. the advisory board of the Regional Project Coordination Agency, participation in events and meetings with industry actors) and thus can provide an insider perspective.

What are risks and chances of emerging e-mobility for the automotive industry?

In general, it is recognized that the automotive business is already highly complex and difficult with regard to numerous aspects, such as technologically complex products and production processes, a competitive market, sophisticated sales and after-sales structures. This alone makes it “difficult to re-define oneself within this industry”[89]. Considering the various accusations that OEMs are not seriously fostering a transition towards e-mobility, one respondent argues that “even if there were one million electric vehicles, this is roughly 2% of the total amount of cars [in Germany] and then they have to focus on those other 98% if they want to earn money, you cannot blame them for that”[90].

At the same time, OEMs are faced with harsh competitive pressure and thus invest in R&D in all possible fields, including e-mobility, because there is uncertainty with regard to future trends and they have to be prepared for any of the technological options, or combination of options, that may eventually become dominant[91]. Another perception is that OEMs are well aware of global trends towards intermodality and new use patterns among younger people living in cities. This is why “they are very active in doing R&D in these fields. Of course, the particular focus of their R&D activities is different, because it is predominantly on the vehicle”[92]. Furthermore, it is acknowledged that there is also public pressure for OEMs to actively deal with sustainability issues and this is a central motivation to engage in e-mobility projects: “If Daimler did not do anything in the field of sustainable mobility – no E-Smart, no Plug-Ins – then they would at some point be confronted by the public on this issue and asked why they don’t do anything. Why they don’t do anything at all. I mean, proportionally they actually don’t do anything, but at least it’s not nothing at all”[93]. OEMs are facing a dilemma situation, because “they want to be informed about what is going on, they are doing their research, but well, they naturally have an interest in selling their ICE cars as long as possible”[94]. The fact that vested interests are at stake is obvious to all

[89] Interview 4
[90] Interview 1
[91] Interview 4
[92] Interview 8
[93] Interview 2
[94] Interview 5

respondents – despite the explicitly expressed understanding for the economically difficult situation of OEMs.

At the same time, early signs for successful change are also emphasized by some respondents. One example is Daimler's car2go, which is on the way of becoming a global success, not necessarily as an electrified carsharing service at all locations, but as an important step towards new business models[95]. Similarly, the example of BMW's new electric model i3 is mentioned and the fact that this car is actively advertised by BMW as a potential element of intermodal mobility patterns, may indicate that BMW "has understood what the future trends in mobility are"[96].

What are risks and chances of emerging e-mobility for the energy sector?

Perceptions of the energy sector and of the role it could play in the process of establishing e-mobility not only as an alternative transport mode but also as an element of a decentralized, renewables-based energy system are even more pessimistic than is the case for the automotive sector. At the beginning of the e-mobility hype phase there were high hopes for new business models and one respondent had the impression that the large energy suppliers "in the beginning aggressively fought off smaller competitors because they wanted to occupy that emerging market"[97]. However, in the following it became obvious that there is no straight-forward business model fitting with existing sector structures[98] and consequently, the situation today is that energy suppliers are increasingly reluctant to get engaged in the field of e-mobility[99]. This tendency is reinforced by the overall more difficult situation of the energy sector due to the nuclear phase-out and the energy transition enforced by the German government[100].

Issues such as business models in a decentralized energy system and e-mobility as a new segment are dealt with in research or business innovation departments and "there are quite some people with innovative ideas, but they are not capable of transferring them into the core business"[101]. Some respondents also have the impression that in terms of R&D in these fields, energy companies have come relatively far already and have realized that "there are

[95] Interviews 1, 3
[96] Interview 8
[97] Interview 1
[98] Interviews 2, 4
[99] Interview 3
[100] Interviews 1, 2, 6
[101] Interview 9

different business models and the options are slowly being sorted out"[102]. The situation of these companies is described in terms of a "wait-and-see"-position, where further action depends on market developments and political framework conditions[103].

What is the role of Information and Communication Technologies (ICT)?

Information and Communication Technologies (ICT) are seen as important elements in developing e-mobility. Especially with regard to mobility services, such as carsharing, or intermodal transport concepts, ICT can function as a central enabler for otherwise "age-old ideas"[104]. IT-solutions and smartphone applications may be one of the key factors for "helping users to overcome the emotional obstacle of fearing range limitations, because they can use their smartphones to reserve a charging station and to see when their vehicle has been fully recharged"[105]. ICT technologies are generally seen as the decisive element necessary for establishing user-friendly and well-functioning integrated mobility services[106]. In turn, the increasingly dominant mobility patterns among younger people in cities to combine different means of transport as well as the various e-mobility initiatives provide incentives for ICT companies to further develop IT-solutions: "Intermodal behavior is only possible because there is ICT. I mean, these things are mutually dependent, supply and demand, it is all interrelated and especially now that e-mobility is pushed to the market via sharing-concepts. They need ICT and this is then again a driver for ICT companies"[107].

4.4.3.4.3 Drivers and Barriers for E-mobility: The Transformative Capacity of Public Funding for E-mobility

Business models for e-mobility

Business models are recognized as an important driver for establishing e-mobility. New business models are being explored in the LivingLab BW^e mobil; however, not so much triggered by the electric vehicle as a new technological option as such, but rather due to the availability of funding and political pressure, which are seized as an opportunity to embed old ideas of intermodal transport and carsharing in this new context of e-mobility.

[102] Interview 10
[103] Interviews 4, 6
[104] Interview 3
[105] Interview 10
[106] Interviews 1, 8
[107] Interview 8

An example is the lead project of the LivingLab BW^e mobil, Stuttgart Services, which focuses on establishing a new business model for intermodal mobility services. A “Stuttgart Service Card” is offered, which provides access to public transport and car2go in Stuttgart (as well as a number of other city services, e.g. access to public libraries or a payback system at local shops). The central motivation of this project is to establish an e-ticketing service, which is common in many Asian cities and in London, for instance. By including a carsharing service on this Service Card, the operating public transport company aims at retaining younger customers, who at some point generally stop using public transport as their predominant means of transport and instead buy a car[108]. The difference to other typical demonstration projects, where intermodal mobility services are being explored with a limited number of test users is that this system is from the beginning open to all subscription customers of the public transport system in Stuttgart: “The technology is available and everybody can participate. There are no restrictions, this is a completely different approach”[109].

This business model is not ‘triggered’ by the emergence of electric vehicles, neither is it dependent on whether the carsharing service is operated with electric vehicles. Rather, the business model is funded as a driver for e-mobility, because e-mobility “must be easy and if it is easy for the customer then such projects will quickly become a success, without the need to preach sustainability to the people”[110]. The basic rationale is to develop a system, which has a noticeably positive effect on everyday mobility, because if this is successful “new business models will emerge and they will be financially independent and self-supporting”[111].

The same rationale is the basis of fleet projects, which address business customers rather than individuals. For instance, there is a fleet project where a full-service system is developed for business customers who want to switch to an electrified company fleet[112]. This is as well rather perceived in terms of a potential driver for e-mobility and not so much as something that becomes attractive because of e-mobility: “Fleets is an issue where we say, this is what gets e-mobility running, because you can quickly achieve scale effects, purchase is not as expensive and the utilization of vehicles is more efficient”[113].

[108] Interview 1
[109] Interview 1
[110] Interview 2
[111] Interview 4
[112] Interview 2
[113] Interview 2

A new business model is also envisaged in the housing project "Rosensteinviertel" where it is planned to build new housing units and offer a carsharing service for residents. The basic idea is that the carsharing service replaces the need for a second car, especially for families with children, which would save the housing company costs for providing parking space and the residents' costs of car ownership[114]. This is another example of an innovative business model for more sustainable mobility patterns, which is however not necessarily linked with e-mobility and might be operated with conventional cars just as well. The occasion to explore this business model in the first place has, however, emerged in the context and due to initiatives aimed at fostering e-mobility.

R&D and demonstration projects

Consequently, the public funding programs are perceived to be important as a 'trigger' for something to happen at all[115]. As has been shown for the case of new business models, concrete projects have been initiated, because there is a larger e-mobility initiative and project funding: "It is good to have these projects, because they serve as a trigger and now there is a lot going on. People join forces and develop projects, which they probably would not have otherwise, because they do get some money from the government[116]. Because the business models, that they are going to explore, are not really clear, they don't know, if they will work out in the end"[117].

Some projects would not have been carried out at all, if it had not been for the overall showcase region and the respective support: "The starting point really was the showcase region, without it I don't think we would have done it"[118]. Even for large companies the availability of public funding can be important: "People don't understand, why companies that make billions of profit still have to rely on public funding. It is because groups of people within these companies do not get a budget for their in-house ideas, they get it only, if they can claim that they have external money, even if it is not much"[119].

Apart from an initiating effect, it is also mentioned that the availability of funding over longer periods of time is important to ensure continuity, bridging the often long phase where new technologies or business models are not yet profitable on their own, and in order to avoid

[114] Interview 5
[115] Interviews 7, 8
[116] Interviews 3, 7
[117] Interview 3
[118] Interview 5
[119] Interview 9

that they are dropped when significant investments have already been made[120]. The availability of public funding is also important to ensure a certain level of commitment. Without concrete projects, it is difficult to get actors to open up to a new issue and really make an effort[121]. If these projects are publicly funded, the commitment of the participating actors is further increased and they have assumed a contractual obligation[122].

Other important functions of project funding, which makes it an important driver for developing e-mobility, include building networks and offering orientation. A major achievement is that in the course of the funding program, networks and structures have been built that form a basis of trust where actors can work together or simply exchange views even in a situation with conflicts and uncertainty[123]. The fact that demonstration projects are funded where things are tried out in practice has a positive effect on building up trust and long-term benefits, because partners have actually worked together[124]. Demonstration projects are also seen as a way of providing orientation where developments of e-mobility might end up, depending on the specific focus of funding programs and selection criteria[125]. This is what the concept of the "lead market" is about, which "aims at showing how it works. This is actually the basic idea of the National Platform Electric Mobility, to demonstrate how e-mobility can be integrated in normal transport systems"[126].

This leads to another important function of the demonstration projects, which is creating visibility and public attention for e-mobility. It is highly appreciated by all of the respondents that people now have a chance to really experience different kinds of electric vehicles and mobility patterns[127], that concepts developed in demonstration projects are continued to be applied by companies[128] and that efforts undertaken to foster e-mobility are visible in everyday life, e.g. by having increasing numbers of electric vehicles on the road[129]. It has been emphasized that a positive aspect of the demonstration projects is their focus on practical applications, because "we had something like a living laboratory with real tasks and real people"[130] and "this shows that these things actually work"[131]. One of the respondents

[120] Interview 6
[121] Interview 4
[122] Interview 4
[123] Interviews 2, 4
[124] Interview 6
[125] Interview 2
[126] Interview 2
[127] Interview 8
[128] Interview 10
[129] Interview 1
[130] Interview 6

even remarked that creating visibility is a key requirement for all showcase projects, and that the showcase region is overall “unfortunately an R&D project”[132].

Besides the general acknowledgement that the existence of the funding program has positive effects, various aspects of it have also been criticized. A major criticism of many respondents relates to the complicated administrative requirements by the governmental funding agencies. The formal requirements of the application process present a fundamental barrier especially for smaller organizations with limited personnel and time resources or those that lack experience with these processes in general[133]. While dealing with the formalities of project administration “one may lose the focus on why and for whom you do all this”[134]. Another difficult aspect is the limited funding period for individual projects, because “when the laboratory was finally up and running, many new ideas had been developed, which could have been tested, but the project had come to an end”[135]. With regard to the overall structure of governmental funding and science policy, it has been argued that a better coordination of individual funding programs and projects is needed[136]. Even though a wide variety of sometimes similar projects can be beneficial[137], it is considered problematic that funding is generally allocated to very distinct projects or topics, such as one specific technology or one specific field of mobility, such as fostering public transport[138]. This can be related to the fact that “the German science system is – despite all wishes and aspirations – completely disciplinary in nature”, which is problematic in so far as “the problems we are facing are simply not of a disciplinary nature”[139]. Consequently, what is perceived to be lacking is “creative space”[140].

Nonetheless, the experience with the two major demonstration projects in Baden-Württemberg, the model region Stuttgart and the LivingLab BW[e] mobile, is positive so far. It is acknowledged that a lot has been learned. While the model region is in retrospect perceived as what can be called “initial steps”[141] with a focus on vehicle technology[142] and projects that

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[131] Interview 4
[132] Interview 2
[133] Interviews 5, 9
[134] Interview 4
[135] Interview 6
[136] Interview 7
[137] Interview 9
[138] Interview 7
[139] Interview 9
[140] Interviews 1, 9
[141] Interview 2
[142] Interview 4

seemed to have been more or less improvised[143], the showcase region now presents a more comprehensive focus on integrated mobility concepts[144].

Market dynamics and user behavior

The emergence of e-mobility as an allegedly new technology or as a political issue does not by itself trigger new market dynamics. These are currently not changing and are rather perceived as a major barrier for the diffusion of BEVs. Some actors, especially in the field of energy and ICT seem to wait and see at this moment, because they have developed concepts, tried them out in pilot projects and now wait for wider change to materialize before they continue their efforts[145].

A central issue occurring throughout the interviews is the question whether the problem of market breakthrough for BEVs is rather a demand- or supply-side problem. The classic chicken-and-egg problem is mentioned: “Without considerable EVs in the market, public infrastructure can never be profitable”[146]. Similarly, a recurring argument is that BEVs are not produced and sold, because there simply is no demand for them. The lacking demand is seen to be problematic, because “it is a fact that in Germany, the industry produces what is demanded”[147].

However, the perception of a majority of the respondents rather is one of a supply-side problem and that it is now up to the OEMs to bring vehicles to the market[148]. It is, for instance, argued that “one cannot expect people to change their behavior, when there is no alternative offer” and that therefore “one has to offer products first and this will then generate demand”[149]. This view may emerge from concrete problems experienced in the context of demonstration projects, because a major obstacle for carrying out projects at all, especially in the context of the model region starting in 2009, was that there simply were no electric vehicles available[150].

With regard to user behavior this is also recognized as a problem, because “many people just don’t know what e-mobility feels like”[151]. Overall, some trends in user behavior,

143 Interview 5
144 Interview 3
145 Interviews 6, 10
146 Interview 6
147 Interview 2
148 Interview 6
149 Interview 1.
150 Interviews 6, 10
151 Interview 8

such as decreasing rates of car ownership among younger people in cities, or more and more people wanting to move to the cities and thus an increasing interest in "livable" cities, are seen as likely push factors for e-mobility[152].

Policy and politics

Apart from market dynamics, the need for political regulation is emphasized, in order to enable a transition towards sustainable e-mobility and it is broadly criticized that "the federal government failed to create suitable framework conditions"[153] with regard to rather trivial aspects, such as regulating parking and charging for BEVs in cities, or more fundamental issues of, for instance, reconsidering what public functions are in the field of transport. When considering e-mobility as an alternative transport concept for sustainable cities, then public functions would probably have to include more than building roads and offering public transport[154]. A variety of necessary policies and distinct political instruments are mentioned, such as road access restrictions through regulation or constructional measures, CO_2-pricing, fleet consumption regulations, tax regulations etc.[155].

At the same time, political pressure has played an important role in fostering e-mobility in the first place. In Baden-Württemberg, there has been very direct political pressure, with the former Prime Minister Oettinger requesting the OEMs to act, because "if Baden-Württemberg as an industrial location and automotive region misses out on the issue of e-mobility, we are going to have a problem"[156]. Apart from that, it has already been shown that the public funding programs have been of major importance, but "we cannot keep using R&D funding in this way, new framework conditions have to be created"[157]. Thus, new policies are required to accommodate a transition around e-mobility. However, existing policies and political initiatives, especially R&D policy, indicate the gap between aspirations for e-mobility and the persistent nature of established routines.

4.4.3.4.4 New Forms of Cooperation for E-mobility: The Important Role of a Neutral Coordination Agency in a Situation of Limited Commitment and Avoided Conflicts

New patterns of interaction

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[152] Interviews 4, 5
[153] Interview 4
[154] Interviews 1, 4
[155] Interviews 2, 3, 4, 9
[156] Interview 2
[157] Interview 9

It has been understood that e-mobility needs to be seen as a systemic challenge of organizing mobility differently in the future and that this requires new forms of cooperation. What is needed is cooperation across the automotive industry, the energy sector and the field of ICT[158]. There seems to be an overall willingness to work together, to "not see each other as competitors, but focus on the common challenge"[159] and the potential for new ideas to emerge from cooperation is recognized[160].

However, despite this general attitude towards cooperation, it can be observed that specific actors are reluctant to work together directly in projects. For instance, cooperation between energy suppliers and OEMs or public transport companies has been particularly difficult in concrete projects in Baden-Württemberg and in general rarely takes place at all[161], because "there are no routines for inter-sectoral cooperation"[162]. Projects where energy and ICT companies or public transport and ICT companies work together are more common and in these projects automotive partners seem to be deliberately excluded. Reasons for this are that "it was extremely difficult to bring an OEM onboard within the project's high pace"[163] or because of concerns that the focus of a project might get lost[164]. There are concerns that if an automotive actor is included, this industry's perspective would be dominating[165]. Cooperation between public transport companies and OEMs are also difficult, because their relationship is rather hostile and especially from the point of view of public transport, the automotive industry is seen as the main competitor[166]. OEMs are also generally reluctant to enter direct cooperation and often rather participate as so-called 'associated partners', because the amount of public funding they could receive as full partners is no sufficient compensation for the business secrets they would have to reveal[167].

There are other types of cooperation that emerge more smoothly. For instance, the housing company engaged in the showcase project 'Rosensteinviertel' plans on cooperating with carsharing services: "There will be synergies, because car2go or Stadtmobil or Flinkster have the know-how of managing a fleet. And we have something that they don't have but

[158] Interviews 1, 6, 9
[159] Interview 1
[160] Interview 6
[161] Interviews 2, 7
[162] Interview 9
[163] Interview 6
[164] Interview 5
[165] Interview 6
[166] Interview 1
[167] Interviews 1, 5

what they are looking for: property and parking spaces[168]. Similarly, projects where ICT and energy or ICT and mobility actors cooperate often work well, because there are synergies, every partner can focus on their individual business goals since the respective fields of business are clearly distinguishable[169].

The fact that there are rarely any projects where actors from all key sectors, i.e. automotive, public transport, energy and ICT, directly cooperate is not perceived to be problematic. It is argued that individual issues not addressed in one project are taken up in other projects and that even though not all actors cooperate directly in one project, the overall portfolio of projects is sufficient in this respect[170]. Even though the systemic challenge involved in developing e-mobility has been widely acknowledged, the involved actors each view the mobility system from their distinct perspectives. For instance, OEMs look at the system around the car, energy suppliers realize that their energy system is threatened and the public transport sector views its system as the already existing system of the future where the others will eventually have to fit in: "On the surface, everything is connected, but in fact everybody re-interprets the critical challenges in the light of their specific core business"[171]. There are no routines for inter-sectoral cooperation and for instance OEMs tend rather to buy in competences in the field of energy technology[172] while energy suppliers want to avoid being dominated by OEMs in a direct cooperation setting[173].

<u>Actor- / power-structures in the innovation system of Baden-Württemberg</u>

There seems to be a general interest in building networks and exchanging experiences – and especially in Baden-Württemberg it is highly appreciated that the Regional Project Coordination Agency manages well to organize this in a way that there is a dialogue between all actors at eye-level[174]. Nonetheless, the observation is that, similar to the federal level and the constellation within the National Platform Electric Mobility, the dominant actors are the large OEMs, automotive suppliers and energy companies. In Baden-Württemberg, the large Fraunhofer research institutes play an important role and, in contrast to the federal level,

[168] Interview 5
[169] Interviews 6, 10
[170] Interviews 6, 7, 8
[171] Interview 9
[172] Interview 9
[173] Interview 6
[174] Interview 5

public transport companies in Stuttgart have a relatively large influence[175]. The Länder government in Baden-Württemberg plays a particularly proactive role, for instance shown by founding and supporting the state agency e-mobil BW[176], which together with the Stuttgart Region Economic Development Corporation makes up the Regional Project Coordination Agency. Furthermore, the city of Stuttgart has also traditionally been supportive, due to persistent local problems of the city's transport system[177].

Overall, those involved in e-mobility issues in Baden-Württemberg still form a "small community"[178], there are only 120 partners involved in e-mobility projects, which is a relatively small number, compared to other model or showcase regions, and can be considered a "nice little family"[179]. It is widely acknowledged that the members of this community are closely interlinked in a well-functioning network, there are always events, where actors meet and exchange information, where new projects are formed and through which trust is built, some actors are part of the advisory board of the Regional Project Coordination Agency or other functions, where it is possible to get involved in the overall design of the innovation system[180]. These networks have been established even before e-mobility became the new hype, for instance, the Stuttgart Region Economic Development Corporation, which is now part of the Regional Project Coordination Agency, has long before been active in providing R&D support and other services for the regional industry. Due to this already existing basis of trust, it was relatively easy to get together actors and projects for the model and showcase regions even in situations of severe time constraints to hand in applications or fulfill other formal requirements[181]. In Baden-Württemberg "you have this kind of informality that you need to bring actors together, compared to the others in Germany, this works best in Stuttgart"[182].

The role of the Regional Project Coordination Agency (PLS)

Especially with regard to building and maintaining well-functioning networks, the Regional Project Coordination Agency (PLS) has been mentioned as the central actor fulfilling this function throughout the interviews. The PLS is complemented for their excellent work,

[175] Interviews 1, 6, 9
[176] Interviews 1, 6
[177] Interview 9
[178] Interview 2
[179] Interview 10
[180] Interviews 1, 3, 6
[181] Interview 4
[182] Interview 9

including the coordination of the various funding programs and individual projects, the provision of administrative support in these projects, creating public visibility for e-mobility, the organization of various types of networking events, lobbying for e-mobility at different political levels, sharing know-how and proactively connecting potential cooperation partners[183]. Some projects, e.g. the Rosensteinviertel housing project, would not have been developed, if they had not been initiated by the PLS in the first place and received further support regarding the search for suitable partners and dealing with formal requirements of project administration[184]. In their networking activities, the PLS puts special emphasis on supporting 'small' actors, such as SMEs, which play an important role in Baden-Württemberg's large (automotive) supply industry[185]. They are invited to events and given the opportunity to introduce themselves to a broad audience[186] and cooperation is fostered especially between these smaller players and large companies or universities and research institutes. The rationale for this focus is explained to be that "'Big' and 'big' already know each other or they are competitors. The big players and the universities also already know each other. It is important to bring the smaller actors together with the bigger ones and with the universities, in order to provide them with some orientation"[187].

An important characteristic of the PLS, apart from its relatively long-standing history, is the fact that it is a "neutral" agency and this further explains the level of trust it has gained among the involved actors. The PLS has been founded and it has received stable political support under successive governments and varying political constellations. The PLS is thus not perceived to be affiliated with a specific political party or political orientation[188]. The fact that the PLS is financed by the Länder-government of Baden-Württemberg is also a major difference when compared to other model or showcase regions. The other regional coordination agencies are usually sponsored by industry actors, which can be problematic because "then you don't have that neutrality anymore. If you don't have that neutrality anymore, you will not be able to integrate some partners, because they say 'no, not with them'. And, what is also crucial, you will not get all the information, if you are sponsored by

[183] Interviews 1, 2, 4, 5, 6, 8
[184] Interview 5
[185] Interview 2
[186] Interview 6
[187] Interview 4
[188] Interviews 2, 9

industry"[189]. Thus, this type of neutrality is vital for fostering cooperation by fulfilling functions of building trust in networks.

Based on this neutrality and well-respected position, the PLS is able to assume a role where they actively shape e-mobility as an issue and develop topics "as part of the job: discovering what is novel"[190]. This is done in a very informal and communicative way and in the case of the showcase region LivingLab BW^{e} mobile this has resulted in an approach of "covering a broad range of issues, ranging from vehicle development to city planning, transport planning, but also integration of e-mobility in residential quarters and buildings. And intermodality. In this way, we intentionally cover a wide range of issues[191].

Conflicts

Overall, it is recognized that e-mobility requires interlinkages and cooperation between automotive, energy, ICT and public transport partners. However, since this is challenging, the strategy seems to be one of splitting this issue up into different R&D fields where only those who do not have obvious conflicts of interest work together directly[192], e.g. an energy supplier with an ICT partner, or an OEM and an ICT partner, an energy supplier and a public transport company – rather than an OEM and an energy supplier or an OEM and a public transport company. However, this is not perceived to be a problem since the individual questions are being dealt with in different projects that are loosely connected via the overall showcase region structure[193]. More generally, most of the interviewed actors did not see any major conflicts between specific groups of actors or between industrial/economic and environmental goals of the funding program[194].

The general perception seems to be that real conflicts in the course of the emergence of new markets and business models will be solved once there is an actual market for e-mobility. Questions will emerge regarding customer retention in intermodal transport systems and the management of interfaces between different sectors in general – it is expected that this will be conflictual, because obviously then different interests will surface more clearly[195]. At this point, it is still a very early stage, too early for major conflicts[196]. Development of

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[189] Interview 2
[190] Interview 4
[191] Interview 4
[192] Interviews 6, 8
[193] Interview 6
[194] Interview 2
[195] Interviews 3, 6, 10
[196] Interview 2

technological solutions in pilot projects is already a step ahead and thus actors are in a relatively comfortable position of waiting for the market: “we feel well prepared for the start of the e-mobility market”[197].

What is most difficult during the current phase, and where conflicts or tensions are seen at most, is the coordination of all the involved actors and finding common ground with regard to project designs. It is emphasized that tensions during this early phase could have been resolved because of the shared basis of trust and close interlinkages in the network and the region as such[198]. In situations where conflicts of interest appeared, an effort was made, especially by the Regional Project Coordination Agency, to work them out together and further develop ideas[199] and the perception by involved actors is that in the end usually everybody is satisfied[200].

Finally, the impression is also that there is a shared sense of meaning: “I believe that there are no open questions of ‘should we do this at all?’ – this is not being questioned. Of course, there are different opinions, but with regard to the purpose of all this, we agree”[201]. So, in general, actors have the impression that current dynamics are on the right track towards economically feasible and sustainable forms of e-mobility[202]. Potential conflicts are thus postponed into the future by avoiding the more challenging cooperation projects and by focusing on further R&D.

4.4.3.4.5 New Actors Entering the Field of E-mobility: Potential for System Innovation through Fresh Perspectives and Resourceful ‘Outsiders’

According to theory, new actors, i.e. niche actors or actors from the fringes of a sector, can play an important role in transition processes, because they are not subject to established regime structures, or have in some way managed to create a protected space for developing regime-deviating behavior. In the case of the ‘system-innovative’ projects identified here, many of the involved actors are not typical niche actors, in the sense of being ‘small’ in terms of financial resources or number of people, but many of them are actors from outside the automobility regime, for instance, a housing company, ICT company or a public transport company. One of the respondents explains that one reason for this is that the hype around e-

[197] Interview 6
[198] Interviews 4, 6
[199] Interview 4
[200] Interview 8
[201] Interview 4
[202] Interview 6

mobility was so huge that “everybody who has a reputation in the region wanted to participate”[203], even if they had not dealt with mobility issues before. They approach the issue of e-mobility from their respective perspectives, such as sustainable and livable cities/housing, questions of energy system transitions, or new markets for ICT applications. These actors report that they were perceived to be “exotic” by other participants, for instance at conferences and events organized in the context of the showcase region, and that their projects are unusual and different from what established actors in this field do[204].

The case of public transport actors is specific because naturally one might assume that they play an important role in developing e-mobility, simply because public transport companies already offer electrified mobility to their customers. However, the overall debate is car-centered and public transport is often ignored[205]. At the same time, actors from the public transport sector are not always very proactive and cooperative, especially at the federal level: “When we had the National Platform Electric Mobility ready, public transport said, no thanks, we don’t need this, we already are electric”[206]. The overall attitude of the public transport sector has been that “we cannot be ignored anyways, eventually the others will come to us”[207]. In Stuttgart, the situation is different, because here the local public transport company has proven to be very proactive and the Stuttgart Services project has turned out as the leading project of the showcase region as a whole. This results from the existence of a strategic opportunity linking the public transport company’s own goals of acquiring new customer segments and developing e-ticketing schemes and the political will to develop and fund e-mobility projects with the Regional Project Coordination Agency trying to engage active partners[208]. E-mobility is thus perceived by some public transport actors as “a new technology that creates an impetus and we should try to utilize this”[209].

Similarly, the housing project emerged out of the funding program and due to the initiative taken by the Regional Project Coordination Agency of inviting the housing company to participate. As described earlier, this project also includes synergies between the housing company and the potential cooperation with carsharing operators. Obviously, this actor constellation does not result in a car-centered project, simply because the motivations and

[203] Interview 1
[204] Interviews 1, 5
[205] Interviews 1, 9
[206] Interview 9
[207] Interview 9
[208] Interview 1
[209] Interview 7

perspectives are not shaped by the (auto)mobility regime: “We were right in the middle of this topic already, with our ecological housing projects and questions of how to provide energy in our buildings. What is new is the focus on mobility and we are only slowly coming to grips with it”[210].

Such novel approaches and perspectives are seen as an important stepping stone towards a transition to e-mobility. These new actors have the advantage that they can operate from a different background, as the case of the housing company shows, and they often are not subject to the same pressures as OEMs or energy companies, as for instance public transport companies are publicly financed and do not operate in a comparably competitive setting[211]. Actively including such new actors, as for instance the Regional Project Coordination Agency is doing in Baden-Württemberg, is important because “if you want to save the world, you cannot expect help from those who own it”[212].

4.4.3.5 Discussion: Future Visions, Transformation and Cooperation in Developing E-mobility

In order to discuss the results of the case study of the innovation system for e-mobility in Baden-Württemberg, the results of the analysis of the interviews in the context of ‘system-innovative’ projects are in the following reflected upon against the background of the theoretical concepts of transformative capacity and system adaptability. Whether or not the potential for a transition to sustainable e-mobility can be realized – thus, whether the transformative capacity of the BEV will actually materialize – depends on the way that actors deal with this technology and adapt to it. System adaptability has been conceptualized in terms of changing rules and resources: What are interpretive schemes that actors draw upon in their communication and that shape social practices? What are the formal and informal norms that they refer to, in order to legitimize behavior and concrete action? With regard to resources, what are the power structures, in terms of economic and political power, within which they perceive to be acting?

The aim is to show how dominant rules and resources, as well as potential tensions emerging between specific rules or with regard to the allocation of resources, shape the way that e-mobility is perceived and dealt with in concrete situations and action. The specific

[210] Interview 5
[211] Interview 1
[212] Interview 4

interplay, between structure and agency as a determinant of system adaptability and then between this system and a technology's transformative capacity, provides insights on the potential for e-mobility developing as a system innovation, or more specifically, can help identify the key factors impeding a system innovation. With regard to dominant rules reflected in the interviews, a number of distinct interpretive schemes or frames of reference can be identified. They can be grouped in terms of specific discourses on future visions of e-mobility, on transformation, and on cooperation.

Discourse 1: Future visions of e-mobility

"E-mobility is the bridge towards sustainable mobility. It is slowly being realized that it is not a question of substituting a drive train, but rather of how to integrate all the different elements."[213]

First, the discourse on future visions evolves out of definitions of e-mobility as a futuristic form of mobility, which is characterized by new types of vehicles, new mobility patterns that are less car-centered, heavily rely on intermodal networks and are enabled by ICT applications. A new system is imagined and ideas regarding the basic components of this new system are shared by most actors. This new form of mobility is related to current problems in the transport sector, e.g. CO_2-emissions and congestion in urban areas, and emerging trends that are increasingly casting doubt on the stability of today's car-centered system of personal mobility, such as the growing number of younger people relying on intermodal mobility routines. Such a development towards new forms of mobility is perceived to be already underway and is not projected into a very distant future.

These visions of the future and the symbolic meaning attached to electric vehicles as an important element of new forms of mobility, maybe even the trigger or central technology around which this evolves, may at first glance be an indicator for changing frames of reference adopted with regard to e-mobility. Certainly, established rules and norms regarding personal mobility that are dominating the system today, e.g. privately owned ICE cars as the main transport mode, are questioned and changing in this future perspective. Thus, actors adapt to the 'new' technology of the electric vehicle in so far as they can picture a different system around this technology and expect change to, basically, be already waiting around the corner.

[213] Interview 4

Discourse 2: Transformation

"If you want to save the world, you cannot expect help from those who own it."[214]

However, there is a large discrepancy between the discourse on future visions and, second, the discourse on transformation. While the future vision seems relatively clear and a transformation process is expected to take place, the form that such a process takes and how it unfolds is much less obvious. Transformation is described in terms of a phenomenon that is hard to grasp and somehow fuzzy. The general perception is that change is already taking place, but that the transformation is itself almost unnoticed and that people are almost taken by surprise when they realize that things have already changed to some extent. Thus, while there is a radically different vision of the future, such "independent" thoughts or images cannot be observed for the process of transformation.

The difference between today's system and the imagined future is so radical that the bridge between these two systems is indeed hard to imagine in great detail. Additionally, there is a tendency to focus solely on today's system as the starting point for a transformation process, instead of adopting a backcasting approach, where the transformation process is imagined 'backwards' from the perspective of the desired future. Consequently, challenges and barriers for the transformation process are perceived to be problems of electric vehicles in the light of current regime structures, such as their limited range, high price and long charging times. These problems are particularly relevant in a situation where the aim is to have electric vehicles that can compete with conventional cars, and where they can do so on the terms of the established regime (privately-owned cars that are able to fulfill all kinds of mobility needs).

However, these are not the central problems on the way to a mobility system, as envisaged in visions of future e-mobility. This discrepancy points towards a potential threat, namely that aspirations are high and still it is not the truly relevant problems that are being addressed. For instance, if the vision of future mobility is characterized by intermodal mobility patterns, it would be less important to focus on improving battery technology to solve problems of high selling prices and limited range – the more important R&D field would be ICT solutions for connecting different means of transport and business models for carsharing fleets. The relatively high costs of electric vehicles are less decisive for a fleet

[214] Interview 4

operator, because if managed well, fleet cars have more optimal levels of use per day, and the limited range of an electric vehicle is compensated by the combination of different transport modes. Thus, overall, what is lacking is a profound understanding of "transformation" as such. Transformation, and related key words, such as societal change and systemic change, are used to describe the radical difference between the system today and the expected future, while ideas on the nature of actual change processes remains relatively vague.

In this context, it is also noteworthy, that conflicts are denied or postponed to the future. The proclaimed long-term goal is achieving a radically different mobility system and, in principle, this implies two major conflicts. On the one hand, simultaneously achieving sustainability benefits and economic benefits for the automotive industry does not necessarily go hand in hand, thus, there are two potentially conflicting goals, which have to be reconciled. While the vision of future e-mobility, as portrayed in the interviews, includes sustainability benefits (intermodal mobility and carsharing reducing the overall burden incurred by transport systems), it is not clear what the position of car manufacturers would be in this system. Their current business model, which is based on selling cars to private customers, is not feasible in such a scenario and if they cannot find a new business model, there is a substantial threat for this industry of overall decline. Achieving economic benefits for the automotive industry, without substantial changes to the current business model, would require the successful diffusion of electric vehicles, replacing conventional cars and opening new markets, especially in Asia. Such a trajectory would form around advancement in battery technology and vehicle technology, in order to reduce the price of BEVs and improve their range. Thus, achieving a situation where BEVs can compete with conventional cars on similar terms. Such a scenario would produce at best limited sustainability benefits, e.g. reduced local pollution and noise. Other problems would continue to persist or even become more urgent, for instance, urban congestion, the environmental burden caused by producing an increasing amount of vehicles and batteries, as well as possibly an even worse CO_2-balance depending on electricity sources for powering electric vehicles.

On the other hand, conflicts are likely to occur between different groups of actors. Even if e-mobility does not develop as a system innovation, but rather stays limited to the diffusion of electric vehicles, the energy sector will have to enter the field of mobility and new types of markets will emerge. Obviously, this will lead to conflicts, or at least open questions, as to how this new mobility market will be divided among established and new players. This situation can become even more aggravated when a more radical transformation takes place with more actors entering the field, such as ICT companies, the public transport sector and city planners.

Even though it is almost self-evident that these conflicts appear on the horizon, they are played down by the interviewed actors. Tensions between sustainability- and industry-related goals of developing e-mobility are either claimed to be non-existent, it is rather argued that e-mobility almost automatically produces a 'win-win' situation, or there is simply a lack of awareness for this issue. The problem is that in no way is it being recognized that the way that this question is dealt with has implications for concrete transformation processes and the varying directions of different transition pathways. Similarly, the ambivalence with regard to this question is related to the lack of a concept or guiding principles for dealing with the issue of transformation as such. Since there is high uncertainty with regard to the process leading towards a radically different future, there is also uncertainty with regard to the role of established players and ways of reconciling different interests in this process. The same is true for conflicts that might emerge between concrete groups of actors. It is often argued that it is still too early for real conflicts to emerge, that there may be tensions during later stages of market formation, but now, in an R&D and market preparation phase, there are no major issues of redefining roles or market positions and allocation of power.

It can thus be argued that the conflicts that are central to the basic problem of transformation are either postponed to a later stage, or they are ignored in combination with a conviction that they will eventually be solved – as pictured in a vision of the future where those struggles have already been overcome somehow. It can also be argued that this problem is replaced by focusing on other "simulated conflicts" that are shared by all involved actors and that can be addressed together, e.g. dealing with the negative attitude of society in general towards change and transformation, while the actual underlying problems of a more fundamental nature are in this way avoided.

The central question thus is, does a change in visions lead to system adaptability in terms of concrete action and daily routines? Does the new technology change not only expectations of the future, but also the view on the system today and the respective consequences for strategies and action – which would eventually lead towards that future? The findings with regard to the discourses on transformation and conflicts imply that this is not the case.

Discourse 3: Cooperation and multi-regime dynamics

"On the surface, everything is connected, but in fact everybody re-interprets the critical challenges in the light of their specific core business."[215]

Similar observations can be made when looking at, third, the discourse on cooperation and concrete cooperation patterns emerging in e-mobility development in Baden-Württemberg. It can be observed that a rhetoric of cooperation is a central element of the overall discourse on e-mobility. It is closely linked to the discourse on future visions, in so far as future e-mobility is portrayed as a completely different system based on new forms of interaction between different groups of actors. The challenge of developing e-mobility is a systemic one and no actor alone can address it in a meaningful way. Also, a great willingness to work together and find new forms of cooperation is articulated by all involved actors. At the same time, the decisive types of cooperation, for instance, in projects where car manufacturers, energy producers and ICT companies directly work together, do not take place to a substantial degree. The fact that this may be problematic is denied in a similar fashion as has been shown for the discourse on conflicts. It is basically argued that all relevant actor groups and sectors are represented in the innovation system and that even though there may not be direct cooperation between some of those actors, the relevant issues and research questions are split up and dealt with across the different projects.

4.4.3.5.1 Synthesis: Lacking Concepts for Dealing with System Innovation and Processes of Transformation in Practice

Overall, it can be argued that system adaptability is relatively low. A limited potential for structural change can be identified with regard to tensions emerging in dominant rules and guiding principles, especially with regard to the discourse on future visions of e-mobility. Based on Giddens' concept of agency and structure, the conditions for structural change are favorable when structures of signification and legitimation regarding appropriate behavior vary. This is the case with the articulated visions of future e-mobility, because, for instance, new forms of symbolic meaning are attached to future forms of mobility that deviate markedly from current cultural values related to car ownership. However, when looking at the discourses on transformation and cooperation, it can be shown that established rules are continually reproduced. Problem perceptions, behavioral routines and guiding principles for action taken today are shaped by established norms, grounded firmly in the current mobility

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regime. Especially with regard to resources, established economic and political power structures seem to persist. Even though there is a discourse on new forms of cooperation in the light of an alternative future, there is a clear lack of regime-transcending cooperation that might put vested interests at risk or threaten the established balance of power. The most prominent example is the almost non-existing cooperation between car manufacturers and energy providers, which would involve a redefinition of markets and business models, and possibly conflicts about who gets the largest slice of the cake.

Synthesis: Potential for system innovation?

"We must find ways of slowly changing our automobile society. (...) It will not be possible to abolish the car, but we have to domesticate (...) it."[216]

This discrepancy between hopeful visions of the future and reproducing dominant regime structures when dealing with transformation and cooperation can have different implications. It may characterize a situation early in a transition process, where change begins to occur in the rhetoric and visions of the future, but has not yet materialized in terms of guiding principles for action and everyday behavior, or in terms of a redistribution of political and economic power. A similar discursive phenomenon can be observed in other political controversies, or situations where societies have to deal with crisis and change, such as the current economic crisis in Europe and discourses on economic growth. However, another interpretation may point to a prospect that is much less promising. The observed discrepancy may also indicate a situation where powerful political actors and industry incumbents have found a way of dealing with an emerging crisis, without however intending to foster substantial change. As a form of strategic behavior, ideas of transformation and alternative visions of the future are embraced rhetorically, while concrete behavior remains safely within established regime boundaries. Eventually, in such a case, the transformation process is going to fail, but not out of unwillingness but, for instance, due to adverse circumstances or because some major barriers simply could not have been overcome. Even if the new ideas on an alternative future are sincere and the commitment to change is serious, dealing with desired, long-term transformation processes is still complex. The discrepancy between future visions and strategies employed today may basically also result from an inability to reconcile the radical difference between today's realities and ideas of the future, and much less so the

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process bridging the time in-between. The fundamental problem inherent in this discrepancy, be it strategically created or not, is that it creates a situation where it is likely that the ‘wrong’ challenges are addressed, depending on the respective vision of the future that should guide the transformation process.

Consequently, the transformative capacity of electric vehicles does not unfold and is, arguably, even proactively hampered. This becomes obvious when looking at what are perceived to be the major barriers for the development of e-mobility. Three dimensions emerge throughout the interviews – the situation of incumbent industries, the market in general, and political framework conditions – that are identified as problematic and where the impression is that there are obstacles that can hardly be overcome. However, one may also argue that these obstacles are either proactively created, or at least efforts are limited and remain within regime boundaries.

First, with regard to risks and chances of developing e-mobility for different sectors, it can be shown that especially car manufacturers and energy companies actively withdraw from the field. It is generally acknowledged that the automotive industry is experiencing a situation where they face various types of pressure, e.g. resulting from competition on global markets and new mobility trends in mega-cities, and basically cannot do much more than focus on R&D across a broad range of (technological) issues. Similarly, the energy sector is facing radical change, especially in the context of the German energy transition, and, apart from R&D projects, now has adopted a “wait and see” strategy with regard to the further development of e-mobility. Thus, the positive future visions of e-mobility do not translate to feasible strategies and development pathways for the automotive and the energy sector. This is not only true for these industry actors themselves, but also the interviewed actors, most of whom are not affiliated with these sectors. A relatively greater potential is seen for ICT companies, but it can be observed that especially the larger German ICT companies, such as IBM or SAP, also tend to act somewhat reluctantly and do not actively fill out the role of a key enabler for e-mobility, which they are generally perceived to be. In sum, perceptions of risks and chances are shaped by current regime structures, i.e. the established business models and R&D strategies of incumbents, and thus the prospects are perceived to be bleak or at least are expected to materialize only at some point in the future.

Second, “the market” is in a similar fashion identified as a problematic dimension hampering the potential of developing e-mobility. The narrative of the market for e-mobility being too slow or simply not ready is repeated again and again. Perspectives may differ, in so far as it is either the car manufacturers that have failed to produce BEVs and create that market, or it is simply the lack of demand for e-mobility that from the start hampers diffusion. This hopeless situation is continuously reproduced in discourses on e-mobility and "the market" is treated as an objective and exogenous factor, almost a law of nature, that independent of industry strategies and political commitment precludes substantial change. This is not to say that market dynamics do not play a role or can be neglected, but it is striking that this issue is not discussed more critically and that, for instance, the very positive visions of future mobility are not reflected against the background of current market dynamics.

Finally, the dimension of politics and concrete policy instruments, or rather the lack thereof, is the third major barrier for developing e-mobility identified by the interviewed actors. While it is generally acknowledged that political support for e-mobility has been a key factor for triggering developments in the first place, it is criticized that the chosen policy instruments are not adequate. Political efforts are basically limited to fostering R&D, instead of adapting general framework conditions, e.g. regarding transport emissions, land use planning or energy-related legislation. Similar to the cases of industry perspectives and market dynamics, established regime structures are reproduced, while actual efforts concentrate on preparing for a future that is expected to be different, without, however, a clear perspective on the transformation process itself and without attempting to produce substantial change right away. Still, the fact that R&D and science policy focus on fostering e-mobility has been an important starting point for developments. Nonetheless, it has become clear over the period of project funding that the employed policy instruments are not well-suited for fostering system innovations. The field of science policy is also characterized by specific regime structures, especially the disciplinary nature of the science system as a whole, which is reproduced by the respective funding strategies. Since e-mobility is a cross-cutting issue and problems in the field of transport can hardly be separated and dealt with along disciplinary lines, such a traditional academic approach will most likely not produce system-innovative results. Thus, politics can also be identified as a dimension with decisive relevance for developing e-mobility, but where despite good intensions and optimistic visions, actual development of a system innovation is in effect hampered.

4.4.4 Baden-Württemberg and the German Innovation System for E-mobility: A Captured Niche?

The aim of this section is to relate the findings of the interviews, reflecting the position of actors involved in system-innovative projects, to the overall case of Baden-Württemberg, its actor network structure (ch. 4.4.3.2) and dominant discourses (ch. 4.4.3.3) in the field of e-mobility. The different elements of the case study can in this way be re-embedded. To provide the complete picture, the findings from the case of Baden-Württemberg will also be reflected against the background of the German innovation system for e-mobility as a whole (ch. 4.4.2).

It has been shown in the preceding section that there is a discrepancy between, on the one hand, visions of a radical innovation unfolding in an evolved system of the future, and, on the other hand, the concrete approaches and strategies chosen, in order to get there, that are deeply rooted in the present. This discrepancy illustrates the basic problems inherent in such systemic transformation challenges. With regard to the concrete case of Baden-Württemberg, as a relatively small-scale innovation system attempting such a transformation, it can be argued that this is a typical case of a "top-down niche".

Political efforts at the federal level have been the starting point for action and a niche for developing e-mobility has been installed in a top-down manner. Including predominantly industry representatives in the process of establishing this niche and actively involving them in the process of determining the strategic direction and topical focus, for instance in the National Platform Electric Mobility (NPE), has created a situation where the niche is captured by regime incumbents. It has been shown that by launching the NPE and giving it a central role in overall strategy development, the German government has actively granted the established industrial actors the opportunity to dominate developments. The NPE is dominated by representatives of the automotive and the energy sector, while public transport actors are not represented at all and interests of civil society organizations and users in general remain underrepresented. This actor structure has shaped the strategic focus of the overall innovation system on e-mobility as a predominantly technological problem separated along sectoral and disciplinary lines. Furthermore, the fact that the problems dominating the debate are those that are most obvious when looking at the BEV in comparison to conventional cars (more expensive, smaller range, longer charging time) – rather than problems related to alternative forms of future mobility (transition to renewable energies, social aspects going beyond vehicle technology) – shows that the current (auto-)mobility regime remains the decisive frame of reference also with regard to visions of future mobility and the transformation process leading there.

The network analysis of Baden-Württemberg's innovation system shows that here the actor structure is similar to that of the NPE at the federal level. Industry representatives dominate the network, followed by universities and research institutes, and a relatively small number of public actors and regional associations. The representation of civil society is weak, except for a few associations that are not industrial in nature or installed by municipalities.

The network analysis also shows that only 4 actors in the network can be characterized as having a high level of influence. These are an OEM, a large energy supplier and two non-university research institutes.

Apart from the actor structure, the analysis of overarching discourses and dominant frames of reference in the context of e-mobility has shown that the topical focus on e-mobility as expressed in the position of the NPE or the government program for e-mobility is also reproduced similarly in Baden-Württemberg with some region-specific accents. While issues of climate change and resource scarcity are basic rationales for engaging in the field of e-mobility in the first place, the discourse focuses more explicitly on three major themes: technology, the regional economy and global markets, and industry convergence. Since Baden-Württemberg has an important automotive sector, e-mobility amounts to a project of technology-oriented structural change in its regional automotive industry. Industry actors are thus seen as important and competent partners in the endeavor of establishing e-mobility. A technology-neutral approach (with regard to specific drive technologies and vehicle concepts) is followed and the overall aim is defined in economic terms, i.e. preserving Baden-Württemberg as an important industrial site and remaining competitive on global markets. A systemic perspective on e-mobility also comes to play a role, because it is argued that some form of industry convergence, including the automotive, energy, and ICT sector, is needed to make e-mobility feasible in the long term. This is in line with the emphasis by the NPE and in the government program for e-mobility that new forms of cooperation will be needed on the way towards the lead market.

Overall, there seems to be a broad consensus that e-mobility is a growing field and will be successful in the long term. Consequently, there is a willingness to invest large sums in e-mobility, while the projects that are chosen as eligible for funding remain largely within 'regime limits', despite the rhetoric of systemic change and cross-sectoral cooperation. For instance, the field of battery technology, as part of the Technological Lighthouse projects on "Energy Systems and Energy Storage", is funded with 80 million € per year over a three-year period, thus more than the showcase region program as a whole. While the pressing technological challenges, e.g. in the field of battery and drive technology, are addressed in lighthouse projects aiming at the production of groundbreaking technological innovations, the challenges of actually creating the „lead market" are dealt with in showcase regions. Here, questions of user acceptance, new mobility patterns, cross-sectoral cooperation in the fields of energy and transport, and city planning are to be integrated in large-scale regional experiments. Despite this „experimental" rhetoric, the basic aim is to „present" e-mobility to a broader public and to demonstrate that it can work. A similar innovation system design can be observed in Baden-Württemberg: While the showcase region shows a more 'systemic' orientation, as compared to the preceding model region, with a focus on intermodality and demonstrating, or literally "showcasing", e-mobility to the public, the Leading-Edge Cluster "Electric Mobility South-West" is clearly a funding program aiming at industrialization for e-mobility. It is more directly addressing OEMs and especially the supply industry than the showcase region program. Thus, the basic idea is to solve technological problems and develop innovations, and then test them in practice with regard to user acceptance and potential for marketability and diffusion. These two processes are, however, clearly separated, also formally, i.e. into two different R&D programs, with room for mutual evaluation, but no room for integrated perspectives or problem perceptions.

A similar separation can be observed at the federal level of strategically designing the innovation system for e-mobility. The cooperation viewed as central in the government program are industry coalitions along new value chains, which should create the market, while science and policy function as innovation support and framework provision. As already mentioned, this approach means actively granting established industry actors the central position in the newly established e-mobility niche. While there is definitely a need to have both top-down and bottom-up dynamics, this type of niche activity is likely to result in the 'wrong' incentives and instruments for affecting substantial change. On the one hand, political initiatives at the federal level have played an important role for triggering developments in the field of e-mobility and momentum has been created by involving powerful actors, but, on the other hand, those actors have vested interests in maintaining the status quo and avoiding a real system innovation that might deprive them of their powerful positions, or simply would require unorthodox behavior deviating from proven success strategies.

Regime incumbents have found a way to deal with this problem strategically: By signaling willingness to cooperate while neglecting the existence of conflicts, they manage to preclude more fundamental change. This is achieved by focusing on "simulated conflicts", and putting them on the public agenda, where the deep structural problems are ignored by shifting the focus on 'lesser' conflicts of procedural issues or problems that do not question fundamental regime structures, thus do not require adapting established rules and patterns of resource allocation. For instance, it has been shown that in Baden-Württemberg the overall consensual discourse on e-mobility has created a situation where some conflicts and tensions tend to be glossed over or ignored. One example in this case is the potential conflict between environmental goals and industry-related goals of developing e-mobility. At most, it is hinted at the fact that there may not always emerge an automatic "win-win" situation. This issue is also taken up in the position of Daimler AG, where it is strategically used to play down the role of e-mobility by emphasizing that it is only environmentally sensible when enough renewable energy is available. One may argue that this line of argument is used as a way to shift the focus on problems that are not part of one's own responsibility.

A similar strategy is to postpone problems into the future. In the NPE, a pattern emerged in negotiations that proved to be a successful way of avoiding dead-lock: when positions of different actors seemed irreconcilable, agreement was reached that with regard to a particular issue, there was a need for further research before definite decisions could be taken (Canzler & Knie, 2011, p. 91).

At a practical level, a strategy for avoiding problems also means, for instance, designing projects in such a way that potentially conflicting parties do not have to work together and by structuring problems in isolated disciplinary ways or simply excluding some issues or questions. It has been shown that cooperation in pilot projects takes place only where every involved partner benefits.

This happens despite the fact that the need for cross-sectoral cooperation and a systemic perspective on e-mobility is widely articulated. For instance, in the NPE it was obvious to all involved parties that developing e-mobility would amount to a challenge that goes beyond sector-specific technological questions. Car manufacturers are aware of the fact that the global trend of growing mega-cities threatens their business model of selling cars and that they will have to find forms of cooperation with the public transport sector. Similarly, energy utilities have realized that e-mobility is not only about changes in the field of transport but that integrating electric vehicles and smart grids eventually implies a fundamentally different system of energy provision. However, discussions in the NPE have also shown that most of the involved actors have trouble coming to terms with redefining their established strategies, business models and patterns of cooperation.

In the case of Baden-Württemberg, Daimler AG and EnBW AG, the two industry actors identified to have a high influence on the innovation system, can both be shown to picture a positive outlook for the future of e-mobility and they expect fundamental change with regard to the structural context, in which they are operating today. However, even though the need for cooperation across sectors and with political actors is emphasized, path dependencies with regard to established perspectives and concrete business models are obvious. The car manufacturer concentrates on vehicle technology and the energy supplier on energy infrastructures. It is, however, not clear how the link between the energy and the transport sector is to be facilitated and what concrete forms of cooperation would be needed – apart from stating that there will be convergence at some point. Similarly, the Leading-Edge Cluster "Electric Mobility South-West" addresses the challenges for e-mobility developing as a sustainable system innovation by clearly emphasizing the need for cross-sectoral cooperation and a systemic perspective by including intermodal transport as a central aspect. However, the structural layout of the cluster indicates that this potential will most likely remain limited, due to the sector-oriented separation of research questions in distinct innovation fields.

The emergence of an increasingly 'systemic' perspective on e-mobility can also be observed during the development phase from the model region to the showcase region, while clearly e-mobility concepts and strategies still remain largely within regime limits. Basic premises of current transport systems and mobility patterns – relying predominantly on private car ownership, basically unlimited range of ICE vehicles, and clear separation of business models in the transport and energy sectors – are not being questioned. Also, despite the rhetoric of cooperation, in practice actual cooperation including partners from the automotive, energy and ICT sectors can be found in only three projects, strikingly none of them part of the showcase region program. Two of them have been part of the model region and they may be seen as early attempts that obviously were for some reason not continued with a similar actor constellation, as could have been possible in the showcase region context. With regard to these three projects, it can further be shown that even in cases of intersectoral cooperation, e-mobility is not automatically looked at from a broad or systemic perspective – the focus may still be on the vehicle itself. In contrast, it is striking that among the more systemic projects there are barely any forms of cooperation including partners from the automotive, energy and ICT fields, directly cooperating in one project. The importance of this type of intersectoral cooperation is time and again emphasized by politicians and actors involved in e-mobility projects and could have well been a more common phenomenon in projects oriented towards a more comprehensive system of e-mobility. Also, this indicates that these forms of cooperation are despite all the hopeful rhetoric particularly difficult in practice, as indicated by the discontinuation of two model region projects that had included automotive, energy and ICT actors.

However, there are nonetheless limited signs of an emerging system innovation. The overall structure of the showcase region LivingLab BW^{e} mobil shows that the dominant focus on vehicle technology and infrastructure build-up that has dominated the preceding model region has to some degree been replaced by a focus on intermodality, fleet applications and questions of integrating e-mobility in housing and city planning as well as ICT-based connections with energy infrastructures. Looking at all the projects carried out in Baden-Württemberg, it can be shown that a relatively large share of projects fall under the category of "vehicle"-focused projects. Most projects in this group are carried out in the context of the excellence cluster, which makes sense, in so far as this is explicitly an R&D funding program for the industrialization of e-mobility. Half of the model region projects also fall within this group. This may indicate that these were the earliest attempts to develop e-mobility and the focus on vehicles was most obvious during this early stage. Consequently, in the showcase region where a systemic perspective and intermodality are emphasized as important aspects, only three projects can be characterized as focused purely on vehicle technology.

Simultaneously, it seems that over time the e-mobility hype has cooled off for dominant actors with high influence, especially from the automotive and energy sector. This can be shown by the observed cooperation patterns that have become (even) less diverse as regards the sectoral background of involved partners, but also more varied as regards the power positions of cooperating partners. Also, the more powerful automotive and energy actors seem to have retreated from the more system-innovative showcase region projects and focus on the excellence cluster. The involvement of automotive actors in the excellence cluster is high, with an automotive partner participating in 10 out of 13 projects, while there are only two projects where actors from the automotive and the energy sector cooperate, one project where actors from the energy sector and ICT cooperate and one project where automotive and ICT are involved together. Overall, there are more actors with moderate to high influence involved in projects of the excellence cluster, as compared to the model or showcase region. This can be explained by the fact that these projects are more explicitly focused on industrialization and it has been shown that particularly large OEMs and energy supply companies are characterized by relatively higher influence.

At the same time, actors from outside the traditional mobility regime increased their activities in the showcase region and managed to utilize the political support and R&D funding for e-mobility, in order to foster their respective agendas. For instance, public transport companies, carsharing services or ICT companies with a focus on transport-related fields have successfully participated in various demonstration projects, in order to develop intermodality, which is their original field of activity. They have thus profited from, and possibly also shaped, the issue of intermodality being prominent in future visions of e-mobility. Furthermore, they have managed to develop mobility services, ICT solutions and the like in this field, even though this has not been in the focus of the key influential actors shaping the innovation system.

It has also been shown that the position of ICT and public transport companies deviate from the general e-mobility discourse to some degree. Due their original fields of activity, they have a more systemic view on e-mobility and generally interpret it in terms of alternative forms of mobility including intermodal mobility and carsharing services. These are the new actors entering the field, who possibly see chances and potential for their business activities and strategic goals – rather than a threatening perspective of structural change and transformation. The central barriers for e-mobility are perceived to be external to their specific fields of activity (infrastructure, vehicle technology etc.), while they will contribute positively once the time is right and suitable framework conditions are in place.

What is striking is that the position of the involved scientific partners, who could have been expected to focus on system-innovative approaches more explicitly, remains relatively close to the industry-dominated discourse. The focus of research is mostly technological, and in fewer cases interested in user acceptance and business models for e-mobility. The overall perspective is firmly centered on the conventional car as the basic frame of reference and standard comparison. Even in the showcase region, many projects focus on disciplinary focused research question relating to either issues of mobility, energy, city planning or user behavior, respectively. This highlights the fact that overall the showcase region is still a typical R&D funding program, with disciplinary research designs and a focus on clearly delineated fields of research that scientists are used to.

Against the background of dominant established principles and structures, in industry and science, the case of Baden-Württemberg also shows that 'new' actors are entering the field of e-mobility. Apart from established automotive or energy actors, the importance of whom is emphasized strongly in public and political discourse, the innovation system of Baden-Württemberg also includes a relatively large number of 'alternative mobility' actors, e.g. from the fields of public transport and carsharing, and also actors not directly linked with the transport sector, e.g. housing, or, more specifically, not linked to the field of automobility and vehicle technology, e.g. traffic and parking management. It has been shown that these kinds of actors can be important for the development of system-innovative projects – even though these projects remain marginalized. Nonetheless, they point to the potential that e-mobility as a system innovation may have, as, for instance, the case of the housing company engaged in a showcase project in Baden-Württemberg shows. Since this actor is not traditionally established in the field of transport, the perspective on e-mobility is fundamentally different and assessed in terms of its integration in city planning, in designing livable city quarters, and in a comprehensive energy concept for housing projects. Thus, the focus is from the beginning not centered on the car and how to accommodate e-mobility in the context of a car-centered regime. This case also shows that such initiatives do not only rely on the fact that outside actors with different perspectives are involved, but also that it is helpful if this outside actor is not the typical niche actor, which is small and has little influence, but rather an actor that is new to the field of mobility, but a powerful actor in their specific field.

In general the majority of 'system-innovative' projects are carried out in the context of the showcase region, strikingly with none of them including a partner from the automotive industry. Almost half of them do not include a scientific partner either. These projects are dominated by "other" actors and actors from the field of mobility services. The Stuttgart Services project is outstanding with regard to its broad inclusion of actors from all fields, except automotive and battery technology. Most of the other project constellations are much less diverse. The only system-innovative project of the model region is an interesting case with regard to its actor structure including an energy supplier, a public transport company and an e-bike manufacturer. Since this is the only system-innovative project in the model region context, this may indicate that in the early phases of experimenting with e-mobility, energy companies were hopeful of finding new and innovative business model, and were ready to experiment. Later on, this seems to have been followed by disillusionment and re-focusing on established business models. In turn, ICT companies seem to have gained a stronger position and perspective on possible new fields of activity in developing e-mobility as a system innovation. Even though there are no very specific patterns of cooperation emerging in system-innovative projects, what can be shown is that intersectoral cooperation including actors from automotive, energy and ICT sectors is obviously not decisive. This type of cooperation barely exists at all, while system-innovative projects do emerge nonetheless. A relatively large share of those projects are not at all based on intersectoral cooperation, rather they are carried out by outsiders ("others", such as e.g. the already mentioned housing company, or a regional association), mobility providers, or researchers.

Finally, a decisive factor for creating favorable conditions for the emergence of system innovations is the design of innovation systems: Coordinating agencies that are trusted, proactive and independent can have a major influence on the direction of developments by creating stable networks, by coordinating and connecting actors, and by actively including outsiders. It can be shown for the case of Baden-Württemberg that the regional innovation system is dominated by established actors, but the Regional Project Coordination Agency, based on their standing and proactive coordination efforts, managed to get a number of unusual, outside actors to get involved, to ensure that intermodality has become the overall focus of the showcase region, thus increasing the overall potential for system innovation. Also with regard to shaping overall discourses and frames of reference, it can be shown that while environmental and resource scarcity concerns are often mentioned as a general reason for developing e-mobility, the state agency e-mobil BW has over time increasingly adopted a broader perspective on sustainable mobility in the context of the energy transition. Since e-mobil BW has been founded and is financed by the state government with a clear mandate of functioning as a politically neutral coordinator and facilitator, it can be assumed that its position represents an overarching discourse carried by relatively broad consent among the involved actors. The Regional Project Coordination Agency in Baden-Württemberg has in fact significantly contributed to an increasing tendency to include system-innovative approaches and projects. It may thus be argued that an actor of this sort can potentially be taking on a strategic position at the niche-regime interface.

In sum, new functionalities emerge to a very limited degree in individual projects, especially on intermodality and carsharing, where actors other than OEMs – particularly from the public transport sector, housing or ICT – strategically use the e-mobility hype and funding opportunities to follow their specific agendas. Thus, system adaptability for e-mobility largely depends on those actors that bring in a new perspective on mobility, i.e. one that goes beyond selling cars. In the German case, it can be argued, that currently there is some potential due to the more systemic design of the most recent showcase region program and the high-level political support, which guarantees continuity of this niche. However, this may also be a problem in terms of niche-regime dynamics, because this potentially green e-mobility niche is from the start captured by regime incumbents and, for instance, the large German OEMs focus on the more technologically oriented demonstration projects for e-mobility while at the same time lobbying for weaker political regulations of CO_2-emissions at the EU level. Guaranteeing that efforts in e-mobility development really lead to sustainable outcomes depends to a large degree on the political framework conditions. Many of the interviewed actors emphasized that the momentum in the development of e-mobility will not be lost, due to landscape factors such as scarcity of resources and especially developments on the Chinese market, but they also felt that achieving sustainable mobility depends on external pressure and political regulation.

4.5 E-mobility and the Potential for Sustainable System Innovation: 3 Traps Revisited

The aim of this section is to relate the empirical findings of chapter 4 to the theoretical framework that has been developed in chapter 3. The results of the case study are therefore taken up and discussed against the background of the theoretical concepts of transformative capacity and system adaptability and the basic theoretical propositions regarding the potential for system innovations to emerge. The overall aim of this thesis has been to provide a conceptual perspective on e-mobility as a sustainable system innovation and apply it to the case of Germany. Along three traps of a sustainable system innovation, it has been argued that in order to assess the potential of a future system innovation, concepts of transformative capacity of new technologies and system adaptability, i.e. regime change and niche-regime dynamics in terms of the MLP, can be helpful. The case of Germany has provided some lessons in this respect and these will be laid out in the following.

4.5.1 The "Quantitative Trap": Purely Market-Based Diffusion of Electric Vehicles is not Feasible

With regard to diffusion (**the first trap**), technological R&D and fostering market breakthrough of BEVs is important, because the sheer numbers of BEVs on the market are still too small to think about an actual transition. The problem of insufficient diffusion has been addressed in the German case by setting the political goal of having one million electric vehicles on the road by 2020 and a steadily increasing number of BEVs is deployed over the course of the governmental funding programs in demonstration projects.

However, since it can be shown that the BEV is a radical innovation that cannot replace ICE cars under current conditions and thus is a technology with high transformative capacity, the possibility of a classical diffusion process fostered by traditional means of public R&D funding and providing economic incentives is unlikely. BEVs do not fit the current mobility system and cannot compete with conventional cars on the established system's terms (e.g. regarding range and price). The consistently low diffusion rate of BEVs therefore has to do with the fact that the BEV can be characterized as a technology with high transformative capacity. It has been argued that this transformative capacity can be located or identified in the BEV's mis-fits with the current mobility regime. These mis-fits can be taken as a starting point for imagining a different regime where they are no longer mis-fits but elements of 'fit' that are the center of a different technological lock-in with different path dependencies developing that are fundamentally different from those of the current mobility regime. In the current regime, multi-purpose cars powered by internal combustion engines have been perceived to be the core of the automotive industry's technological profile, the 'norm' for customers, the standard of design and engineering principles, and the central subject of governmental regulation, policy-making and market relations. The BEV poses a threat to established industry structures, especially in Germany where OEMs focus on powerful internal combustion engines and the premium segment and also to the automotive supply industry, which plays an important role in Baden-Württemberg, for instance. Furthermore, sector boundaries will shift and long-established relationships, e.g. with the oil industry, will become obsolete, while new forms of cooperation with previously unfamiliar partners need to be established, e.g. from the energy or ICT sector, public transport companies or mobility service providers.

These mis-fits do not only point to the transformative capacity potentially inherent in the BEV, they also show that 'normal' diffusion is not feasible. The mis-fit with the current system is too large and the prospect for developing electric vehicles that can replace conventional cars, in terms of range and price, is at least uncertain and depends on substantial technological advances in battery technology. Essentially this might mean that the BEV is doomed to fail eventually, because it does not fit within the current mobility system and cannot compete with ICE cars.

4.5.2 The "Qualitative Trap": Advancing System Adaptability for E-mobility through Outsiders and Coordinating Actors

Thus, the **second trap** referring to the emergence of new functionalities is not only important from a sustainability transitions perspective, but is also crucial for the success of BEVs in general. Socio-technical co-evolution may turn the technological shortcomings of BEVs into triggers for change. Dealing with high prices and small ranges of BEVs by integrating them in intermodal mobility systems or carsharing schemes would solve a problem that is currently perceived as a technological weakness (batteries as still immature technologies). This would be a systemic type of change evolving from this mis-match and a contribution to more sustainable forms of mobility. Similar effects are expected when BEVs are deployed in commercial fleets, where fleet management allows for using BEVs as flexible storage space for electricity. An important link could be created between sustainability transitions in the fields of energy and transport, which is of high relevance especially for Germany, with a transition to renewable energies underway.

Thus, whether there is momentum also in the future depends on system adaptability (rather than technological developments in battery technology etc.). The theoretical framework developed in this thesis suggests that multi-regime dynamics play an important role for the development of system innovations. In the case of e-mobility, actor groups are interlinked that currently have been part of clearly separated regimes (transport and energy most importantly). It has been assumed that new points of contact and new common challenges can be a context where own frames of reference and guiding principles are being questioned and re-defined, thus altering the deep structures of a specific regime. This might over the long term even evolve in terms of a new (e-)mobility regime with different logics than currently separated transport or energy regimes.

Looking at the structure of the German innovation system, e.g. the actor constellation and strategy of the National Platform Electric Mobility, and specifically the case of Baden-Württemberg, it can be observed that intersectoral cooperation between automotive and energy companies is avoided, and that 'system-innovative' projects are more often carried out by actors of completely different backgrounds (neither energy nor automotive). A general pattern has been observed where only those actors work together that mutually profit from cooperation and difficult issues are disintegrated into individual projects or work packages within projects. This empirical observation casts doubt on the theoretical proposition on multi-regime dynamics. It can be shown that multi-regime dynamics play a less important role than theory would suggest. It can theoretically be assumed that e-mobility brings together a range of different actors, particularly from the fields of the automotive industry, the energy sector, and ICT, and that this leads to tensions between different rule systems and in power constellations, thus increasing system adaptability. However, practical experience has shown that actual cooperation between those actors does not emerge to a substantial extent and thus the potential of such multi-regime dynamics remains limited in practice.

Still, it can be shown that system-innovative projects do emerge but that they are often carried out by actors from non-transport regimes, or more distant regimes, such as public transport or housing companies. Also for these actors it can be shown that they do not adapt dominant rules and resources to a substantial degree and get involved only where they expect benefits in the context of their specific fields of interest and activity. This is similar to the case of automotive or energy actors, who only cooperate when there are more or less direct benefits, thus precluding the emergence of multi-regime dynamics that challenge established rule systems. The potential of cooperation in general is therefore not utilized, but since actors from outside the typical range of actors related to the transport system do get involved, new perspectives emerge and system-innovative projects do occur. This is exactly where limited potential for an emerging system innovation can be identified, i.e. where it is driven by powerful actors from outside the mobility regime.

This overall limited adaptability in terms of changing rules and power structures has also been demonstrated by the discrepancies observed within discourses on e-mobility and transformation. The case study shows an overall discrepancy between a positive stance towards "e-mobility" of the future and a general inability to picture something different than today's mobility regime. Apart from guiding visions among central actors in the National Platform Electric Mobility, this also becomes obvious when looking at the allocation of governmental funding. The general attitude towards e-mobility is positive and hope for a societal transition towards new forms of mobility is articulated, while at the same time, established technologies, infrastructures and use patterns serve as a performance measure against which e-mobility is assessed and these shape (or rather restrict) the range of ideas and visions. There seems to be an overall ambiguity, which is also reflected in the interviews, with on the one hand, visions of e-mobility as a radical innovation, as a future more sustainable and networked mobility system, and on the other hand, dealing with e-mobility today as if it were an incremental innovation, limited to questions of technological substitution and improvement. Nonetheless, it can be shown that the German initiatives for fostering e-mobility amount to a niche that has gained momentum as regards the volume of funding and projects and with an increasing number of projects that focus on system-innovative aspects, such as intermodality and carsharing.

So, with regard to system adaptability in general, the signals are mixed when observing the German case. On the one hand, changes in visions of future mobility can be identified and there are a number of successful pilot projects where new mobility patterns are put into practice and new actor constellations are emerging with new players entering the field of (auto-)mobility. On the other hand, the overall innovation system is dominated by regime incumbents, the guiding principles and rule systems are in line with a predominantly market-oriented and technology-focused problem perception and especially OEMs and energy suppliers are reluctant to engage in new forms of cooperation. This discrepancy stemming, very basically, from uncertainties about the future, which are at the core of any transformation process has been shown to be reproduced not only in discourses but also in the actor constellation, strategies and project designs. Such a dynamic situation characterized by uncertainty is prone to be dominated by resourceful regime incumbents with vested interests, as has been shown for the German case. It has been shown how discursive discrepancies are strategically utilized to position oneself as innovative and future-oriented actor, while maintaining activities within established regime logics and aiming at incremental change. The German innovation system for e-mobility may thus be characterized as a niche that is captured by regime actors.

"Captured niches" are a common phenomenon, which has also been observed, for instance, in the context of Dutch transition management efforts in the fields of energy and transport. In many projects on fostering renewable energies and sustainable mobility, the government and established industry actors were involved and ambitious future visions were developed, similar to the German case. However, working towards those goals for the future, strategies and approaches were limited to optimization strategies that do not substantially threaten established regime structures. At the same time, a central position of incumbents in official transition projects has made it even more difficult for more radical alternatives to gain foothold, because they are in this case not only opposed to regime structures, but largely also to the 'official' niche. Furthermore, involving industry incumbents has increased caution among involved governmental actors to exert political pressure, in order not to frustrate industry actors that have shown willingness to engage in transition processes. This has resulted in a situation where established regime structures are being reproduced while an allegedly consensual discourse on sustainability and transition is commonly referred to (Avelino, 2009, p. 381; Kern & Smith, 2008, p. 4101 f.). Similar dynamics can be shown for the German case, where the e-mobility niche has been 'installed' by the government. It has thus emerged within a regime-context with the government giving much influence to industry actors in the National Platform Electric Mobility and a large share of governmental funding being allocated to industry incumbents and technology-focused projects.

However, the discrepancies emerging in discourses on e-mobility and transformation cannot only be used strategically by regime incumbents. It has been shown that in Baden-Württemberg ambiguous terms and concepts, such as e-mobility or sustainability, are utilized also by other actors. Different ideas have been attached to these concepts ranging from sustainable mobility, including visions of intermodal transport and urban livability, to 'systemic' innovations in vehicle technology. Ideas of sustainable mobility and alternative mobility patterns have gained prominence, because they are attached to the official and politically supported project of fostering e-mobility. The case of Baden-Württemberg has also shown that this situation entails a particular potential for intermediary or coordinating agencies, such as the Regional Project Coordination Agency. The state agency e-mobil BW and the Stuttgart Region Economic Development Corporation have a public mandate and function as coordinators and facilitators being well-respected by all involved actors. From this position they have managed to engage 'outsiders' and thus supported the emergence of (the still relatively few) system-innovative projects.

4.5.3 The „Sustainability Trap": Avoiding Conflicts

With regard to the **third trap**, the question is raised whether the developments in the field of e-mobility are potentially also producing sustainable outcomes. While it has been shown that achieving sustainable development is in most cases not feasible by technological innovation alone, thus requiring the emergence of new functionalities, it is at the same time obvious that not every regime change automatically results in a more sustainable system. This central issue is not always explicitly reflected in transition studies and therefore this third trap has been included. The importance of including an explicit sustainability dimension has become obvious in the case of Germany. A discrepancy, similar to that related to the issue of transformation, can be observed in sustainability discourses in the field of e-mobility. Climate change and resource scarcity are common rationales for engaging in e-mobility and, at the same time, it is assumed that this environmental motivation is coherent with industry objectives. Referring back to the transformative capacity of electric vehicles and their potential threatening of established industry structures and business models, especially in the automotive industry, it is at least doubtful whether there is a straight-forward 'win-win'. There is a large discrepancy between efforts to develop electric vehicles that can compete on the market and efforts to experiment with new forms of sustainable mobility that focus on intermodality, a new role of the car in a decentralized energy system, and livable cities. The in-depth interviews carried out with actors involved in the innovation system of Baden-Württemberg has shown that this potential conflict between environmental and economic goals of developing e-mobility is not explicitly discussed and sometimes simply denied to exist. Thus, the basic motivation for engaging in the development of e-mobility is based on incoherent goals, which necessary leads to inconsistent instruments and strategies. The potential threat inherent in this particular situation is that none of the envisaged goals will be achieved. The described incoherence does not only limit the potential for a sustainable system innovation, it also leads to weak results regarding the industry-related goals. Since the BEV can be characterized as a radical innovation, it will not diffuse as a 'normal' substitute would be able to. Thus, one may argue that the case of Germany shows how the process of fostering a system innovation is captured by regime incumbents from the beginning, leading to inefficiencies and unintended outcomes for everyone. 'Sustainability' serves as a common frame of reference and legitimation, while a large variety of motivations for developing e-mobility are concealed under this heading, and in this way the real conflicts are altogether being avoided. This needs to be reflected, at least, on an overarching political and strategic level, in order to shape outcomes in desired ways.

4.5.4 Synthesis: A Need for Experiments and Learning in Developing E-mobility as a Sustainable System Innovation

In sum, developments in the field of e-mobility are at best at a threshold from the niche to the regime and whether the momentum that has been created around the year 2009 will last and whether sustainable results can be expected depends on the emergence of new functionalities, a more precise definition of goals and explicitly dealing with inherent conflicts. Currently, system adaptability is rather low and the niche is obviously captured by regime incumbents, but there are signs that actors from outside the regime, which are still not the typical small innovative niche actors discussed in the literature (in the German case large public transport, ICT or housing companies) also try to capture the field of e-mobility. This may contribute to transition patterns, as discussed by Geels and Kemp (2012) such as an "add-on and hybridization pattern" (p. 61), where elements that are new to the field of transport begin to play a role, or a "fit-stretch pattern" (p. 63), where perceptions of the car in general change.

Finally, what do these empirical findings imply for the theoretical framework developed in this thesis? First, they lead to a more critical reflection on the concept of transformative capacity. While the emerging visions of future e-mobility do indeed indicate the transformative capacity of the BEV as a new technology, e.g. new forms of mobility patterns, system structures and sectoral configurations can be imagined around the BEV as the central technology, this is not the case when it comes to current industry structures, market dynamics or political framework conditions. The system-innovative potential in current projects does not emerge from technological implications for core actors, i.e. automotive and energy, but rather from the fact that e-mobility as a broader concept is utilized strategically by outsiders who want to develop their specific business interests or follow alternative political agendas, e.g. in the case of ICT or public transport companies, respectively. This broader concept has indeed emerged from visions created around the technological characteristics of electric vehicles, but the seed for change comes from outside and could have used other entry points than e-mobility. Thus, the transformative capacity merely points to the inherent potential of a technology in relation to given regime structures. As an analytical concept it captures the virtual range of possibilities or alternatives that become feasible with this technology. Actual change results from the interplay that unfolds within the social configuration of a system and its constituting actors.

For the case of e-mobility this means that its potential can only be revealed where it is applied in practice and where experimentation and learning can take place. Only when there is actual, micro-level socio-technical interaction, is it possible that the electric vehicle gains meaning and a symbolic value of its own, independent from the conventional car as standard frame of reference. This will then also prepare the ground for new mobility patterns, car culture and symbolic meaning, industry structures, business models and an altogether new concept of mobility.

5 Conclusions and Outlook

The aim of this thesis has been to answer the question whether there is potential for e-mobility to develop as a sustainable system innovation and how this could be assessed *ex ante*, at this critical early stage. In chapter 2, e-mobility has been related to broader concepts of sustainable mobility and transitions towards renewable energies and it has been shown that these interlinkages imply potential benefits as well as major challenges. These can be grasped in terms of a system innovation. Three traps of e-mobility as a sustainable system innovation have been identified that have served as a guide for the following analysis. In chapter 3, a theoretical framework has been developed for assessing, *ex ante*, the potential of an emerging system innovation by analyzing current patterns of socio-technical co-evolution, determined by the transformative capacity of new technologies and system adaptability, and embedding these in a broader framework of structural change in the MLP. In chapter 4, the theoretical framework has been applied to the case of developing e-mobility in Germany and Baden-Württemberg more specifically. The theoretical framework facilitates a better understanding of potential for system innovations in an *ex ante* situation, because its focus on underlying regime structures, socio-technical co-evolution and an explicit sustainability perspective has revealed some important insights.

Applying the concept of transformative capacity of new technologies to the case of e-mobility offers a new perspective on the technological shortcomings of battery-electric vehicles that are commonly discussed as the major barrier for market breakthrough. Adopting a multi-level perspective on transitions, it can be argued that these shortcomings are defined in the light of current regime structures and are shaped by path dependencies characterizing established system configurations. However, the MLP also points to the fact that, in principle, new and fundamentally different system configurations are possible. This implies that the costs, limited range and long charging times associated with electric vehicles are shortcomings only under the specific current circumstances, and not shortcomings per se. The concept of transformative capacity takes this insight a step further, highlighting that shortcomings may not just 'disappear' under changed circumstances but that they may even contribute to the process of change. Therefore, the approach chosen in this thesis is to identify the 'mis-fits' of the electric car with the existing system structure, thus what is discussed as the technological shortcomings of the electric car in current debates. It is the mismatch between the potential of a new technology and the feasible possibilities of using it under given circumstances which can be characterized as the transformative capacity inherent in a new technology. The fact that the electric car presents a 'mis-fit' is alone an indication of its transformative capacity.

The analysis of discourses related to the topic of e-mobility and basic frames of reference with regard to the future pictured for electric vehicles observed in the case of Baden-Württemberg provide some evidence of such transformative capacity. Future visions of e-mobility have been shown to include fundamentally different forms of mobility – more integrated, intermodal with less (privately owned) cars – that are expected to develop together with the diffusion of electric vehicles. Thus, it can be argued that the transformative capacity of electric vehicles at least triggers change in visions and perspectives on a potential system innovation in the future. At the same time it has been observed that while there is a radically different vision of the future, a similar effect of the transformative capacity of electric vehicles cannot be observed in the context of concrete strategies guiding the actual change process. Problem perceptions regarding the diffusion of electric vehicles and guiding principles for transformation to the envisaged future system remain couched in existing regime structures, i.e. revolving around shortcomings of BEVs as compared to conventional ICE cars.

This clearly shows that an in-depth analysis of system adaptability is needed, because as these examples illustrate, system adaptability must be more than the existence of 'cracks' in a regime (e.g. environmental and economic pressure on the transport sector in this case), which then serve as a window of opportunity for new technologies to emerge and diffuse, resulting almost automatically in an ensuing process of socio-technical co-evolution. Emerging 'cracks' as an analytical category may give hints regarding instances for potential system adaptability at an aggregated level. However, whether or not a concrete system is adaptable depends critically on *the way* that actors perceive and deal with change, and not just the fact that on a macro-level things change, trends and crises occur. Similarly, the transformative capacity merely points to the inherent potential of a technology in relation to given regime structures, thus as a concept it captures the virtual range of possibilities or alternatives that become feasible with this technology. Actual change results from the interplay that unfolds within the social configuration of a specific context and the involved actors.

For the case of Germany and Baden-Württemberg it has been shown that the dynamics emerging in this context can be described in terms of an e-mobility niche that is captured by regime actors. Incumbents utilize the discursive discrepancies in their favor and strategically position themselves in the niche. Conflicts that are central to the basic problem of transformation are either ignored, postponed to a later stage, or replaced by simulated conflicts that shift the focus away from issues of fundamental change. Similarly, while a general willingness to cooperate is articulated, conflicts are avoided by focusing on cooperations with mutual benefits for all involved parties and splitting up difficult systemic issues into separate projects within disciplinary and sectoral boundaries. Thus, an overall openness with regard to alternative futures and a willingness to cooperate is signaled, while at the same time substantial change is in effect hampered.

The empirical analysis therefore shows that multi-regime dynamics play a less important role for increasing system adaptability as had been expected based on the theoretical framework. It has been assumed that the emergence of a technological artifact such as the electric vehicle that creates linkages between formerly separated regimes (especially energy and mobility in this case) can have a potential for inducing second-order learning and structural change. Theoretically, in a setting where multi-regime dynamics unfold, actors are confronted with the diverging logic of another regime, its modes of signification and legitimation, its established patterns of resource allocation and accepted power constellations, and they are thus in a way forced to reflect on their own premises and guiding principles, in order to be able to make sense of the new situation. However, the case of Baden-Württemberg shows that the cooperation settings for emerging multi-regime dynamics did not get established, or were even purposefully avoided. There is only a very small number of projects, where a broad range of actors from different sectors and fields cooperate directly. Especially project consortia involving actors from the automotive industry, the energy sector and ICT firms are rare. Furthermore, it can be shown that even in cases of intersectoral cooperation, e-mobility is not automatically looked at from a broad or systemic perspective – the focus may still be on the vehicle itself. Thus, none of the observed actors seems to have changed their basic frames of reference due to new interlinkages and cooperation in the field of e-mobility (sometimes because these new forms of cooperation did not take place at all).

Therefore, it has made sense in this particular case to shift the focus of the analysis away from the expected forms of intersectoral cooperation and also focus on the level of projects and their specific contents, in order to find out whether projects with a potential for system innovation do emerge at all. A number of projects following ‘system-innovative’ approaches could in fact be identified and strikingly these were mostly carried out by powerful actors from outside the transport or energy regime – powerful in terms of size and resources, thus not the typical smaller niche actors. These actors, e.g. from the field of public transport, housing or ICT, have a different outlook on mobility, e.g. in terms of integrated concepts of housing and mobility in urban quarters, offering intermodal mobility services, or as the central link between vehicles and the energy system, and thus open up new perspectives on (electric) cars and their context of use. The involvement of these actors does not imply that they contribute to shifting rule systems, and neither are they motivated by sustainability concerns, but their specific motivations and strategies contribute to overall more sustainable outcomes. In this way, it can be argued that the electric vehicle possesses an ‘indirect’ transformative capacity: by triggering shifting system boundaries and including new actors, the conditions for its own further development and the way it becomes embedded in its social environment are, to some limited degree, shaped by actors with a less car-centered perspective on mobility. Also, even though there are no very specific or typical patterns of cooperation emerging in system-innovative projects, what can be shown is that intersectoral cooperation including actors from automotive, energy and ICT sectors is obviously not as decisive as has been assumed.

The theoretical framework developed in this thesis has helped to identify episodes where system-innovative dynamics begin to emerge, in small-scale demonstration projects in the context of Baden-Württemberg’s efforts to develop e-mobility. While some important lessons have been learned (e.g. regarding relevant actors) at this local level, this alone does not suffice to arrive at conclusions with regard to the potential of e-mobility to develop as a system innovation at a larger scale. Possible seeds for a system innovation have been identified in this way, but the explanatory value of the theoretical framework has been more pronounced when it comes to assessing the barriers and obstacles impeding the further development of these seeds. Through the case-based in-depth exploration the theoretical framework has contributed to a better understanding of the underlying barriers for system innovation and by what mechanisms developments are hampered. Together with the findings related to the few system-innovative projects, this can provide insights into what may be drivers for system innovation, or at least starting points for improving the prospects for sustainability transitions in the field of transport.

Thus, what has been learned for the concrete case of Germany and Baden-Württemberg? Overall, it has been shown that the system-innovative potential of this e-mobility niche remains limited, due to the powerful influence of incumbents, conflicting political goals and traditional science approaches. A few more system-innovative activities emerge where powerful actors from outside are involved, who are capable of viewing mobility in a more systemic way. Thus, the prospect for the further development of e-mobility, let alone in terms of a sustainable system innovation, seems rather bleak.

However, considering the turbulent history of e-mobility over a period of more than 100 years, one may also argue that there is a relatively large potential for the current momentum not to be lost, due to a number of interrelated factors, such as the economic challenges facing the automotive industry, more pronounced political commitment and macro-economic trends such as resource scarcity, as well as global trends of urbanization especially in China. In a similar vein, Dijk et al. (2013) find that this time "electric mobility is able to benefit from self-reinforcing co-dynamics" (p. 144). For the concrete case of Baden-Württemberg, it can be shown that over the course of time and consecutive funding programs the focus on vehicle technology and infrastructure build-up for e-mobility has to some degree been replaced by a focus on intermodality, fleet applications and issues of integrating e-mobility in city planning and in energy system infrastructures. Furthermore, there are signs of increasing entrepreneurial activities towards more innovative business models in the field of e-mobility, of greater acceptance of new forms of mobility in urban settings, while a central barrier for up-scaling such trends are the unfavorable political framework conditions and disciplinary structures in R&D and science system institutions.

Whether the current window of opportunity will be utilized depends therefore on a change in perspective towards more systemic approaches in policy making, public R&D funding and science. Even though there has been a trend towards more 'systemic' perspectives on e-mobility during the development phase from the model region to the showcase region in Baden-Württemberg, e-mobility concepts and strategies still remain largely within regime limits, i.e. having a systemic focus, in terms of interlinkages between transport and energy systems, but without questioning basic premises of current transport systems and mobility patterns. Similarly, while the importance of intersectoral cooperation is time and again emphasized by politicians and actors involved in e-mobility projects it rarely takes place in concrete project settings. The observed discrepancy between cooperation rhetoric and hopeful visions of the future on the one hand, while on the other hand reproducing dominant regime structures when dealing with concrete transformation strategies and cooperation, points towards a potential threat: namely, that aspirations are high and still it is not the truly relevant problems that are being addressed. The potential for a system innovation is limited by dealing with the 'wrong' problems, while the overall rhetoric is positive and creating expectations.

This is critical because it has been shown that the diffusion of electric vehicles as well as the more basic changes required for a mobility transition towards sustainability depend on the development of e-mobility as a system innovation. This in turn means that strategies for developing (sustainable) e-mobility require a move away from car-centered forms of mobility, which are already being pictured in future visions. A central problem is that the commonly shared frames of reference against which electric vehicles are assessed are established use patterns, business models, market mechanisms, cultural values, thus in short, the social system in which the car is embedded today. Nonetheless, the car is also a boundary object to which actors from different fields can relate and it can thus also be an important starting point for discovering the root causes of the complex and deeply entrenched causes of current unsustainability – as well as the repeated failures of the electric vehicle. Creating the conditions for processes of socio-technical co-evolution are therefore crucial because they can over time lead to social learning processes and a re-framing of the (electric) car and its social context.

What do the results of this thesis imply for the further development of e-mobility, in terms of policy recommendations and further research?

The German e-mobility niche has been initiated by the federal government and therefore, political actors play a central role for the design of the niche and its potential to be a nucleus for system innovation. In general, it has been shown that political commitment and especially public R&D funding programs are an important trigger for anything to happen at all in the field of e-mobility. However, it has also become clear that science policy approaches are needed that go beyond traditional R&D funding, in order to create spaces for experiments and more creative approaches fostering second-order learning. So far, conventional cars and their characteristics are the standard frame of reference for assessing and developing e-mobility. As a consequence, funding strategies are geared towards industry R&D working towards an environmental fix of the car that produces an economic and environmental win-win outcome. This can be observed in the case of Baden-Württemberg where different funding programs are combined, in order to solve technological problems and develop innovations, and then test them in practice with regard to user acceptance and potential for marketability and diffusion. These two processes are, however, clearly separated, also formally, i.e. into different R&D programs, with room for mutual evaluation, but limited room for integrated perspectives or problem perceptions. In that sense, what can be observed are typical R&D funding programs, with disciplinary research designs and a focus on clearly delineated fields of research that also scientists are used to, e.g. questions of integrated e-mobility are split up into research questions on either mobility, energy, city planning, or user behavior.

However, it has been shown that achieving even a narrowly defined form of sustainable e-mobility, let alone 'simple' diffusion of electric vehicles, will not be feasible with the help of narrow approaches, i.e. narrowly delineated research questions and approaches staying within disciplinary academic, or sectoral, boundaries. This is simply due to the fact that sustainability challenges in the field of mobility are complex and inherently interdisciplinary and, apart from that, the transformative capacity of electric vehicles indicates that a 'simple' process of technological substitution is not likely. Finally, the potential of e-mobility as a link connecting the mobility and energy transitions will hardly be realized without interdisciplinary and systemic scientific and policy approaches. It is thus important to focus on e-mobility as a field of innovation that cuts across the boundaries of sectors and academic disciplines.

New forms of funding and R&D settings are needed that transcend disciplinary boundaries and a strictly market-oriented logic of the diffusion of 'green' technologies. For the case of Baden-Württemberg it has been shown that the most promising projects have been those that are practice-oriented ("living laboratories") in the sense that, for instance, concrete business models have been established that remain in place after the project is over, instead of the more typical pilot or demonstration projects with a limited number of test users and a limited duration. In strategic niche management, such approaches are characterized as "selective exposure" where an experiment is not completely shielded from regime pressures and a process of mutual adaptation can emerge (Schot et al., 1994, p. 1073). Other lessons from strategic niche management and transition management can also be useful for designing more experimental settings (even though these approaches have been neglected as theoretical frameworks for analyzing currently ongoing developments). For instance, basic principles in strategic niche management aim at creating the conditions for experiments, which question and challenge underlying assumptions, e.g. regarding suitable technological options, suitable strategies, and 'normal' use practices. It is further emphasized that project goals should be formulated in terms of qualitative learning goals, rather than quantitative goals of diffusion rates or market shares. Similar to other approaches of transdisciplinary and transformative science, such basic principles are well-suited for addressing complex real-world problems, problems characterized by uncertainty, and they facilitate a better understanding of the fundamental, underlying challenges, in this case, of established car-centered mobility regimes.

A final and more concrete recommendation is related to the role of intermediary actors, such as the coordinating agency in the case of Baden-Württemberg. It has been shown that these types of intermediary actors are able to position themselves at the niche-regime interface and manage to steer discourses and overall strategies and they can play an important role by involving actors from outside the traditional mobility regime, or actors that currently play a marginal role. It is crucial that coordinating agencies are politically neutral and not sponsored by industry, in order to function as a central information and connection hub that is trusted by all involved parties and establishes a stable network. Intermediary agencies can be important translators and network facilitators, especially in a situation where the boundaries between niche and regime become blurred, as in the case of the captured e-mobility niche. The basic dilemma in niche-regime interrelations, and in any transition process in general, is that radical niche innovations will rarely change stable regimes while niche innovations with a higher degree of fit with established regime structures are more likely to diffuse widely, without however leading to the emergence of a system innovation. Thus, in the case of e-mobility where there is potential for a system innovation and also broad involvement of regime incumbents, a resourceful intermediary that is able to facilitate social learning processes can play an important role. The aim of this thesis has been to show that such social learning processes, together with technological advancements in the field of e-mobility, are crucial for understanding the actual potential inherent in e-mobility, i.e. in terms of a sustainable system innovation that cuts across disciplinary and sectoral boundaries because "[w]e no longer have the luxury of dwelling on single problem dimensions" (Cohen, 2006, p. 34).

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LIST OF INTERVIEWS

Interview 1: managing director and project leader, public transport company, 28.03.13., Stuttgart

Interview 2: representative of regional project coordination, 24.04.2013, Stuttgart

Interview 3: researcher, 24.04.2013, Ulm.

Interview 4: representative of regional project coordination, 10.10.13, Stuttgart

Interview 5: project leader, housing company, 17.10.2013, Stuttgart

Interview 6: manager at a regional energy company, project coordination, 18.10.2013, Mannheim

Interview 7: researcher, 28.10.2013, Karlsruhe

Interview 8: project manager at ICT/consulting firm, 28.10.2013, Karlsruhe

Interview 9: project leader, public transport company, 30.10.2013, Berlin

Interview 10: project leader, ICT, 11.11.2013 (telephone interview)

APPENDIX

A.1 Overview of projects in the model region „Region Stuttgart“

MR “Region Stuttgart” Total volume of public funding: 14.023.509 €	**Project Focus**	**Involved Actors** (and amount of public funding they received)
Project Coordination Share of funding: 390.053 € (2,8 %)	Establishing a Regional Project Coordination Agency	Wirtschaftsförderung Region Stuttgart GmbH (WRS)
500 Elmotos for the Stuttgart Region Share of funding: 2.343.446 € (16,7%)	Public awareness for electric vehicles; analyzing user behavior; building up charging infrastructure **Deployed vehicles**: 500 e-bikes, 100 e-scooters	ID Bike GmbH in cooperation with: EnBW AG (2.343.446 €)
S-Hybus – diesel-hybrid buses for Stuttgart Share of funding: 1.329.553 € (9,5%)	Testing hybrid-electric busses **Deployed vehicles**: 5 Citaro BlueTec Hybrids	SSB AG (1.329.553 €) in cooperation with: TÜV Nord, PE International
ELENA – Electrification-Retrofitting-Kit for diesel delivery vans Share of funding: 1.659.344 € (11,8%)	Developing an electric drive retrofit kit for conventional delivery vans **Deployed vehicles**: 1 retrofitted prototype (Mercedes-Benz Sprinter 313)	Fraunhofer IPA (377.456 €) in cooperation with: ARADEX AG (161.925 €), J. Eberspächer GmbH & Co. KG (25.281 €), Research Institute of Automotive Engineering and Vehicle Engines Stuttgart (FKFS) (119.391 €), Heldele GmbH (108.779 €), Hochschule Esslingen (315.474 €), Huber Automotive AG (310.321 €), Kompetenznetzwerk Mechatronik BW e.V. (26.090 €), Lauer & Weiss GmbH (75.000 €), Telemotive AG (72.907 €), TÜV Süd (41.595), WSEngineering GmbH & Co. KG (25.125 €)
E-mobility links sustainably Share of funding: 1.065.127 € (7,6%)	Integration of electric vehicles in municipal fleets **Deployed vehicles**: 7 BEVs, 5 e-scooters, 5 Pedelecs, 4 E-Bikeboards, 2 Segways, 2 modified Pedelecs	City of Ludwigsburg (37.575 €) in cooperation with: Stadtwerke Ludwigsburg-Kornwestheim GmbH (38.700 €), University of Stuttgart (IAT) (581.266 €), Fraunhofer IPA (327.486 €), Cargo-Logix GmbH (80.100 €)
IKONE – Integrated concept for sustainable e-mobility Share of funding: 4.134.374 € (29,5%)	Testing suitability for daily use, customer acceptance, business models **Deployed vehicles**: 170 Mercedes-Benz Vito E-CELL vans	Daimler AG (3.101.244 €) in cooperation with: EnBW AG (179.941 €), Fraunhofer IAO (589.586 €), TÜV Süd (263.603 €)
Boxster E – E-mobility in sports cars Share of funding: -	Developing marketable BEVs in the premium segment **Deployed vehicles**: 3 Porsche Boxster E	Porsche Engineering Group GmbH
E-mobile City Share of funding: 1.013.598 € (7,2%)	Integrating infrastructure for e-mobility in city planning; Identifying drivers for change in future city planning and integrating e-mobility in cities **Deployed vehicles**: 8 BEV, 2 e-bikes	Zweckverband Flugfeld Böblingen/Sindelfingen (91.800 €) and Stadtmarketing Böblingen e.V. (14.670 €) in cooperation with: Wirtschaftsförderung Sindelfingen GmbH (14.562 €), Langmatz GmbH, Fraunhofer IAO (171.185 €), University of Stuttgart (400.808 €), Fernwärme Transportgesellschaft mbH (FTG) der Stadtwerke Sindelfingen und Böblingen (51.582 €), Max Holder GmbH (128.328 €), Langmatz GmbH (132.053 €), Siedlungswerk gemeinnützige Gesellschaft für Wohnungs- und

		Städtebau mbH (8.610 €)
PEDELEC - e-Call A Bike Share of funding: 1.997.014 € (14,2%)	Further develop Deutsche Bahn AG's service „call a bike" as „e-Call a bike" and integrate Pedelecs; build up infrastructure for charging as well as renting and user registration **Deployed vehicles**: 100 pedelecs	Landeshauptstadt Stuttgart (1.255.224 €) in cooperation with: DB Rent GmbH (741.790 €), EnBW AG

(Sources: BMBF 2011, Tenkhoff et al., 2011)

A.2 Overview of projects in the Leading-Edge Cluster "Electric Mobility South-West"

Cluster „Electric Mobility South-West“	Project Focus	Involved Actors
Field of Innovation: Vehicle		
GaTE "Holistic Thermal Management in the E-Vehicle" Public funding: 2.9 mio. €	Improving energy efficiency, in order to increase the range of electric vehicles.	Behr GmbH in cooperation with: Robert Bosch GmbH, Daimler AG, sitronic GmbH & Co. KG, Research Institute of Automotive Engineering and Vehicle Engines Stuttgart (FKFS)
DiNA "Diagnosis and Repair for Electric Vehicles" Public funding: 2.8 mio. €	Improving safety of high voltage systems in electric vehicles, in order to create user acceptance.	Robert Bosch GmbH in cooperation with: DEKRA Automobil GmbH, Fraunhofer EMI, Research Institute of Automotive Engineering and Vehicle Engines Stuttgart (FKFS)
ELISE* "Autonomous Charging Unit and Integrated Data Gateway for Electric Vehicles"	Developing ICT-based applications increasing efficiency, reliability and safety of electric vehicles, in order to increase user acceptance	RA Consulting in cooperation with: CarMediaLab, Karlsruhe Institute of Technology (KIT)
Field of Innovation: Energy		
BIPoLplus "Contactless, Inductive and Position-Tolerant Charging" Public funding: 5.1 Mio. €	Developing a quick and convenient charging system, in order to increase user acceptance	Daimler AG in cooperation with: Robert Bosch GmbH, Conductix-Wampfler GmbH, EnBW AG, Porsche Engineering Groupd GmbH, German Aerospace Center (DLR), University of Stuttgart, Karlsruhe Institute of Technology (KIT)
InnoROBE* "Innovative Regenerative On-Board-Energy Converters"	Developing on-board charging systems improving energy efficiency and thus range, costs, and charging time	GreenIng GmbH in cooperation with: Robert Bosch GmbH, German Aerospace Center DLR, Fraunhofer ICT
AUTOPLES "Automated Parking and Charging of Electric Vehicle Systems" Public funding: 2.3 Mio. €	Developing spatial management and business models for parking and charging, in order to increase user acceptance	TransEnergyPartners GmbH in cooperation with: Conductix-Wampfler GmbH, CTC cartechcompany GmbH, FZI Karlsruhe
Field of Innovation: ICT		
SGI "Smart Grid Integration" Public funding: 1.1 Mio. €	Developing concepts for the integration of electric vehicles in a decentralised energy system	MVV Energie AG in cooperation with: BridgingIT GmbH, ENERGY4U GmbH, FZI Karlsruhe
GreenNavigation*	Developing strategies based	IPG Automotive GmbH in cooperation with:

	on ICT applications to increase the range of electric vehicles and improve user acceptance	Robert Bosch GmbH, CarMediaLab GmbH, Daimler Fleetboard GmbH, Harman Becker Automotive Systems GmbH, PTV AG, FZI Karlsruhe
E-Fleet "E-Fleet and Charging Management" Public funding: 1.3 Mio. €	Developing concepts for an integrated management of fleets and charging infrastructure	Fraunhofer IAO in cooperation with: Ametras Rentconcept GmbH, Daimler Fleetboard GmbH, Frosys GmbH, Infoman AG, PTV AG
I-eMM "Intermodal E-Mobility Management" Public funding: 1.67 Mio. €	Developing ICT-based mobility solutions for intermodal transport, in order to make car-sharing and public transport more attractive	PTV AG in cooperation with: RA Consulting GmbH, Rhein-Neckar-Verkehr GmbH, Stadtmobil Rhein-Neckar AG, Karlsruhe Institute of Technology (KIT), FZI Karlsruhe
Field of Innovation: Production		
AutoSpEM "Automated Approach for Process-Capable and Efficient Manufacture of Storage Batteries for Electric Mobility" Public funding: 1.5 mio. €	Developing automated battery production processes, in order to reduce cost and establish a German battery production industry	Schunk GmbH & Co. KG in cooperation with: ads-tec GmbH, Dürr Systems GmbH, Festo AG, teamtechnik GmbH, Karlsruhe Institute of Technology (KIT)
Epromo "Research of a Modular Process Manufacturing Concept for E-Motor Production" Public funding: 1.8 Mio. €	Developing production technologies that are able to adapt to rising demand for different types of electric vehicles in the future	Teamtechnik GmbH in cooperation with: Daimler AG, Faude Automatisierungstechnik GmbH, MAG IAS GmbH, WITTENSTEIN cybermotor GmbH, Fraunhofer IAO and IPA
ProBat "Project Planning for Quality-Oriented, Flexible Batetry Production Systems" Public funding: 1.7 Mio. €	Developing concepts for ensuring quality and safety of emerging battery production systems	Dürr Systems GmbH in cooperation with: Carl Zeiss Industrielle Messtechnik GmbH, Daimler AG, Karlsruhe Institute of Technology (KIT)

(Sources: e-mobil BW, Projects in the "Leading-Edge Cluster Electric Mobility South-West" (http://www.emobil-sw.de/en/aktivitaeten-en/current-projects.html#view=all-items);
*no data available with regard to the total amount funding provided by the BMBF

A.3 Overview of projects in the showcase region „LivingLab BW^e mobil“

Showcase Region „LivingLab BW^e mobil“	Project Focus	Involved Actors
Key topic: Intermodality		
Stuttgart Services	Introducing an intermodal e-mobility service including public transport and carsharing	SSB AG in cooperation with: VVS, Fraunhofer IAO, MRK Management Consultants GmbH, Verband Region Stuttgart, Mentz Datenverarbeitung GmbH, Landeshauptstadt Stuttgart, BW-Bank, EnBW AG, Bosch SI, Cubic, EOS Uptrade, highQ, Scheidt & Bachmann; Associated partners: DB, Stadtmobil Carsharing AG, Parkraum BW GmbH, Stuttgart Marketing GmbH, car2go GmbH, City Initiative Stuttgart e.V.
e-Flinkster & e-Call a Bike in Stuttgart	Further developing Deutsche Bahn AG's renting system by including electric vehicles	Deutsche Bahn AG (DB Rent GmbH / DB Fuhrpark System GmbH)
Netz-E-2-R “Interconnected mobility with e-bikes at train stops”	Broad regional introduction of a Pedelec renting service for commuters connecting them to public transport stations; vehicles powered by renewable energy.	Nachhaltig Mobile Region Stuttgart (NAMOREG) in cooperation with: App. 10 regional municipalities
Hy-Line S	Integrating (plug-in) diesel-hybrid buses on a Stuttgart public transport service line	SSB AG in cooperation with: PE International
GuEST - E-taxis in and for Stuttgart	Developing an operating model for electric vehicles in taxi fleets	University of Stuttgart in cooperation with: Bosch GmbH, Research Institute of Automotive Engineering and Vehicle Engines Stuttgart (FKFS) , Taxi-Auto-Zentrale Stuttgart eG, DEKRA Automobil GmbH
Key topic: Fleets and commercial transport		
Get eReady	Developing integrated solutions for electrified fleets of different operators in urban agglomerations.	Bosch Software Innovations GmbH in cooperation with: Fraunhofer ISI, Athlon Car Lease GmbH & Co. KG, Heldele GmbH, Karlsruhe Institute of Technology (KIT)
Landesfuhrpark – Municipal fleet of the state Baden-Württemberg	Electrifying the state-owned fleets of Baden-Württemberg	State ministries of Baden-Württemberg
RheinMobil	Demonstrating efficient and economical operation of electric vehicles in fleets	Karlsruhe Institute of Technology (KIT) in cooperation with: Fraunhofer ISI, Michelin, Siemens AG
Urban Logistics and Commercial Transport	Electrification of inner-urban postal and delivery services	Fraunhofer IAO in cooperation with: Deutsche Post DHL, DPD, UPS Assoicated partners: Daimler AG, Cities of Karlsruhe, Stuttgart and Ludwigsburg
eFleet - E-mobility at Stuttgart airport	Electrifying the vehicle fleet operated at Stuttgart airport	Flughafen Stuttgart GmbH in cooperation with: German Aerospace Center (DLR), Cobus, Schopf, Volk, Mulag
Environmentally friendly municipal vehicles	Electrifying municipal vehicles (e.g. cleaning vehicles)	Alfred Kärcher GmbH & Co. KG in cooperation with: Hoppecke, Universities of Stuttgart and

		Rostock
Key topic: Energy, Infrastructure and ICT		
ALIS – Build-Up of Charging Infrastructure in the Stuttgart Region	Building up the charging infrastructure for eelctric vehicles	EnBW AG in cooperation with: The state of Baden-Württemberg, Cities of Stuttgart, Böblingen, Esslingen, Sindelfingen and Geringen, car2go
LIS - Charging Infrastructure in the Stuttgart Region	Operating and testing charging infrastructure and integration of carsharing fleet	EnBW AG in cooperation with: Fraunhofer IAO, Daimler AG Associated partners: car2go, City of Stuttgart
InFlott – Integrated Fleet Charging	Field trial of integrated fleet charging and developing software solutions	EnBW AG in cooperation with: Fraunhofer IAO, University of Stuttgart, ensoc, Gigatronik, Parkraumgesellschaft BW, swarco
charge@work	Operating charging infrastructure at company parking lots	Daimler AG in cooperation with: Fraunhofer IAO, University of Stuttgart
Key topic: Living and electric mobility		
Fellbach ZEROplus – E-mobility in private life	Developing a comprehensive energy management concept for "energy-plus" houses including charging stations for electric vehicles.	Fraunhofer Institute for Solar Energy Systems (ISE) in cooepration with: Architekturbüro brucker.architekten, city of Fellbach
Rosensteinviertel – Living and electric mobility	Developing an urban housing district with an integrated e-car-sharing concept, where renewable energy is produced on-site and the aim is to offer alternatives to the privately owned car.	Siedlungswerk GmbH
Aktivhaus B 10 – Architecture and mobility for tomorrow	Demonstrating a smart building concept ("plus-energy" building) and integrating e-mobility	Werner Sobek Group in cooperation with: ILEK, Schwörer Haus, alphaEOS, Daimler AG
Key topic: Urban and traffic planning		
Ludwigsburg Intermodal	Developing and intermodal mobility concept and virtual platform connected to Ludwigsburg central station	City of Ludwigsburg in cooperation with: University of Stuttgart, Stadtwerke Ludwigsburg-Kornwestheim GmbH Associated partners: Deutsche Bahn AG, DOBA Grund Beteiligungs GmbH & Co., MediaCluster, Neue Arbeit gGmbH, LHI Leasing GmbH
e-carPar Sindelfingen	Developing an integrated energy and e-mobility concept in an industrial park	EFG Engineering Facility Group in cooperation with: University of Stuttgart, Schäfer GmbH & Co. KG
eTraffic Stuttgart	Integrating e-mobility in traffic models and planning tools	Karlsruhe Institute of Technology (KIT)
Key topic: Vehicle technology		
Audi NEoS – user behavior and electric vehicles	Fleet test with a focus on user behavior, commercial applications and charging	Audi AG in cooperation with: Malteser Hilfsdienst e.V., EnBW AG
E-mobile test fleets	Fleet test with (plug-in hybrid) electric vehicles: Mercedes B-/S-Class	Daimler AG
Panamera Plug-In Hybrid	Vehicle prototype is tested by 12 different users	Porsche AG in cooperation with: Karlsruhe Institute of Technology (KIT)

Key topic: Communication and participation		
eCube	Accessible "exhibition-cube" for raising public awareness	Wirtschaftsförderung Region Stuttgart GmbH, State Agency e-mobil BW
Online Showcase E-mobility	Digital information and communication platform	Fraunhofer IAO in cooperation with: YellowMap AG, State Agency e-mobil BW
E-citizen-bus & Wiki	Introducing privately organized and operated e-bus services as an addition to minimal public tranport in rural areas. A wiki is established as an information platform for interested citizens.	University of Stuttgart in cooperation with: Gemeindeverwaltungsverband Raum Bad Boll, Verkehrswissenschaftliches Institut Stuttgart GmbH (VWI), highQ, „Bürgerbus"-Associations
Key topic: Training and qualification		
MSE – Mobile Training Center E-mobility	Information and training for groups of students	Technische Akademie für berufliche Bildung Schwäbisch Gmünd e.V.
Exhibition workshop e-mobility	Professional training and qualification, developing competences in the field of e-mobility in established industries (automotive and suppliers)	IG-Metall BW in cooperation with: Technische Akademie für berufliche Bildung Schwäbisch Gmünd e.V., Technische Akademie Esslingen e.V. Associated partners: City of Stuttgart, GreenIng, Handwerkskammer Region Stuttgart, German Aerospace Center (DLR), TÜV Süd, etz, Verband des Kraftfahrzeuggewerbes Baden-Württemberg
e-driving school	Integrating e-mobility in driving schools, qualifying driving instructors	Weiterbildungszentrum für innovative Energietechnologien e.V. in cooperation with: vpa Verkehrsfachschule GmbH
Key topic: Interdisciplinary accompanying research		
Business models and ICT-based services for e-mobility	Developing ICT-services and business models for e-mobility, analyzing load shifting potential	Fraunhofer IAO, FZI Forschungszentrum Informatik Karlsruhe
Strategies for market expansion of e-mobility	Representative and market-oriented study on the diffusion potential of e-mobility in Baden-Württemberg	Fraunhofer ISI, Fraunhofer ISE, innoZ
Urban mobility comfort – Stuttgart region	Assessing mobility comfort in intermodal transport chains	Fraunhofer IAO, Dialogik, Hochschule Esslingen
E-mobile: Energy and Environment Baden-Württemberg	Scenario-based analysis of energy system and environmental effects of e-mobility	Fraunhofer ISI, Fraunhofer ISE, Institut für Energie- und Umweltforschung Heidelberg GmbH

(Most recent overview from spring 2014; data used throughout the thesis may be older, due to subsequent admission of new projects and project partners; Sources: e-mobil BW (2014); http://www.livinglab-bwe.de/projekte/)

B.1 Overview of actors and levels of influence in the innovation system for e-mobility in Baden-Württemberg

Actors	**Cluster**	**Actors**	**Cluster – differentiated**	**Influence high**	**Influence moderate**	**Influence low**
78	Automotive					
		4	OEMs	1		3
		56	Suppliers		4	52
		18	Electric vehicle producers			18
8	Battery producers				1	7
9	Energy					
		1	EVU	1		
		8	Regionale Versorger und Stadtwerke		1	7
26	Information and Communication Technology				3	23
10	Mobility Providers					
		5	Public Transport		2	3
		5	Carsharing, Rental Services			5
35	Businesses/Industry – "OTHER"					
		3	Logistic companies			3
		3	Standardisation			3
		13	Consultancies		1	12
		4	Housing/Buildings			4
		4	Traffic Management/Parking			4
		8	(Kärcher, Schäfer, BW-Bank)			8
40	Research & Education					
		16	Universities		2	14
		17	Non-university research institutes	2	3	12
		7	Education & propfessional qualification institutions			7
7	Public				1	6
26	Associations					
		7	Industry			7
		5	E-mobility			5
		14	Regional			14
239		239				

B.2 Patterns of cooperation in the showcase region “LivingLab BW[e] mobil” based on affiliation and influence of projects partners

Projects showcase region	**Automotive**	**Battery technology**	**Energy**	**ICT**	**Mobility services**	**Other**	**Research**	*Low influence*	*Moderate influence*	*High influence*
Stuttgart Services			**X**	**X**	**X**	**X**	**X**	16	4	2
e-Flinkster & Call-a-Bike in Stuttgart					**X**				1	
Netz-E-2-R						**X**		4		
HyLine-S					**X**				1	
GuEST – E-taxis in and for Stuttgart	**X**					**X**	**X**	4		
Get eReady				**X**	**X**		**X**	3	1	1
Landesfuhrpark – Municipal fleet of the state Baden-Württemberg						**X**		1		
RheinMobil	**X**						**X**	3		1
Urban Logistics and Commercial Transport						**X**	**X**	5	1	2
eFleet – E-mobility at Stuttgart airport	**X**					**X**	**X**	5		
Environmentally friendly municipal vehicles		**X**				**X**	**X**	3	1	
Charging Infrastructure in the Stuttgart Region	**X**		**X**				**X**	1	1	3
InFlott - Integrated Fleet Charging			**X**	**X**		**X**	**X**	5	1	2
Charge@work	**X**						**X**		1	2
Fellbach ZEROplus							**X**	3		2
Rosensteinviertel						**X**		1		
Ludwigsburg Intermodal						**X**	**X**	3		
e-carPark Sindelfingen						**X**	**X**	3		
eTraffic Stuttgart							**X**			1
Audi NEoS	**X**		**X**							2
E-mobile Test Fleets	**X**									1
Panamera Plug-In Hybrid	**X**							1		
E-citizen-bus and Wiki				**X**	**X**	**X**	**X**	4	1	
Business models and ICT-based services for e-mobility							**X**			1
Urban mobility comfort – Stuttgart region							**X**	2		

B.3 Patterns of cooperation in the leading-edge cluster "Electric Mobility South-West" based on affiliation and influence of projects partners

Projects cluster	**Automotive**	**Battery technology**	**Energy**	**ICT**	**Mobility services**	**Other**	**Research**	*Low influence*	*Moderate influence*	*High influence*
AUTOPLES	x		x			x	x	5		1
BIPoLplus	x		x				x	2	3	3
GreenNavigation	x			x			x	5	2	1
eFlotte				x	x		x	4	1	1
I-eMM				x	x	x	x	2	2	1
Smart Grid Integration			x	x			x	3	1	1
DiNA	x					x	x	3	1	
ELISE	x					x	x	1	1	1
Epromo	x						x	3	1	2
GaTE	x						x	3	1	1
ProBat	x						x	1	1	2
AutoSpEM	x	x					x	1	2	1
InnoROBE	x						x	2	2	

C.1 Projects focusing on vehicle technology

	Projects	Automotive	Battery technology	Energy	ICT	Mobility services	Other	Research
Model region	S-Hybus					x	x	
	ELENA	x			x		x	x
	IKONE	x		x			x	x
	Boxster E	x						
Showcase region	HyLine-S					x		
	E-mobile Test Fleets	x						
	Panamera Plug-In Hybrid	x						
Leading-edge cluster	GaTE	x						x
	DiNA	x					x	x
	ELISE	x					x	x
	InnoROBE	x						x
	GreenNavigation	x			x			x
	AutoSpEM	x	x					
	Epromo	x						x

C.2 Projects with a systemic perspective on innovation

	Projects	**Automotive**	**Battery technology**	**Energy**	**ICT**	**Mobility services**	**Other**	**Research**
Model region	500 Elmotos			x	x		x	
	E-mobility links sustainably	x		x	x	x	x	x
	E-mobile City	x		x	x		x	x
Showcase region	Get eReady				x	x		x
	Landesfuhrpark						x	
	RheinMobil	x						x
	Urban Logistics and Commercial Transport						x	x
	Environmentally friendly municipal vehicles		x				x	x
	Charging Infrastructure in the Stuttgart Region	x		x				x
	InFlott			x	x		x	x
	e-carPark Sindelfingen						x	x
	eTraffic Stuttgart							x
	charge@work	x						x
	GuEST	x					x	x
	eFleet	x					x	x
	Urban mobility comfort – Stuttgart region							x
	Business models and ICT-based services for e-mobility							x
	Audi NeoS	x						
Leading-edge cluster	BIPoLplus	x		x				x
	AUTOPLES	x		x			x	x
	Smart Grid Integration			x	x			x
	eFlotte				x	x		x
Other projects	MeRegioMobil	x		x	x			x
	CROME	x		x				x

C.3 Projects with a focus on system innovation

	Projects	Automotive	Battery technology	Energy	ICT	Mobility services	Other	Research
Model region	PEDELEC			x		x	x	
Showcase region	Stuttgart Services			x	x	x	x	x
	e-Flinkster & Call-a-Bike					x		
	Ludwigsburg Intermodal			x		x	x	x
	E-citizen-bus and Wiki				x		x	x
	Netz-E-2-R						x	
	Fellbach ZEROplus							x
	Rosensteinviertel						x	
Leading-edge cluster	I-eMM				x	x	x	
Other projects	iZEUS	x	x	x	x			x
	Future Fleet			x	x			x

C.4 Overview of System-innovative projects

Project info	Project focus	Project partners
PEDELEC 04/2010 - 12/2011	"PEDELEC – e-Call a Bike Stuttgart" Aim: Integrating Pedelecs in DB's „Call a Bike" service, building up infrastructure and embedding the project in Stuttgart's public transport system.	Landeshauptstadt Stuttgart (lead), DB Rent GmbH, EnBW AG
Stuttgart Services 01/2013 – 12/2015	"Stuttgart Services" Aims: introducing the "Stuttgart Service Card" and providing access to public transport and car-sharing services fostering intermodality and facilitating the integration of electric vehicles and mobility services.	SSB AG (lead), VVS, Fraunhofer IAO, MRK Management Consultants GmbH, Verband Region Stuttgart, Mentz Datenverarbeitung GmbH, Landeshauptstadt Stuttgart, BW-Bank, EnBW AG, Bosch SI, Cubic, EOS Uptrade, highQ, Scheidt & Bachmann; Associated partners: DB, Stadtmobil Carsharing AG, Parkraum BW GmbH, Stuttgart Marketing GmbH, car2go GmbH, City Initiative Stuttgart e.V.
e-Flinkster & e-Call a Bike in Stuttgart 12/2012 – 11/2015	„e-Flinkster & e-Call a Bike in Stuttgart" Aim: Further developing DB's renting system for including more electric vehicles and better integrating it with regional and national public transport services. Developing charging infrastructure that can be used by many operators and privately, in order to foster modal split.	Deutsche Bahn AG (DB Rent GmbH / DB Fuhrpark System GmbH)
Netz-E-2-R 12/2012 – 12/2014 1.3 mio. €	"E-2-Rad-Anschlussmobilität an Bahnhaltepunkten" Aim: broad regional introduction of a Pedelec renting service for commuters connecting them to public transport stations; vehicles powered by renewable energy.	Nachhaltig Mobile Region Stuttgart (NAMOREG) (lead), Ca. 10 regional municipalities
E-Bürgerbus & Wiki 01/2013 – 12/2015	„E-Bürgerbus und Wiki" Aim: improving mobility in rural areas by introducing privately organised and operated e-bus services as an addition to minimal public tranport in rural areas. A wiki is established as an information platform for interested citizens.	University of Stuttgart (lead), Gemeindeverwaltungsverband Raum Bad Boll, Verkehrswissenschaftliches Institut Stuttgart GmbH (VWI), highQ, „Bürgerbus"-Associations
Ludwigsburg Intermodal (LUI) 05/2013 – 04/2016	„LUI – Mobility HUB am Bahnhof Ludwigsburg" Aim: Developing the central station of Ludwigbsurg as an e-	City of Ludwigsburg (lead), University of Stuttgart, Stadtwerke Ludwigsburg Kornwestheim, Associated partners: DB AG, Neue Arbeit gGmbH, Arena

	mobility hub, including an integration of public transport with e-mobility services and an internet platform.	Ludwigsburg Objekt Westausgang GmbH, DIBAG Industriebau AG
Rosensteinviertel 12/2012 – 11/2015	“Wohnen und Elektromobilität im Rosensteinviertel“ Aims: Developing an urban housing district with an integrated e-car-sharing concept, where renewable energy is produced on-site and the aim is to offer alternatives to the privately owned car.	Siedlungswerk GmbH
Fellbach ZEROplus 11/2012 – 10/2015	„Fellbach ZEROplus – Elektromobilität im privaten Alltag“ Aim: Developing a comprehensive energy management concept for “energy-plus” houses including charging stations for electric vehicles.	Fraunhofer Institute for Solar Energy Systems (ISE) (lead), Architekturbüro brucker.architekten, city of Fellbach
I-eMM 06/2012 – 09 /2015 1.67 mio. €	“Intermodal E-Mobility Management” Aim: developing ICT-based mobility solutions for intermodal transport, in order to make car-sharing and public transport more attractive	PTV AG (lead), RA Consulting GmbH, Karlsruhe Institute of Technology (KIT), FZI Karlsruhe Associated partners: Rhein-Neckar-Verkehr GmbH, Stadtmobil Rhein-Neckar AG
Future Fleet 09/2008 – 09/2011	“Future Fleet – Integrating Electric Cars in Company Vehicle Fleets” Aim: testing BEVs in company fleets, developing ICT-applications for fleet management and charging, in order to address issues of range and charging time; vehicles are powered by renewable energies.	SAP AG (lead), MVV Energie AG, Hochschule Mannheim, Institute for Social-Ecological Research (ISOE), Öko-Institut e.V.
iZEUS 2012 – 2014	“iZeus - intelligent Zero Emission Urban Systems” Aim: Developing an integrated, multimodal smart traffic concept, including ICT-applications for fleet management, an innovative charging and billing concept, and concepts for integrating electric vehicles in smart grids, in order to support the development of renewable energies.	EnBW AG (lead), Adam Opel AG, ads-tec GmbH, Daimler AG, PTV Group, SAP AG, TWT GmbH Science & Innovation, Fraunhofer Institute for Solar Energy Systems (ISE), Fraunhofer ISI, Karlsruhe Institute of Technology (KIT)

(Source: e-mobil BW homepage, overview projects and individual project homepages)

D. Questionnaire for semi-structured expert interviews

Einstieg

Leitfrage	*Research Question*
Was verstehen Sie unter dem Begriff Elektromobilität?	*Begriffsklärung; Wahrnehmung aus spez. Akteurssicht*

1 Die Organisation / Das Projekt

Wie kam es zur Gründung der Organisation? / Wie kam es zur Idee für das Projekt?		
Inhaltliche Aspekte	*Nachfragen*	
Initiatoren & Hintergründe Art der Kooperation Inhaltliche Motivation	Wer hat die Idee entwickelt und initiiert? Gibt es weitere Projektpartner? Wie haben sie sich zusammengefunden? Baut das Projekt auf bestehenden Kooperationen auf? Wie definieren Sie Ihre Rolle?	*Welche Akteure sind dominant und initiieren bzw. prägen Prozesse?*
Was sind die Aufgaben und Ziele der Organisation/ des Projekts?		
Inhaltliche Aspekte	*Nachfragen*	
Ziele Definition „Erfolg“	Wie sehen konkrete Ziele aus? Die langfristige Vision? Was sind für Sie Kriterien für eine erfolgreiche Arbeit?	*Wie sehen etablierte Regelsysteme aus?*
Wie sollen diese Ziele erreicht werden?		
Inhaltliche Aspekte	*Nachfragen*	
Konkrete Maßnahmen Budget	Welche konkreten Maßnahmen werden ergriffen? Was sind zentrale Meilensteine? Wie wird die Organisation/ das Projekt finanziert?	*Wie systeminnovativ ist das Projekt?* *Wie sehen Macht-gefüge aus?*

2 Akteurskonstellation im Schaufenster LivingLab BWe-mobil

Was sind die inhaltlichen Schwerpunkte im Schaufenster LivingLab BWe-mobil?		
Inhaltliche Aspekte	*Nachfragen*	
Technologie Nutzerakzeptanz Erneuerbare Energien	Gibt es entscheidende technologische Schwachstellen für die Umsetzung von Elektromobilität? Wie werden diese adressiert? Gibt es eine Nachfrage für Elektromobilität? Worin besteht diese konkret? Welche Rolle spielt die Verknüpfung mit erneuerbaren	*Wo zeigt sich die Transformative Kapazität des Elektroautos? Wie hoch ist die System Adaptability?*

Intermodalität & Carsharing Elektromobilität & Interessen etabl. Akteure in Wirtschaft/Politik Rolle des spez. Akteurs	Energien in Schaufensterprojekten? Welche Rolle spielen alternative Mobilitätskonzepte in Schaufensterprojekten? Wer prägt denn nach Ihrer Einschätzung die inhaltliche Ausgestaltung des Schaufensters? Wie kam es zu Ihrem Engagement? Wie würden Sie Ihre Rolle sehen? Konnten Sie die inhaltliche Ausprägung mitgestalten bzw. Ihre Perspektiven einbringen?	
Wie gestaltet sich die Zusammenarbeit zwischen den Akteuren im Schaufenster?		
Inhaltliche Aspekte	*Nachfragen*	
Interaktion der Projektpartner und ihre jeweiligen Rollen Konfliktlinien (am Beispiel konkreter Einzelprojekte) Wann sind Projekte ‚gut'?	Wie sehen unterschiedliche Visionen aus? Welche Rollen haben die unterschiedlichen Akteure innerhalb der Umsetzung von Elektromobilität? Gab es da Unklarheiten? Wie sehen unterschiedliche Zielsetzungen aus? Wo gibt es kein „win-win"? Gibt es Meinungsverschiedenheiten in der Zusammenarbeit? Wo bestehen Abhängigkeiten? Gibt es neue Kooperationen? Haben bestehende Kooperationen sich verändert? Wie sehen besonders erfolgreiche Projekte aus? Gibt es Akteure, die Sie noch gern dabei gehabt hätten?	*Wie sieht die Akteurskonstellation aus bzgl. Macht-verteilung/Ressourcen und Regel-systeme/Bezugs-rahmen, auf die sich unterschiedliche Akteure beziehen?* *Wie hoch ist die System Adaptability, d.h. zeichnen sich Konflikte/neue Koalitionen ab?* *Wo gibt es system-innovative Projekte?*
Wie bewerten Sie die Förderinitiativen im Bereich Elektromobilität?		
Inhaltliche Aspekte	*Nachfragen*	
Entwicklung des Förderprogramms Ziele der Förderung Defizite des Förderprogramms Einschätzung Status Quo	Wie hat sich das Förderprogramm der Regierung seit 2009 entwickelt? Was hat sich verändert seit den Modellregionen? Was sehen Sie als größte Hürden für die Entwicklung von Elektromobilität? Sehen Sie wesentliche Zielkonflikte? Was würden Sie sich wünschen? Was wären geeignete Maßnahmen? Welche Akteure sollten eingebunden werden?	*Wie systeminnovativ ist die spez. Perspektive?* *Wie stark ist sie mit politischen Zielen und Zielkonflikten verknüpft?* *Gibt es eine kritische Perspektive?*

	Wo steht Elektromobilität heute?	

3 Schaufensterregion Baden-Württemberg: Kontextfaktoren

Was sind Besonderheiten der Region Baden-Württemberg?		
Inhaltliche Aspekte	*Nachfragen*	
- Akteurskonstellation Baden-Württemberg/ Stuttgart Inwiefern unterscheidet sich das LivingLab BWe-mobil von den anderen Schaufenstern?	Welche Rolle spielt die Landespolitik? Welche Rolle spielt die Industrie? Gab es Interessenkonflikte? Gibt es einen Austausch zwischen den einzelnen Schaufenster- und Spitzenclusterprojekten? Wie gelingt die Integration umwelt- und industriepolitischer Ziele? Was sind spezifische inhaltliche Schwerpunkte? Wo sehen Sie Stärken und Schwächen im Vergleich zu anderen Schaufenstern?	*Welche Akteure dominieren das bestehende Regime? Was sind BaWü-spezifische Einfluss-faktoren und Akteurs-konstellationen?*

Wie gelingt die Integration umwelt- und industriepolitischer Ziele?		
Inhaltliche Aspekte	*Nachfragen*	
Ziele der Förderung	Sehen Sie wesentliche Zielkonflikte? Was würden Sie sich wünschen? Was wären geeignete Maßnahmen?	*Gibt es eine kritische Perspektive?*

Abschluss

Was sind wichtige Punkte, die bisher nicht angesprochen worden sind?	

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