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Analysing the potential for sustainable e-mobility – The case of Germany

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Abstract

The current momentum in the electrification of the car fuels hope for a transition in mobility. However, electric vehicles have failed before and it is thus asked: What is the potential of e-mobility developing as a sustainable system innovation? In order to deal with this challenge analytically, a theoretical framework is developed: the concepts of transformative capacity of a new technology (do electric vehicles trigger 'social' innovations, e.g. new business models or use patterns?) and system adaptability (how stable is the mobility regime?) are introduced and the issue of sustainability is discussed. This framework will be explored for the German innovation system for e-mobility. It can be shown that electric cars will only be successful when part of a system innovation and that the German innovation system is dominated by regime actors and thus potentially used as a way to fend off more substantial change.

Keywords

E-mobility, Sustainability in transitions, Multi-Level Perspective, Co-evolution

1 Introduction

From a sustainability perspective, the environmental burden caused by transport must be reduced significantly. The pressure exerted by increasingly strict environmental regulation (e.g. regarding CO_2-emissions) leads 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 (Köhler et al., 2009, p. 2986), such as the battery-electric vehicle (BEV). 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. Second, the charging infrastructure for BEVs needs to be built up. 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).

Nonetheless, the current momentum in dealing with these problems is strong, or at least this is what various national policy initiatives and debates within the industry seem to indicate. The important question addressed by this Special Issue is whether this momentum will last, or whether we should be prepared for another failure of the electrification of the car. The aim of this paper is to offer an analytical framework for dealing with this question and applying it to the case of Germany, where a number of large-scale R&D and demonstration projects are currently funded by the government.

Transition studies explicitly deal with system innovations, thus the paradigmatic changes hoped for when looking at the electrification of the car. The multi-level perspective on transitions (MLP) has proved to be a useful analytical concept for understanding the broader dynamics involved in these transformation processes. In order to deal with the concrete case of e-mobility, it is argued here that a closer look should be taken at socio-technical co-evolution: How do new technologies trigger socio-economic changes? How are new technologies perceived and dealt with by actors in a socio-technical system? If it can be shown that co-evolutionary processes actually do take place, then chances are high that the momentum of developments in the field of e-mobility will last.

Transition studies are furthermore motivated by a concern for sustainability and the second aim of this paper is to reflect on the question whether the current momentum of the electrification of the car may potentially contribute to a more sustainable transport system. This raises the question of what a sustainable transport system entails. A narrow conceptualisation of sustainable e-mobility would focus on reducing the environmental burden of vehicle and drive technology, while a broader conceptualisation would also address issues of urban livability, equitable access to mobility and, in general, car-dependency as a cultural phenomenon deeply embedded in modern societies and lifestyles (Cohen, 2006). Such a differentiation is important because it shows that the current focus in political and public discourses on technological development and the 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 (Zimmer et al., 2011, pp. 23 f.) as well as resource-intensive, considering the production of batteries (Stamp et al., 2012). Congestion and issues of sustainable mobility in dense urban areas should be addressed as well, but tend to be backgrounded (Weisshaupt, 2006, p. 86).

This implies that a more radical change is needed: The focus on technological innovations, such as the BEV, will hardly suffice to deal with the problems inherently connected to the modern car-based transport system (Høyer, 2008, p. 68; Rammler, 2011, p. 23). 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 and Knie, 2011, pp. 101 ff.). 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? What is the potential of a system innovation developing around e-mobility? How can potential in such a premature state be assessed?

In order to address these questions, an analytical framework is introduced in section 3, which is based on the MLP and introduces the concepts of transformative capacity of technologies and system adaptability, in order to focus more explicitly on socio-technical co-evolution. After introducing the methodology in section 4, the analytical framework is explored by applying it to the case of Germany. Some preliminary results regarding the potential for continued momentum towards e-mobility as a sustainable system innovation are discussed for the German case.

2 Theoretical background: A transition towards e-mobility?

A first step is to define more clearly what is meant by “e-mobility”. The common understanding of e-mobility is in terms of a shorthand for ‘electrified automobility’ (Sauter-Servaes, 2011, p. 25). The problem is that it will most likely not become feasible for a BEV to compete with a conventional car powered by an internal combustion engine (ICE) 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 fulfil the same functions as a conventional car in similar ways, the pure BEV points towards a more paradigmatic change in the transport system, because it can be characterised as a radical innovation (Weider and 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 (Hoogma et al., 2002, pp. 53 ff.). However, this also indicates that the BEV can only be successful when evolving in terms of a more systemic change. The technological shortcomings of the BEV as compared to conventional cars in the context of today's car-centred transport system become irrelevant or may even turn into advantages when the BEV is envisioned as part of a system innovation towards e-mobility. This would include an increased emphasis on integrated forms of mobility including BEVs, but also electric bikes or scooters as well as public transport, relying on mobility-related services rather than privately owned vehicles and where the BEV is part of a changed energy infrastructure (Weider and Rammler, 2011, p. 6, 10).

In transition studies, the dynamic process by which system innovations unfold is captured in terms of a multi-level perspective (MLP). The MLP provides an overarching heuristic framework that has a particular strength in analysing transition processes in socio-technical systems (e.g. transport) delineated by a specific societal function (e.g. providing mobility). It is thus a suitable approach in cases where the research question is concerned with "future more sustainable alternatives to fulfil these functions and not primarily in the fate of a specific technological configuration" (Konrad et al., 2008, p. 1192). The MLP conceptualizes transitions as a dynamic interplay of processes across three levels – landscape, regime, and niches – that interact and reinforce each other and the aim is to identify characteristic patterns and mechanisms playing out in these processes (Geels, 2011, p. 26; Geels and Kemp, 2012, p. 74; Grin, 2010, p. 4; Rotmans and Loorbach, 2010, p. 131).

3 Socio-technical co-evolution and "transitions in the making"

The MLP has proven to be especially useful for analysing historical cases of transitions (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) argue 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 regime-shifts, 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).

The broad heuristic focus of the MLP on macro-level processes of transitions means that there is no explicit focus on concrete co-evolutionary dynamics at a micro-level. In that sense, van den Bergh et al. quite insightfully characterise the MLP approach 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). In order to apply the MLP to a specific case, such as the possibility of a transition around e-mobility, 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 and Norgaard, 2010, p. 691). Analytically separating the particular elements that are co-evolving 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).

3.1 Introducing 'transformative capacity' and 'system adaptability'

A more explicit focus on socio-technical co-evolution is developed by Dolata in his framework for analysing technology-based sectoral change (Dolata, 2009, 2011). It is argued that such a framework is needed because the various approaches used to study the interrelations between technology and society, i.e. the socio-technical 'match' between technologies and socio-economic structures and institutions as described by Freeman and Perez (1988), focus primarily on the way that technological change is embedded in societal structures. It is further argued that a focus is lacking on the way that technologies themselves shape their social surrounding and how this influences socio-technical change. To address this problem, Dolata conceptualizes technology-based sectoral change as a function of two interrelated influencing factors. First, there is the *transformative capacity* of a new technology. It describes the degree to which the new technology provokes changes in a given sector's (a) technological profile; (b) its established patterns of research and development, production, distribution, products and market relations; (c) its established patterns of cooperative and competitive interaction; (d) its institutional architecture; and (e) its borders, separating the sector from (so far) unrelated others (Dolata, 2009, p. 1069). A technology may have a high transformative capacity, exerting direct and disruptive pressure, or a low transformative capacity, 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 analysing the impact on socio-economic and institutional structures of a technology in its own right. This is not to say that a new technology 'automatically' results in socio-technical change, but it creates a situation where new options become apparent and the new technology is a trigger for change (Schneider, 2001; Rohracher, 2007; Mayntz, 2009). 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. 1069).

Second, *sectoral adaptability* describes how the established sectoral structures, institutions and actors react to a new technology. The degree to which a sector is able to adapt can be determined at (a) the organisational level, where established routines and strategies have to be adjusted; (b) the institutional level, where formal and informal rules have to be adjusted; (c) the structural level, where the overall sector – i.e. research, production, market and demand conditions – has to adapt to the impact of a new technology. Sectors characterised by low adaptability lack elements or mechanisms that allow for anticipating or proactively fostering substantial change. Technological innovations are usually developed by either external actors or at the fringes of the sector and change usually means crisis. Sectors with high adaptability are characterised by institutional mechanisms and actors that anticipate and actively deal with technological change (pp. 1070 ff.).

The analytical separation of the transformative capacity of new technologies on the one hand, and of sectoral adaptability on the other, allows for a better understanding of processes of co-evolution between technological and social dimensions of change. This type of co-evolution is a contingent process characterised by uncertainty and conflicting expectations by different actors regarding future developments (van Lente and Rip, 1998; Bender, 2006; Böhle, 2007). The resulting sectoral change is understood as a long-term process featuring phases with varying degrees of institutional and structural transformation (Dolata, 2009, p. 1073).

Assessing the transformative capacity of a new technology can be shortly summarised as an approach that identifies the mis-matches of a new technology with the established elements of a socio-technical system and thus also with the underlying regime. These mis-matches become apparent in the technological shortcomings that are attributed to a new technology. Technological shortcomings are, at least in principle, shortcomings only with respect to the existing structures and thus may point to the new technology's transformative capacity.

Even though a quantitative operationalization of transformative capacity is hardly possible, a number of qualitative criteria can be assessed (adapted from Dolata). The transformative capacity of a new technology can be determined by analysing 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 behaviour),
- facilitates new patterns of interaction between actors,
- initiates institutional readjustments,
- opens up or widens existing borders of the socio-technical system.

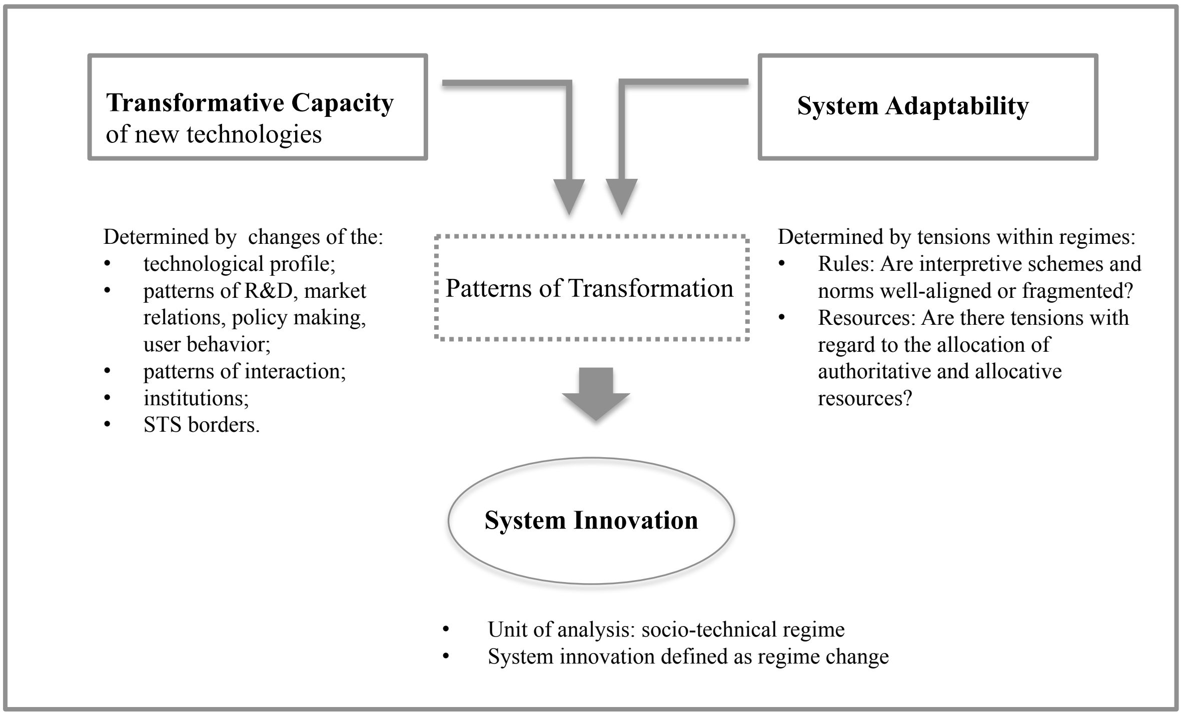

Fig. 1: Analysing system innovations as co-evolutionary socio-technical change (adapted from Dolata, 2009, p. 1067)

The concept of sectoral adaptability can be understood as system adaptability in transition terms, where the focus is not limited to a specific sector, and is used to describe the way that a technological innovation is perceived and dealt with in the context of established regimes. In cases where a regime is destabilized or is in a phase of adjustment, the system is more adaptable than in phases of relatively great stability. One approach is thus to identify ‘cracks’ in the regime (Geels et al., 2012), i.e. instances where established structures do not manage to fulfil the system function as well as they used to. 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. Studies of transition management policies have shown that in many cases incumbent actors manage to capture green niches and sustainability discourses, in order 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. 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.

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.

3.2 Introducing a more explicit sustainability perspective

What is the potential for e-mobility developing as a system innovation that can be characterised as sustainable? In order to focus on this question, three traps for e-mobility as a sustainable system innovation will be discussed. These traps are derived from the basic characteristics of a system innovation with an added focus on sustainability. According to the definition by Geels (2004, p. 19), a system innovation is characterised 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 fulfil 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. It is suggested that including these 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 first 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.

The second 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 regime shift depends on whether or not such new functionalities emerge. These result from the interplay of the new technology with other elements, 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. 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 the case of e-mobility, this would include new ways of fulfilling mobility needs and measuring performance as well as changed perceptions of the role of the car (e.g. as one element of an intermodal transport system, or as a means of transport as well as a means of storing electricity).

The third trap would be that the new system configuration does not deliver sustainability benefits. 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, which include not only improving the environmental performance of vehicles, since this would mean to "promote sustainability in only the shallowest and most delimited sense" (Cohen, 2006, p. 34). The more fundamental causes for unsustainability need to be addressed as well, such as car-dependency, related cultural images and social practices. Thus, apart from improving efficiency of engines and fuels, in order to decrease the negative impacts of the amount of transport that cannot be reduced or substituted, criteria of sustainable mobility should also include that the overall volume of transport would have to be reduced. This means that the need to travel should be reduced where possible and average trip lengths should be reduced, e.g. via measures of city and land-use planning. In addition, 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 (Banister, 2008, p. 75; Kemp and Rotmans, 2005, p. 34; Vergragt and Brown, 2007, p. 1105). Based on such a broad conceptualisation of sustainability, it is proposed that when analysing 'ex-ante' cases, such as the electrification of the car, a first step would be to delineate ideal-typical criteria guiding the analysis, in this case: forms of e-mobility where renewable energies are the main electricity source and where intermodality and car-sharing are important elements.

4 Methodology

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. In the following, a brief case study is presented: First, official documents and studies on the goals and actor structure of the German innovation system are screened, in order to identify power structures and the dominant rule systems influential actors refer to. Second, the allocation of funding is studied briefly, in order to show how established power structures are reflected in the distribution of resources. Finally, a closer look has been taken at a number of specific projects (focusing on intermodality, carsharing, housing and e-mobility, integration with renewable energies) and interviews[1] have been carried out with actors involved in these projects. These were the project managers of involved firms (in the fields of energy supply, public transport, ICT, housing), researchers, and representatives of the respective regional project coordination office (PLS), i.e. the public agency responsible for coordinating these different projects. The

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

semi-structured interviews focused on general perceptions and visions of e-mobility as well as the concrete projects, the funding programme in general, actor constellations and conflicts. It should be noted that the presented results are preliminary and provide only a brief overview of the German case.

5 Early evidence: the case of Germany

After a first (unsuccessful) hype phase during the 1990s, e-mobility appeared on the surface again in 2007 when debates about global warming and 'Peak Oil' were high on political and public agendas (Schwedes et al., 2013, p. 75). Furthermore, the international economic crisis had negative impacts on the automotive industry, which already had 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).

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 favoured technological option can be explained by a number of aspects. With the German energy transition underway, BEVs are 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 play an important role (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.).

Political efforts of the German government are articulated in the „National Development Plan for Electric Mobility" (NEPE), which was launched in 2009 and spells out the aim for Germany to become a „leading 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 included in the strategy development process. The government provides 500 million euros in the context of its 'Economic Stimulus Package II' implemented to deal with the economic crisis in 2009 (p.

24). The most visible efforts are two major funding programs. First, the programme "Electric Mobility in Model Regions" was launched, where eight regions have been selected as model regions for the period from 2009 to 2011. As a follow-up program, four "Electric Mobility Showcases" were launched in 2012: Berlin/Brandenburg, Lower-Saxony, Baden-Württemberg and Bavaria/Saxony. Each showcase will receive up to 50 million € of governmental funding from 2013 to 2015 (Bundesregierung, 2012).

5.1 The transformative capacity of the BEV

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 (Gnann and Plötz, 2011, p. 38; Hüttl et al., 2010; Kampker et al., 2013). This 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 behaviour* (acatech, 2010). Research is needed in the fields of chemical and electrical engineering. New business models are needed to deal with the high prices of batteries. New use patterns, car-sharing and intermodal mobility could help dealing with the high selling price and limited range of BEVs as well as the lacking charging infrastructure. With regard to *institutional readjustments*, debates are ongoing regarding standardization of plugs and charging infrastructure, regulating billing systems, as well as new regulations regarding drivers' licences. The BEV also points towards *new patterns of interactions*, for instance cooperation between original equipment manufacturers (OEM) and battery producers (Gnann and Plötz, 2011, p. 24 f.), or mobility providers and energy suppliers (Kasperk and Drauz, 2013, pp. 123 ff.). The *borders of the socio-technical system* will further be opened, for instance by sectors entering the mobility field that have not been part of it before, e.g. battery producers and ICT companies.

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. Thus, their success depends on the degree to which the socio-technical system around it can be characterised as adaptable.

5.2 System Adaptability in the German Innovation System

This section is going to assess system adaptability within the German innovation system for e-mobility in terms of dominant rules and power structures that can be observed in the federal government's activities, resources and power structures that are reflected in the allocation of funding, and discourses and cooperation patterns in concrete projects.

Based on the NEPE, the German government has invited representatives of industry, science, politics, labour unions and civil society to build a "National Platform Electric Mobility" (NPE) in 2010. The members of the NPE decided to follow an approach that is systemic, market-oriented and technology-neutral (NPE, 2010, p. 5). They committed themselves to the 2020-goal of establishing a leading market and having 1 million electric vehicles on the road. 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). 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. A study conducted on behalf of the Federal Ministry of Transport, Building and Urban Development, finds that the composition of the NPE follows similar guiding principles (Zimmer & Rammler, 2011): 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 might 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 and Rammler, 2011, p. 84).

A similar bias can be seen with regard to the design of the funding program "Electric Mobility in Model Regions". The volume of funding made available in this programme amounts to 130 million € with roughly 70% of the funds being allocated to private businesses.

Together with industry investments, the total project volume amounts 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 were deployed and a charging infrastructure comprising roughly 1,000 charging stations was built up (Tenkhoff et al., 2011, p. 12).

Based on an overview of the government's allocation of funds (BMBF, 2011) and the 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. 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, inter-modality, car sharing, fleet applications). Any project that fulfils one or more of these criteria has been selected, based on the project description in the official evaluation report. 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. The results of this comparison are depicted in table 2.

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

Table 2: 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. 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 were successful and achieved the envisaged goals and a follow-up funding programme has been launched in 2012: the “Electric Mobility Showcases” (Bundesregierung, 2011, p. 28). In the description of the showcase programme, 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.). A closer look has been taken at Baden-Württemberg, the third-largest of the German Länder and an important automotive region, where two of the largest OEMs as well as important suppliers and a large number of small- and medium-sized component suppliers are located. Furthermore, one of the four largest German energy suppliers as well as renowned universities and research institutes in the field of energy and automotive/transport research can be found in Baden-Württemberg, which is governed by the Green Party in a coalition with the Social Democrats. It is thus an exemplary case for the German innovation system for e-mobility, as regards the actor structure.

The showcase region “LivingLab BW^e mobil” follows a systemic approach and aims at developing a sustainable mobility system, according to their own representation on the website and in brochures of the regional project coordination (PLS) office (www.e-mobilbw.de). Nine key topics for the development of e-mobility are identified and 40 individual projects are grouped within these fields: 1) Intermodality; 2) Fleets and commercial transport; 3) Energy, 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. 5). This overall structure shows that the dominant focus on vehicle technology and infrastructure build-up that dominated the preceding model region (Interview 2) 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. This is reflected in the interviews: the key topic of intermodality is perceived to be central and especially the leading project “Stuttgart Services”[2] is referred to. This project aims at introducing an intermodal mobility service via a card that allows access to public transport, car-sharing and a number of other services (e.g. access to public libraries and swimming pools). It is connected with the other projects in the intermodality field and it is open to ‘normal’ customers from the start, in contrast to typical R&D or pilot projects with test users (e.g. in fleet projects) or research projects where virtual concepts are developed (e.g. for city and traffic planning).

The overall composition of topics and projects with intermodality, including car-sharing, taking center stage implies that e-mobility is understood in a wider sense. All of the interviewed actors, when asked for their personal definitions, emphasize that the term ‘e-mobility’ is more than the BEV but a new, somehow futuristic form of mobility that includes all kinds of electric propulsion systems and vehicles as well as public transport. In some of the interviews, ideas of e-mobility correspond directly with a broader concept of sustainability, e.g. it is argued that since efficiency gains will not suffice, issues such as fostering intermodality and car-sharing need to be integrated in visions of e-mobility (Interview 10). Some of the respondents express views of e-mobility as a holistic concept for urban mobility in liveable cities (Interview 1,5). Especially the interviewed representatives of the PLS see their role as facilitators of societal change and advocate e-mobility as a form of sustainable mobility (Interview 2). 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” (Interview 4). Developments and challenges related to e-mobility are perceived in terms of “transformation” (Interview 10) , “societal change” (Interview 2) and questions of changing dominant mind sets, habits and thought patterns (Interview 10). 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 (Interview 2,8). 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 (Interview 3). 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 from all of a sudden and what has

[2] http://www.livinglab-bwe.de/Project.aspx?id=92AB70A80FADB245A51A3DFD8F5CC02A#.UqM2IuJff3U

happened to their ICE cars. It will be a slow and almost unnoticed process that we are now beginning to experience" (Interview 2).

However, 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 name problems such as limited range, high prices, long charging times and lacking infrastructure for BEVs (Interview 5,7,10). These problems are particularly relevant when the diffusion of BEVs as a perfect substitute for ICE cars is the goal.

Similarly, motivations for individual projects are rarely grounded in explicit concerns about sustainable mobility. Rather, the availability of 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" (Interview 2). One example is the development of car-sharing 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 (Interview 3). This even leads to situations where "it can be a balancing act to justify to the funding agencies that what we are doing is an e-mobility project" (Interview 1). Another example is the field of public transport. Here, fostering intermodality and developing e-tickets and smartphone applications has already been an issue and public funding for e-mobility now provides a window of opportunity to receive not only financial support but also a network of potential cooperation partners (Interview 1,6,7,8). This latter aspect is a central motivation for participating in e-mobility projects: building up networks, being informed about the activities of others and publicity, which is relevant especially for OEMs (Interview 2,5,6).

While there seems to be a general interest in building networks and exchanging experiences – and especially in Baden-Württemberg it is highly appreciated that the PLS manages well to organize this in a way that there is a dialogue between all actors at eye-level (Interview 5) – it can at the same time be observed that specific actors are reluctant to work together directly in projects, e.g. OEMs and public transport organizations, or large public transport companies and smaller or non-commercial car-sharing organizations (Interview 1). Especially direct cooperation between OEMs and energy suppliers is difficult and rarely takes place at all (Interview 2,7). It is understood that e-mobility needs to be seen as a systemic challenge of organizing mobility differently in the future – however, the involved actors each view the mobility system from their distinct perspectives, e.g. 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” (Interview 9). There are no routines for inter-sectoral cooperation and for instance OEMs tend rather to buy in competences in the field of energy technology (Interview 9) while energy suppliers want to avoid being dominated by OEMs in a direct cooperation setting (Interview 6).

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 (Interview 6,8), 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 (Interview 6,8). More generally, most of the interviewed actors do not see any major conflicts between specific groups of actors or between industrial/economic and environmental goals of the funding program (Interview 2). 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. At this point, development of technological solutions in pilot projects is already a step ahead and thus actors are in a relatively comfortable position of waiting for the market while the general dynamic is perceived to be on the right track towards economically feasible and sustainable forms of e-mobility (Interview 6). Potential conflicts are thus postponed into the future by avoiding the more challenging cooperation projects and by focusing on further R&D.

Consequently, the public funding programmes are perceived to be important as a ‘trigger’ for something to happen at all (Interview 7,8). However, it is criticized that a real concept for the transformation process is lacking and that it will not suffice to set a goal (“1 mio. EVs”) and invest a certain amount of money without a clear vision and strategy (Interview 1) and a better coordination of individual funding programmes and projects (Interview 8). It is argued that a detailed roadmap for developing e-mobility as a future mobility system is not feasible, but that a nonetheless major achievement is that in the course of the funding programme 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 (Interview 4). 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 (Interview 6,10). Apart from market dynamics, the need for political regulation is emphasized, in order to enable a transition towards sustainable e-mobility, e.g. via road access restrictions, CO_2-pricing, fleet consumption regulations etc. (Interview 2,3). Nonetheless, there seems to be an overall conviction that e-mobility will remain a relevant topic, especially due to issues of oil scarcity and developments in transport in China (Interview 2, 7, 9) and that momentum will not be lost even after the public funding programmes have run out.

5.3 Results and discussion

It has been shown that the transformative capacity of BEVs is high. 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. However, these shortcomings may turn into triggers for change. Dealing with high prices and small ranges of BEVs by integrating them in intermodal mobility systems or car-sharing 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.

Whether this potential can be realised depends on system adaptability. The brief overview of the German innovation system 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 NPE, 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 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 car-sharing. The basic problem of diffusion is addressed by setting the political goal of having 1 million electric vehicles on the road by 2020 (which is of course still a small percentage of the total number of cars) and an increasing number of BEVs is deployed over the course of the funding programme in demonstration projects. New functionalities emerge to a very limited degree in individual projects, especially on intermodality and car-sharing, 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. Due to their different backgrounds, the engagement of these actors leads to more diverse understandings of what constitutes mobility or transport systems, which, in turn, may "lead to unexpected futures: innovations may spring from parts of the system that were not previously identified as niches" (Pel and Boons, 2010, p. 1257). 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 regions" 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 leads to sustainable results 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.

6 Conclusions

The aim of this paper has been to provide a conceptual perspective on e-mobility as a sustainable system innovation and apply it to the case of Germany. 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.

Based on the findings for the case of Germany, a few aspects in the debate about the momentum of the electrification of the car can be clarified. With regard to diffusion, 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. However, since it can be shown that the BEV is a radical innovation that cannot replace ICE cars as it is and thus is a technology with high transformative capacity, the possibility of a classical diffusion process 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 emergence of new functionalities – which in essence means redefining the role of the car – is thus not only important for achieving sustainability benefits that go beyond increasing ecological efficiency. The success of BEVs in general depends on new functionalities and systemic innovation due to its described mis-fit with current regimes, and it does so independent of sustainability concerns. Thus, whether there is momentum also in the future depends on system adaptability (rather than technological developments in battery technology etc.) and here 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 technological problem perception and especially OEMs and energy suppliers are reluctant to engage in new forms of cooperation. What can be observed is an overall discrepancy between future visions of sustainable e-mobility and problem perceptions and solution strategies deeply rooted in current regime structures. Following familiar routes of problem-solving, i.e. developing BEVs as a technological fix replacing conventional cars, may jeopardise 'deeper' sustainability where future e-mobility evolves as an element of a less car-dependent mobility system. It is therefore important to acknowledge the conceptual and normative diversity inherent in broad or narrow conceptualisations of sustainability and their practical implications (Stirling, 2011).

In essence, developments are at best at a threshold from the niche to the regime and whether the momentum will last and whether sustainable results can be expected depends on the emergence of new functionalities. 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. Such hopes have been expressed in one of the interviews (9): "It won't be possible to abolish the car, we have to domesticate it, intermodalize it, make it more ecological". If the electrification of the car is to contribute to sustainable mobility in a broader sense, questioning the role of the car in this way is essential, and it requires openness with regard to the conceptual diversities and practical ambiguities inherent in sustainability transitions.

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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)