Socio-Economic Aspects of Electric Vehicles: A Literature Review

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Abstract The dependence on fossil fuels and the climate change led not only in Germany to a debate on how the future of mobility might be designed. In this context the importance of electric mobility has especially grown in the public perception since the National Development Plan for Electric Mobility was published by the German federal government in 2009 and the eight model regions for electric mobility were established. The goal of the federal government is to bring a total of 1 million electric and hybrid vehicles on German roads by 2020 and establish Germany as lead market and lead provider of mobile electric mobility solutions. To achieve these objectives many questions on technical feasibility, ecological impacts or on the acceptance of the products by customers need to be answered for a successful market launch. Therefore this contribution gives an overview of important topics and issues related to the introduction of electric vehicles with a focus primarily on socio-economic topics. The literature review addresses existing studies and classifies main insights in seven thematic areas.

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1 Introduction

In Germany, being able to use a car is one element of individual freedom and is a cornerstone of individual mobility. 82 % (2008) of all German households possess a car and in just over a third of these households two or more cars are available. Despite the already high degree of car availability in the past, the motorization has even further increased in recent years (Follmer et al. 2010). In the new millennium the high dependence of individual mobility on private cars led to a discussion of alternatives to the internal combustion engine, initiated particular by significantly increasing oil prices. Worldwide, many governments and interest groups moved the issue of sustainable mobility in the foreground (Greenpeace 2010, Kendall 2008). Hybrid and electric vehicles (EV) are seen as an important part of a technology portfolio targeted at reducing greenhouse gas emissions as well as the dependence on oil by funding the expansion of renewable energies, developing new mobility concept, e.g. for public transport, or supporting technological developments (Greenpeace 2010, Kendall 2008). The electrification of the drive-trian could lead to a sustainable technology path which benefits the consumer by lower and less volatile (electricity) prices for mobility (Schill 2010a, c). This discussion is encouraged by the fact that electric mobility is benefitting from high oil prices (Conrady 2012, Dijk et al. 2012).

The rise of interest in the topic electric mobility may be particularly well traced by looking to the internet. This can be done by considering first the number of search inquiries of internet users over a time span and second by analyzing the number of hits displayed by search engines over a period for a specific topic. We have first investigated different frequently used keywords with Google Insight for Search (Fig. 1). There are three search inquiries related to electric mobility that were most often searched in Google: electric mobility, electric car and electric vehicle. After that we have investigated the number of searches in the period from the beginning of 2004 till the end of June 2012. It turns out that especially the term 'electric car' was asked with peaks in 2006 and 2008.

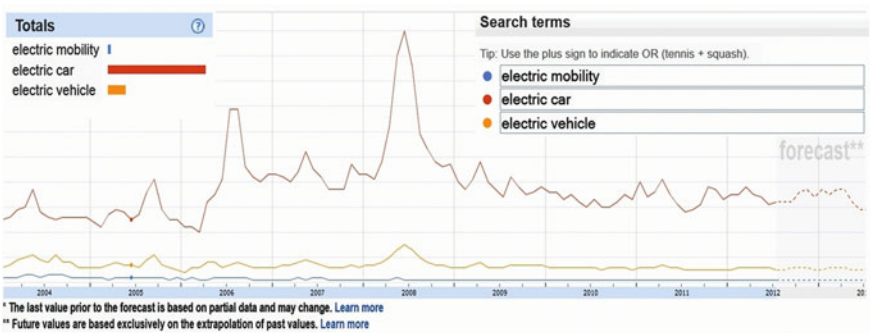

Fig. 1 Search request "electric car" (Google insight 2012)

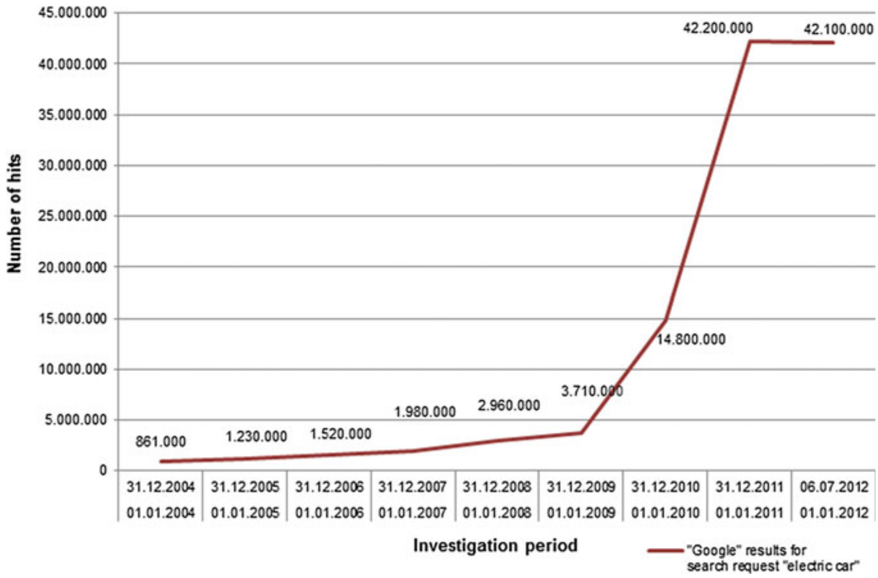

Fig. 2 Number of hits "electric car" (Google search 2012)

After that we analyzed how many entries the search engine Google could find for the most searched term 'electric car'. In Fig. 1 it is shown that the entries only slowly grow up to the year 2009 and then sharply increase. The figure also indicates that although for the year 2012 only the first half could be examined, currently the hits continue to increase. However, it is suspected that the increase levels off. This suggests that the topic could reach its climax in the public debate in the near future. Nevertheless, this excursion suggests that the public has a great interest in the topic of electro mobility. Such an interest will also have an impact on many companies, e.g. managers consider how their company can benefit from the latest developments. Especially for such managers but as well for policy makers it is important to understand the actual (scientific) debate in the field of electric mobility.

Consequently the following search questions arise: What are important socio-economic fields in the area of electric mobility? Which state-of-the-art results can be derived from research in these areas? In order to answer these questions the contribution aims at summarizing key topics and presenting the main findings.

In the following, we turn to the scientific examination of the topic in Sect. 2 to Sect. 8 by reviewing current literature on electric vehicles. The Sect. 2 focusses on the management perspective (e.g. innovation management, technology strategies), the Sect. 3 addresses usability topics (e.g. range or safety) and in the Sect. 4 issues of standardization are presented (e.g. charging cable and battery). Afterwards economic conditions (e.g. business models) (Sect. 5), social conditions (e.g. customer needs) (Sect. 6), ecological conditions (e.g. emissions) (Sect. 7) and politic conditions (e.g. subsidies or regulations) in Sect. 8 are discussed. We searched by key words in online databases like sciencedirect.com, springerlink.com and webofknowledge.com to receive an overview on the current debate. As a supplement grey literature was also partly used by employing for example scholar.google.de. Section 9 finally summarizes the developments and presents implications for the management of companies within the field of electric mobility as well as for further research requirements.

2 Management Perspectives

From a management perspective, electric mobility especially relates to the development, planning and implementation of content, objectives and guidelines in the company based on such new technological trends (Johnson et al. 2011). It is necessary to examine how the developments of electric mobility affect strategies (e.g. orientation of a company), structures (e.g. design of a company) or systems (e.g. infrastructures of a company).

Strategic opportunities for companies and public organizations arise especially from an understanding of the functioning and production of components of electric cars, which can e.g. be demonstrated by technology roadmaps (Bai et al. 2012). This helps to get deeper insights into specific aspects of the developments and also to establish support schemes according to the forecasts that could lead to a breakthrough of that technology. To achieve this goal it is important to recognize key factors (such as the oil price) which are affecting the mobility of the future and to compare potentials and limitations of different propulsion concepts (Hanselka and Jöckel 2010, Li 2007). As major driving forces Hanselka and Jöckel mention the growth of world population and urbanization, i.e., mobility in large cities is becoming increasingly important and is linked with the desire for a livable urban environment without traffic noise or fine dust (Dudenhöffer 2010, Hanselka and Jöckel 2010). However, it is still not identified which future technological solution ensures such future mobility.

Electric mobility is still in a niche and competes for example with the hydrogen car (Bakker et al. 2012). Bakker et al. show that the niche technology is shielded from normal market forces by government subsidies on the one hand and compete with alternative drive technologies in terms of R&D funding, regulation and the construction of supporting infrastructure on the other hand. It turns out that big hopes follow later disappointments of various component technologies. Therefore, it is important to monitor sales and product evolution. With a growing market companies are motivated to develop new strategies based on market preferences (Orbach and Fruchter 2011). In terms of innovation management it is important to understand the process of technological change. This includes questions such as how the involved actors manage their early moves and how the knowledge base could rise to achieve competitive advantages. Also spill-over and their consequences for business sectors, e.g. sectors like energy or IT, should be analyzed (Pohl 2012, Pohl and Elmquist 2010).

Furthermore, it should be noted that certain developments require different materials and resources. The raw material of lithium which is widely used for most batteries and accumulators (Peters 2010), is still available for decades, but otherwise it is located only in a few global regions which usually are known as (politically) less stable and reliable regions. In order to secure the raw materials, considerations are to be made how such batteries can be effectively recycled or which alternative battery systems exists. In addition, the entire system of electric mobility should be examined in terms of shortages of raw materials (e.g. cobalt, copper, indium and neodymium) and also answers have to be developed how actors could strategically respond to these shortages (Angerer et al. 2009).

With a look on the structures of companies, the challenge for the automotive industry is the emergence of new value chains. Automobile manufacturers must prepare themselves technologically and organizationally for an increasing demand for green technologies, but otherwise it is also important that they focus on their competencies which are conventional drives (Bechmann and Scherk 2010). Thus, there are opportunities and risks for the automobile industry which could lead to positional changes in the value chain. The impacts for innovation and marketing strategies are controversial discussed. Kasperk and Drauz (2012) e.g. assume that the automotive value chain will change by shifting the share of value added upstream (Kasperk and Drauz 2012). Therefore, the new car designs will have a completely new architecture around the power train and will have a huge impact on manufacturers and supply industry. Especially in the area of battery development and production European companies face major challenges, because appropriate technologies have been neglected for years and especially Asian manufacturers gained great experience and thus have strategic advantages (Deutsche Bank Research 2011). Changes are also expected in the energy sector, because an increase in the number of electric cars raises many questions regarding the network integration of these vehicles (Leitinger and Litzlbauer 2011).

Huelsmann and Colmorn suppose that competition in the automotive sector will increase and the forces will shift in favor of customers and suppliers. The authors assume that in the short-term the strategic and in the long-term the logistical complexity of the value-added networks increase, but they also come to the conclusion that only limited changes are taking place in the strategic behaviour of the firms and therefore it is expected that there are only perceptible changes in the value chain (Huelsmann and Colmorn 2011).

Also an important challenge for companies is to be prepared for volatile future automobile markets in an ongoing globalization and in terms of economic ups and downs of local economies as in the economic and financial crisis. This should not lead to an ignorance of future trends to develop sustainable products and alternative mobility concepts by using green technologies (Bechmann and Scherk 2010).

In conclusion it can be said that the firms' managements are responsible to develop strategies for a **payable sustainable mobility**. But electric mobility is not the only option to achieve this goal. Management strategies must also consider other **alternatives like biogas or fuel cell** (Avadikyan and Llerena 2010, Contestabile et al. 2011, Shinnar 2003). This can be achieved on the one hand in connection with the **development of mobility technologies**, e.g. power drive, battery, chassis, driving safety, or infrastructures like charging infrastructure. On the other hand it can be done by focusing on the development of **sustainable business concepts**, e.g. new mobility offers like car sharing (Canzler 2010, Canzler and Knie 2010). Another challenge is the potential change of the value chain. Companies must therefore derive consequences from the current developments for their business and examine which **capabilities** from other companies or sectors could be integrated (Knoppe 2012b, Thoma and O'Sullivan 2011). For all these issues, it is important to answer the question **which target groups** should be addressed and to analyze what customer classification can be employed (Knoppe 2012a). It is also interesting how the **technical understanding** of the (final) customer is addressed (Franke et al. 2012, Zhang and Shi 2011), because this determines how the products will be accepted which is one of the most crucial factors for the successful market launch (Dütschke et al. 2012, Franke et al. 2012, Sammer et al. 2008, Zhang et al. 2011).

3 Usability

In the following aspects of usability are considered. Usability means how a product or a service system can be used by certain users to achieve goals like effectiveness, efficiency and satisfaction. The usability of electric cars is closely related to the acceptance of the user. Thus, a positive attitude towards the development and diffusion of new technologies and consumer products as well as the consequent behavior and actions based upon these attitudes is central for market penetration. Acceptance also relates to the advantages of the consumers' use of these electric automobiles in comparison to other mobility means (e.g. trains, or even other drive systems in the automotive sector). The level of acceptance is affected by hard factors such as safety or range and soft factors such as design or image (Sammer et al. 2008, 2011).

Since electric cars still have disadvantages with regard to the hard factors, it is possible that individual factors such as comfort or a better personal image could convince the customer of the new products (Knoppe 2012a). Here also arises the question, how the general mobility orientation of the society looks like which is strongly based on the desired or frequently cited role models in the media. Sustainable aspects of public and personal perceptions play an increasingly important role, but only a few people use electric cars currently. Since it turns out that the experience of the new technology by driving electric vehicles triggers learning processes maybe mobility routines can change in the future (Zimmer and Rammler 2011). Hence, perhaps in the future the range will no longer be quite so critical for the customer.

But today one of the main characteristics of usability is still the range which is significantly affected by driving style and battery capacities (Bingham et al. 2012, Chlond et al. 2012). Others are charging time and the amount and distribution of charging possibilities or safety issues which in addition influence the price of electric cars and have a big influence on public awareness and acceptance (Franke et al. 2012, Lunz et al. 2012, Zhang et al. 2011).

The charging times of electric car batteries are significantly different from those related to refueling internal combustion engines. Usually a distinction is made in the literature between the loading scenarios based on conventional household sockets with 230 volts or those at fast-charge stations with up to 400 volts (Fraunhofer-IAO 2010a). The charging takes between 6 and 8 hours (230 volt socket) and is re-duced to 30 minutes with a capacity of approximately 80% by fast charging infrastructure (Fraunhofer-IAO 2010b). The downside of such a fast charging process is the reduction of the life time of the batteries. Another concept relies on the replacement of the whole battery at battery-changing stations. The battery replacement just takes a few minutes (Betterplace 2012, Johnson and Suskewicz 2009).

Based on observed mobility patterns it is expected that electric vehicles will be available especially for driving short distance for individual transport due to the limited range of the batteries and drive systems (Raykin et al. 2012). Therefore the vehicles are likely to operate in cities and are used as a second car (acatech 2010a). There are also studies that deal with the optimal range of electric vehicles in relation to the development of the oil price. It turns out that the oil price level and the driving habits have a strong impact on the cost-performance and the ideal electric driving range (Özdemir and Hartmann 2012).

In connection with the discussion of the necessary range there are also questions of the optimal state of charge. Studies have examined e.g. the optimizing of charging cycles, how the increased demand of renewable energy can be satisfied (Finn et al. 2012), how charging operations can be controlled intelligently (Schill 2010a), how a design system of charging infrastructures should be layout in terms of numbers of charging station in an area (Brauner 2008, Hiwatari et al. 2012) or how fast loading should take place (Schroeder and Traber 2012).

Another aspect of usability is security, which can be viewed from two perspectives. First there are questions on the failure of components of the electric drive train and how safe the electrical components are in accidents. In contrast to the voltage employed in household sockets (230 V) electric cars are powered with 400 V. The potential additional threat can be countered with a special risk switch, switching off the current electric flows in the car completely in case of an accident (Kulkarni et al. 2012, Peters 2010).

Second there exist safety aspects focusing on the safety of other traffic users like pedestrians and cyclists. Current models of electric cars are already almost silently and can be a risk for blind and visually impaired persons (ANEC 2010).

In summary it can be stated that the user must gain **experience** with the electric vehicles so that in addition to price or range some positive experiences of everyday usability are perceived. However, crucial questions remain unanswered: When starts the nationwide introduction of electric vehicles (Driscoll et al. 2012, Hugosson and Algers 2012)? How will the user charge their car (Axsen and Kurani

2012, Richter et al. 2012)? Which **charging standards** (charging infrastructure) will prevail (Brown et al. 2010)? Could the car also be recharged during long distance travels to other areas or who provides a comprehensive **infrastructure** (Reichert et al. 2012, Wang et al. 2011)? Which **business models** (owned vehicles vs. car sharing) will prevail (Baur et al. 2012, Dosch 2012)?

4 Standardization

Standardization, which designated the unification of products and product components, as well as adherence to rules in the manufacturing and administrative processes in enterprises, is critical to the successful introduction of electric mobility (Arnold et al. 2010, Reichert et al. 2012). Uniform standards will facilitate market participants to use their resource development efficiently and give customers transparent and interoperable offerings. To find the optimal time to establish standards is very difficult, because an early setting may exclude new and relevant (technical) knowledge. On the other hand, it is also problematic to set standards later, because if various solutions are on the market there are numerous resistance which leads to increased costs and coordination time until standards are agreed upon (acatech 2010a).

Standardization is an established process and in Germany these processes are promoted by the German Institute for Standardization (DIN 2012). The private club offers business, science, consumers, test institutes and authorities the possibility to work in an organized way on the development of consensus standards. The special challenge in the field of electric mobility issues is that many players from different business sectors need to work effective and purposeful together. In Germany a committee that developed a coordinated standardization roadmap was established under the National Development Plan for Electric Mobility (Federal Goverment of Germany 2009). The first version of the roadmap was presented in November 2010 as a result of the "Working Group 4 standardization" of the National Platform for Electric Mobility (AG 4 „Normung Standardisierung und Zertifizierung" 2010), in January 2012 an update and supplement was published (AG 4 „Normung Standardisierung und Zertifizierung" 2012). This roadmap is the central element of standardization for the coming years in Germany. The roadmap also provides an overview of the standardization landscape and identifies blank spots and demonstrates recommendations and actions to fill them. Accordingly, the standardization activities focus on topics that result in standard interfaces (AG 4 „Normung Standardisierung und Zertifizierung" 2012) in order to provide an unrestricted worldwide secure and free use of vehicles using alternative fuels.

It is discussed that standardization can create synergies and avoid duplication of efforts (Brown et al. 2010). Furthermore, requirements for cross-border payment systems (e.g. for data protection) or auditing standards for comparability of product characteristics (e.g. regarding the performance and life of batteries) are defined. Standardization also seeks to limit the variety of alternatives. Consumers will benefit from such an approach because a comparison of products is much easier. Organizations benefit because they do not have to offer multiple options of their products and thus can often reduce costs. This also contributes to the reduction of investment risks and to reduce trade barriers. The key issues (AG 4 „Normung Standardisierung und Zertifizierung“ 2012 see pp. 23–38) of standardization are:

- **Electric vehicle and smart grid** with sub-themes such as charging (locations, functions or vehicle functions during operation on stationary power), billing or electrical safety (for developments in this area see also (Brown et al. 2010, Gallardo-Lozano et al. 2012, He et al. 2012b, Ramezani et al. 2011, Wang et al. 2012),
- **Interfaces, energy flows and communication** with sub-themes such as vehicle versus charging infrastructure, driver versus customer, vehicle versus energy trading (pricing), charging infrastructure versus network (Brauner 2008, Bunting 2012, Wang et al. 2012),
- **Electric vehicles** with sub-themes such as system approaches to power drive, system approaches for loading, safety (electrical safety, crash), fuel-cells, battery, capacitors (Axsen and Kurani 2012, Werther and Hoch 2012),
- **Charging stations** with the sub-themes provision of the energy flow or control (Dong and Lin 2012, Hiwatari et al. 2012, Leitinger and Litzlbauer 2011, Lunz et al. 2012, Schuster and Leitinger 2011).

Currently the utilization of used batteries (“second life”) is discussed as a stationary back-up (e.g. for wind and solar energy). In addition energy recovery or communication and inductive charging are current issues of standardization.

Other relevant sources of information are:

- **DIN-study** on “standardization needs for alternative power and electric mobility”, which identified relevant standards and gives an overview of standards and recommendations for the development of a standardization roadmap (Bremer 2009).
- **VDE study** “E-Mobility 2020: Technology—Infrastructure—Markets”, which shows estimates of the current technology as well as to Germany’s position and also discusses opportunities and challenges of electric vehicles (VDE 2010a).
- **VDE study** “electric vehicles”, which represented the potentials of the electric vehicles in connection with batteries (VDE 2010b).
- **PwC study** on socioeconomic components of electric mobility. This study examines mainly socioeconomic issues such as business, law, policy and user in connection with standardization (PwC AG 2012).

In summary it can be said that standards need to be developed which support the introduction of electric vehicles, e.g. those standards which are comparable to those of internal combustion engines with regard to security issues. As a key challenge the establishment of **international standards** can be identified. For this the current situation in the respective countries must be analyzed. The **energy systems** in the various countries strongly differ from one another, which has consequences for the etablishment of an optimal **charging infrastructure**. Further, the most important issues of standardization are the charging stations in terms of structure and protection, the **charging plug**, the **communication infrastructure** between the vehicles, power stations, infrastructure and network operators (acatech 2010a).

5 Economic Conditions

Economic conditions of electric mobility, which means the planned masures and actions covering the human needs, are examined in this section. This includes issues like integration of the automotive manufacturing in the economy or the development of fuel prices. Other aspects are costs for electric cars or challenges of the future such as the finiteness of resources.

As one of the major economic sectors in Germany and Europe the automotive industry faces enormous challenges. Besides economic globalization trends (Bechmann and Scherk 2010) this also includes the politically supported issues like the reduction of waste emissions (Bernhart and Zollenkop 2011). Many OEMs have reacted and introduced new car models with reduced emissions and more fuel-efficient technology in their portfolio (Baur et al. 2012). This development also occurs against the background of rising oil prices (Bunting 2012, Dijk et al. 2012), so that for the companies the question arises, which are the automobile technologies of the future and in which field should they invest (Avadikyan and Llerena 2010). It is quite controversial which trends in the energy sector like biofuels and biomass to liquids have a major influence on current developments in the mobility market. However, it should be noted that the energy landscape changed in terms of energy prices or local energy use preferences (Bunting 2012).

Companies must also be aware that changing mobility needs and new value creation potential in the entire mobility system lead to changes in the customer's decision criteria (Canzler 2010, Dütschke et al. 2012). New business models allow not only to define some elements of the new mobility, it could also come to an altered interaction which creates business models such as car sharing, mobility shops or e-mobility provider services (Canzler and Knie 2010, Knoppe 2012a). New business models also aim at the combining mobility with the mobile internet (Heinrichs et al. 2012) or with charging infrastructure (Kley 2011). Further, companies also need to initiate R&D in new business fields without begin able to anticipate a clear market for each innovation and at the same time they must continue to grow their daily business, e.g. in terms of increased market turnover or by increasing the efficiency of existing vehicles (Deutsche Bank Research 2011).

It also raises the question of availability of the necessary raw materials. For example current electric cars or those close to market introduction mostly use lithium-ion batteries. However, it should be noted that in the strict sense the rechargeable energy storage are not batteries, which cannot be re-charged, but accumulators (Peters 2010). The preferred use of the lithium technology could be explained by the experience in other areas such as the computer industry, which already resulted in a learning curve (Peters 2010). It is forcasted that in the next four decades there are sufficient reserves of lithium. However, these reserves are concentrated in a few countries and some of them are located in geopolitically unstable regions (Angerer et al. 2009, Kushnir and Sanden 2012). So it is of strategic importance for the economic success to ensure the necessary resource base early.

As a key issue for the future market success, the direct and indirect costs of these vehicles can be identified (Biere et al. 2009). This includes purchasing costs and variable costs such insurance rates, energy prices or costs for maintenance and repairs. Others are costs for the construction of the necessary charging and intelligent navigation infrastructure and last but not least costs for training of skilled workers. Basically the question arises how much consumers would be willing to pay for vehicles or services. Some surveys suggest that first mover would pay up to 3,000 € as a premium in comparison with conventional vehicles (Schlick et al. 2011). But how the loss in value of the vehicle will develop largely dependents on the attractiveness of the overall system and the individual brands (Hanselka and Jöckel 2010). The purchasing costs at the market launch phase of electric vehicles are much higher due to high battery costs and high expenses for R&D in comparison to conventional vehicles. That will have a major impact on customer's willingness to buy an eletric vehicle (Hidrue et al. 2011). The price of the battery and its expected life time have significant influence on the overall purchasing and probably maintenance costs (DeLuchi et al. 1989, Hidrue et al. 2011). It is forecasted that these costs will be reduced significantly in the coming years (Baker, Chon and Keisler 2010) which in turn should increase the attractiveness of buying an electric car. This is of course closely connected to the development of the energy price, which is influenced by factors such as the development of the world economy, or local preferences (Bunting 2012, Özdemir and Hartmann 2012).

Economic conditions are also affected by political and economic institutions. For example there are mobility restrictions such as city tolls for cars in many cities (Sammer 2012). An increase in user costs leads to a reduction in car use and selection of alternative modes of transport. Furthermore it is important how the value chain of electric mobility is established in the region. From a regional perspective the question rises if there exist only sales and service institutions or if there develops a value chain which includes manufacturer of raw materials and auxiliary materials, component manufacturers and OEMs (Cooke 2011, Knoppe 2012a, b).

It can summarize that electric mobility enable the reduction of dependence on fossil fuels. The **change of the value chain architecture** is a challenge and also a chance for the automotive industry. On the one hand many manufacturers and suppliers in Germany and also in Europe own **key technologies** for future mobility developments, have **market leadership** and invest heavily in this approach, on the other hand threats arise mainly by the massive **government support** of new actors, especially in China and the USA (acatech 2010, Yang 2010). The challenge for companies is to find a sustainable and economically competitive solution.

6 Social Conditions

Under social conditions the requirements and necessities of the users as well as mobility behavior is summarized. The success of electric mobility products depends on the fulfillment of users' expectations (Pierre et al. 2011, Sammer et al. 2008). But in the past, electric vehicles were not able to meet all the needs of users. Hence, in Germany the population of electrically powered vehicles accounts for less than 1 % of all cars (Sammer et al. 2008).

Based on the current mobility patterns and behavior projections for future developments are made, e.g. in terms of willingness to pay or ecological settings. From this the market potential of electric vehicles can be deduced (Lieven et al. 2011, Link et al. 2012). Not only in Germany there exists social movements which are dedicated to increase environmental awareness by educating consumers and thereby influencing development processes of companies which provide green technologies (Ustaoğlu and Yıldız 2012).

Based upon acceptance and attractiveness studies the potential of electric vehicles, especially among private users, are forecasted (He et al. 2012a). For example in a simulation based on interviews of new car buyers it could be shown that in 2020 two-thirds of all new car buyers in Germany would opt for an electric vehicle, battery electric vehicle or a plug-in hybrid car (Götz et al. 2012). Depending on the vehicle class the likelihood to choose a battery electric vehicle is between 12 and 25 %. Especially for smaller cars, the acceptance is already high in 2020. For larger vehicles an increasing acceptance is forecasted until 2030. As one reason for this increase it is stated that the technological progress leads to falling prices. Besides the price, enviromental aspects also play an increasing role for purchasing decisions. The analysis demonstrates that there is already a large acceptance potential for electric vehicle concepts and that this may even further increase in the future. It is also shown that the acceptance of electric vehicles is influenced by different individual factors such as academic degree, annual income and number of previous vehicles or government policies. The price sensitivity for electric vehicles additionally depends on the number of family members, the opinion of peers, maintenance costs and degree of safety (Zhang et al. 2011). Besides the price, buyers also consider subjective aspects such as prestige or style (Sammer et al. 2011) and it is also crucial how people get information on electric vehicles, e.g. by interpersonal communications or by the media, and how preferences, e.g. on environmental issues, change over time (Gould and Golob 1998).

This is consistent with studies on the mobility needs. Electric vehicles already meet the daily requirements in terms of average required ranges and flexibility, especially if the electric vehicles can be charged at home (Arnold et al. 2012, Pearre et al. 2011). However, a main obstacle is still the limited range of

150–300 km (Hawkins et al. 2012). Users have become accustomed to the fact that conventional vehicles have a range of up to 1,000 km (Chlond et al. 2012). That means that for some long trips, e.g. for vacations, electric vehicles do not seem suitable. To increase the acceptance for electric mobility, the development of integral mobility systems is required to offer alternatives for long-distance travel, e.g. combinations of electric vehicles with the use of public transportation or car sharing (Canzler 2010, Canzler and Knie 2010).

Overall it can be said that electric vehicles have great potential from a user perspective. But for a successful market penetration numerous technological and economic challenges must still be managed. Particularly critical are the attitudes towards the **range** as well as towards the **high cost of the vehicles**, mainly caused by the **high cost of the battery**. For the future it is still to be analyzed how the customer will accept **new mobility concepts**, which combine electric vehicles with other **services** to compensate the weaknesses of electric mobility. Furthermore, it seems necessary to investigate how the previous mobility habits which lead to **physiological barriers** could break up so that the people rethink their mobility decisions.

7 Ecological Conditions

The full potential of electric mobility is only visible in connection with innovative business plans which include the use of renewable energies (Barkenbus 2009, Brady and O'Mahony 2011, Pehnt et al. 2007, 2011, Schill 2010a). Electric vehicles have a high efficiency and by charging renewable electricity they almost create no emissions. This of course assumes that the required sustainable electricity can be provided in the right amount at the right time.

Nevertheless, it can hardly be estimated how big the ecological potential of electric mobility really is. In fact there is only few data on environmental effects based on empirical cases and experiments, e.g. the CO_2 emissions of electric cars, so that many studies deal with model calculations (Kudoh et al. 2001, Ramezani et al. 2011, Schill 2010a, Yabe et al. 2012). It is also little known about the impacts of electric vehicles and their components over their life cycles (Held and Baumann 2011).

Furthermore, the question arises, what the market potential of electric mobility is to make realistic assumptions of future electricity demand (Lieven et al. 2011, Link et al. 2012). Although the real consumption of electric vehicles in practice is higher than according to manufacturer's instructions, the potential for reducing emissions is very high. This applies even when the energy would originate from fossil fuels. At the same time it is pointed out that the increasing use of electric cars would not radically increase electricity demand (Nischler et al. 2011).

More central questions relate to the geographic distribution of charging stations as well as to the impact of charging strategies on the utilization and stability of the electricity network (Hartmann and Özdemir 2011). Without a smart control of the charging processes demand peaks might be generated at points in time when there already exists a high demand for energy originating from other applications. A solution could be to use intelligent charging to move the load peaks to different time windows, e.g. those with a high feed-in of wind energy (Pehnt et al. 2007, Schill 2010a).

Another issue is the analysis of the efficiency of the drive train. Here the focus is on the development of efficient vehicle systems, which allow a good driving performance with low energy and resource usage (Estima and Marques Cardoso 2012). In this context the energy consumption under different environmental conditions is also studied (Hwang and Chang 2012). The energy efficiency in terms of driving patterns should be measured from the provision of primary energy up to the wheel so called 'well to wheel' contemplation (Raykin et al. 2012, van Wee et al. 2012). In addition to the vehicle, the entire infrastructure for fueling and maintenance of vehicles could also be analyzed in terms of resource consumptions. It can be shown that the infrastructure for electric vehicles is more carbon and energy intensive than for diesel and petrol vehicles (Lucas et al. 2012).

Some open issues are the investigation of mobility patterns and climate effects in terms of using electric vehicles. That means how and to which extent the use of electric cars really substitutes other motorized individual mobility or whether it rather leads to additional traffic. It should also be considered how the **resource requirements** develop with regard to particular **(rare) commodities** and which environmental impacts result from a rising demand. Another often neglected field deals with the recycling of components, vehicles or infrastructures. Resource-efficiency or the prevention of supply constraints make it necessary to develop **strategies for recycling systems**.

8 Politic Conditions

The promotion of electric mobility by policy makers is not without controversy (Arnold et al. 2010, Dudenhöffer et al. 2012, Indra 2012, Krutilla and Graham 2012, Schill 2010a, b, Yang 2010). To support the development and the launch of electric cars, there are different approaches. Current projects e.g. in Germany aimed at the development and demonstration of technology, infrastructure and business models (Brauner et al. 2012, Knoppe 2012a, b). This overview also includes other measures such as financial support, the provision of information and the granting of privileges.

There is a lot of controversy whether and how financial support of electric vehicles should take place. Policy might subsidize the purchase price, support market penetration, support the market launch and increase production to achieve economies of scale and by public procurement (Dosch 2012, Lieven et al. 2011). The discussion focuses primarily on the promotion of sustainable mobility systems, which includes motorized vehicles, electric bikes and cars and also heavy commercial vehicles (Buller et al. 2009). The importance of electric vehicles for climate protection is often highlighted (Ahrens et al. 2011, Gnann and Plötz 2011, Indra 2012). It is also emphasized repeatedly that the automotive industry in many countries is an important sector of the economy and the public assistance shall be seen as a stimulus program to help an injured industry to recover from the financial and economic crisis (Baur et al. 2012, Canzler and Knie 2010).

The financial assistance can take different forms. First, purchase subsidies are granted to reduce the purchase price the customer pays for an electric car in order to narrow the price gap between conventional and electric vehicles and hence to make electric cars more attractive for customers (Kley et al. 2010). While in Germany no such subsidies are granted at the moment, they already exist in many other countries. But the approaches differ considerably between the countries. While for example in the U.S. direct grants are awarded, the Japanese government supports car buyers by paying parts of the price gap between electric and conventional cars. China mainly supports electric mobility while other alternatives are limited (Yang 2010).

In addition to direct funding, there are also indirect incentives. In the discussion are measures such as a waiver of taxes, which incurred on the purchase of an electric car in the respective States (e.g. sales tax). Furthermore the users of electric vehicles could be supported by a reduction of the motor vehicle tax. Taxes could also be designed for a differential promotion of electricity and gasoline or diesel to achieve savings by driving electric vehicles compared to internal combustion engines (Gallagher and Muehlegger 2011). Of course this can lead to a decline in the revenue from oil in the future (Indra 2012). Depending on the budget situation states maybe faced to develop new sources of income. From a financial view other measures are the promotion by low-interest loans or improved possibilities of tax depreciation.

Because it is important for the market introduction that customers are willing to buy the products, they must be supplied with information in advance. Measures which are affecting the attitude and the willingness to buy are the coverage in everyday media (e.g. by the provision of information on television or online portals) or the own driving experience of electric cars (e.g. during open house presentations or as a test driver within government-funded research projects in the model regions). It is central that the new technology is "experienced" and thus directly affects the perception of the consumer (Dütschke et al. 2012). The public sector has also the possibility to directly affect market demand by public procurement and equip public carpools with electro mobiles, for example busses for public transport or vehicles for waste management (Rudolph 2012). The increase in consumer acceptance can further be achieved by exhibition performances, where visitors can collect information on electric vehicles and the necessary infrastructure.

In addition to the financial aspects of the promotion there are also non-monetary options of support. These include the joint use of bus or taxi lanes or parking facilities with charging infrastructure. Furthermore, the toll exemption or the driving in green zones are considered as incentives to use or buy electric cars (Sammer 2012). Specifically in city centers the possibility to access pedestrian zones with electric delivery vehicles at night could represent an important sales stimulus for logistic firms (Clausen and Schaumann 2012). For all this a marker for the distinction of electric vehicles would be necessary.

Political measures can also address the transparency for customers, for example the different energy consumption of drive types are made comparable. Hence, in electric battery-powered vehicles the indication of consumption can be made in "kWh/km" or in kilowatt-hours per mile. However, it is important that the customer can compare different parameters between battery-powered, hybrid and conventional vehicles (Chlond et al. 2012, Contestabile et al. 2011).

In summary it can be said that a variety of monetary and non-monetary conveying opportunities exist or are discussed to support the introduction of electric vehicles. However, it is still unresolved how the concrete funding scenery shall look like, especially in Germany, so that other alternative drives are discriminated or also claim special rights. Kley, Wietschel and Dallinger analyze also the effectiveness, efficiency, flexibility and practical political acceptance of electric mobility funding in Europe and come to the conclusion that the **efficiency of the funding must be increased**. In addition, **non-monetary incentives** such as free parking help to overcome existing technical and economic barriers (Kley et al. 2010). In the future it has to be clarified whether and how the sale of electric vehicles should be supported, where the money to support the market launch can come from, which **reasons for or against** a government support exist and how the efficiency of the subsidy programs can be measured. Last but not least it remains to be investigated how **government objectives** can be achieved and whether they result in **ecological and macroeconomic benefits** (Raich et al. 2012).

9 Conclusions

Due to the dynamic development in recent years, it is difficult to get an overall perspective on the development of electric mobility. This dynamic can be illustrated by the google search terms and search results. To receive a common understanding, the aim of this article was to get some insights in the influential socio-economic fields in the area of electric mobility and identify those fields which are currently under investigation. The research questions which were addressed by this contribution were the following: What are important socio-economic fields in the area of electric mobility? Which state-of-the-art findings can be identified? The short answer to the last question are as follows:

Management perspectives: Managements should consider different future mobility options such as electric mobility, biogas or fuel cell and their complementarities. Companies are challenged with a magnitude of consequences such as changes of value chains or radical innovations changing the market drastically. Strategies should also aim at the identification of new capabilities and their timely integration.

Usability: It shows that the user must gain experience with the electric vehicles so that perceived negative aspects like price or range can be opposed by some positive experiences of everyday usability. The user friendliness can also be evaluated as positive especially with regard to new business models and services like car sharing.

Standardization: For a successful market launch international standards, e.g. in terms of structure and protection, the charging plug, the communication infrastructure between the vehicles, power stations, infrastructures and network operators, are essential. By standardization electric vehicles must be put into a position comparable to internal combustion engines.

Economic conditions: The automotive industry is facing a radical turn. The value chain architecture changes due to the development of sustainable mobility systems. Indeed some incumbent companies possess important technologies, but they are challenged especially by new competitors from other countries and sectors. From the perspective of the user the purchasing and utilization costs must be transparent and comparable to other mobility systems or conventional drives.

Social conditions: Electric vehicles have great potential from a user perspective. Particularly users who drove electric vehicles are already excited about the new technology. But due to existing weaknesses in comparison to competitive technologies, e.g. with regard to the range, it should be analyzed how the customers will accept new mobility concepts, which combine electric vehicles with other services. Furthermore, psychological barriers must break up, so that people reconsider their mobility behavior.

Ecology conditions: The environmental considerations of electric mobility target primarily the eco-balance and the question where the electricity comes from or should come from. Challenges exist in terms of resource requirements and by the environmental impacts generated by a rising demand for electric vehicles.

Political conditions: There exists a variety of monetary and non-monetary opportunities to support electric mobility. The efficiency of the funding programs is currently not always guaranteed. Moreover, it is clearly important which causes are for or against a government funding and where the money might come from.

Consequently, further research requirements result mainly from the comprehensive issue of the research. It is first necessary to analyze separate aspects in more detail to get deeper insights in single challenges. Further it may be advantageous to **monitor** some **topics** like business models which are subject to a constant change because of **persistent technology changes**. For such a monitoring the initially introduced techniques for searching catchwords in the internet could be a good approach. Therefore, the research landscape could benefit from further research in all presented topics. This is also affected by ongoing dynamic technological developments. Many **research questions** and the gained insights **need to be adjusted to new progresses** e.g. in battery technology or the introduction of new service or business models. On the other hand it is also shown that it is probably still a long way for the electric mobility to have a **significant market share**. On the economic side companies may have to pay attention that the foundation of their success of tomorrow has to be laid today. That means that the developments must be followed precisely to compete with old and new rivals and with focus of **core competencies** or core products it is very important that necessary skills are developed in time if electric mobility leaves the niche.

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