TAB

OFFICE OF TECHNOLOGY ASSESSMENT
AT THE GERMAN BUNDESTAG

Anja Peters
Claus Doll
Fabian Kley
Patrick Plötz
Andreas Sauer
Wolfgang Schade
Axel Thielmann
Martin Wietschel
Christoph Zanker

Electric mobility concepts and their significance for the economy, society and the environment

Summary

October 2012
Working report no. 153

SUMMARY

Electric mobility is seen as being an essential element in designing passenger and freight transport sustainably. All the predictions expect that global transport capacity will continue to increase. Several studies assume that the global stock of vehicles will double by 2030. This is accompanied by an increasing shortage of fossil energy sources, especially crude oil, and therefore rising fuel prices. In view of ambitious climate targets, the necessity to redesign transportation systems is underlined by extensive studies, e.g. of the Intergovernmental Panel on Climate Change (IPCC) or the International Energy Agency (IEA). According to the national targets formulated in the German government's Energy Concept, greenhouse gas emissions (GHG emissions) are to be reduced by 80% in Germany compared to 1990 emission levels. The final energy demand of transport should be reduced by 40% compared to 2005; this will not be achievable just by improvements to conventional cars. Alongside an ambitious climate policy and the necessity to reduce the consumption of fossil energy sources, lowering local pollutant and noise emissions is another global driver of electric mobility. In Germany as well as other automobile producing countries, keeping the automobile industry competitive also plays an important role during a global diffusion of electric vehicles in order to safeguard jobs and economic output.

Against this background, electric mobility was declared an essential element of sustainable mobility in the German government's National Development Plan Electric mobility (NEP). The objective set in agreement with industry is to have at least 1 million electric vehicles in Germany by 2020 and at least 6 million by 2030. The term »electric vehicle« here refers to four-wheeled vehicles with a battery which can be charged externally by connecting it to the mains. These are purely battery-electric vehicles (BEV) and hybrid vehicles with a mains connection, so called plug-in hybrids (PHEV).

It is of major importance for political decisions to know which impacts are linked with a diffusion of electric mobility and how a socially desirable development can be achieved. In view of these concerns, this report provides a comprehensive analysis of the topic of electric mobility. The ecological, economic and social aspects of electric mobility are brought together, documented and evaluated for Germany for the next 1 to 2 decades, in order to derive conclusions and options for action based on this. A broad range of current studies was assessed to answer the extensive set of questions and new or complementary analyses were conducted.

The focus is on four-wheeled electric vehicles (BEV and PHEV), especially passenger cars. Light-duty commercial vehicles (LCV) and buses as well as micro electric vehicles (like electric bikes) are only marginally considered. Hydrogen-powered fuel cell electric vehicles (FCEV) are included in this report for comparison purposes and as another long-term realisable alternative to conventional cars.

What are the technological challenges?

The battery plays a key role in the development of the technology, because of its high share in the vehicle costs and because the range of electric vehicles is determined by the energy density achieved with the respective battery technology. Besides reducing the costs and improving the energy density, battery development is currently focused mainly on increasing performance characteristics, lifespan and safety.

Due to the comparatively high energy densities achievable with lithium-based batteries, this technology seems viable for use in electric vehicles; it is distinguished by different generations of current and future battery types. Lithium-ion batteries of the 1st generation are widespread in consumer electronics applications, but are not suitable for mobile applications for safety reasons. While vehicles with lithium-ion batteries of the 2nd generation are currently entering the market and expected in the near future (e.g. based on the safe iron phosphate technology), the full market roll-out of electric vehicles is expected to use different configurations of 3rd generation lithium-ion batteries as well (high voltage, high power developments). Due to physical-chemical limits, however, electric vehicles with these battery generations will by no means reach the range of conventional cars. In contrast, post lithium-ion batteries of the fourth generation (e.g. lithium-sulphur) seem to be able to greatly increase the energy densities and achieve the range of conventional vehicles. However, experts are not reckoning with the market launch of such batteries until well after 2020.

Because BEV are thus predicted to have limited driving ranges in the longer term, PHEV are thought to represent a promising alternative. The hope here is to use them to overcome users' fears regarding the restricted range of electric vehicles and to be able to almost fully match the range of today's cars. The battery can be designed to be smaller and therefore cheaper than in BEV. To enable broad-scale introduction to the market, however, it seems necessary to reduce battery costs to under 300 euro/kWh.

Solving other technical challenges is as well an important prerequisite to a successful and comprehensive market introduction of electric vehicles: Electric motors and the on-board power electronics have to be improved. The development of systems which enable faster charging can also help to make up for the limited driving range of electric vehicles.

Can electric mobility be successful on the market?

Currently there are only a few electric cars being offered on the market. The sales figures of electric vehicles are correspondingly still very low in Germany, but also the rest of the world, and are in the range of only a few thousand. Many leading automobile producers have announced concrete plans for car models to be introduced to the German market in the near future. Alongside the currently limited offer, from a consumer perspective, the high purchasing costs of electric vehicles and the limited range of BEV represent significant barriers to people actually purchasing such vehicles.

Under the current framework conditions and without significant purchase inducements or other incentives, it will be difficult to achieve the target of getting 1 million electric vehicles on the roads in Germany by 2020. There is still uncertainty about important framework conditions. For example, a sharply rising oil price or a steep decline in battery or vehicle costs could lead to dynamic market developments. The target of at least 6 million electric vehicles by 2030 seems more realisable, because it can be expected that the conditions for electric mobility will continue to improve in the future. Possible developments in the framework conditions and influencing factors should therefore be continuously monitored and measures should be designed so that they permit flexible reactions to any changes.

In the medium-term, PHEV are expected to have bigger market shares than BEV. PHEV could prove an attractive option, especially for medium-class vehicles and for consumers with regular daily driving profiles. BEV tend to be more interesting for the smaller car segment, but these require matching user profiles or they have to be integrated into multimodal mobility services due to their limited range and the necessary charging times. If major technological advances are made in fuel cells and hydrogen tanks, FCEV will probably become interesting for large cars with higher daily and annual mileages. PHEV are less attractive for this segment, because these profiles have a very high share of combustion engine driving.

International policy measures

Over the last 5 years, numerous governments around the globe have begun to initiate state support programmes to prepare for the spread of electric mobility in the near future. Most countries are focusing here on market preparation measures and setting incentives in the form of financial subsidies when buying an electric vehicle, granting tax reductions, e.g. based on CO2 emissions or want to expand infrastructures by promoting private and public charging points for electric vehicles. Only a few countries have the potential to become lead suppliers and lead markets for electric mobility, and are specifically promoting R&D and the production of key components of electric vehicles.

The governments of the US, China and South Korea have announced R&D programmes worth billions for the near future. The funding programmes of the US are focusing on rapidly industrialising the production of battery cells and systems. China‘s government is concentrating on the key components of battery, drive and power electronics for electric vehicles and FCEV. South Korea is planning to develop and expand battery production with the help of multibillion investments in the next 10 years. Japan, in contrast, has been funding R&D in battery and fuel cells for electric mobility since the 1990s. These funding activities are supplemented systematically by other market preparation measures of the national government and local authorities, e.g. regional infrastructure expansion and various inducements to purchase electric vehicles. In comparison, Germany is focusing on R&D cooperations between science and industry. The necessity and design of commercialisation measures, especially of purchase incentives and the expansion of infrastructure, are being controversially discussed and it has not yet been decided how to structure the promotion of electric mobility in Germany in detail in the period up to 2020.

Are electric vehicles environmentally-friendly?

When assessing the ecological impacts of electric vehicles, a distinction has to be made between local air pollutants and greenhouse gases (GHG). One of the main characteristics of electric vehicles is that they have quasi zero emissions when operated locally. In contrast, however, manufacturing electric vehicles causes greater environmental pollution than producing conventional cars. To achieve a positive balance, therefore, this »ecological rucksack« from manufacturing the vehicle has to be offset by lower pollution when driving it.

In the analyses which include the environmental impacts due to obtaining raw materials in the respective countries of origin, electric vehicles cannot be assigned clear advantages with regard to the emissions of local air pollutants. In Germany, the eco-balance of electric vehicles is certainly more favourable than that of conventional cars, especially if renewable energy is used to power them. However, pollution due to the local emissions of conventional cars will also continue to decrease in the future due to ever stricter emission standards and technological improvements.

An ecological rucksack from the production of electric vehicles also exists for the GHG emissions, but is much smaller than for local air pollutants and can already be offset if renewable energies are used at relatively low annual mileages. A main to exclusive use of renewable energies seems possible given the amount of electricity required. For the 1 million electric vehicles in 2020, this lies well under 2% of the total amount of electricity supplied by renewable energies. If smart charging is applied and geared towards the availability of renewable energies, electric vehicles can also help to integrate renewables into the grid.

In order to counteract possible rebound effects due to the operating costs of electric vehicles, it seems sensible to use electric vehicles in commercial fleets as well as in carsharing, as taxis and especially in comprehensive multimodal mobility services which link different transport modes with each other. In this way, electric mobility can become a major building block of a sustainable system of transport in the long term.

Noise reduction versus safety

Noise reduction is viewed as one of the main advantages of electric vehicles. The external costs of noise due to health problems or in terms of medical expenses as well as drops in the value of real estate are estimated at 8.2 billion euros across Europe. These are mainly caused by noise emissions in built-up areas and during night-time hours.

The noise reduction which can be achieved with electric vehicles is decisively influenced by the driving speed and the total mix of vehicles on the roads. While the achievable noise reduction is negligible at speeds over 40 km/h and a high share of freight traffic, electric vehicles offer significant benefits in residential areas, especially during evening and night-time hours and can greatly improve the quality of life here.

Electric vehicles also offer the opportunity to shift services to off-peak hours which has not been possible so far because of specific noise limits. Thus, an increased use of electric vehicles in low speed ranges represents an effective measure to reduce road traffic noise. The advantages of electric vehicles will be felt in these areas even if the noise emissions of conventional vehicles continue to decrease in the future.

However, at the same time, this raises questions about an increase in the frequency of accidents with other traffic participants because of the reduced warning which signals an oncoming vehicle. Accordingly, there is some controversy about whether electric cars should be fitted with artificial noises. To what extent reduced noise emissions from electric vehicles without other safety measures also imply an increased risk of accidents cannot be answered given the current limited database. It seems to be indispensable to develop new safety technologies concerning a general noise reduction of cars in future. Introducing permanent artificial noises should, if at all, only be considered as an interim solution. Better suited would be the sensor-controlled temporary generation of (warning) sounds for pedestrians and cyclists.

National economic potentials

Germany's automobile industry is currently in a globally leading position both economically and technologically. This could be endangered at least in the medium term due to value added shifts based on the expected global diffusion of electric mobility. A significant growth of value added potentials is anticipated in the future primarily for electric mobility-relevant components, especially batteries, power electronics and electric motors, while only weak growth at best is expected for conventional components.

The battery has the biggest share of the value added in electric vehicles. The production of battery cells is currently dominated by industrial and newly industrialising Asian countries; German companies play hardly any role here internationally. It is still open whether or when they can catch up. To safeguard the value added position of the German car industry and in the expectation that electric mobility will become established on the car market in the medium to long term, it should be considered to build up development and production capabilities for high-performance batteries in Germany, too. However, because Germany has hardly any specific scientific or industrial capabilities in this field, these would have to be developed from scratch. In the medium to long term, there is the opportunity for Germany to open up this market through its already very well positioned chemical and materials research. Investments in the next generations of batteries seem to be much more promising than in the lithium-ion technology used today. In contrast, German industry has considerable expertise in producing battery systems from single battery cells, so that relevant market shares in this field are possible for Germany even in the short term; but the main share of value added is attributed to battery cells.

After the battery, power electronics has a high value added potential. Germany holds a very strong competitive position here. This future field is important for automobile manufacturing, but for other future technologies as well, e.g. in the fields of energy efficiency and renewable energies as well as control of the electricity grids. It is essential to safeguard the position Germany holds in power electronics.

There are technological capabilities and innovation potentials, spanning several sectors, in the area of manufacturing electric motors in Germany which could be successfully transferred to automotive applications. German system suppliers, specialised technology providers or car makers are demonstrating activities of using these capabilities for the development and production of electric motors and could play a major role in this field in the future.

In the next 10 to 15 years there will probably be more PHEV than BEV. With their two types of energy storage and motor, PHEV are characterised by a complex system structure. Because these vehicles have smaller battery sizes, the battery's value added share is less relevant. There could be advantages here for the German automobile industry.

In general, the value added in the automobile sector will change as the result of electric mobility. So far, primarily automobile producers and large system suppliers have been anticipating these changes and are reacting pro-actively to them by changing the orientation of their R&D activities as well as by forming new partnerships. At lower levels of the supplier pyramid, activity to date has been very low regarding the challenges of electric mobility. Therefore it seems necessary to make these usually small and medium-sized enterprises more aware of the approaching transition and the resulting opportunities and risks accompanying it.

Analysing the macroeconomic effects shows that the market development of electric mobility up to 2020 will not result in any significant structural changes, i. e. in any shift of value added between the economic sectors regarded. GDP and employment will rise slightly by 0.2% compared to the reference scenario without electric mobility. By 2030, GDP grows by 0.8% and employment by 0.6%. These results indicate that a future diffusion of electric mobility in Germany does not lead to additional costs macroeconomically, but that a slightly positive effect on GDP and employment can be expected. However, the simplified assumption made in the analyses was that the target of 1 million electric vehicles in 2020 can be reached without monetary incentives.

Raw materials for electric mobility

For the economic, ecological and social assessment of electric vehicles, cost and supply aspects play a role as do environmental impacts due to obtaining the critical raw materials both for vehicle batteries and for the electric motors. These include, e.g. lithium, copper, platinum, neodymium and other rare earths. Supply shortages could occur with rising demand from the automobile sector. In addition, the extraction of these resources is often associated with heavy environmental pollution or takes place in regions with few or no environmental regulations. There are still many uncertainties surrounding the topic of critical raw materials and a lot more research is required. Forecasts of the global demand for lithium and copper, their geological range and recyclability show that a global supply shortage need not be feared, but that their prices could increase noticeably up to 2030 due to the strongly rising global demand and the concentration on only a few supplier countries. For other rare earths, the situation looks quite different – and there could well be a supply shortage in the short to medium term. However, it is hard to make general quantitative statements about availability or price developments, for example.

Important future topics in the field of critical raw materials are the further development of recycling processes, waste and urban mining, developing substitutes and designing a raw material strategy. It is difficult to judge the impacts and life cycle assessments of current and future recycling processes from today's point of view, because of the lack of data and relevant studies. In principle, however, recycling seems to be essential as does the setting of standards for extracting the raw materials in order to counteract negative impacts on GHG emissions, environmental quality and social standards in the countries where the extraction takes place.

Promising first markets and target groups

The results available so far from research and pilot projects on the acceptance by potential and actual users of electric vehicles as well as analyses of the vehicles' profitability indicate that there are indeed promising first buyer or first user groups in both commercial and private domains. The different drive concepts and vehicle types as well as possible forms of utilisation or mobility concepts have to be taken into account when discussing them.

From a user perspective, the relevant advantages of electric vehicles include environmental benefits, low noise emissions and low running costs – but also driving behaviour and comfort as well as their image. In contrast, major obstacles are their high purchasing costs and the limited driving range.

In view of the high share of commercial consumers in newly registered passenger vehicles (approx. 60%) as well as in the new electric vehicles registered up to now (more than 90%), these buyers are assigned an important role on the early market for electric vehicles. Especially fleets with high annual mileages, but regular, planable tours seem promising, particularly because an economic use of electric vehicles would be possible here. For example, the use of BEV in the small and compact car segments seems economically feasible in mobile healthcare or within the scope of larger carsharing fleets. In the segment of light-duty vehicles, promising applications for BEV are seen in postal and package services with their delivery fleets in towns and cities and diverse tradesmen services. In comparison to this, PHEV enable longer distances to be covered due to their additional combustion engine so that they have a broader field of application and a larger market potential. Specific incentives for electric vehicles in commercial traffic could enlarge this economically attractive area in the next few years, such as e.g. allowing longer access times to inner cities for quiet vehicles with zero local emissions.

Among private buyers, promising target groups seem to be characterised by technology affinity, their interest in a specific vehicle and not least environmentally-friendly driving. Actual buyers are expected mainly in rural areas, in small and medium-sized towns or in the areas surrounding bigger cities, because cars are used more frequently here due to the lack of alternatives or suboptimal services. Younger and/or environmentalist target groups in large cities are less probable as a broad group of buyers of electric vehicles. Because of their financial situation and/or values and mobility habits they seem more likely to be users of electric vehicles within sharing schemes or multimodal mobility offers. Especially sharing schemes give users the chance to experience and test electric mobility on a daily basis without having to pay the high purchasing costs of the vehicles on their own.

Several important prerequisites regarding the diffusion of electric mobility among the described target groups seem relevant, before these become actual buyers or users of electric vehicles. These include: a drop in the purchasing price, a greater choice of models with the usual standards of quality and comfort, the offer of attractive mobility and business models and possibilities to test drive the vehicles. Not least with regard to user acceptance, a transparent and positive eco-balance and the use of electricity from renewable energies should be guaranteed for electric mobility, because this is what the large majority of potential buyers or users require and, correspondingly, doubts about this could be fatal for the acceptance of electric mobility.

A comparison of electric and fuel cell vehicles

FCEV were used as a comparison in the report for selected issues because they may be an alternative or a rival to electric vehicles in the long term. FCEV are still in the R&D stage. The remaining challenges concern, among others, the high purchasing costs and the short life span of the fuel cell stack so that successful market introduction of FCEV only seems possible if there are the corresponding technological breakthroughs. In addition, constructing the infrastructure needed for the market roll-out of FCEV represents a bigger challenge than it does for electric vehicles. Competition between electric vehicles and FCEV is only seen to a limited extent, even given a relevant progress in technology and infrastructure, because different car segments and buyer groups might be addressed, at least in the next 1 to 2 decades.

FCEV are better suited to long distances than electric vehicles. This is a field of use which is not very large in terms of volume, but whose impacts on the environment and resources seem significant because of the high mileages involved. If renewable energies are used for driving, FCEV have much lower GHG emissions than conventional cars. However, they perform less well with regard to energy efficiency and GHG emissions when compared to BEV and, depending on the proportion of driving done with the internal combustion engine, when compared to PHEV, too. Similar to BEV and PHEV, manufacturing FCEV is more energy-intensive than conventional cars, so that their use only makes sense ecologically if they are being driven a lot over long distances.

Promotion options for electric mobility

The current debates about promoting electric vehicles in the coming years primarily revolve around expanding public charging infrastructure and offering financial purchase incentives. An extensive development of public charging infrastructure does not seem necessary at present. Experiences from demonstration projects show that the majority of users of electric vehicles so far charge at home or at work, and that already existing public charge points are hardly being used. Especially in rural regions or small and medium-sized towns and cities where the majority of the early buyer groups is expected to live, there is a high density of private garages or parking places close to dwellings, so that the relevant conditions for charging at home are easily realisable. At present, therefore, the construction of public charging infrastructure should focus on easily accessible and visible places in order to overcome inhibitions or fears about insufficient range and, at the same time, enhance the visibility of electric mobility.

As empirical surveys show, the high investment costs are a major barrier for the purchase of electric vehicles. At present, the purchasing price for an electric vehicle is still much higher than for a comparable conventional vehicle; even with purchase subsidies of several thousand euros per vehicle the prices are probably still too high for many potential consumers – even if there is a certain willingness-to-pay a higher price on the part of interested consumers. In the next few years, therefore, such purchase incentives would primarily address applications and utilisation concepts with high vehicle mileages. At a later point in time, once the purchase prices have fallen, incentives could be more effective in order to appeal to broader consumer groups.

Determining the level of possible incentives to buy electric vehicles can be based on different approaches. One method targets the positive impacts on the environment and estimates avoided external costs. Another option is to calculate the macroeconomic growth stimulated by electric mobility. The macroeconomic impacts of such measures have, however, not yet been adequately studied and so there are not yet any basic principles for determining the level of incentives from a macroeconomic perspective. Based on avoided external costs monetary incentives of 1,800 to 3,200 euros could be justified if additional renewable energy sources are used; however, this does not take into account the ecological rucksack from manufacturing the vehicle. Including these environmental impacts reduces the calculated figures by approx. 10 to 25%.

At present, it seems appropriate to support R&D activities above all else. Batteries play a key role for the value added of electric vehicles. Excellent basic research in the field of battery technologies should be developed and established in Germany in the long term in order to achieve relevant market shares of future battery technologies, and to be able to use batteries produced in Germany. It is absolutely essential to safeguard the good position Germany already holds in other relevant components like electric motors and power electronics.

Alongside monetary incentives to promote electric mobility, there are also non-monetary incentives such as free or reserved parking for electric vehicles and permitting them to use bus lanes. Practical experiences with these are still very limited, however, and so the actual impacts of such non-monetary incentives cannot be predicted at present. If this type of promotion proves effective, care should be taken that this does not result in conflicts with the environmental alliance, i.e. local public transport, cyclists and pedestrians.

Regulations and non-monetary incentives to use electric vehicles in commercial fleets and carsharing fleets and multimodal mobility concepts concern, e.g. environmental zones and delivery windows for electric vehicles, providing parking places for sharing schemes, standards for booking and invoicing systems and compatibilities between different mobility service providers.

Because of the decisive significance of renewable energies for the environmental advantages of electric vehicles and for user acceptance, a transparent and trustworthy system of utilising electricity from renewables should be ensured. Concerning the significant influence of air pollution, GHG emissions and energy consumed while manufacturing the vehicles and extracting the raw materials, a sustainable raw material policy aiming at a social and ecological balance and the highest possible recycling rates are recommended.

In principle, promoting electric vehicles should be done within the framework of an approach which is open to all kinds of technologies. Furthermore, focusing on improvements to conventional cars will have a greater influence in the short term on the significant reduction of GHG emissions in the transport sector – and should not be neglected even in the long term.

In general, it becomes clear that the potentials and challenges of electric mobility can only be correctly assessed from a comprehensive and long-term perspective. In the long run, electric mobility offers significant ecological advantages and economic opportunities. For these potentials to be realised, however, the existing problems have to be tackled consistently, by continuing to push research and development and by implementing suitable policy measures.

The Office of Technology Assessment at the German Bundestag is an independent scientific institution created with the objective of advising the German Bundestag and its committees on matters relating to research and technology. Since 1990 TAB has been operated by the Institute for Technology Assessment and Systems Analysis (ITAS) of the Karlsruhe Institute for Technology (KIT), based on a contract with the German Bundestag

OFFICE OF TECHNOLOGY ASSESSMENT
AT THE GERMAN BUNDESTAG

BÜRO FÜR TECHNIKFOLGEN-ABSCHÄTZUNG
BEIM DEUTSCHEN BUNDESTAG

KARLSRUHER INSTITUT FÜR TECHNOLOGIE (KIT)

Neue Schönhauser Straße 10
10178 Berlin

Fon +49 30 28491-0
Fax +49 30 28491-119

buero@tab-beim-bundestag.de
www.tab-beim-bundestag.de