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Roadmap E-Mobility Germany

Objectives, Chances, Risks,
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Summary

In one of its focal areas the Evolution2Green project aimed to identify obstacles and path dependencies in the field of electromobility, to identify successful approaches to the transition to electromobility, as well as necessary measures. The facts summarized in the roadmap answer many questions that are currently being raised in the field of electromobility:

- Are electric cars with batteries actually more climate-friendly than efficient hybrid cars or fuel cell vehicles?
- Why is the change of path from combustion engine to electric drive of so grave economic importance?
- Which measures and which actors can help to initiate these changes of path?

In terms of economic policy, there is an opportunity to develop Germany into a leading market for electromobility in the coming years. Such a lead market would have to merge the normative idea of climate-neutral passenger car traffic over the entire lifecycle of a car with the huge head start that the German automotive industry has in the production of high-quality passenger cars. However, the realization of a German lead market for electromobility and thus the aspired technological leadership of German manufacturers requires a rapid growth of the national sales market.

From today's perspective, electromobility can make a major and comparatively rapid contribution to combating the greenhouse effect, reducing pollution in city centres and reducing local noise emissions.

But what should we do? How can the existing strong link to the combustion engine be overcome and the new technological field of electric, digital and increasingly autonomous automobiles be opened up? For the successful and large-scale introduction of electric vehicles into the German automobile stock, both short (until 2020) and medium-term (until 2030) measures are required.

The task of the short-term measures is primarily to build up the charging infrastructures in a systematic manner and to prepare the sales market for the market launch of numerous electrical models from major German manufacturers planned for the year 2020.

It is of central importance that electric cars become more competitive compared to cars powered by internal combustion engines. This applies to both the sales price and the range of coverage as well as to a wide range of user-oriented variants. What is important is the development of automobiles that are "electric" from the outset and can thus be produced more cheaply than cars that are virtually converted "burners", such as the E-Golf or the E-Up. The development of the Post-Streetscooter, the eGo Life, the Tesla Model 3 and also Volkswagen's Modular Electrical Construction Kit (MEB) with its planned models show that this path is promising. The basic model of the Volkswagen ID, which is now being developed, is to have a price structure comparable to that of the Golf. The TCOs will then benefit from lower operating costs.

It is also necessary to change the wishes, expectations and routines of a wide range of customers with regard to automobiles. Even today, the unquestioned basic idea that a car is humming, howling at full throttle and filling up in just a few minutes is still in many minds. It is expected that one can also spontaneously set off on long journeys. Some of these ideas have to change, at least in view of today's battery technology and charging infrastructure. Although it is possible that in the future, with radically shorter charging times, these differences between the combustion engine and the battery-powered vehicle will almost disappear, they are undoubtedly present today. The alteration of these unquestioned ideas and wishes is ultimately a process of changing the mobility culture and it is to be expected that this process will take

comparatively much time - in any case several years. If the production start-up of the mass-produced electric models of German manufacturers is to meet a market that is ready to take up production in 2020, action must be taken quickly here.

Regional alliances can support the transition to electromobility. These could set the development in production, manufacturing and location marketing around possible clusters of "electromobility" in motion. But also the distribution and use of electric vehicles by private individuals, fleet customers and in tourism could be promoted by such alliances. Information events for car dealerships, fleet and private customers would be organized by such alliances. The cooperation with the municipalities and municipal utilities is just as useful here as the cooperation with electricity suppliers in order to coordinate the charging infrastructure, and to ensure that it makes sense in the future.

The German automotive industry employs a total of over 800,000 people. It exports about 60% of its products worth approximately €250 billion per year. That this industry remains competitive even after the transition to electromobility and that high-priced premium vehicles are successfully exported, is crucial for Germany as a business location. The measures necessary in the medium and long term are aimed at securing and enhancing the competitiveness of German car manufacturers with premium electric vehicles in the world market in the second half of the 1920s and build on the success of the short-term measures.

The importance of battery technology, on which the range, charging times, costs and eco-efficiency of the production of electric vehicles depend decisively, can hardly be overestimated. Coordinated by the Federal Government and supported by research funding, work should be carried out on research and development as well as on scaling up the production of battery cells and batteries. R&D on new, more powerful, cheaper and resource-saving battery concepts should be stepped up considerably.

A central strength of the German manufacturers is their ability to produce premium quality products. This even gives them the objective chance of not being the first to introduce electric cars, but to make them better. However, German manufacturers also need a strong lead market with demanding customers in Germany, for which considerable incentives to buy will be required for several years to come. Only from a strong domestic market can feedback and impulses come into the R&D of the manufacturers, which help to improve the premium production of German manufacturers. At the beginning of 2018 there seems to be movement here. New press releases report that delivery times are getting longer and that the E-Golf and other electric vehicles on the German market are already sold out for 2018.

In order to be able to implement such a demanding programme of measures, active coordination by the Federal Government and the constructive cooperation of the participating ministries for economy and energy, environment and transport is required.

The debate on the question of the phasing out of the internal combustion engine, which has been raging with emotion time and again, obscures the view that such a phasing out is likely to happen in the next 30 years, whether we want it or not. In order for this not to result in avoidable misappropriation of manufacturers and suppliers and thus to unnecessarily destroy both private and economic values, it is necessary to have a less emotional, factual debate about how such an exit can be carried out and how its consequences can be mitigated. It is already evident that large groups of farsighted manufacturers and suppliers are preparing for the change of path.

Content

Figures

Abbreviations

BEV	Battery Electric Vehicle
FCV	Fuel Cell Vehicle
HEV	Hybrid Drive Vehicle
ICEV	Internal Combustion Engine Vehicle
NPE	German National Platform, Electromobility
PEV	Plug-in Hybrid Vehicle
TCO	Total Cost of Ownership

1 Introduction

In one of its focal points, the Evolution2Green project has aimed to identify obstacles and path dependencies, successful transformation approaches and necessary measures for path change in the field of electromobility. The insights gained answer many questions that are currently being raised in the field of electromobility:

- Are electric cars with batteries actually more climate-friendly than efficient hybrid cars or fuel cell vehicles?
- Which path dependencies bind the German automotive industry so effectively to the combustion engine?
- Why is it so important for the economy to switch from internal combustion engines to electric drives?
- Which measures and which actors can help to initiate this change of path?

The project Evolution2Green is carried out by adelphi together with the Institute for Future Studies and Technology Assessment and the Borderstep Institute and is funded by the Federal Ministry of Education and Research.

This article presents an overview of the results of the projects work on electromobility, focusing on measures and political initiatives that seem to be necessary in the context of the transformation into climate-neutral and environmentally friendly motorised individual mobility with an internationally competitive automotive industry in Germany. A sustainable transport system also requires a reduction in traffic volume, the promotion of public transport as well as pedestrian and bicycle transport including electric bikes (NABU Bundesverband, 2016). Nevertheless, there is still a focus on automotive drive systems at this point, as passenger cars will continue to play an important role in the modal mix for decades to come.

The work is based on the systematic analysis of path dependencies that counteract transformation to the green economy. In the context of mobility, the fields of passenger car drives (Clausen, 2017e), roads (Clausen, 2017f) , mobility behaviour (Korte, Göll, & Behrendt, 2017) and the disposal of end-of-life vehicles (Tappeser & Chichowitz, 2017). were examined.

Furthermore, case studies of successful transformation processes have been prepared in order to identify success factors for a transformation as well as solution-oriented approaches to action and control. Country studies on electromobility were conducted for Norway (Clausen, 2017d), California (Clausen, 2017c), China (Beigang & Clausen, 2017) and the Netherlands (Perleberg & Clausen, 2017).). In addition, the development of the Streetscooter (Clausen, 2017a) and the Tesla company (Clausen & Perleberg, 2017) were analysed.

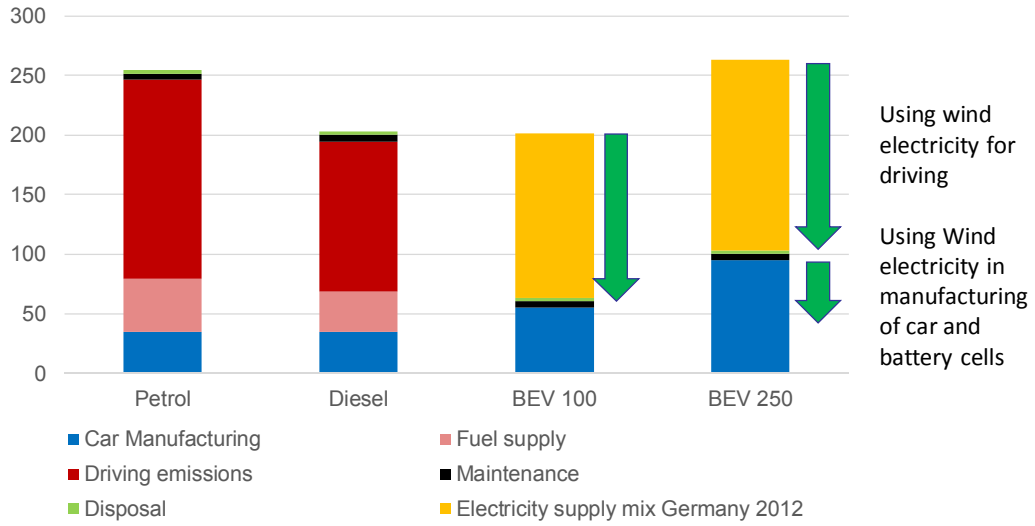
Together with trade union IG Metall Emden, a workshop to explore a strategy for change was held in October 2017, attended by 30 players from the worlds of automotive business, politics and science. Measures and strategies have been developed in 7 focused thematic areas, which have been incorporated into the work programme in chapter 6.

2 Potentials of alternative car drives

The German Federal Environment Agency (2016, p. 19) sees passenger car drives as a continuum from the conventional drive by internal combustion engine (ICEV) via various hybrid variants (hybrid, plug-in, range extender) to the battery electric vehicle (BEV) and the fuel cell vehicle (FCV). The battery-electric vehicle (BEV) and the fuel cell vehicle (FCV) are classified as a pure electric vehicles.

In addition to the battery size for 100 km (BEV 100) or 250 km (BEV 250) range, the question of whether the electricity comes from the German country mix (2012) or from renewable sources, e. g. wind power, is decisive for assessing the climate impact of BEV. Further improvements can be achieved by supplying both vehicle and battery cell production with renewable electricity.

Figure 1: Greenhouse gas emissions of various vehicle concepts under today's average conditions in Germany in g CO2/km



Source: Borderstep based on Umweltbundesamt (2016, p.19)

2.1 Battery electric vehicles

For the pure electric drive of a car, the combustion engine with its components is left out and instead one or two electric motors are installed on the axles or in the wheel hubs as well as a power electronics for engine control and a battery. Although power electronics and electric motors are considerably lighter than an internal combustion engine, there is a weight disadvantage because the batteries are still very heavy. The production of a battery is also expensive and involves considerable (electric) energy and resources. Various studies are investigating the production of Li-ion batteries in terms of their life cycle assessment, most recently Romare and Dahllöf (2017), who see a considerable need for increasing eco-efficiency in battery production from an environmental point of view. In view of the variety of battery systems currently in development, the concept of a sodium-glass battery with significantly increased capacity per kg (Braga, Grundish, Murchison, & Goodenough, 2017) is an example, as well as a battery with an ultra-short charging time of 6 minutes for 32 kWh (Toshiba Corp Japan,

2017). It is not unlikely that considerable efficiency potentials can still be tapped with this technology.

The Federal Environment Agency (2016) currently concludes that when electric vehicles are operated with renewable electricity, they will have clear climate advantages both in the use phase and over the entire lifecycle, and that the expenditure of vehicle production still required today will become significantly more efficient by improving specific battery characteristics and increasing recycling, also for economic reasons. This advantage can be further enhanced by production using renewable energy.

Electric vehicles do not emit any emissions such as NO_x or particulate matter during use. Harmful emissions are more likely to be associated with production, meaning that the inner cities would be relieved considerably. Since the noise generated by a passenger car's drive system is only one of three important reasons apart from wind noise and tyres, the quiet electric drive only has an effect on noise emissions at low speeds of up to 30 km/hr.

Since the first electric vehicles, which are considerably more economical than combustion engines, have already been available for a short time (Clausen, 2017b), their use is expected relatively soon. These vehicles initially develop cost advantages on the short-haul route. Their small and thus inexpensive batteries enable ranges of 100 to 150 km.

At the same time, the network of charging stations will be intensively expanded and the range of available vehicles will increase significantly by 2020, thus extending the advantages of electric vehicles to other market segments. The driving dynamics of electric vehicles should also play an important role in their further diffusion (Clausen, 2017e, p. 27; Valentine-Urbschat & Valentine-Urbschat, 2014, p. 22).

2.2 Fuel cell vehicles

In a fuel cell, hydrogen and oxygen meet on an electrolyte membrane and are chemically converted to water. This reaction releases current that can be used to drive an electric motor. In comparison to the BEV, however, this method has a clear disadvantage in terms of efficiency: in order to have 20 kWh of electricity available for 100 kilometres at the car wheel, the BEV requires around 26.3 kWh of electricity produced by e g. a wind energy plant (Eaves & Eaves, 2004). A power network efficiency of 92%, the charger's efficiency of 89%, the battery of 94% and the powertrain of 89% also "consume" electricity. The FCV, on the other hand, requires 67.3 kWh of power generation, which is about 2.5 times as much as a BEV. Here, electrolysis with an efficiency of 72%, pipeline transport with 86%, fuel cells with 54% and the electric drive train with 89% efficiency "consume" the largest share of the renewable electricity generated, so that only just under 30% is available for driving (Eaves & Eaves, 2004; Lunz & Sauer, 2010, p. 3). The advantage of FCV is that hydrogen can be stored in principle.

Many of the world's major automobile manufacturers have been working on the fuel cell for 25 years now (Greene & Duleep, 2013, p. 3). But the fuel cell is still far from a breakthrough on the market. The cars currently on offer are expensive. The production figures are accordingly still minimal. Navigant Research estimates the stock of approximately 1,000 fuel cell vehicles worldwide at the end of 2015 and expects a stock of just 240,000 by the mid-2020s (Kane, 2015). It is therefore to be expected that the fuel cell will remain a relatively insignificant engine for a long time to come.

The charging infrastructure is even worse than for BEV. Petrol and diesel fuel are available in over 14,000 filling stations in Germany, while hydrogen is currently only available at around 30 public stations (Micksch, 2017). Beezero, a car sharing company owned by the Linde Group, a manufacturer of technical gases, has been offering 50 fuel cell SUVs since August 2016. The goal is to inspire first pilot users with the new technology (Losch, 2016).

2.3 Hybrid drive vehicles

A hybrid drive is a combination of two types of drive. The most common is the combination of an internal combustion engine with an electric motor and a slightly more powerful battery than in a car with an internal combustion engine. In the Audi Q5 Hybrid it has a capacity of 1.3 kWh, in a plug-in hybrid it requires a capacity of approx. 5 to 8 kWh to achieve an electrical range of 30 to 50 km.

The fuel-saving effect of a normal (non plug-in) hybrid car is achieved by the fact that these cars can recover the braking energy by means of recuperation and feed it back into the battery. The braking energy is then available for renewed acceleration. Especially in the case of permanent city traffic, e. g. in the case of taxis, this is the explanation for lower consumption. The plug-in hybrid additionally has the ability to charge the (small) battery at the home outlet and then drive the first 30 to 50 km all-electric.

Hybrid cars are sold in the largest quantity of all the drive concepts presented here. In Germany, 47,996 hybrid cars have already been registered in 2016, of which approx. 28% are plug-ins (Kraftfahrtbundesamt, 2017a, p. 11).

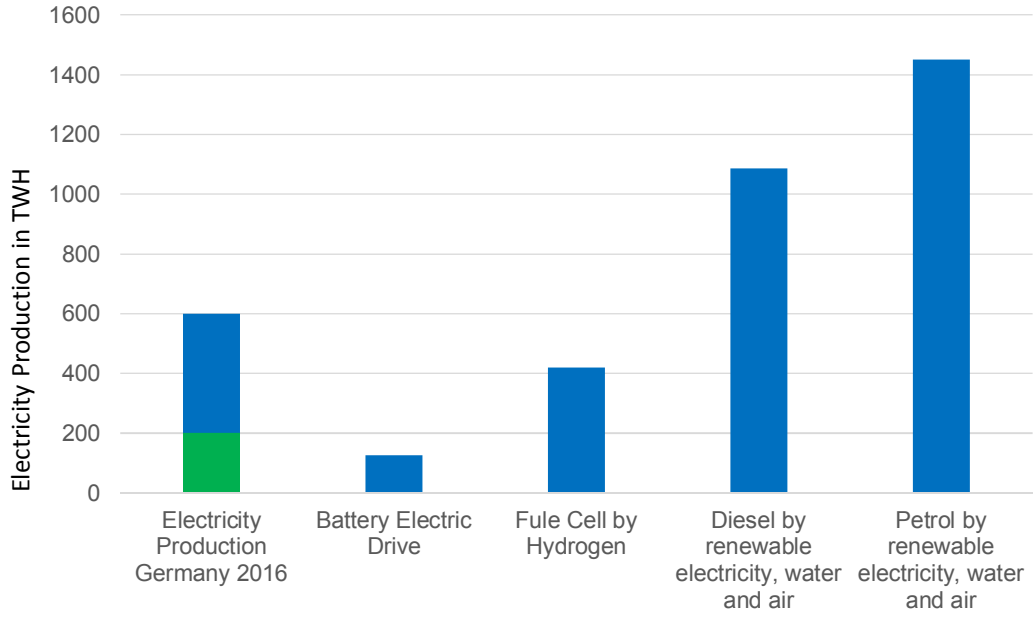
Figenbaum and Kolbenstvedt (Figenbaum & Kolbenstvedt, 2016, p. III) report that about 55% of the annual mileage of over 2,000 interviewed owners of a plug-in hybrid was fully electric, with the proportion of electricity being higher for (usually short) journeys to work and in summer, and lower in winter.

2.4 Evaluation of alternative drives with a view on the year 2050

In order to achieve Germany's climate targets, 100% climate-neutral car traffic in 2050 is necessary. The simple hybrid cars and improved gasoline and diesel engines do at the end of the day not contribute to climate-neutral car drives. The group of plug-in hybrids and natural gas vehicles, on the other hand, is more likely to reduce average energy consumption and emissions in a transitional phase. Fuel cell vehicles can already be bought at high prices, but their production in large quantities changing the market seems unlikely before the middle of the 2020s (Clausen, 2017e).

In addition, fuel cell vehicles have the disadvantage of a system efficiency that is about 2.5 times worse than that of a battery-powered electric vehicle. All technologies for the production of liquid fuels based on renewable electricity, water and air also have such low system efficiency. Although it is possible to produce climate-neutral fuels in theory, the cumulative energy consumption is very high (Forschungsvereinigung Verbrennungskraftmaschinen, 2013). This is shown by the calculation of the necessary power generation to have enough energy for the current 626 billion km of driving distance of passenger cars in Germany (Kraftfahrtbundesamt, 2017b). For the various climate-neutral drive systems, it would be necessary to increase the power generation by approx. 23% for the entire fleet passenger cars in 2050 - the same mileage as today's assumption - for the battery drive system, to increase approx. 60% for a fuel cell fleet and up to 230% when powered by "renewable gasoline". This increase in electricity generation must always be based on renewable technologies.

Figure 2: Necessary power generation to have enough energy for 626 billion km of vehicle mileage (2016) for different climate-neutral propulsion systems



Source: Borderstep

From an energy-policy point of view, the transformation of car drives into fuel-efficient and low-pollutant drives must therefore essentially be achieved by battery-powered electric vehicles.

The battery, with the range and charging time determined by it, its costs and the effort required to manufacture it, is likely to be the central component. The question of raw material security for battery production is currently the subject of intense discussion. At the same time, however, very different, high-performance battery concepts are being developed, each requiring different raw materials. When selecting battery concepts for large-scale production, it will be necessary to take into account not only their performance and costs, but also their raw material basis and environmental compatibility as well as the social aspects of raw material production.

The availability of renewable electricity is another necessary condition for the climate impact of this transformation. This is particularly evident when current life cycle assessments criticise electromobility with regard to electricity production from the current electricity mix. This criticism is justified, but does not address the problem. After all, large numbers of electric cars will only be used in the passenger car fleet between 2025 and 2040. And the achievement of the goals of the sustainability strategy, which has always been higher than planned to date, leads us to expect a renewable electricity share of well over 65% in 2040 and well over 80% in 2050 (Die Bundesregierung, 2016).

3 Path dependencies

Due to the increasing number of automobiles in society, the Modal Split shifted more and more towards motorised private transport since the 1950s. At the same time, the size of car manufacturers and suppliers as well as the number of employees in production and workshops grew. The automobile - with an internal combustion engine - developed into a natural element of everyday life and infrastructures were gradually changed in a certain direction: Apartments were built or rented far from workplaces and schools, shops were built on a greenfield site instead of in the city centres (Clausen, 2017f). The path of motorised private transport has stabilised continuously and leads, among other things, to the fact that a traffic turnaround focussing on bicycles and local public transport is too short in many places.

The (path) dependence on the automobile itself is greater than that of the "component" combustion engine. The most important path dependencies of the combustion engine as a car drive are the following (Clausen, 2017e, p. 40):

- **Economical:** Low prices for gasoline and diesel make it possible to drive a car at a price that motorists are obviously willing to pay - in view of its usefulness. The willingness to pay for the purchase of the car itself is also available to the general public. While 12.5% of final consumption expenditure of private households was channelled into transport in 1970, the figure was 20.3% in 1990 and 24.9% in 2010. About a quarter of all jobs in the supply industry are tied to the powertrain for combustion engines.
- **Technically:** Until well into the 1990s, no serious efforts were made to develop alternative drives. Although electric drives were used for stationary applications in industry and therefore continuously improved, since they were not used in mobile applications, battery technology slowly disappeared from the German universities and private research landscape. Today, most of the patents for the electric drive train are held by companies in East Asia and by Tesla (Clausen, 2017e, p. 19). The German automotive industry has invested a little in hydrogen drives and fuel cells, but here too, unlike Toyota and Honda, it does not have any saleable products. It is also lagging behind in electric drives.
- **Organisational:** The ties between manufacturers and suppliers to the combustion engine are strong. Just a few years ago, the large manufacturer Volkswagen was unable to believe that Deutsche Post / DHL really wanted an electrically powered delivery vehicle, and the Deutsche Post / DHL then set it up independently with a start-up from RWTH Aachen University (Clausen, 2017a). Even today, 54% of European managers still expect the electric car to fail, and 69% agree with the expectation that it is only the fuel cell with the "fuel" H2 that will bring about the breakthrough of electric mobility (KPMG, 2018).
- **Legal:** Few effective environmental regulations to reduce the emission of greenhouse gases, nitrogen oxides and particulate matter make it attractive for manufacturers to carry out small-scale improvements instead of relying on fundamental changes in the drive concept (Clausen, 2017e).

Economically, too, it is of great importance and there is a great dependency on the automotive industry with its 471,300 employees plus 302,700 employees in German suppliers. In 2016, the automotive industry increased its sales to €404.6 billion, setting a new record. At € 256.3 billion, almost two thirds of sales came from exports[1]. Car exports account for more than 20% of all German exports. Success and competitiveness of the automotive industry are therefore essential factors in national prosperity.

Path dependencies with varying degrees of intensity affect the distribution of the alternative drives presented in Chapter 2. The production and use of Hybrid cars, which are quite similar to conventional combustion engines are less hindered than the marketing of battery-powered

[1] Source https://www.vda.de/de/services/zahlen-und-daten/jahreszahlen/allgemeines.html as of 22.1.2018.

vehicles and those with fuel cells. In addition to the link to path-bound structures of the automotive industry with its internal combustion engines, the spread of both fuel cell vehicles and battery electric vehicles is associated with specific obstacles.

Significant specific obstacles for fuel cell vehicles lie in the still high costs of fuel cells and, from an infrastructural point of view, in the number of filling stations that are still extremely low today. In the future, however, the system efficiency, which is considerably lower than that of battery-powered vehicles (about a factor of 2.5) and is in principle associated with all power-to-gas concepts, should prove to be very significant. Ultimately, the advantage of storing the fuel only exists as long as the power grid does not have large storage facilities with high efficiency.

Specific obstacles for battery electric vehicles are the limitation of use due to the limited range combined with a charging infrastructure that is still under construction. Uncertainties with regard to the range planning, the practical implementation of the charging process and the payment as well as the real range possible by the vehicle are stoked by the press to such an extent that they almost seem like a fictitious debate. The myth that only a "fuel" can be driven with seems to be persistent not only in the automobile industry but also in the press.

There are interrelationships between the various path dependencies insofar as they can only explain the high stability of the socio-technical system "automobility with combustion engine" together. Low fuel prices combined with the high willingness of customers to pay, which is promoted by immense advertising expenditure, and in view of the still not very effective environmental pressure to change, have led manufacturers and suppliers to develop and successfully market ever more powerful vehicles with combustion engines.

In addition, manufacturers are facing the challenge of structural change. Germany (also from a Chinese point of view) has an almost unattainable technological lead in the design and construction of combustion engines. Not least as a result of demanding customers in Germany, the German mid- and upper-class automobiles have developed into international export hits. Changing the path to the electric vehicle endangers this position. Not only that there are hardly any customers of electric vehicles in Germany whose reaction and feedback are indispensable for manufacturers to achieve top international quality, but also the number of patents for many of the key technologies of electric mobility in Germany was rather small compared to other countries just a few years ago (e-mobil bw (Hrsg.), 2015), and the supply chain at least shows clear gaps in battery construction. The target set by the National Platform for Electric Mobility to establish an international lead market for electric mobility in Germany by 2020 seems to be hardly attainable with this starting position (Nationale Plattform Elektromobilität, 2016, p. 14).

4 Targets and trends in German electromobility

The central goal of the transformation of car engines towards sustainability is to reduce three major environmental impacts:

- reduced CO2 emissions due to higher efficiency and the potential for efficient use of renewable energy,
- reduce emissions of harmful substances in vehicle operation especially in city centres and
- reduce local noise emissions.

The goal of climate neutrality in 2050 is imperative from the point of view of environmental policy, and from today's point of view it will only be achievable with BEV in the foreseeable future. Although FCV might be climate neutral as well the system efficiency of FCV is not suited to fit into the energy framework.

The most radical solution is the conversion to a pure electric drive, always intended for the long term in connection with a supply of 100% renewable power. In the "Scenario 450" developed by the International Energy Agency with a view to meeting the 2°C target, the IEA calculated in 2009 the need to sell a global average share of 7% BEV, 21% PEV and 29% HEV in the new car market in 2030 (Valentine-Urbschat & Valentine-Urbschat, 2014, p. 145). Only 43% of the global market in this scenario should remain with petrol and diesel by 2030.

Valentine Urbschat (2014, p. 145) derive the plausible necessity to establish a share of approx. 25% BEV in the vehicle population of the OECD countries by 2030 from the figures for the reduction of energy consumption for mobility in scenario 450. Since 2011, the German target has been to bring one million electric vehicles onto the road in 2020 (Nationale Plattform Elektromobilität, 2016), and the 450 scenario would make it necessary to have around 10 million electric vehicles by 2030.

Civil society forces in the Climate Alliance Germany (Klima Allianz Deutschland, 2016, p. 20) are also demanding the market ramp-up of alternative drives:

> The core of a successful climate protection strategy for the transport sector is the maximum reduction of final energy requirements. In addition to measures to avoid and shift traffic, it is essential to fully exploit the efficiency-enhancing potential of drives for all motorised modes of transport and to boost the market for alternative (partially) electric drives. Passenger car traffic in particular can be almost completely decarbonized by 2050 through further efficiency enhancements and the gradual switch to electromobility, which will take place in parallel.

From the environmental associations' point of view, electromobility as an element of a transformation towards sustainability promises to have a truly positive effect on the environment only if it is part of a traffic turnaround and the energy transition is successfully continued in parallel (Lottsiepen, 2014). Only by the success of the energy turnaround can a renewable electricity supply for electric vehicles be secured and only by a successful turnaround in traffic can the modal split be shifted away from the car so far that we could be able to cope with the material cycles around the large number of heavy cars. Canzler and Knie (2014) go even further in their vision of the future and see electricity as well as heat and transport as part of a social supply structure that must be further developed into a synergistic "Gesamtkunstwerk".

For a long time, the German government has emphasized its goal of one million electric vehicles by 2020 (Nationale Plattform Elektromobilität, 2016), which is, however, more and more unrealistic from year to year and is increasingly being called into question. The new sustainability strategy (Die Bundesregierung, 2016) also contains statements, but no verifiable targets for electromobility. Assuming that the Federal Government will actually implement its climate protection target of reducing greenhouse gas emissions by 80 to 95% by 2050, the termination of sales of internal combustion engine by 2030 to 2035 is almost mandatory.

Other countries are pressing ahead with electric mobility with much greater determination, such as Norway (Clausen, 2017d), California (Clausen, 2017c) and the Netherlands (Perleberg & Clausen, 2017). But there is hardly any automobile industry in these three countries that produces vehicles with internal combustion engines and would resist a policy of electromobility and so there are no "veto players". Increasingly, decisions are being taken or prepared to stop the sale of vehicles with internal combustion engines: The Netherlands for 2025, India and Norway for 2030, Great Britain, France and California for 2040, plus a number of major cities such as Los Angeles, Mexico City, Seattle, Barcelona, Vancouver, Milan, Quito, Cape Town and Auckland (Muoio, 2017). It might be noted that about 50% of German car exports go to these countries.

It's different in China. According to the current Chinese "Development Plan for Fuel-efficient and New Energy Vehicles" in 2016-2020, the development of electric and hybrid vehicles in China is to be resolutely pursued (Beigang & Clausen, 2017). By 2020, Chinese manufacturers are expected to achieve global technology leadership and climb to the top of sales figures for New Energy Vehicles (Tagscherer, 2012, p. 4). In China, 700.000 BEV have been sold in 2017, 2.1 million electric vehicles are expected to be sold in 2020, five years later 5.25 million and then 15.2 million electric vehicles in 2030, which would represent a market share of 40% by 2030 (Mizuho Bank, 2017).

Chinese manufacturers such as BYD are already leading the list of companies with the highest production number of BEV. With Borgward in Bremen and Beijing WKW Automotive in Lusatia, two Chinese companies are preparing the production of BEV in Germany. Together with Tesla, Streetscooter and e. Go Mobile AG, the new start-up scene in the automotive industry is growing rapidly.

However, the traditional German automotive industry is not only challenged by new manufacturers. Through company acquisitions, both Chinese and Tesla enter German companies that stand for efficient production technology and high quality. In recent years, for example, Techni SAT Automotive with 6,200 employees in Dresden, Carcoustics with 1,900 employees in Leverkusen, Brötje Automation with 800 employees in Rastede and Kuka with 12,300 employees in Augsburg were taken over by Chinese investors (Ernst & Young, 2017). In May 2017, the starter division of Bosch was also sold to China with 7,000 employees. Through the acquisition of the Rhineland-Palatinate plant manufacturer Grohmann Engineering, Tesla gains significant automation expertise from the German semiconductor, electronics and automotive industries (Handelsblatt Online, 2016; Tesla, Inc., 2016). The acquisition of the specialist for highly automated manufacturing is linked to Tesla's objective of increasing production capacity to 500,000 electric vehicles per year by 2018 (Tesla, Inc., 2016).

The German manufacturers Volkswagen, BMW and Daimler have announced all new electric models in 2016. BMW plans to sell 100,000 electric cars by 2017, Volkswagen plans to produce 2 to 2.5 million, BMW 500,000 and Daimler 400,000 electric cars by 2025. Taken together, that would be 2.9 to 3.4 million cars. With a battery capacity of 35 - 50 kWh per car, a battery requirement of 100 - 170 GWh is calculated, while the NPE is striving for a production capacity of 13 GWh in 2025 which would result in the import of 84 to 93% of batteries (Nationale Plattform Elektromobilität, 2016, p. 13).

5 Opportunities, risks and challenges

5.1 Opportunities

Chances in environmental and economic policy are associated with a fundamental change of path from internal combustion engine drive to electric mobility.

In terms of economic policy, there is an opportunity to develop Germany into a leading market for electromobility in the coming years. Such a lead market would have to merge the normative idea of climate-neutral passenger car traffic over the entire lifecycle of a car with the huge head start that the German automotive industry has in the production of high-quality passenger cars. In line with Porter's understanding of clusters (Porter, 1998, p. 6), it should be noted that clusters and lead markets require high-performance research, manufacturers and suppliers, but are also inconceivable without a group of demanding customers. The realisation of a German lead market for electromobility and thus the aspired technological leadership of German manufacturers therefore requires a rapid growth of this national sales market.

Another opportunity is to achieve technological leadership in battery technology. With regard to the importance of battery technology for the function of electric cars (range, duration of charging time) as well as for the costs (price and service life of the battery) and the environmental impact (resource efficiency of the battery), the battery will become a key technology of electromobility. National competences seem to be hardly dispensable here. Toshiba with its recently introduced 32 kWh rechargeable battery, which can be charged in 6 minutes (Toshiba Corp Japan, 2017), points the way to an electromobility, in which the tiresome discussion about charging infrastructures dissolves and fokussifies itself to a necessary conversion of the filling stations on motorways and in city centres into fast charging stations.

From today's perspective, electromobility can make a major and comparatively rapid contribution to combating the greenhouse effect, reducing pollution in city centres and reducing local noise emissions.

With regard to the impetus for a path change, there is a chance out of Dieselgate[2], albeit ambivalent in the end. Although Dieselgate has called on the supporters of propulsion by internal combustion engines, it is precisely in the case of fleet operators active in city centres such as the Deutsche Post / DHL (Clausen, 2017a), the Fish Trading Company “Deutsche See” (2017) and nursing service “Caritas” (eGo Mobile AG, 2017) that the first decisions are currently being made to convert larger vehicle fleets to electric propulsion. Dieselgate's cost and climate-friendliness as well as the absence of pollutants in vehicle operation have become significant arguments.

These decisions by fleet operators also point to a further opportunity for electric mobility. The second generation of electric vehicles offers significantly lower Total Cost of Ownership (TOC) than the previously produced rather high-priced cars and are also competitive compared to vehicles driven by internal combustion engines. A good cost-benefit ratio is central to the dissemination of innovations and thus the further cost reduction, which is also evident in the case of the major manufacturers, is another important opportunity for a change of path.

[2] Dieselgate refers to the controversy triggered in September 2015 by an action brought by the EPA against VW concerning shutdown devices for exhaust gas purification systems of diesel engines.

5.2 Risks

As well as opportunities, the risks of electromobility are linked to environmental and economic policy. The economic risks are serious. If it is not possible to establish a leading market for electromobility quickly and before the companies of other nations have achieved a significant lead, then the loss of the technological leadership and possibly also a drastic drop in exports threatens to occur. This would again lead to a significant loss of jobs in the automotive industry, which today exports 2/3 of its German production. Technology leadership could be closely linked to mastery of battery technology. The almost complete dependence on imported batteries that is currently possible for 2025 could marginalise the German automotive industry. Both the new start-ups in electromobility and the acquisition of central suppliers of production and automation technology by Chinese and US companies pose additional risks for the German automotive industry.

From an environmental point of view, the risks are a failure to limit climate change and, accordingly, catastrophic and global long-term consequences, whereby the climate protection contribution from electromobility in Germany could increase through international effects through the exemplary effect of Germany. Another environmental risk is that it will not be possible to make the production of batteries much more material and energy efficient by making progress in efficiency. The resource-policy implementation of better recycling and material cycles in the automotive industry is also still outstanding (Tappeser & Chichowitz, 2017).

With a view to coordinating the path change to electromobility with strong German manufacturers and market leadership in premium electric vehicles, there is a considerable risk that the "Deutschland AG", with its political and industrial players, will be unable to set an effective economic policy framework and coordinate promotional activities in the best possible way. This requires a coherent and coordinated approach by political actors from different ministries, which cannot be distracted or confused by lobby interests. Too strong a slowdown on the part of the stakeholder groups - from industry and trade unions to regions and federal states with hitherto strong production sites - could delay the realisation of the above-mentioned opportunities to such an extent that, with a view to the target year 2030, all nationally involved actors could be on the losing side. Since the number and complexity of components in electric motors are much lower than in internal combustion engines, it can be assumed that electric vehicles can be produced in development and production with 30 percent less working time. According to OEM's development departments, the "elapsed time per vehicle" should be reduced by about 15 percent for electric vehicles. Trade unions therefore often take a critical view of the change of path and point out that qualification and employment adjustment measures will be necessary.

There is even some evidence that key players still have no real interest in building a lead market for electromobility. This is, on the one hand, the still often poor purchasing advice in the car dealerships of the major manufacturers (Helmer & Gnannt, 2017) and, on the other hand, the repeatedly critical rather than constructive debate on the public charging infrastructure, which in part assumes the character of a fictitious debate. While electric vehicles initially appear to be more likely to establish themselves as second cars and delivery vehicles, which, as Norwegian experience has shown, can be loaded at home for millions of households, in Germany the electric vehicle is repeatedly measured by the use of the passenger car using the "one-fits-all" approach. Stoking the "range anxiety" is even associated with the risk of putting too much money into a charging infrastructure, which could be obsolete in 10 years' time in view of improved battery technology.

5.3 Challenges

The establishment of an action programme to promote electromobility is therefore facing major challenges. Although there is a group of innovative start-ups in electromobility not only internationally (Geely, BYD, Tesla, Polestar) but also nationally (Streetscooter, e-Go Mobile AG), the presence of large automotive companies in the market for electric cars is not yet where it should be. Just as in politics and society, supporters and opponents of the path change within the German automobile industry are likely to fight for strategic leadership. Effective national coordination and a good narrative of the "strong German manufacturers with the world's best premium electrical products" could also accelerate developments in the group of entrepreneurial actors and create more unity.

Germany has successfully mastered key steps in the transformation of its energy policy in the area of renewable electricity generation and the development of a wind power industry. In retrospect, however, efforts to establish a national PV industry have failed. However, the German automobile industry is so large and so significant in terms of economic policy that a further failure would be economically and socially critical. The challenge for government and industry to effectively coordinate the change of path process is correspondingly great. This involves the creation of a national coordinating body, which orchestrates activities more effectively than the Nationale Plattform Elektromobilität (NPE). The next step is to evaluate the necessary path change costs realistically and fearlessly and to mobilise the necessary financing.

In many ways, the legal framework also requires adaptation to the requirements of climate-friendly and electric mobility. These are national, European and municipal regulations, some of which require international coordination and cannot be implemented in the short term. This point is also of great importance for a successful path change, since an effective redirection with high investments of billions of € in vehicle development, battery construction and charging infrastructure should not lead to a situation in which the success of the efforts cannot be siphoned off due to legal obstacles.

In view of the timing of events that has already taken place and is expected to continue, it should be noted that a window of opportunity has opened around 2015, which may remain open for a number of years but will also close again at some point. Essential references to the "window opening" are:

- The start of sales of the first second-generation, cheaper electric cars such as the Streetscooter and the Tesla 3 (the real production start of which has yet to be completed),
- the introduction of the electric car quota in China, and
- Announcement of plans to suspend the sale of cars with combustion engines in India, France, Great Britain, the Netherlands and Norway.

Dieselgate also contributes to the opening of windows in Germany. It is a considerable challenge both for car manufacturers and the coordination of national policies to make optimal use of this window of opportunity in the interests of German economic and environmental policy before it closes again.

6 Change of path: measures and initiatives

The successful and large-scale introduction of electric vehicles into the German automobile stock requires both short- (until 2020) and medium-term (until 2030) measures. Long-term developments such as e. g. autonomous driving to be expected from 2025 or 2030 are not (yet) taken into account. The following sections list the necessary measures together with the required actors and desirable periods of time for implementation.

The task of the short-term measures is primarily to build up the charging infrastructures in a systematic manner and to prepare the sales market for the market launch of numerous electrical models from major German manufacturers planned for the year 2020.

The medium- and long-term measures are based on the success of the short-term measures and aim to secure and expand the competitiveness of German car manufacturers with premium electric vehicles in the world market of the second half of the 1920s.

6.1 Simple and practical charging infrastructure

Priority should be given in the coming years (until 2019/2020) to solving the problems of charging infrastructure. Charging offers must be set up for the home, the workplace and on the road. Possible solutions may vary depending on the progress of battery technology. If Toshiba, for example, succeeds in mass production of the recently introduced 32 kWh battery, which can be charged in 6 minutes (Toshiba Corp Japan, 2017), downtown residents could continue to drive to a "petrol station" in the future and wait for charging. An area-wide network of charging points in city districts with multi-storey buildings would then be unnecessary. From today's point of view, in addition to the number and performance of charging points, problems with payment systems are also of great importance:

- A sufficient number of public charging points in cities and at motorway service stations is important. Manufacturers and Federal Government, 2018 to 2020.
- The equipment of public parking lots with charging facilities is to be improved. Visibility must be optimised and a ban on stopping vehicles with combustion engines must be made possible (and effectively enforced) at charging points for electric cars. Federal government 2018.
- A "right to charge at home" should also be enshrined in rental apartments and condominiums with parking space or garage. Private and commercial charging points should also be eligible temporarily. The problems of calibration law (electronic data transmission) for charging stations must also be solved. Federal government, 2018.
- Roaming agreements for charging systems are important, so that you can pay anywhere with your own fuel card, as well as transparent costs, so that you are not surprised by the costs of charging activity. In both cases, regulatory regulation is likely to be necessary in analogy with the activities of the Federal Network Agency. Federal government 2018.
- The integrated development of electromobility and digitisation could be helpful, e. g. the use of apps for searching for free charging points or for billing as well as for interfaces to multimodal mobility (public transport, e-bikes, bicycle rentals, car sharing). Start-ups, mobility and internet companies, 2018.
- Innovative solutions such as "plug surfing" should be supported with R&D funds if necessary. This is an app that leads to private owners of a wall box, where you then charge your car individually and it will be billed automatically. Start-ups, mobility and internet companies, 2018.

6.2 Inexpensive and user-friendly electric cars

It is of central importance that electric cars become more competitive compared to cars powered by internal combustion engines. This applies to both the sales price and the range of coverage, as well as to a wide range of user-oriented variants. This can be achieved in various ways:

What is important is the development of automobiles that are "electric" from the outset and can thus be produced more cheaply than cars that are virtually converted "combustion engines", such as the E-Golf or the E-Up. The development of the Post-Streetscooter, the eGo Life, the Tesla Model 3 and also Volkswagen's Modular Electrical Construction Kit (MEB) with its planned models show that this path is promising. The basic model of the Volkswagen ID, which is now under development, will have a price structure comparable to that of the Golf (Philipp, 2017). The TCOs will additionally benefit from lower operating costs.

- Development of low-cost models by the manufacturers, 2018 to 2020ff.

A wider range of models with a higher range is also important. While currently electric vehicles are primarily offered in the luxury class (Tesla S, Tesla X) and the small car class (Renault ZOE, Nissan Leaf, VW E-Up, BMW i3), midsize cars, vans, station wagons, SUVs or convertibles are still missing as well as vans. Since the vehicle class desired by customers is not geared to the drive train, it is to be expected that with a broader range of models, the number of buyers of an electric car will also increase. Furthermore, it is necessary to increase the range of the offered models to the minimum level of nominal approx. 400 km.

- Development of broad model families with a minimum range of 400 km by the manufacturers, 2018 to 2020ff.
- Information campaigns that a nominal range of 400 km is completely sufficient. Manufacturer and NPE, 2018.

6.3 Setting the economic framework for electromobility

In order to make electric cars competitive, it is also necessary to define the framework of economic policy instruments in such a way that such competitiveness can be realistically achieved. In order to convince fleet customers of electric cars in particular, stable long-term framework conditions are of great importance. Such measures have also proved to be effective in the case of the EEG's commitment to feed-in tariffs for more than 20 years. In the context of electromobility this means:

- The conversion costs of the energy system should not increase the price of electricity unilaterally via the EEG levy, but should be allocated to all fossil energy sources (including fuels, heating oil and natural gas). Tax relief on diesel should be abolished. Federal government 2018.
- A reliable exemption from the motor vehicle tax, which is permanently valid for a registered electric car. Federal government 2018.
- The commuter package and company car privilege should initially be differentiated according to energy consumption and pollutant emissions and abolished in the long term within the framework of transport policy. Federal government 2018.
- Increase in the purchase premium for a limited period of approx. 2 to 3 years, in order to "get used to" an increasing number of private and professional users as quickly as possible, and to increase the number of users of electric cars who spread their positive experiences in their respective social environment or region. Federal government 2018 to 2019.

6.4 Attracting user groups for electromobility

It is necessary to change the wishes, expectations and routines of a wide range of customers with regard to automobiles. Even today, the unquestioned basic idea may still be in many - mostly male - minds that a car hums, howls at full throttle and can fill up in a few minutes. It is expected that one can also spontaneously set off on long journeys. Some of these ideas have to change, at least in view of today's battery technology and charging infrastructure. Although it is possible that in the future, with radically shorter charging times, these differences between the burners and the battery-powered vehicle will almost disappear, there is no doubt that they exist today. The change of these unquestioned ideas and wishes is ultimately a process of changing the mobility culture and it is to be expected that this process will take comparatively much time - in any case several years. This could be the "critical path" of the path change to electromobility.

- Simple possibilities to test drive an electric vehicle for one or more days and low-threshold test offers such as the “Nordseeflitzer”[3] should prove to be a central instrument for spreading the experience of electric driving and reducing inhibition thresholds. Manufacturers and regional actors, 2018 to 2020.
- By the fact that electric vehicles are available as company vehicles, the affected employees get used to these vehicles and usually a pleasing acceptance arises. In this way, an "economic" driving style can be learned in order to really achieve the forcasted range and reduce uncertainties. The establishment of electric vehicles in vehicle pools with many different users is therefore important. Manufacturers in cooperation with fleet customers, 2018 to 2020.
- The advantages of using electric cars should be clearly perceptible and tangible for the users. In addition to the economic instruments mentioned in Section 6.3, exclusive and cost-effective parking facilities for electric cars could be created. Federal government, federal states and municipalities, 2018 to 2020.

6.5 Regional activities and communication measures

Regional alliances can support the transition to electromobility. These could stimulate the development of production, manufacturing and location marketing around possible clusters of "electromobility", but also promote the distribution and use of electric vehicles by private individuals, fleet customers and tourism through such alliances. Information events for car dealerships, fleet and private customers would be organised by such alliances. Cooperation with municipalities and municipal utilities is just as appropriate here as cooperation with electricity suppliers to further expand the charging infrastructure in a coordinated, sensible and sustainable manner. The coordination of the individual activities could lead to regular feedback to the Federal Government, whose framework conditions are very important for the overall development and whose effect in regional practice, however, requires regular feedback.

- Formation of regional alliances for electromobility. Manufacturers, state governments, municipal parliaments, NGOs, 2018 to 2020.

[3] The small BEV of “Nordseeflitzer” (North Sea Speedster) can be rented free of charge in some of the tourist communities in East Friesland with the spa card and can also be rented. With the electric North Sea speedster, of which there are already 6 Renault ZOE units in 6 municipalities, many tourists are gaining their first experience with electric mobility. The possibility of a free "trial rental" is so attractive that in summer of 2018 there could be North Sea speedsters from the Dutch border to high up to Denmark.

- Activities to develop the charging infrastructure should be accompanied by communication measures to convince potential customers that a complete and efficient charging infrastructure will be available by 2020. Federal government, manufacturers and regions, 2018 to 2020.
- Communication activities that disseminate the (positive) experiences of both private and professional electric motorists should be supported by manufacturers and the NEP. Simple formats such as "Die Sendung mit der Maus" (The “programme with the mouse” for kids) would be possible, but also cross-border public relations work, such as e-mobilists' regulars' tables in car showrooms, which would attract public attention, but which would also bring numerous car sellers into contact with positive e-car experiences. Manufacturers and municipalities could use large information events for car salespeople and fleet customers to address professional users and intermediaries, inform them and win them over for electromobility. Manufacturers in cooperation with regional players, 2018 to 2020.

6.6 Political prioritisation and allocation of electromobility

The National Platform for Electromobility (NPE) has been in existence since 2010. In 2016, it published a forecast in the Guide to Electric Mobility (Nationale Plattform Elektromobilität, 2016) that by 2017 there would be about 200,000 electric vehicles in the German vehicle population. In real terms, however, there were only 34,000 cars as of December 31,2016. The work of the NPE as a whole has so far been anything but successful. The number of publications the NPE has published on this key issue for the country's economic future has been around two publications per year since its creation until 2017. The establishment of a leading national market is still a long way off. The German Chancellor also considers the long-term goal of having one million electric vehicles on German roads by 2020 to be currently unrealistic (Tagesspiegel, 2017). Electromobility units exist in various federal ministries. However, the forthcoming change of path will require strong and consensus-oriented coordination by the Federal Government.

- A strong electro-mobility coordination unit, possibly stemming from the NPE, should be based on a long-term political objective and a strong narrative, supported by all participating Federal Ministries (BMWi, BMUB and BMVDI) and have sufficient resources at their disposal or be able to mobilise them in order to accompany a successful change of path. Energy turnaround and electromobility in particular must be coordinated. It is also essential to coordinate the work on adapting the legal framework. Federal government 2018.
- By promoting the debate, clarifying facts and positions, as well as an information campaign aimed at the public and decision-makers in business, politics and administration, the foundations for coordinated and effective action by ministries and companies could be laid. Federal government 2018.

6.7 Long-term competitiveness of the German automotive industry in the world market

The German automotive industry employs a total of over 800,000 people. It exports about 60% of its products worth approximately €200 billion p. a. That this industry remains competitive even after the transition to electromobility and that high-priced premium vehicles are successfully exported is central to Germany as a business location.

- The importance of battery technology, on which the range, charging times, costs and eco-efficiency of the production of electric vehicles depend to a large extent, cannot be overestimated. Coordinated by the Federal Government and supported by research funding, work should be carried out on both research and development and on scaling up the production of battery cells and batteries. Significant support should be given to R&D for new, more powerful, cheaper and resource-saving battery concepts. Production should be scaled up by the manufacturers and the target volume of domestic battery production should be increased from 13 GWh in 2025 (Nationale Plattform Elektromobilität, 2016, p. 13) to at least 100 GWh. Federal Government and NEP, 2018 to 2025.
- A central strength of the German manufacturers is the ability to produce high-quality premium models. This even gives them the objective chance of not being the first to introduce electric cars, but to make them better. However, German manufacturers also need a strong lead market with demanding customers in Germany, for which considerable incentives to buy will be required for several years to come. Only from a strong domestic market can feedback and impulses come into the R&D department of the manufacturers, which help to secure the premium production of German manufacturers. Manufacturers and the German government by 2020.

6.8 Climate-neutral and environmentally friendly car production

Whereas the production of vehicles with internal combustion engines account for only 15 to 20% of total life cycle greenhouse gas emissions, the production of vehicles powered by renewable energy sources account for more than 90% of total life cycle greenhouse gas emissions (Umweltbundesamt (Hrsg.), 2016, p. 19). Climate-neutral production is therefore particularly important for the long-term optimization of these vehicles with the aim of climate neutrality.

The limit value for fleet emissions of 95g CO2/km for all newly registered passenger cars, which will come into force in 2021, cannot be reduced by CO2-free car production because there are no political instruments to do so. However, climate-neutral (vehicle) production in Germany should be supported politically, as it must make an increasingly important contribution to the achievement of climate targets over time. Renewable electricity is available in many places at competitive prime costs, but is so much more expensive due to institutional costs of the energy system that it is virtually impossible to obtain it from manufacturers internally. The same problematic factors, which in energy law repeatedly place decentralised generation at a disadvantage, will in future also impede the "physical" supply of energy-intensive production sites with renewable energy sources from local proximity.

- The supply of production sites with "physical" regional and renewable electricity should be enshrined in energy law as an objective and institutionalised in such a way that the advantages of short transmission distances are reflected in cost advantages. Such a network fee structure should also lead to networks being operated more efficiently and cost-effectively. Federal Government 2018 to 2020.
- Vehicles produced with renewable energy sources should be considered with a factor and depending on the type of propulsion system used to achieve the 95 g CO2/km target. Federal government 2018 to 2020ff.
- Climate-neutral production should be used as an argument for promoting sales to fleet and major customers as well as for enhancing the company's image by means of suitable marketing measures by the manufacturers' sales force. Manufacturer 2020ff.
- Energy-intensive battery cell production is central to achieving climate-neutral production. The resulting production facilities for battery cell production should therefore be located

primarily at sites where the highest possible proportion of renewable electricity can be supplied without problems. As a rule, this should mean that these production sites should be located in regions with a high surplus in the production of renewable electricity. Manufacturers and regional actors, 2018 to 2020.

- The raw materials for batteries and electronics, some of which have a high environmental impact and are obtained under poor social conditions, should be recycled and reused as often as possible. Federal government 2020ff.

6.9 Coordination of the exit from combustion technology

The debate on the question of the phasing out of the internal combustion engine, which has been raging with emotion time and again, obscures the view that such a phasing out is likely to happen in the next 30 years, whether we want it or not. In order for this not to result in avoidable misappropriation of manufacturers and suppliers and thus to unnecessarily destroy both private and economic values, it is necessary to have a less emotional, factual debate about how such an exit can be carried out and how its consequences can be mitigated. It is already evident that large groups of farsighted manufacturers and suppliers are preparing for the change of path.

- Innovative manufacturers and suppliers begin to prepare plan B in R&D. In addition to the development lines for products for internal combustion engines, it is also analysed which product lines and manufacturing competencies will have potential during the period of electro-mobility (Stieber, 2017). The less innovative companies should be publicly supported in this process, e. g. through regional initiatives of the business development agencies. Manufacturers, suppliers, state governments 2018 to 2020.
- New products often mean that new qualifications are needed. Education and training courses are required. Manufacturers and suppliers 2018ff.
- A political exit scenario could be helpful in getting the less agile and innovative actors to prepare for a changed future. Since the change of path to electromobility is likely to be market-driven rather than politically driven, political exit plans may not be particularly important at all. However, it is conceivable that they can be used as a signal to help the Laggards limit the damage caused by path changes. Federal government 2022.
- For companies whose starting position is too poor or whose efforts to change paths are ultimately unsuccessful, an emergency fund for social plans should be kept in place. Federal government 2022.

7 Actors and time horizons

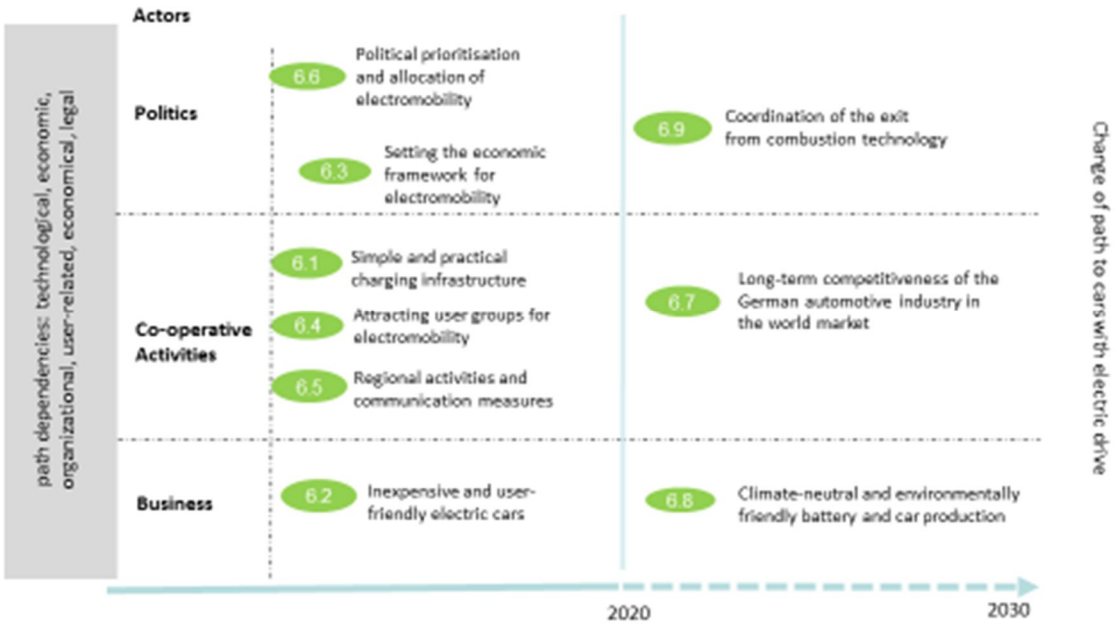
7.1 Overview of the E-Mobility Roadmap

The successful and large-scale introduction of electric vehicles into the German automotive stock requires both short- as well as medium- and long-term measures.

The task of the short-term measures is primarily to build up the charging infrastructures in a systematic manner and to prepare the sales market for the market launch of numerous electrical models from major German manufacturers planned for the year 2020. The aim is to build up a leading national market that challenges and supports automobile manufacturers with its demanding customer base.

The medium- and long-term measures build on the success of the short-term measures, exploit the power of the lead market and aim to secure and expand the competitiveness of German car manufacturers with premium electric vehicles in the world market in the second half of the 1920s.

Figure 3: Path change roadmap for electromobility in Germany at a glance



Source: Borderstep

The presentation of measures in a roadmap basically gives the impression of ultimately being politically controllable. It is therefore important to point out that the change of path to electromobility has some aspects that indicate a market-driven change of path rather than a political transformation project. Such aspects are:

- The significantly lower number of parts in an electric car means that sales prices can be lower in the medium term, as is already evident with Streetscooter, Tesla 3 and eGo Life. Together with the already lower operating costs of electric cars, this will provide a high buying incentive.
- The high R&D intensity and many innovations in battery technology could also make more powerful batteries with radically shorter charging times, lower costs and fewer raw material

problems available in the medium term. This would also be a considerable additional incentive to buy.

- The digitization of driving is bringing the automobile closer to ICT. Market-driven processes are leading the way in ICT in particular through additional benefit promises.

For market-driven path changes, for example the flat screen monitor, very high speeds of change are typical. The goal of the competitiveness of the German automotive industry in the context of a fast, market-driven path change should therefore be considered by all those actors who are currently focusing on delaying change.

7.2 The roles of the actors

The automobile manufacturers and their suppliers are at the centre of the change of path, whose core task is the development and production of low-cost and user-friendly electric vehicles, but which should also be involved in many other activities out of their own interest. Energy suppliers and regional planning actors can and should also participate in the development of the charging infrastructure. Regional actors can ensure that the activities are carried out regionally and in cooperation with regional networks.

In many large and decisive groups of actors, especially within the automobile industry, politics and trade unions, there are contradictions between those who want to promote electromobility and groups who want to delay the change of paths. Their arguments focus on a feared loss of jobs associated with the change of path, fears of a shortage of raw materials for battery production and much more. A better and cross-party networking and coordination of the supporters seems to be necessary in order to bring the forces of the innovation community behind electromobility to fruition (Fichter & Beucker, 2012b, 2012a). Support from science and civil society should also be important in this respect.

In the medium term, three groups of actors are likely to be of particular importance at the centre of the path change:

For a number of regulatory and promotion policy tasks, an active role of the **federal government** is obligatory. When setting up the charging infrastructures, in addition to coordination, it is also responsible for adapting the calibration law, adapting road traffic law, regulating network-related regulations, e. g. for "charging card roaming", and much more besides. In addition, only the Federal Government can decide on the funding rates required for the market ramp-up and, in general, design the economic framework in such a way that it supports more strongly the path changes from fossil technologies to renewable, electrical and thus sustainable solutions. Only the Federal Government can set research policy priorities in the field of batteries and initiate the long-term phase-out of combustion technology. To this end, the Federal Government needs a strong interministerial committee.

The second important group of players are the established and **large automobile manufacturers**. They have the role of developing high-quality electric cars for mass production and producing them in large quantities. And only they can influence the industry right down to the car dealerships in such a way that electric cars really do reach fleet and private customers. Only the major automobile manufacturers are able to produce the large number of electric cars for export, which are in demand after the already planned exit of combustion engines in many countries and which are important for securing numerous jobs in Germany.

The third central group is the **pioneers in production and use**. The pioneers of manufacturing, from Tesla and Deutsche Post with the street scooter to start-ups such as eGo Mobile AG, set the range of electric vehicles in motion and put the major automobile manufacturers under market pressure. Through their different corporate culture, which goes back more to the

ICT industry and relies heavily on low-cost production through Industry 4.0, they bring a lot of innovation to the automotive industry. And the pioneers in use, private electric vehicles, as well as Deutsche Post / DHL, the fish dealers “Deutsche See” and other pilot customers in the fleet operation, are of great importance for ensuring that electric vehicles reach more and more people. They disseminate their experience, thereby reducing uncertainties and thus opening up the group of the "early majority" for electromobility.

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