

Chapter 1

Electromobility—The Current State

1.1 Introduction

E-Mobility, short for Electromobility, means the electrification of individual transport. Unlike mass transport, which was electrified long ago in the case of trains and cable cars, individual transport, i.e. cars, trucks and motorcycles, has been dominated by the combustion engine for over one hundred years. But meanwhile a number of manufacturers have emerged that offer electric vehicles from series production. According to data of the Federal Motor Transport Authority 6,051 new electric vehicles were registered in 2013.¹ The number of first time registrations rose by 40.8 % to 8,522 electric vehicles in 2014.² The Federal Motor Transport Authority defines electric vehicles as vehicles with a solely electric powertrain, although no distinction is made between a pure battery electric vehicle (BEV) and a BEV with a range extender, which is a combustion engine for charging the battery.³ In the year 2014 BEVs accounted for a vanishingly low 0.28 % of the total new passenger car registrations in Germany.⁴ Including the month of September 7,385 new BEVs have already been registered in 2015, an increase of 22.1 % compared to the same period of the previous year.⁵

¹Federal Motor Transport Authority (2014).

²Federal Motor Transport Authority (2015c).

³Federal Motor Transport Authority (2015a, p. 3).

⁴Federal Motor Transport Authority (2014).

⁵Federal Motor Transport Authority (2015b, p. 12).

1.2 Legal Framework

The following short overview of the legal framework shall highlight the legal foundation for E-Mobility, which is already in place and which suggests that E-Mobility will probably not be a temporary phenomenon.

1.2.1 National Measures

As early as 2009 the federal government adopted a “National Development Plan Electromobility” (NEP) in which the central objective of one million electric vehicles on Germany’s roads in 2020 was declared.⁶ The federal government reaffirmed this goal in 2012⁷ and reconfirmed in the coalition agreement of 2013 the call for establishing a lead market for electric mobility.⁸ Deciding on the NEP in 2009 is remarkable in so far as that electromobility still led an absolute niche existence at that time: According to figures from the Federal Motor Transport Agency by the end of 2009, only 1,588 electric vehicles in Germany had been registered.⁹

The NEP proclaims 19 concrete goals, of which the first four are to be quoted here because of their relevance to the issues discussed herein:

1. *“Electric mobility shall make a significant contribution to achieving climate protection targets.*
2. *Through the use of renewable sources to meet the energy demands of electric vehicles a contribution can be made to the implementation of the expansion targets for renewable energies and for improved integration of fluctuating energy producers into the grid. This contributes to an increasing security of supply in the long term.*
3. *The power grids in Germany should become more efficient through the use of modern information technologies and the integration of electric vehicles.*
4. *The additional demand for electric energy in this sector is to be covered by electricity from renewable sources. For that, the otherwise unusable power from fluctuating renewable energies should be used primarily as part of the load management by electromobility. Further expansion potentials of renewable energies need to be developed for going beyond current demand for electric mobility.”¹⁰*

Thus, the NEP formulates within its first goals the energy industry relevance of this new transport sector and addresses the key challenges for the energy sector.

⁶Federal Ministry of Education and Research (2009, p. 2).

⁷The Press and Information Office of the Federal Government (2012).

⁸CDU/CSU Parliamentary Group in the German Bundestag (2013, p. 15).

⁹Federal Motor Transport Authority (2010, p. 24).

¹⁰Federal Ministry of Education and Research (2009, pp. 17–18).

Moreover, the government program for 2011 created so-called “showcase regions”, i.e. state-subsidized regions where e-mobility projects with various focus areas were specifically implemented. The “National Platform for Electromobility” (NPE) acts as an advisor on electric mobility for the federal government. The NPE is a committee consisting of representatives from industry, science, politics, trade unions and associations. There are seven working groups in the NPE, which analyse key topics and make recommendations to the government.¹¹

A first legislative initiative towards e-mobility took place in 2012, when an exemption of electric vehicles from motor vehicle tax was decided upon, see § 3d KraftStG. In 2013 the Law regarding company car taxation was amended, which led to a lesser tax load for employees driving an electric company car, see § 6 Abs. 1 Nr. 4 EStG.¹²

The most recent legislative initiative, the Electromobility Act (EmoG), allows for special facilities in road transport for e-vehicles, e.g. municipalities get the possibility to grant special parking rights or the use of bus lanes to e-vehicles, see § 3 EmoG.

Not least, the Programme of Action for Climate Protection of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety stresses the great importance of e-mobility for reaching climate targets in Germany.¹³ The action program describes the planned measures by Germany in order to achieve the national target to reduce greenhouse gas emissions by 2020 by at least 40 % compared to 1990.¹⁴ In regard to the CO₂ reduction targets it is stated:

“The consistent introduction of electric mobility in passenger transport—with electricity from renewable sources—in particular with regard to the medium and long-term climate change targets is of very great importance.”¹⁵

As a first, concrete step to promote e-mobility a special amortisation for companies and tradesmen when purchasing an electric vehicle is planned.¹⁶ This would be the first direct subsidy to a great extent for this market.

All in all it can be said that the federal government despite all the criticism, e.g. in regard to the lack of direct support for private purchase of e-vehicles, adopted the topic of e-mobility very early and in many fields.

¹¹Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2010).

¹²The list price of the e-vehicle is reduced by 450 EUR/kWh of the battery capacity (to a maximum of 9.500 EUR) and the reduced price is basis for the 1 %-rule of the company car taxation. Therefore the tax burden for the employee is lowered significantly.

¹³Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2014).

¹⁴Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2014, p. 6).

¹⁵Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2014, p. 22).

¹⁶Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2014, p. 56).

1.2.2 *European Measures*

The European Union adopted the climate and energy package in 2009,¹⁷ which set the following three key targets to be met by the EU in the year 2020:

- a reduction of greenhouse gas emissions in the EU by 20 % in comparison to the year 1990;
- a share of renewable energies of 20 % of the energy consumption in the EU;
- and a 20 % improvement in energy efficiency, i.e. a 20 % cut in primary energy consumption.

Accordingly, these goals were briefly summarized as “20–20–20 by 2020”. The climate and energy package consists of several legislative proposals on these three topics that are briefly summarized below, as it leads to very concrete points for the promotion of electromobility by the European legislation. These points should also have a direct effect in the next few years due to the not so distant target year 2020.

1.2.2.1 **Reduction of Greenhouse Gas Emissions**

Already in the Regulation (EC) No. 443/2009 of the European Parliament and of the Council of 23 April 2009 concrete specifications were regulated, which should lead to a reduction of CO₂ emissions from passenger cars and light commercial vehicles. The recitals of the Regulation (EC) No. 443/2009 explicitly reference the goal of reducing CO₂ emissions in the framework of the “Strategy 2020”. The provisions in this regulation were amended in 2014 by Regulation (EU) No. 333/2014.

This regulation package designates a maximum limit of 95 g CO₂/km for CO₂ emissions from passenger cars as a target for the year 2020, see Art. 1 pt. 1 of the Regulation (EU) no. 333/2014. The regulation specifies in Art. 1 pt. 5 a complex calculation mechanism which allows the determination of the average CO₂ emissions of each manufacturer. Vehicles that have CO₂ emissions of less than 50 g/km, count as 2 vehicles and therefore will lower the emission count of the manufacturer even more. A glance at the current values of vehicles with internal combustion engines shows the incentive effect for manufacturers: A VW Golf, equipped with the most fuel-efficient engine, still causes CO₂ emissions of 92 g/km,¹⁸ while even the Toyota Prius with a hybrid engine still shows CO₂ emissions of 70 g/km.¹⁹ The plug-in version of the Toyota Prius shows, however, the positive effect of the larger battery: The CO₂ emissions of the plug-in model are measured at 49 g/km.²⁰ Therefore, in order to bring a vehicle with an output of less than 50 g CO₂/km on

¹⁷European Commission (2009).

¹⁸Volkswagen AG (2016b, p. 29).

¹⁹Toyota Deutschland GmbH (2016a).

²⁰Toyota Deutschland GmbH (2016b).

the market, manufacturers will need to switch to plug-in hybrids and pure electric vehicles. How ambitious the target of 95 g CO₂/km will be for some manufacturers, is shown in the latest figures: According to the figures by the European Environment Agency, the average CO₂ emissions for new cars in 2013 remained below the threshold of 130 g CO₂/km and thus stayed below the target for 2015,²¹ but no vehicle with a petrol or diesel engine with CO₂ emissions of less than 95 g CO₂/km—the target number for 2020—is currently available.

In order for the manufacturers to reach the target of 95 g CO₂/km for the new car fleet, a significant change of direction towards alternative drive trains, such as hybrid vehicles and especially electric vehicles, will be needed. The impact of this regulation is already visible: Almost all car manufacturers with a European brand have electric vehicles from mass production on offer for the first time.²²

Although the amendment of the regulation was actually a softening of the goals of the original version in 2009, the new regulation still has a strong incentive effect and ambitious CO₂ reduction targets and should therefore significantly contribute to the success of e-mobility in the European Union.

1.2.2.2 Promotion of the Use of Energy from Renewable Sources

The conditions for the development of renewable energies in the European Union are governed by Directive 2009/28/EU. There are two key targets named in recital 20 of the Directive: Firstly, the share of renewables of the final energy consumption in the European Union shall account for 20 % in 2020 and secondly the share of renewables in final energy consumption in the transport sector shall amount to 10 % according to the 20–20–20 rule.

Accordingly, the Directive recognizes the importance of renewable energy for the transport sector in other recitals. The goal of a 10 % share of renewables in final energy consumption in the transport sector is intended to be achieved not only with biofuels, but also through new technologies, thereby using diversified renewables.²³ The issue of storing energy from renewable sources is addressed in the recitals of the directive as well and is designated as a topic worthy of support.²⁴

The Directive addresses the issue of “e-mobility” in specific support schemes, especially in Art. 3 para. 4, which states that the proportion of renewable energy, which is consumed in road vehicles with an electric drive train, is weighted by a factor of 2.5 for the calculation of the proportion of energy from renewable sources in gross final energy consumption in 2020. Hereby, a significant improvement is made reaching the target of the Directive and it is a considerable incentive for the

²¹European Environment Agency (2014).

²²A good overview of the current offer of e-vehicles in Germany can be found at: <http://www.goingelectric.de/elektroautos/>.

²³See recitals 2, 18 und 29 of Directive 2009/28/EU.

²⁴See recital 57 of Directive 2009/28/EU.

expansion of electromobility. This betterment of e-mobility is useful because electric vehicles have significantly better energy efficiency than conventional vehicles with combustion engines. Not only can CO₂ emissions be prevented this way, but primary energy can be saved as well.

The privileged grid access for renewable energy is governed by Article 16 of the directive and is a centerpiece of the European legal standards, since the priority (or guaranteed) grid access for renewables ensures the actual promotion of renewables by way of third party access and thus is an important tool for the conversion to a sustainable energy supply in the European Community. Without this network access regulation, the delivery of energy from renewable sources to final customers would be put into serious question; therefore those provisions are an important jump start for renewables in the energy market. This regulatory approach at European and national level will play an important role in regard to the following research of the charging infrastructure for electric vehicles.

1.2.2.3 Improving Energy Efficiency

The topic of “energy efficiency”, the third cornerstone of the climate and energy package, is governed by the Energy Efficiency Plan 2011 and the Energy Efficiency Directive, the Directive 2012/27/EU. The Energy Efficiency Plan 2011 stresses the importance of the transport sector in paragraph 7 to the effect that the transport sector is in terms of energy use the fastest growing sector with the greatest dependence on fossil fuels. However, the energy efficiency roadmap dispensed with further clarifications on the measures to be taken and instead refers to the “White Paper on transport.”²⁵

The White Paper, however, has it all, because as the first target among the 10 targets listed the following is stated:

*„Halve the use of ‘conventionally-fuelled’ cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially CO₂-free city logistics in major urban centres by 2030”*²⁶

Among the numerous initiatives, which are annexed to the White Paper, a new legal framework for CO₂ requirements in road transport is envisaged (see Sect. 1.2.2.1) as well as a legal framework for the interoperability of charging infrastructure for clean vehicles.

The issue of interoperability of charging structures, i.e. the question what connectors should be used, is regulated by the directive on the on the deployment of alternative fuels infrastructure, Directive 2014/94/EU (“AFI Directive”), which entered into force on November 17, 2014. Pursuant to Annex B of the directive,

²⁵European Commission (2011).

²⁶European Commission (2011, para. 2.5).

recharging points for electric vehicles shall be equipped with connectors of Type 2 as described in standard EN 62196-2.²⁷

In addition, the AFI Directive also contains numerous other provisions in the field of e-mobility, which should allow for significant development. This includes in particular the obligation of Member States to draw up a national strategic framework, which in turn, for example, must provide for the establishment of an adequate number of public charging points. This Directive therefore undertakes the hitherto clearest commitment of the European Union to e-mobility.

Another cornerstone of the “20–20–20 by 2020” program is the Energy Efficiency Directive, Directive 2012/27/EU, which entered into force on December 4, 2012. The aim of this Directive is to save primary energy, i.e. promote a more efficient use of energy. Pursuant to Art. 3, para. 1a) of the Directive the Union’s energy consumption must not exceed 1,474 Mtoe of primary energy or must not amount to more than 1,078 Mtoe of final energy in 2020. By comparison, the consumption of primary energy in the Union accounted for 1,666 Mtoe in 2013.²⁸ Therefore a reduction of around 11.5 % is still required to reach the target for the year 2020.

The Directive obliges Member States to establish national energy efficiency action plans, in which the relevant actions and contributions to achieve these targets are specified.

Since the energy conversion in electric vehicles is done very efficiently with an engine efficiency of 65 %, ²⁹ this technology could significantly help to achieve the goals of energy efficiency in the transport sector. By comparison, the overall efficiency of gasoline and diesel engines is just 15–20 %. ³⁰ Accordingly, incentive measures for electromobility in the form of financial subsidies for the construction of charging stations and the purchase of electric vehicles are included in the National Energy Efficiency Action Plan for Great Britain. ³¹ The German NAPE in comparison is far more reluctant with direct financial support measures, but a promotion of commercial electric vehicles is at least considered in the form of a special allowance for depreciation. ³²

Moreover, the Directive especially addresses the energy sector and specifies a number of measures in the recitals to ensure the achievement of efficiency targets. In recitals no. 44 and 45, two areas are mentioned with the topics “load control” and “smart grids” in which e-mobility can be an important component. The batteries of electric vehicles can be integrated via an intelligent control system in the electricity supply system and thus allow for more efficient management of the network. In this

²⁷The connector of Type 2 has already been adopted by German car manufacturers as the standard application.

²⁸Eurostat (2015).

²⁹Ifeu—Institut für Energie und Umweltforschung Heidelberg GmbH (2009, p. 3).

³⁰Golloch (2005, p. 1).

³¹Department of Energy & Climate Change in the UK (2014, p. 38).

³²Federal Ministry for Economic Affairs and Energy (2014, p. 41).

use case e-vehicles are connected bidirectionally to the grid and may purchase energy from the grid or feed energy back to the grid, depending on the load situation (so-called “vehicle-to-grid technology”).

The specific rules are laid down in Art. 15 of Directive 2012/27/EU, which states, *inter alia*, non-discriminatory market access by third parties to the markets of ancillary services. Providers of demand response solutions, especially aggregators, are entitled for such a claim against the operators of the transmission and distribution grids.

Therefore this Directive could also provide some significant impetus for the breakthrough of e-mobility.

1.3 Advantages of E-Vehicles

At this point, it shall be briefly shown why electric vehicles probably are not a temporary phenomenon, and not only due to the previously mentioned national and European political decision-making, but will rather replace conventional vehicles with combustion engines in the medium to long term in all likelihood:

- E-vehicles are almost silent in city traffic: The electric motors cause almost no noise, compared to gasoline and diesel engines, which are limited to a driving noise of a maximum of 74 (dB).³³ In order to alert pedestrians to the presence of silent electric vehicles, even an obligation to install an Acoustic Vehicle Alert System (AVAS) has been introduced at EU level.³⁴ But not only the engine noise is omitted; typically electric vehicles also have no gearbox, so that no acceleration noise exists (except for airstream noises). This benefit should not be underestimated for vehicle passengers, road users or local residents. The positive impact on urban development and life in the city will probably be enormous in the long term. Busy streets with heavy traffic will clearly cause fewer emissions and thus bring a significant improvement in living and housing standards for residents.
- E-vehicles have a considerable acceleration potential, since electric motors provide power without any perceptible delay. Even electric vehicles from the small car and midsize car segment have acceleration values, which are otherwise only found in the sports car segment. As a gearbox is unnecessary, there is no gear shift in the classical sense, but rather the settings forward, reverse and neutral, comparable to an automatic transmission. As the author himself was able to find out in test drives with a Tesla Model S and a BMW i3, the

³³See subparagraph 2.1.1 of Annex A of Directive 2007/34/EC.

³⁴See Art. 8 of Regulation (EU) No. 540/2014 of the European Parliament and of the Council of 16 April 2014 on the sound level of motor vehicles and of replacement silencing systems.

acceleration, combined with the silence of driving, leads to superior handling and a better driving experience.³⁵

- Compared to conventional vehicles, e-vehicles are built with significantly fewer moving parts, so that electric vehicles are virtually maintenance free. Brake pads must be changed significantly less frequently due to the recuperation. Gearbox, clutch and exhaust systems do not exist, and neither do oil changes. In addition there are lower costs for electric charging compared to refueling with gasoline, diesel or natural gas. The running costs of electric vehicles are therefore significantly lower than for conventional vehicles with combustion engines.³⁶
- The energy density of the battery is considerably lower, compared to a gasoline, diesel or natural gas tank. From a purely statistical point of view electric vehicles are therefore likely to be less susceptible to explosive or fire accidents.³⁷
- A further advantage is the significantly higher energy efficiency, since most of the energy actually gets to the drive train, unlike with an internal combustion engine, in which a large part of the energy is converted into heat loss.³⁸
- But perhaps the strongest argument in the end is the ability to power electric vehicles with green electricity, i.e. to charge with CO₂-free generated electricity, and therefore enable sustainable road transport with virtually no CO₂ emissions.
- Another effect, in addition to reducing CO₂ emissions, would be the reduction of economic dependence on oil imports.³⁹
- And last but not least electric vehicles can be integrated intelligently by means of “vehicle-to-grid” applications in distribution networks, i.e. they can provide added value for the distribution network by means of new energy business models for grid stability and the inclusion of fluctuating renewable energies.

1.4 Problem Description

Besides the described benefits of electric vehicles there is, in addition to the currently much higher selling prices, another negative factor and that is the significantly shorter range compared to vehicles with combustion engines. The currently highest range of an electric vehicle series is offered by the Model S of the US car maker Tesla Motors with up to 528 km range per charge through the 85 kWh version with all-wheel drive.⁴⁰ However, the typical range of an electric vehicle,

³⁵See Auto, Motor und Sport (2014).

³⁶Auto, Motor und Sport (2012).

³⁷According to calculations by Tesla Motors, Inc. (2013).

³⁸Ökoinstitut e.V. (2011, p. 9).

³⁹Federal Ministry of Education and Research (2009, p. 8).

⁴⁰Tesla Motors, Inc. (2016).

such as the BMW i3⁴¹ or VW e-Golf is closer to 100–200 km.⁴² As with conventional vehicles, the driving style and the weather play a significant role for the actual achievable range. Cold weather and faster driving can cause the actual possible range to decrease by 30 % or more compared to the manufacturer's official data.⁴³ As a result, this means that electric vehicles have a significantly shorter range than conventional vehicles with internal combustion engines. In addition to a higher purchase price, the so-called range anxiety is thus probably the most common counter-argument for switching to an electric vehicle. To enable longer overland trips, a comprehensive and functional charging infrastructure is especially needed (besides larger batteries).

According to the German Association of Energy and Water Industries (BDEW) 5,500 publicly accessible charging points were available in Germany in December 2014.⁴⁴ But in addition to the construction and operation of charging stations, efficient access to these charging stations is also needed to offer final consumers a real possibility of charging. Drivers of electric vehicles are provided technical access to almost every public charging station through the legally required standardization of the connectors⁴⁵ and in case of doubt an adapter will enable the driver to connect the vehicle to the charging station.

The driver of an electric vehicle, however, is currently faced with four key problems in regard to charging his vehicle on the road:

1.4.1 Conclusion of Contract with the Charging Station Operator

Before the e-vehicle driver can take advantage of the respective charging station, he has to enter, usually in advance, into a contract with the respective charging station operators. With more than 100 charging station operators⁴⁶ in Germany, this quickly turns into an obstacle to the charging process.

⁴¹BMW AG (2016).

⁴²Volkswagen AG (2016b, p. 8).

⁴³auto, motor und sport (2014).

⁴⁴BDEW (2015a).

⁴⁵See Art. 4 para. 4 of directive 2014/94/EU.

⁴⁶At BDEW alone over 100 charging station operators (EVSE Operator) are registered: <https://bdew-codes.de/Codenumbers/EMobilityId/OperatorIdList>.



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