HOCHSCHULE FURTWANGEN UNIVERSITY HFU

Research Project A:
Scenario Planning with INKA 4

Electromobility in Germany

M. Sc. International Management

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"You have to match the convenience of the gasoline car in order for people to buy an electric car"

-Elon Musk-[1]

[1] See Musk on Twitter (2017)

Abstract

Vehicles powered by electricity are the future of mobility in Germany. At the present time, electromobility is rather hesitantly implemented in Germany, particularly due to concerns regarding charging infrastructure and battery power/technology.

The purpose of this research project is to forecast – by using scenario planning techniques - how electromobility will influence the way we move in Germany by 2035. The outcome are three distinct scenarios that reflect the possible shift towards E-Mobility in Germany, especially taking into consideration the charging infrastructure, different battery technology and type of electric vehicle. In order to generate scientifically significant scenarios, input factors (Descriptors) were designed in accordance with the newest research findings from literature. Additionally, special ratios between all possible manifestations of input factors were defined, compared and evaluated.

Keywords: *Scenario planning, Electromobility, Germany, Battery technology, Vision 2035, new mobility, charging infrastructure*

Key findings

- Whether or not electromobility will be implemented in Germany by 2035 depends largely on four factors: Charging infrastructure, the technological development in regards to battery power, governmental and political regulations and incentives, and the preference of consumers on the type of vehicle.
- With the help of INKA 4 (Scenario Planning Software), 14 scenarios were generated from which the three most probable where chosen to give an outlook on how E-Mobility could look like in Germany by 2035.
- Due to the goal of a CO_2 emission reduction, the German "Bundesrat" did pass a resolution to completely prohibit the sale of gasoline powered vehicles by 2030.

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List of Abbreviations

AC	Alternating Current
BEV	Battery Electric Vehicle
DC	Direct Current
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GM	General Motors
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
PHEV	Plug-in Hybrid Electric Vehicle
REEV	Range Extended Electric Vehicle
R&D	Research and Development
VW	Volkswagen

1 Introduction

In the upcoming month, the number of electric vehicles on European roads will surpass the one million mark. Does this mark a milestone in electrification? Considering the fact that electric vehicles were basically non-existent half a decade ago, this can indeed be seen as a remarkable achievement.[2]

Volvo recently announced – as first big manufacturer - that from 2019 onwards, all new cars launched by them will be hybrid or fully electric. CEO Hakan Samuelsson calls this development the *"end of the solely combustion engine-powered car"*[3] and adds that this is the natural reaction to the customer and market demand and that many other manufactures will follow rather sooner than later.

News like the ones mentioned above are not uncommon anymore and awareness is increasing. Involved parties - such as governments, manufacturers and consumers - realize the importance of electric cars when it comes to the future of mobility.

Due to the currentness and increasing relevance of this topic, this scientific paper will discuss the following research question:

"How does Electromobility look like in Germany in 2035?"

In the following chapter, the basic principles of electromobility and the different types of Electric Vehicles are being introduced and the terms *Internal Combustion Engine* and *Electric Motor* will be explained. Additionally, the authors will outline the different energy sources and give an overview of the competitors within the market. Germany as a consumer market is the focus of the third chapter. Chapter four and five introduce Scenario Planning as a management tool to forecast future outcomes and give an insight into the methodology used by the research team. Chapter six describes the three most probable scenarios selected by INKA 4. The final chapter will conclude and shortly summarize the main findings of this paper, before giving a brief outlook into the future.

[2] Cf. Platform for electromobility (2018)
[3] See Samuelsson (2017)

2 Introduction to E-Mobility

2.1 Basic Principles

The electric drive train in its most basic form is hardly a revolutionary concept. Successful electric vehicles already existed around 1900. One of the first of its kind was the "Lohner-Porsche" carriage car (**Figure 1**), developed by Ferdinand Porsche and powered by two battery electric motors. Despite the fact that Germany has long been convinced of the importance of electromobility, almost 100 years had to pass until a large scale electric vehicle trail was carried out between 1992 and 1996 on the Island of Rügen to test the technology´s applicability. Although the "Rügen Trial" did not go as planned due to – at that time – low efficiency rates of electric energy storage units and other shortcomings, the "Rügen Trial" served as a stepping stone for Germany to pursue the development of electric vehicles.[4]

Much has changed in the following years. Drive systems as we know and understand them today consist of electric motors, high-voltage cabling, transmissions and an array of various other electric units and components. Within this highly complex system, the battery is the key component. It determines the efficiency of the electric vehicle and therefore represents the element with the greatest wealth creation share, the unique selling point, so to speak.

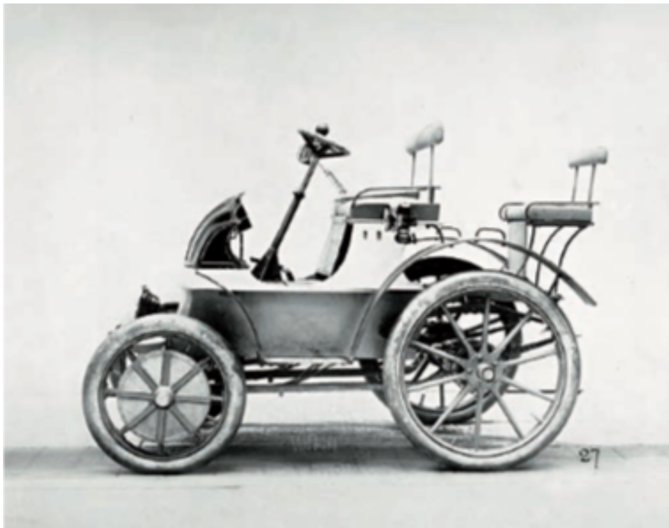

Figure 1: Lohner Porsche (1900) - the world´s first zero emission vehicle

[4] Cf. MacDougall (2015), p. 3.

Nowadays, electric mobility is considered as the fundamental technology for the replacement of fossil energy sources in the long run. Drive electrification represents the key to a sustainable mobility future, with battery and fuel cell technologies representing mutually complementary paths to creating emission free vehicles.

2.1 Internal Combustion Engine vs. Electric Motor

Considering the far-reaching consequences that society is going to experience by transitioning from the internal combustion engine (ICE) to electric motors, the authors consider it appropriate to give a quick overview of how these two competing forms of propulsion work in their most basic form.

An ICE is the prime component in Petrol cars. The fuel supply to the engine produces combustion and enough pressure and temperature energy to move the pistons. The linear motion of the piston is then transferred to rotary motion using a slider crank mechanism. Last but not least, a transmission is used to transfer this rotation to the drive wheels.

In an electric car, the power source is a battery pack. An inverter converts the direct current (DC) battery power into three-phase alternative current (AC) electricity. The three-phase AC turns the induction motor which will thus rotate the drive wheel.

Table 1 showcases - on the basis of two examples, BMW Z4 and Tesla Model S - the basic differences between the internal combustion engine and electric vehicle technology.

	Tesla (BEV)	**BMW (ICE)**
Power Source	Battery pack	IC engine
Motor type	Induction Motor	IC engine
Weight	31.8 kg	180 kg
Power	270 kW	140 kW
Weight / Power	8.5 kW/kg	0.8 kW/kg
Refuel / Recharge Time	1 hour	5 min

Energy Density	250 Wh/kg	1200 Wh/kg
Power Dynamics	Single speed transmission	Complex transmission
Cost of Traveling	$0.03/mile	$0.1/mile
Environmental Aspect	No tailpipe emission	Greenhouse gases/pollution

Table 1: BEV vs. ICE [5]

2.2 Electric Vehicles – An Overview

In its broadest sense, an electric vehicle is any vehicle that has at least one electric (motor) component in the power train accelerating the vehicle. In its purest form, it is only powered by electricity and therefore considered to be an electric vehicle (EV). The electricity required to power the motor can be gained from two different sources: derived from a battery ("battery electric vehicle" - BEV) or generated through hydrogen in a fuel cell ("fuel cell electric vehicle" – FCEV).[6]

Battery Electric Vehicles (BEV)

BEVs are fully electric vehicles, meaning that they are solely powered by electricity (chargeable batteries) and do not have an additional petrol engine, fuel tank or exhaust pipe.

[5] Cf. Morris (2017)
[6] Cf. MacDougall (2015), p. 5.

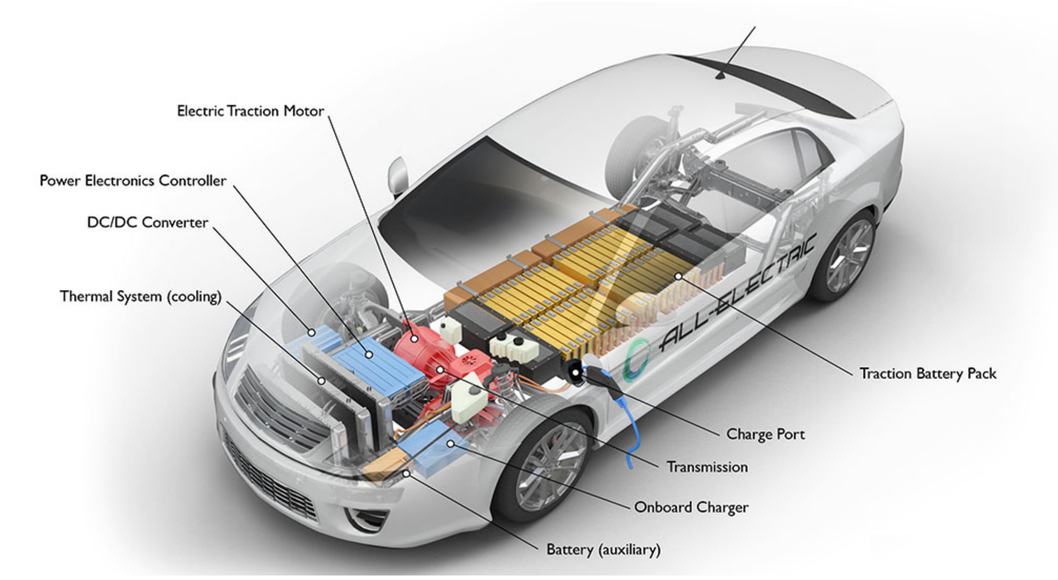

Figure 2: Battery Electric Vehicle [7]

Range Extended Electric Vehicles (REEV)

An REEV drives mainly in electric mode but has an additional range extender (small hybrid ICE) to extend the range when the batteries are low or there is an absence of charging infrastructure.

Hybrid Electric Vehicles (HEV)

HEVs combine a conventional ICE with an electric drive system. The electric energy is generated by the car´s own braking system in order to recharge the batteries. The Toyota Prius was one of the first HEVs on the market.

[7] See U.S. Department of Energy (2018)

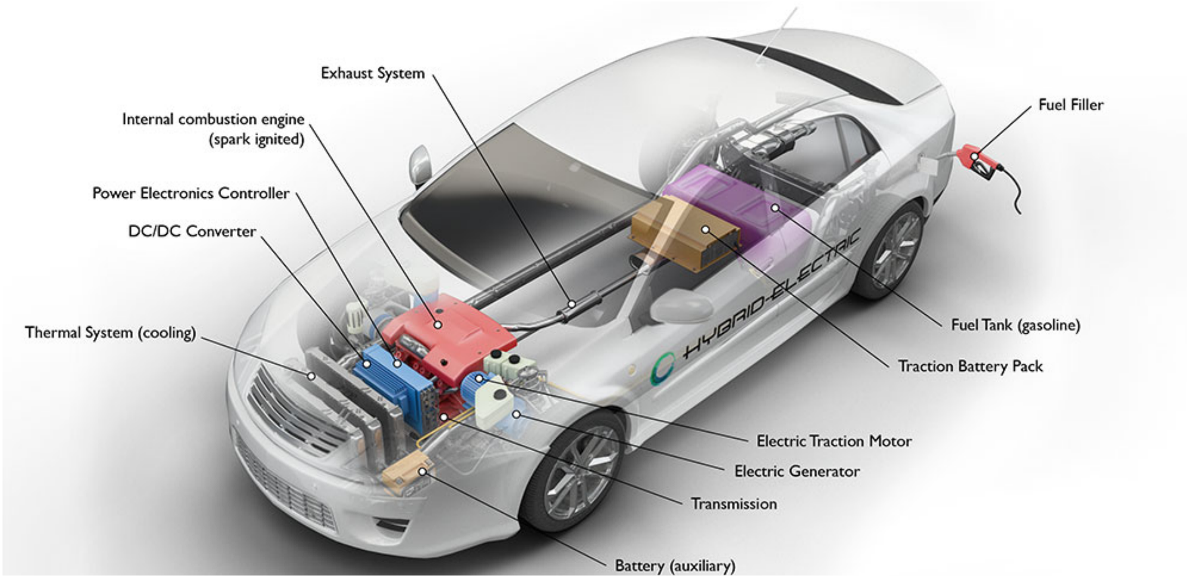

Figure 3: Hybrid Electric Vehicle [8]

Plug-in Hybrid Electric Vehicles (PHEV)

PHEVs operate under the same technology as HEVs but additionally offer the option to utilize a bigger battery that can be charged through the power grid.

Fuel Cell Electric Vehicles (FCEV)

An FCEV converts hydrogen to mechanical energy by burning in an ICE or by reacting with oxygen in a fuel cell to power an electric motor. By producing only water as a byproduct, this type of power source is emission free and climate neutral.

[8] See U.S. Department of Energy (2018)

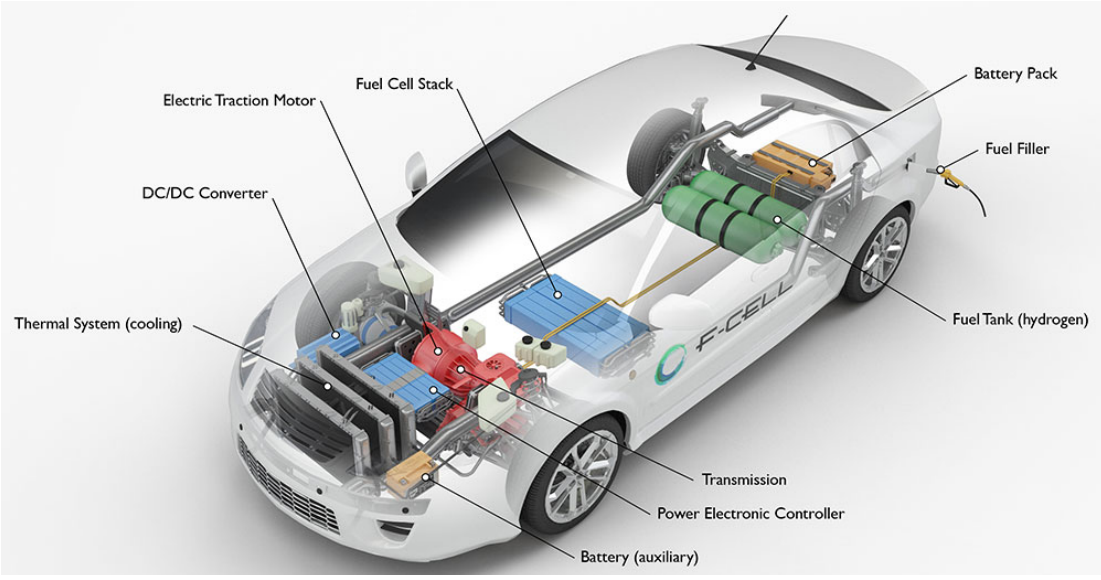

Figure 4: Fuel Cell Electric Vehicle [9]

On first glance, it might seem confusing that there are so many different drive train models out there, but there is a very good reason for this phenomenon. The world is developing and is moving away from being dependent on a single power train model (ICE) to having a portfolio of options designed for every possible driving scenario. In addition to that, the different technologies will have to undergo further development and evolution until they are able to power all cars purely by electric means. Therefore, the conventional ICE still has a bridging role to play – at least for the time being.

Depending on vehicle size, type and travel distance requirements, a number of different drive technology solutions can be applied. For example, BEVs are currently best suited to small cars driving in urban environments with a short travel time and distance. In contrast, FCEVs and HEVs represent the better solution in the medium and large size car segment where longer distances are covered.

Taking all of this into consideration, the authors of the paper decided to solely focus on BEVs, HEVs and vehicles powered by Fuel Cell Technology.

[9] See U.S. Department of Energy (2018)

2.3 The Big Three

When it comes to electric cars, there are certain key components that can be found in every type of EV, for example a battery, transmission and DC/DC converter. Nevertheless, there are still a lot of different components and technical nuances depending on the type of e-vehicle (**Table 2**).

Key Components	BEV	HEV	FCEV
Battery (auxiliary): provides electricity to start the car before the traction battery is engaged and also powers vehicle accessories	✓	✓	✓
Charge port: allows vehicle to connect to external power supply	✓	✘	✘
DC/DC converter: converts higher-voltage DC power from traction battery pack to the lower-voltage DC power needed to run vehicles accessories and recharge the auxiliary battery	✓	✓	✓
Electric traction motor: by using power from the traction battery pack, this motor drives the vehicle´s wheels	✓	✓	✓
Onboard Charger: converts incoming AC electricity to DC power in order to charge the traction battery	✓	✘	✘
Power electronics controller: manages the flow of electrical energy delivered by the traction battery and therefore controls the speed of the electric motor	✓	✘	✓
Thermal system (cooling): maintains a proper operating temperature for all components of the vehicle	✓	✓	✓
Traction battery pack: stores electricity for use by the electric motor	✓	✓	✘

Transmission: transfers mechanical power from engine/electric motor to drive the wheels	✓	✓	✓
Electric generator: generates electricity from wheels while breaking, transferring it back to the traction battery pack	✘	✓	✘
Exhaust system: channels exhaust gases from engine out through tailpipe	✘	✓	✘
Fuel filler: used to add fuel to the tank	✘	✓	✓
Fuel tank (gasoline): stores gasoline in vehicle until it is needed by engine	✘	✓	✘
Internal combustion engine (spark-ignited): fuel is injected into either the intake manifold or the combustion chamber, where it is combined with air and ignited by a spark	✘	✓	✘
Fuel tank (hydrogen): stores hydrogen gas in vehicle until it is needed by the fuel cells	✘	✘	✓
Battery pack: stores energy generated from regenerative braking and provides supplemental power to electric motor	✘	✘	✓
Fuel cell stack: assembly of individual membrane electrodes that use hydrogen and oxygen to produce electricity	✘	✘	✓

Table 2: Key Components of Electric Car[10]

2.4 The Energy Source – The Key to Electric Mobility

As the internal combustion engine gets ever closer to "extinction" within the next decades, the "race is on" to find the most suitable energy source to power future cars. Over the last couple of years, a lot of ideas for clean energy sources to power cars have

[10] Cf. U.S. Department of Energy (2018)

emerged, compressed air and nuclear power being some of the more unconventional ones.

Unless a new technology is invented that diminishes all of the disadvantages of currently existing ones, it will boil down to Lithium Batteries vs. Hydrogen Fuel Cells. Both technologies have their advantages and disadvantages (see **Table 3**) and the big car manufacturers are divided, not knowing which technology will be the superior one. While Volkswagen, Toyota and General Motors invest heavily in hydrogen fuel cell, Tesla CEO Elon Musk, the most prominent and well known proponent for Lithium Batteries, calls the fuel cell technology *"…"mind-boogingly stupid", "incredibly dumb" and "fool cells"…"*.[11]

Hydrogen Fuel Cells		Lithium Batteries	
Pro	**Contra**	**Pro**	**Contra**
• Quick charging • Long range	• Hard to capture and store • Production of pure hydrogen takes a long time and creates emission in the process • Charging infrastructure (big commercial hydrogen refueling stations need to be built) • Hydrogen storage is inefficient • Essentially an electric car without the benefits (smart grid buffer, regenerating	• Infrastructure is easier to set up (once it is set up, possible to charge at home or while you are at work) • Higher energy efficiency	• Limited range • Long recharging time • Indirect pollution (since most electricity is still generated through non-renewable energy sources)

[11] See Musk (2017)

	energy during braking, recharging with own power source)		

Table 3: Future Energy Sources for E-Mobility

The following paragraph is going to outline that, while there are indeed two promising technologies out there, most car producer focus on lithium batteries or a combination of battery and ICE (HEV) in regards to their power train structure for the future.

2.5 Players in the Market

For many people, cars powered by electricity still seem like a trend of the future and more like a technical toy/gadget instead of a real alternative to diesel and gasoline powered vehicles. In reality, major car manufactures have early on realized the importance of zero emission cars and as of right now, there are more than 25 different models of BEV, HEV and FCEV on the market (**Table 4**).

Car Manufacturer	Type and Model of Electric Car		
	BEV	HEV	FCEV
Tesla	Model S / X		
BMW	i3	i8	
Nissan	Leaf		
Chevrolet	Bolt	Volt	
Ford	Focus Electric	Fusion Hybrid	
Volkswagen	E-Golf		
Kia	Soul EV	Optima	
Daimler		S400/E400	GLC F-Cell

Toyota		Prius/Camry/Avalon	Mirai
Lexus		CT/NX/GS Hybrid	
Infiniti		Q70 Hybrid	
Honda		Accord Hybrid	Clarity Fuel Cell
Audi		A3 Sportback E-Tron	
Hyundai		Ionig	
Porsche		918 Spyder	

Table 4: Electric Vehicle Manufacturers

Headquartered in Japan, Nissan has sold the most BEV of any manufacturer worldwide, making the Nissan Leaf the world's most popular electric vehicle thus far. Introduced in the United States in 2001, the Toyota Prius paved the way for hybrid cars and today, almost every car manufacturer offers at least one hybrid vehicle, often including a version of their most popular model. Any of the above-mentioned vehicles can be a great alternative to the internal combustion engine. The key difference between the models is the price, warranty, size and range per charge.[12]

3 Germany as Consumer Market

Since the focus of the scenario planning is set on the German automotive market, the next chapter of the paper will have a closer look at the specific situation in Germany. The goal is to predict the future of Germany in terms of electromobility in the year 2035. Assumptions will be based on experts´ opinions in the field of electromobility. In order to understand the current situation of the German car industry, the authors start with a chapter about the status quo before having a closer look at the method which was used: the so-called "Scenario Planning Technique."

[12] Cf. energysage (2017)

3.1 Status Quo

Germany is known worldwide for its exceptionally strong and successful automotive industry, which is at the same time the biggest industrial sector in Germany. German car manufacturers like Volkswagen (VW) or Daimler, some of the leading companies in the automotive industry worldwide, are not only successful innovators, but also famous for reliability, high quality, and safety, as well as for the design of their cars.[13], [14]

The German automotive industry sector is the fourth largest worldwide, after China, the USA and Japan. In 2017, 820.000 employees worked in this industry and generated a turnover of about 423 billion Euro, which amounts to about 20% of the total revenue generated in Germany.[15]

Germany delivers over one third of the whole quantity of automobile production within Europe thanks to -in total- 40 automobile construction and engine production plants.[16]

Since the production of the first car by Karl Benz in 1886, there have been a lot of changes in the industry.[17] Nowadays, big investments towards electromobility are significant worldwide. The climate change, the development of new markets, and the need for being substantially less dependent on fossil fuels lead to innovative ideas and alternative solutions to combustion engines. Experts predict that e-vehicles will play a key role in terms of energy transition in the near future.[18]

However, currently, people in Germany still tend to buy ICE not only because it is more comfortable to find a charging station, but also because the purchase costs of BEV or Hybrids are still much more expensive today. [19]

[13] Cf. Germany Trade and Invest (2018)
[14] Cf. Handelsblatt (2018)
[15] Cf. Bundesministerium für Wirtschaft & Energie (2018)
[16] Cf. Germany Trade and Invest (2018)
[17] Cf. Daimler AG (2018)
[18] Cf. Federal Ministry for Economic Affairs and Energy (2014), p.3.
[19] Cf. Handelsblatt (2017), p.24-25.

According to the "Kraftfahrt-Bundesamt", out of in total 3.351.607 new registered vehicles in 2016, 1.746.308 were petrol cars, 1.539.596 diesel, 47.996 hybrids and 11.410 e-vehicles.[20]

If one compares the life time costs for an ICE-car with an electric vehicle, it is obvious that an e-car is still more expensive to hold in Germany as the following example shows: According to Handelsblatt in 2017, today the purchase cost of a e-golf is 35.900 Euro, a golf with diesel engine 30.000 Euro and a golf with petrol engine just 27.250 Euro. The so-called buyer's premium of 4.000 Euro for an e-golf does reduce the purchasing cost but, in the end, an e-golf is still more expensive than other alternatives. Even though the running cost for e-vehicles are lower due to tax reduction as well as lower charging costs for electricity, the life cycle costs for an e-vehicle will be higher as ICE vehicles up until 5 years after purchasing. [21]

However, the amount of people willing to buy e-cars is constantly growing, as the chart below shows. In 2006, only 1.931 e-vehicles were on German roads, compared to nowadays (2018), where this number increased to 53.861 e-vehicles.

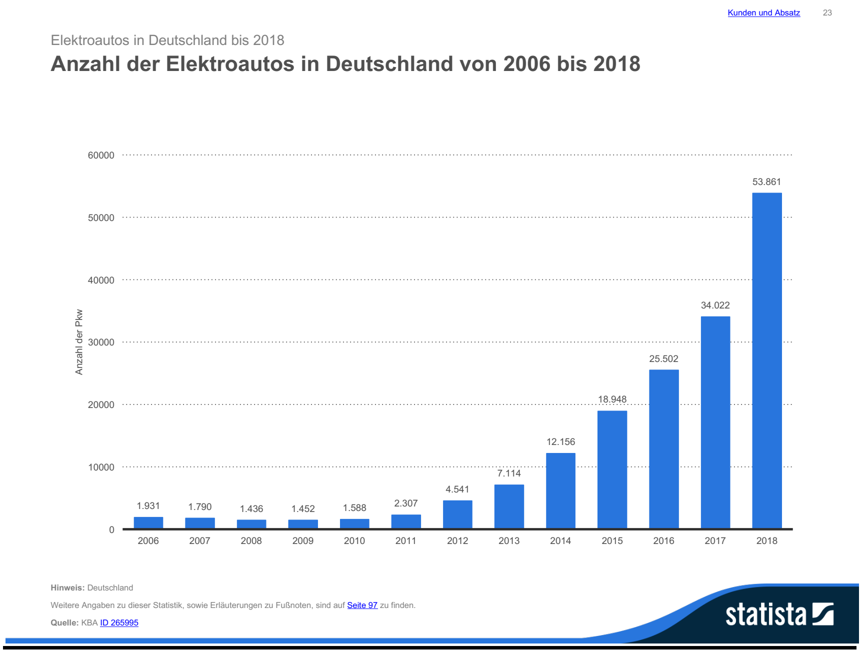

Figure 5: Number of E-Cars in Germany from 2006-2018 [22]

[20] Cf. Kraftfahrt Bundesamt (2018)
[21] Cf. Handelsblatt (2017), p.24-25.
[22] See Statista (2018)

But who are the people who buy these innovative and more expensive e-cars? According to a study of the German Aerospace Center (DLR) Institute for Traffic Research,, which has analyzed 3.111 people in Germany who either own a BEV or a Hybrid, the typical electric car holder shows the following characteristics: They tend to be well-educated and have an average age of 51. Most of these owners live in provincial or rural areas. Only one fifth of the e-car holders live in bigger cities with more than 100.000 habitants. [23]

On the other hand, electric car sharing is widely used by younger people from an average age of 39, according to the "Frauenhofer Institute for System and Innovation Research". E-car sharing users tend to be highly educated, employed people in comparatively small households. They mainly live in central residential areas and have no car, but rather use several offers of public transportation. [24]

However, experts predict a demographic change which will lead – on average - to an older generation in the future due to less birth rates, emigration as well as the mortality rate, which could change the demand for e-cars in future years future. [25]

With all these figures and information in mind, the importance of the automobile industry for Germany is without question. Therefore, it is all the more essential to keep this competitive advantage of one of the leading industries and to invest in the future. But how exactly will the future of the automotive industry in Germany look like?

3.2 National Development Plan

Since the automobile industry is Germany's strongest sector, it is no surprise that the goal of German politicians, scientists, trade unions and the civil society is to become "the leading supplier and lead market by 2020" in regards to E-Mobility technology. [26] German manufacturers are technological front-runners in terms of e-mobility, including batteries and web-based services along the whole value chain. Therefore, the aim is to achieve the ambitious goal of "one million electric vehicles on Germany's roads by 2020". [27] The government welcomes e-cars especially for reducing the CO_2

[23] Cf. Wiese & Trommer (2015)
[24] Cf. Dütsche & Schneider (2016)
[25] Cf. Kühn (2017)
[26] See Nationale Plattform für Elektromobilität (2018)
[27] See Nationale Plattform für Elektromobilität (2018)

emissions. Nevertheless, this CO_2 emission reduction can only be achieved, if renewable energy sources will be used to produce the electricity for electric cars and to reduce the amount of coal mine power stations in Germany. This point will be discussed in the next section in detail.

In order to reach this goal, the National Electromobility Development Plan conducts different procedures with a budget of about 500 million Euro for incentives, the development of energy storage devices as well as the charging infrastructure.[28]

In terms of charging infrastructure for electric vehicles, the government plans to drastically improve this situation, as well as a public procurement program, which is planned in order to increase sales for e-cars in the public sector.[29]

However, even the German Chancellor Angela Merkel admitted to “Handelsblatt” already in 2017 that it is most likely that this ambitious goal of becoming the leading supplier in e-mobility as well as the target of 1 million e-cars on German roads until 2020 cannot be reached in time. [30]

3.3 Energy Situation

But where does the energy for e-cars in Germany currently come from? In 2011, 50% of the energy in Germany still came from coal fired power stations. Coal is an energy source which will, according to experts, still be available in a huge amount in the future. Around 140 new coal fired power stations are built worldwide every year. However, coal is the biggest CO_2- producer, which means, that the population is polluting the climate in a large amount by producing energy for electric cars. A CO_2 friendly environment can only be guaranteed if renewable energy is used in order to produce the required electricity for e-cars. Taking this into consideration, it is obvious that renewable energy will get more and more important as an alternative energy source. During the last 10 years, the cost for wind energy decreased by 50% and keeps declining.[31]

[28] Cf. Germany Trade and Invest (2018), p. 21 ff.
[29] Cf. Federal Ministry for Economic Affairs and Energy (2018)
[30] Cf. Handelsblatt (2017)
[31] Cf. Welzer & Wiegandt (2011), p. 206.

The goal of the German Government is that renewable energy will amount to up to 45% of power generation by 2025. For 2050, 80% are projected. [32] In terms of e-mobility, it is planned that charging stations in Germany will be powered only by renewable energy in the long run.[33]

The Energy Concept in Germany also includes the development of the “smart grid”. A “smart grid” is broadly defined as an energy network that integrates the consumption and feed-in patterns of all market participants connected to it. It ensures an economically efficient and sustainable supply system with low losses and high availability by combining traditional ways of generating energy (coal fired and nuclear energy plants) with renewable sources. More than 30% of electricity is already generated through renewable sources. There is a need for a system that recognizes and distributes energy according to demand. [34]

The company Sortimo plans to build the largest and fastest charging stations in Germany along the A8 highway in the Bavarian-Swabian area. The company announced that 100% of the electricity will be produced by renewable energy.[35] As already mentioned, it is predicted that in 2050, 80% of electric consumption will come from renewable energy sources. In regard to that development, as a first step, Germany passed its *“Act on the Digitization of the Energy Transition”* in July 2016, which will result in a nationwide deployment of smart meters as well as an investment of $23.6bn in the smart grid infrastructure. [36] Despite much discussion about the smart grid, the development has been slower than expected. Mainly three factors are responsible for that:

- Lack of clear regulatory framework and incentives
- Absence of significant consumer demand
- Segment-specific issues.[37]

For the future, it is assumed that a regular private house could be at the same time a small energy factory, as it might be possible to produce more energy than it needs,

[32]Cf. Die Bundesregierung (2018)
[33] Cf. Wacket et al. (2017)
[34] Cf. Germany Trade & Invest (2018)
[35] Cf. Ayre (2017)
[36] Cf. Federal Ministry of Economic Affairs and Energy (2016)
[37] Cf. Giglioli at al. (2018)

thanks to a further developed technology which might allow a much more efficient energy usage. [38]

3.4 Infrastructure for E-Mobility

Today, there are about 4138 electric charging stations all over Germany, according to the Bundesnetzagentur (15 January 2018). The program "Electric Mobility in Pilot Regions", funded by the Federal Ministry of Transport, Building and Urban Development, is working on the realization of new charging points. Germany works out pilot projects to increase the number of charging stations for e-vehicles with a purpose of bringing the production of electric cars to a new level. [39],[40]

It is without a question that the number of electric cars in Germany is highly dependent on the available charging infrastructure. According to the research of the "Bundesnetzagentur", existing charging stations are available especially in big German cities, such as Stuttgart, Hamburg, Berlin, Dresden, Munich and in the largest metropolitan region Rhein-Ruhr with over 11 million inhabitants. **Figure 6** shows a section of south Germany with all currently available electric charging points. As already mentioned, most of the e-charging stations are located in and around bigger cities.

[38] Cf. Welzer & Wiegandt (2011), p. 206.
[39] Cf. Bundesnetzagentur (2018)
[40] Cf. Technology collaboratioin programm (2018)

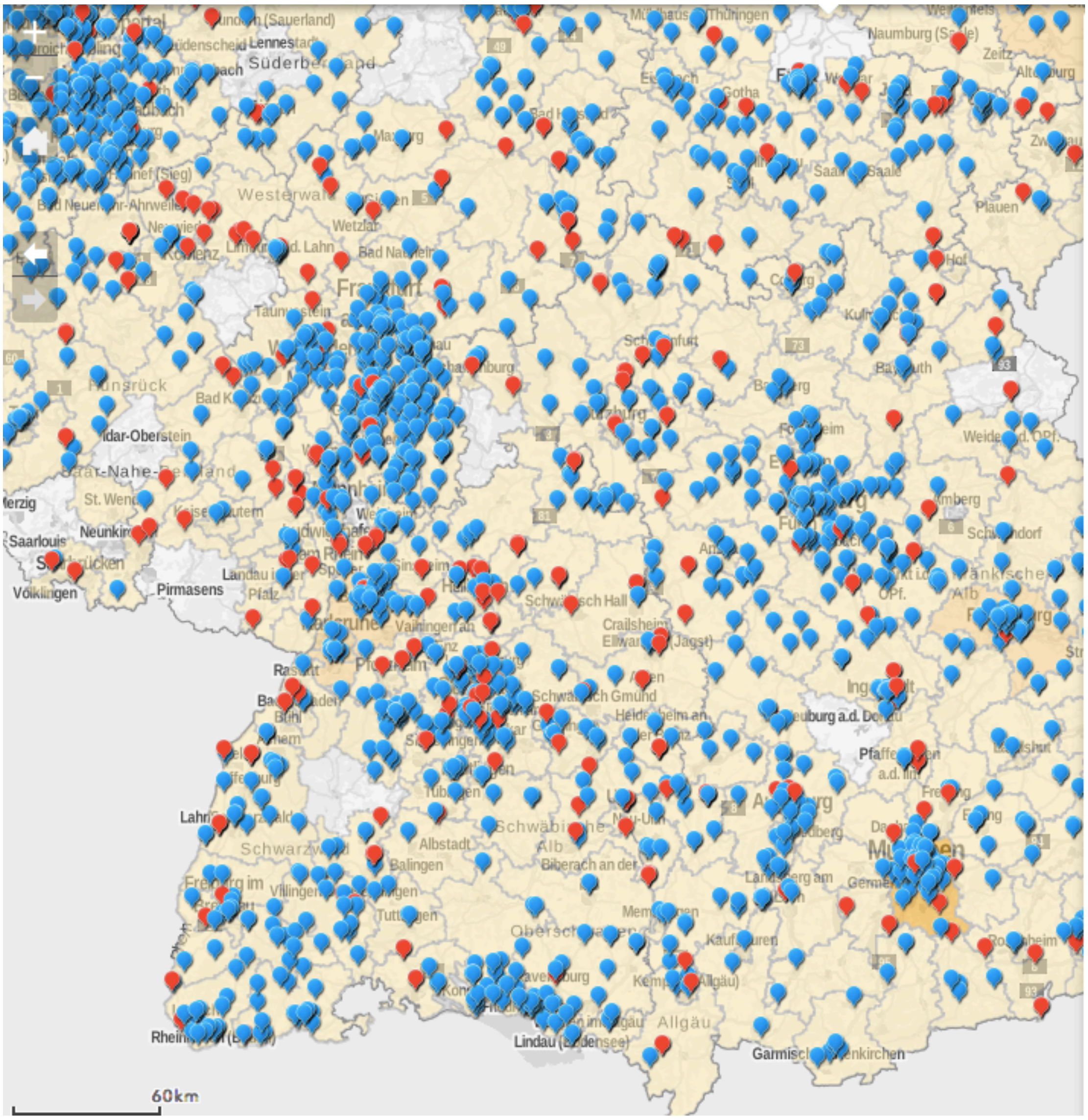

Figure 6: Electric charging points in southern Germany [41]

The Federal Ministry of Transport and Digital Infrastructure reports that the European Commission approved to invest 300 million Euro in charging infrastructure, so Germany has started to install charging stations along all motorway stations. Furthermore, it is planned to additionally spend 300 million Euro for installing further 15.000 charging stations in the country.[42] , [43] , [44]

The charging infrastructure in Germany for e-vehicles consists not only of public charging stations, but also of private ones. For future developments, it is assumed that

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[41] See Bundesnetzagentur (2018)
[42] Cf. Bundesregierung für Wirtschaft und Energie (2018)
[43] Cf. Nationale Plattform für Elektromobilität (2018)
[44] Cf. Federal Ministry for Economic Affairs and Energy (2016)

there will be a combination of private and public charging stations in Germany in order to increase the number of electric vehicles in the country.
It is convenient for e-car holders to have the possibility of recharging their cars not only at home, but also in public areas, for example during parking times. However, public charging stations need high investments. Germany would spend 140 million Euro (based on 24,000 Euro per station) between 2017-2020 in order to reach this ambitious goal. At the same time, The German Federal Government has already invested 1 billion Euro for hydrogen and fuel cell technology research and development for a ten-year period. [45]

With this information in mind, it is clear that huge investments are planned in order to create a charging infrastructure in Germany which is sufficient for e-car holders.
On the other hand, there is the hydrogen technology which is not as much established as the lithium technology. Nevertheless, the hydrogen technology is growing as well.

Today, the number of hydrogen fuel stations in Germany exceeds the number in the United States. According to research, there are 45 hydrogen fueling stations that are available for public use (21 February 2018). Germany had the highest rate of increase in hydrogen fueling stations in 2017. [46]
Even though hydrogen vehicles do have a significant advantage compared to battery electric vehicles in terms of faster charging times (only a few minutes), nowadays, the recharging infrastructure is significantly better for BEV (charging times lasts hours). The missing infrastructure for FCEV is one of the reasons why experts predict this technology not to be significant in the near future. [47]

[45] Cf. German National Platform of Electric Mobility (2015)
[46] Cf. Voelecker (2018)
[47] Cf. Offer at al. (2010), p.24-29.

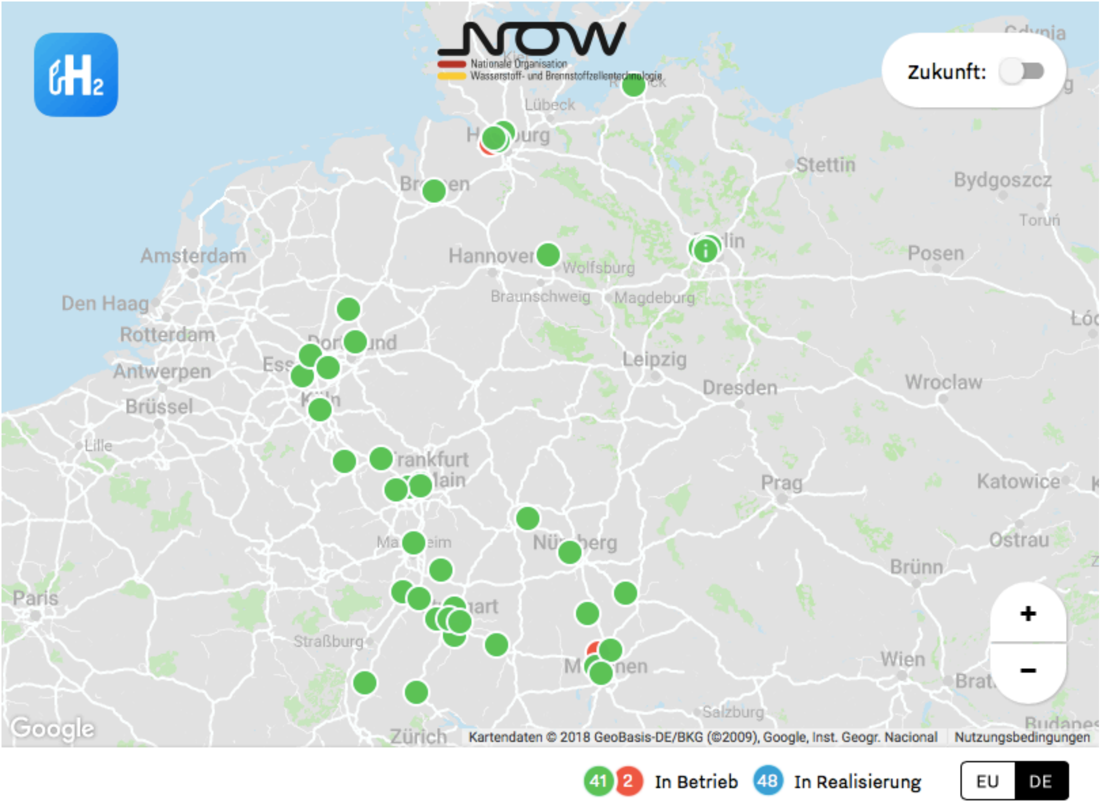

Figure 7: Currently available hydrogen charging stations[48]

The chart above shows the current situation in Germany in terms of available hydrogen charging stations.

Germany added 24 operational hydrogen fuel cell charging stations during one year in 2016. The report made by the "Institut für Elektrochemische Verfahrenstechnik" says that electric charging and hydrogen fueling need roughly the same investment. Despite the fact that electric charging has higher efficiency, hydrogen charging is better suited for longer distances and heavy transport.

Daimler, Linde, OMV, Shell und Total as well as other partners created the Joint Venture H_2 MOBILITY Deutschland GmbH & Co. KG. The goal is to set up at least 400 hydrogen tanks in Germany until 2023. [49]

Tesla, on the one hand, is the pioneer for Lithium Batteries in electric cars. Meanwhile, a lot of other car manufactures including Toyota, Honda, Hyundai, General Motors (GM), VW and Mercedes are mainly focusing on Hydrogen Fuel Cells. [50]

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[48] Cf. Nationale Plattform Wasserstoff- und Brennstofftechnologie (2018)
[49] Cf. Nationale Organisation Wasserstoff- und Brennstofftechnologie (2018)
[50] Cf. Energy and Capital (2017)

Nevertheless, it is obvious that it is still a long way until hydrogen charging stations will cover the whole country. Based on this fact, specialists forecast that hydrogen will need several years in order to become important for the automobile industry of the future.[51]

3.5 Government and Politics

In order to motivate the German society to buy electric cars, the government set up several regulations and offers incentives. First of all, the costs of insurance for electric vehicles compared to ICE vehicles in Germany differ. According to a study of "Handelsblatt" in cooperation with Statista, e-vehicle holders today do not have to pay any kind of taxes. Petrol car owner, on the other hand, have to pay an average of 64 Euro per year and diesel vehicle owner 222 Euro. The liability insurance and a fully comprehensive cover of the car comes to 866 Euro per year for e-vehicles. Diesel cars holders have to pay 850 Euro on average and petrol car holders only 768 Euro.[52]

Moreover, insurances and taxes for e-car holders are planned to be supported and funded by the government in the future as well. These financial incentives should lead to a reduction of the total cost of ownership as well as to motivate people in investing in e-mobility in order to reach the ambitious goals stated in the Paris Agreement of limiting the increase of the global temperature to 1,5° C. Experts predict a full cost-competitiveness of BEV and PHEV with ICEs in Europe by 2030, due to expected high fuel taxes as well as advantages in electrifications till then. [53]
Due to the goal of a CO_2 emission reduction, the German "Bundesrat" did pass a resolution to completely prohibit the sale of gasoline powered vehicles by 2030. [54],[55] Another way to motivate people not to buy ICEs anymore is the e-car buyers´ premium. This money incentive of 4.000 Euro is payed by the government to consumers when purchasing an e-car. [56]

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[51] Cf. Offer at al. (2010), p.24-29.
[52] Cf. Handelsblatt (2017), p.24-25.
[53] Cf. Bloomberg (2017), p.21.
[54] Cf. Ruffini & Wei (2018), p. 329-341.
[55] Cf. Offer at al. (2010), p. 24-29.
[56] Cf. CosmoDirekt (2018)

Other advantages for e-car holders are, for example,: special parking spots, the suspension of restricted entry accesses, special traffic lanes as well as the use of bus lanes. In addition to that, the government is "punishing" drivers of ICE vehicles by putting a fine on petrol and diesel cars as well as increasing the tax on mineral oil.[57]

To put it in a nutshell, the German government is offering several incentives to encourage the German society to invest in electromobility. On the other hand, ICE car holders can already notice several disadvantages and extra payments. With this concept, the government tries to "push" the German society away from ICEs and towards electromobility. The race is on and might also be highly influenced by other major countries decisions.

4 Methodology – Scenario Planning

4.1 The Origins of Scenario Planning

"Scenario planning is a management tool that is designed to allow organizations to evaluate the efficiency of strategies, tactics, and plans under a range of possible future environments."[58]

The first documented scenario planning strategies can be traced back to the 19th century; they were written by Carl von Clausewitz (Prussian General and Military Theorist) and Helmuth von Moltke (German Field Marshal). Since then, the method has been used by people in order to predict the future of societies as well as to make strategic decisions based on it. However, scenario planning as a management tool has been mainly applied in the military industry – first by Prussian military strategists - focusing on the war game simulation.[59]

After World War II, the US government was concerned about their defense system and understood that they needed a specific plan and decision-making for weapon regulation, its development and investments. The political environment in the country was uncertain and it led to the decision of experts to develop the Delphi technique. The

[57] Cf. ADAC, (2018)
[58] See. Chartered Global Management Accountant (2015), p. 2.
[59] Cf. Bradfield et al. (2005), p. 797.

need of simulation models led to the creation of system analysis that included scenario techniques. These techniques were created by the Rand Corporation in the 1950s. The research group developed a joint project with Douglas Aircraft Company and US Airforce for defense management studies. With the help of the project, computers were developed that provided data processing features for simulating solutions (game theory), with a background for the determination of social interaction and game simulation models that provided a platform for scenario techniques. After that, Herman Kahn, the ranking authority on Civil Defense and strategic planning at the Rand Corporation, developed scenarios for the Air Defense System Missile Command, a large scale early warning system. He gave an explanation for critique of US military strategy in the thermonuclear age.[60]

The first scenario planning techniques for business environment were deployed by Shell and General Electric in 1967. At that time, Shell predicted discontinuity in the oil industry, causing the group of companies to come to a well-known "Horizon Planning". Pierre Wack, who was a planner of Shell France, decided to apply the theory of Kahn in France. The result of the scenario forecasts was not successful, but the company understood that this approach could be a good technique for future thinking. [61]

4.2 Scenarios as a Planning Tool

Scenario planning is a tool that provides organizations with different possible outcomes of future events in order to analyze them and make strategic, operational and financial decisions. [62] The technique helps managers to look into the future in specific business environments and make a plan of action in order to respond to changing events and difficulties. Today, many companies use scenario planning in risk management, planning, budgeting, competitive analysis and forecasting. [63] The following examples represent scenario planning techniques[64]:

- *Capital investment decisions*: building of new production factories;
- *Market strategy decisions:* entry of a new product to a new market;

[60] Cf. Bradfield et al. (2005), p. 798.
[61] Cf. Bradfield et al. (2005), p. 800.
[62] Cf. Chartered Global Management Accountant (2015), p. 3.
[63] Cf. Chartered Global Management Accountant (2015), p. 3.
[64] Cf. Chartered Global Management Accountant (2015), p. 3.

- *Financing decisions*: resource availability, revenue, profits;
- *Human resource decisions*: staff, salary differences, bonus payments, trainings.

The scenario planning is mainly based on PEST analysis that includes the following categories: **p**olitical, **e**conomic, **s**ocial and **t**echnological influencing factors. The factors could be different and include others depending on the topic and project. [65]

- *Political:* How can events influence industries? How can the government intervene in the economy?
- *Economic:* Exchange rates, inflation, interest rate, economic growth – how can these factors influence organization?
- *Social:* What are the socio-cultural factors that influence the attitude/decision-making of a population?
- *Technological:* What are new ways of producing products and services? Are there new ways of distributing goods and services? What are new ways of communication?

"Scenarios deal with two worlds; the world of facts and the world of perceptions. They explore for facts but they aim at perceptions inside the heads of decision-makers. Their purpose is to gather and transform information of strategic significance into fresh perceptions." [66]

4.3 The Scenario Building Technique

The scenario building technique is an effective multi-step approach for long-term planning in highly uncertain and unpredictable environments. The scenario software INKA 4 represents the integrated algorithm for scenario planning developed by Geschka & Partner. The program systematically supports scenario creation for a chosen topic using descriptions of influencing factors to evaluate scenarios based on alternative assumptions of the descriptors.[67]

[65] Cf. Chartered Global Management Accountant (2015), p. 5.
[66] See. The Economist (2008)
[67] Cf. Schwarz-Geschka (2017)

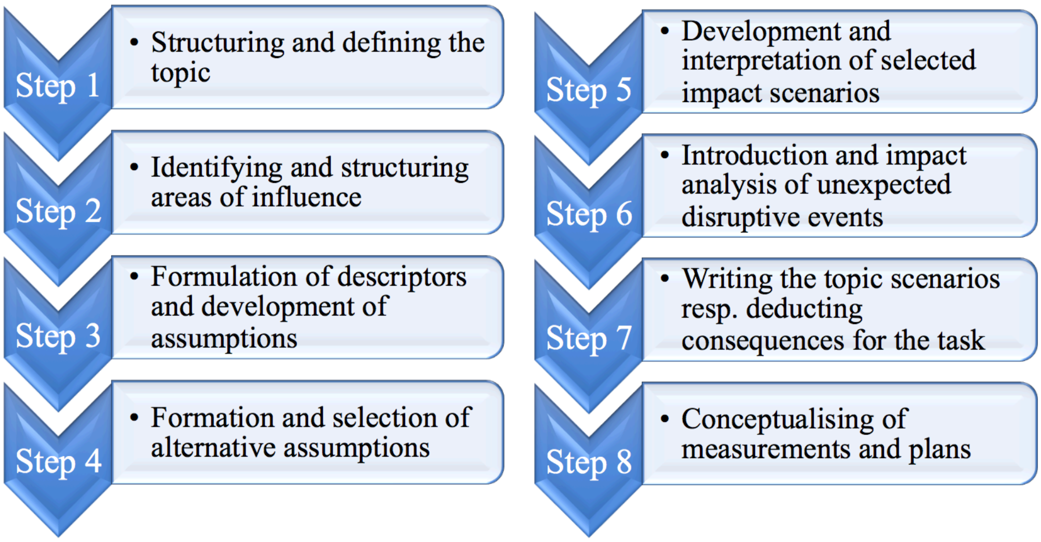

Figure 8: Eight steps of the scenario planning technique[68]

Figure 8 illustrates the 8-step procedure INKA 4 is based upon:

1. **Identification of objectives:** The topic should be defined and the following questions should be answered: In which region and to which time will the topic be analyzed? There should be a list of questions at the beginning of a scenario project with strategic questions for which an answer is needed. Also point out problems which have to be solved.
2. **Analysis of input factors:** The most important input factors of the "scenario topic" should be identified and structured in influence zones. It is possible to enter a description and the current situation for each influencing factor in the INKA 4 program.
3. **Analysis of the future:** It is possible to determine for each parameter one to five scenarios together with an explanation.
4. **Impact assessment:** An important aspect in this procedure is analyzing cross-linking factors. For this step, the effect-analyze method is used.
5. **Illustration of the input factor's impact:** The results of the effect-analyze method will be shown in two different charts - the "driving" factors and the "driven" factors. The program shows how much those factors are connected to each other. A graphic shows the result.

[68] Cf. Schwarz-Geschka (2017)

6. **Construction of scenarios:** In this step, the software will create a "consistency matrix analysis". All alternatives will be compared and rated. A specific algorithm identifies a coherent scenario.
7. **Election of scenarios:** A ranking proposed by INKA 4 helps to choose the scenarios which are most likely. It is also possible to determine key figures for different scenarios.
8. **Documentation:** The last step is the documentation. All information which has been entered can be downloaded as a report in PDF format.

5 Team Methodology and Process Outline

The team was working on a project in a cloud version of INKA that allowed all of the members to put relevant information from different computers into the software and build scenarios. The results for the project were obtained with the help of scenarios that INKA projected on the basis of data given by the team members. The data included different descriptors that were considered as important factors that influence electromobility in Germany.

The scenario-planning project considers the automobile industry in Germany in the context of moving forward from internal combustion engine to electric cars with an incentive to reduce CO_2 emissions and save resources. Today, there are different viewpoints towards E-Mobility. On the basis of some sources, it could be concluded that the number of e-cars on the roads might significantly increase due to investments in production and political incentives. On the other hand, the German National Electromobility Development Plan announced that by 2020, there would be 1 million electric vehicles on German roads[69]. Contrary to that, according to Statista, there were only 54.617 electric cars in Germany in 2017.[70] At the same time, the development of electric vehicles is still growing, the government tries to identify different incentives as subsidies for car users in order to switch from gasoline to batteries.[71] In order to create scenarios, research was conducted that considered infrastructure in Germany, different types of vehicles and batteries, and the economic and political situation in the country.

[69] Cf. Germany Trade & Invest (2015)
[70] Cf. Statista (2018)
[71] Cf. The Guardian (2016)

The literature review was conducted in order to collect data about predictions for electromobility in Germany from different perspectives. After considering a significant number of sources, the following areas of influence were detected: **Infrastructure, Research and Development (R&D) & Technology, Society, Politics, Industry, Finance.**

Infrastructure

The infrastructure plays an important role for further development of electric vehicles in Germany. One of the factors that has a strong influence on electromobility is the Smart Power Grid. It improves the supply chain of electricity that goes from power plants to the end consumer. The technology allows to combine and use different energy sources, such as wind energy, solar energy, nuclear energy, coal and other sources.[72] The smart grid infrastructure is a step-by-step implementation of electrification of road transport that creates an incentive to use electric cars and charge it with renewable energy. *"The e-mobility success rate can be linked to smart grid development, because intelligent charging infrastructures will help the large scale adoption of electric vehicles. This dependency works both ways of course: large scale adoption of e-mobility helps large scale infrastructure investments to be profitable."*[73]

Another important factor that influences electromobility is the development of charging stations in the country. If there are not enough charging stations, people will have no reason and motivation to buy electric vehicles. The distance between charging points also plays a significant role. Today, therefore, there are 4138 charging stations in Germany,[74] and it is planned to invest an additional 300 million Euro in charging infrastructure[75]. It could be concluded that infrastructure stimulates the growth of electromobility in Germany in a positive way.

Research and Development & Technology

Technological progress, scientific and technical research and the transition to mass production can lead to a rapid drop in prices and productivity improvements in the

[72] Cf. NEMA (2018)
[73] See. Joint Research Centre (2018)
[74] Cf. Bundesnetzagentur (2018)
[75] Cf. Federal Ministry of Transport and Digital Infrastructure (2017)

automobile industry. Nowadays, there are many disputes about the type of battery that would be used for electric vehicles in Germany. The efficiency of the battery is defined by its charging time and clean energy source. Therefore, the main task for R&D teams is to create batteries that can be charged in a fast way and produce no emissions. For example, Tesla focuses on lithium batteries, while other car manufactures such as Toyota, Honda, Hyundai, GM, VW and Daimler are mainly focusing on Hydrogen Fuel Cells[76]. After conduction the research, the question regarding lithium vs. hydrogen batteries in Germany remains open. The development of the battery type in Germany is also highly depended on infrastructure (source of energy at charging points and type of charging points). Besides, the cost of a battery for a hybrid vehicle, according to the International Energy Agency, fell from $1000 per kilowatt-hour in 2008 to $268 per kilowatt-hour in 2015, which corresponds to a 73% decrease .[77] **Figure 9** illustrated this point.

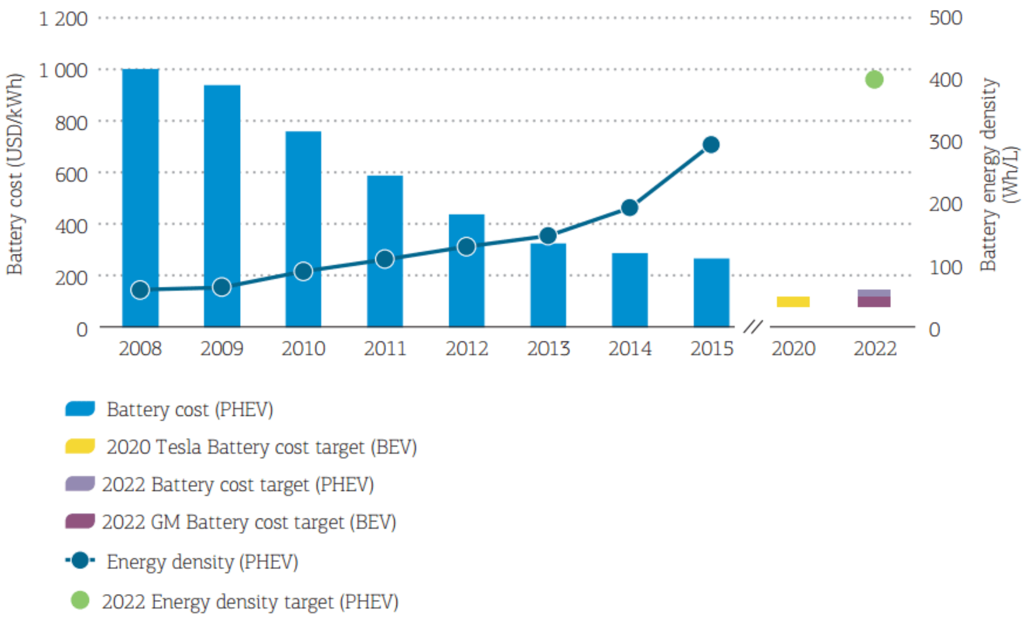

Figure 9: Cost of Battery (USD/kWh)

[76] Cf. Energy and Capital (2017)
[77] Cf. International Energy Agency (2016)

Society

Today there are many disputes and thoughts about whether or not German society will accept the change from gasoline powered to electric vehicles. At a first glance at German consumer behavior, it might be concluded that elderly people will have a positive attitude towards electromobility due to their more stable financial position as well as their concerns about safety and environmental protection. At the same time, younger generations have lower incomes which also influences their car purchasing behavior, but they still care about sustainability issues. Another argument that could arise among society is having no opportunity to buy a standard engine in the future anymore, and later no possibility to drive one at all. However, it will take some time before that becomes reality.

Simultaneously, the government needs strong incentives in order to create a motivation for consumers to switch to electric vehicles and also to prove to car manufactures that new vehicles would bring a profit and high sales volume to the industry.

Despite the fact that the automobile industry will need many years to completely switch to electric vehicles, Bloomberg predicts that there are five factors that could increase electric vehicles' acceptance among society:

1. Short term regulatory support in the EU market
2. Falling lithium-ion battery prices
3. Increased EV commitments from auto markets
4. Growing consumer acceptance as a result of competitively priced EVs across all vehicle classes
5. Increasing role of car sharing and autonomous driving.

In addition to that, the report shows that, by 2040, more than 50% of all new cars sold will be electric.[78]

[78] Cf. Bloomberg (2018)

Politics

According to The Guardian, every German who is going to buy an electric car or a rechargeable hybrid will have governmental support.[79] Buyers of electric vehicles in Germany will receive 4.000 Euro, and those who want to buy a hybrid car will save 3.000 Euro. In addition, huge funds will be spent on developing a network of universal charging stations, where any owner of a hybrid or electric car can quickly (re)charge the car for a few Euro. The goal is very ambitious: by 2020, the total share of electric cars in Germany is supposed to reach 25%.[80]

Norway is a prime example of encouraging the population to buy electric cars. Due to various tax benefits, privileges and additional payments for the purchase, Tesla is selling more cars than Ford today. Last year, France introduced a 10.000 Euro money incentive for consumers buying an electric vehicle.[81]

Therefore, the government plays a significant role in increasing electric cars on German roads via money incentives. Besides, it can be also predicted that in the future, the government will introduce taxes for driving Internal Combustion Engines in order to get rid of cars that are powered by gasoline and/or diesel.

Industry

The growth of electromobility in Germany strongly depends on the development of efficient batteries and the manufacturing of engines. The German automobile market is well known for its engineering and high quality car manufacturers such as BMW, VW and Daimler. The companies have already started to actively work on producing batteries for electric cars and invested large sums of money. For example, Volkswagen has concluded contracts with Samsung and Chinese battery maker Contemprorary Amperex Technology Co Ltd for battery supplies. The investment was 25 billion dollars, which gives an idea about the country´s serious intentions in regards to producing electric vehicles.[82]

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[79] Cf. The Guardian (2016)
[80] Cf. The Guardian (2016)
[81] Cf. Onliner (2016)
[82] Cf. A Wood Mackenzie Business (2018)

According to a study from the Boston Consulting Group, the automobile industry worldwide will increase the efficiency of electric batteries and vehicles worldwide due to the consequences of Industry 4.0 by 6-9% until 2025. By expecting continuous growth rates, the efficiency and productivity might reach a rate of at least 15-20% by 2035. The growth in sales rate will increase 22% by 2025.[83]

Finance

The finance situation significantly influences further developments of E-Mobility in Germany. One of the factors that plays an important role for people in order to buy electric vehicles the purchasing cost of BEV or Hybrids that is still much more expensive than that for ICEs.[84] For instance, charging costs and running costs for an electric vehicle are lower than for a gasoline powered car, but living-time costs are still higher. The situation is predicted to remain the same for the next five years.[85]

Another finance factor that influences the number of electric vehicles in the country is insurance and tax cost. As the government has planned to invest 300 million Euro in the charging infrastructure in Germany by 2020[86], it could be predicted that there is a high probability for the state to increase tax and insurance costs for petrol and diesel cars in the future in order to support owners of electric cars and create an inventive to switch from Internal Combustion Engine.

The areas of influence have been defined in order to combine a group of descriptors under them. The descriptors were found out with the help of research and the aim is to put each of them to a certain area of influence in the software program INKA. These factors are very significant for the project, because they identify the most important trends and show which of them have the strongest impact on future scenarios. Each descriptor has up to three possible assumptions with defined probability that had been set up on the basis of literature review. The total sum of all assumptions always equals up to 100%.

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[83] Cf. Wirtschaftswoche (2018), p.1
[84] Cf. Statista Kaufverhalten Deutschland Autos (2018)
[85] Cf. Handelsblatt (2017), p.1
[86] Cf. Nationale Plattform Elektromobilität (2018)

For the first try, the project team defined a set of 15 different descriptors, where each had two or more areas of influence. Due to this wrong estimation and assumption, the scenario planning software gave the project team more than 2000 scenarios, which created a confusion in the first round of working on the project. For the final calculation, 14 descriptors were agreed upon, each of them dedicated to one of the areas of influence with different specifications. The results became more specific and INKA calculated 14 different scenarios from which the three most probable ones were chosen. The scenarios were created with the help of a consistency matrix that helped to evaluate each descriptor against others. The relationship between descriptors has to show a certain value that ranges from -3 to 3, as seen in **Table 5** and **Figure 10**.

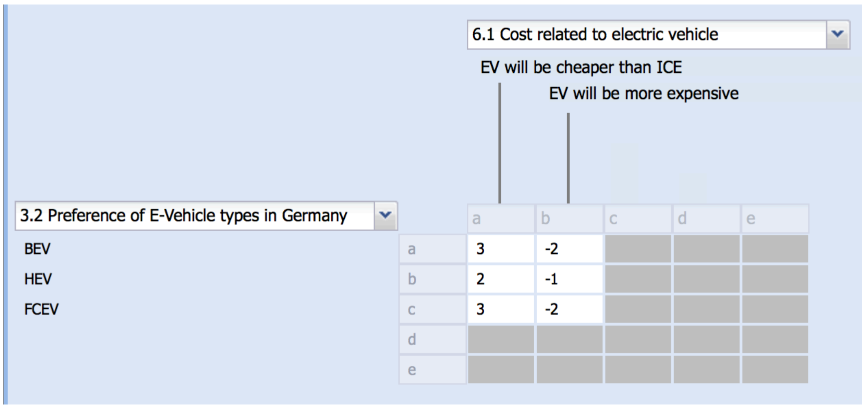

Figure 10: Relationship between Descriptors

Values	Meaning
3	Mutually dependent
2	Mutually supportive
1	Fitting into the same category
0	Unrelated
-1	Fitting adversely
-2	Contradictory
-3	Mutually exclusive

Table 5: Explanation of Values

The values were estimated by the team members in accordance with the reviewed literature. After given values for the consistency matrix, the three most probable scenarios out of fourteen were chosen. The given scenarios have a sum of consistency that shows the quality of each chosen scenario by the program. The sum of consistency is the result of the qualitative descriptors and frequency of their use in the INKA program. Finally, the scenarios were ranked in accordance to the sum of consistency. **Figure 11** illustrates the Scenario portfolio and the associated consistency sum

In the next paragraph, the three different scenarios will be outlined, elaborated upon and explained.

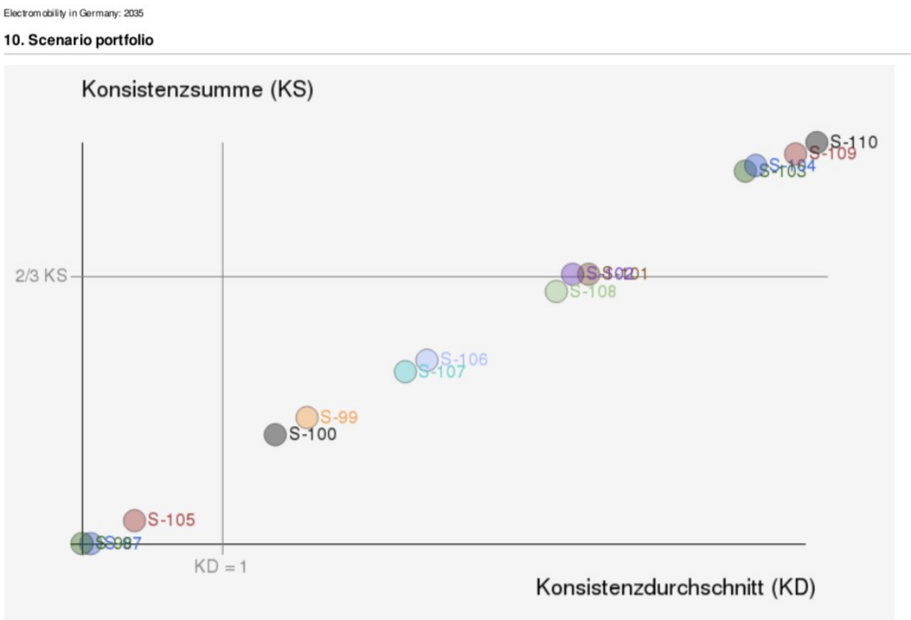

Figure 11: Scenario portfolio

6 Results

6.1 Scenario S-1 (Rank 1) – Going Electric? Yes, please!

INKA 4 selected scenario one based on a consistency sum of 123 and a probability parameter of 61. The most probable Scenario shows that a “smart” electric grid will be broadly developed in Germany by 2035. This means that the technology will be available in cities with a population of 10.000 people and more. This factor is significant for further expansion of electromobility as it ensures renewable and sustainable ways of generating energy for charging stations. However, it was also conducted that there will still be a combination of renewable and fossil power sources by 2035 due to existing ICE on the roads. The government has a strong motivation to switch to completely renewable sources of energy, but studies have shown that 20% of energy source will be still fossil by 2050[87]. In addition, the scenario assumes that battery charging stations will be widely available in Germany in 17 years with a probability of 80%. The result shows that the average distance between charging stations will be 20km, which in return should create high incentives for drivers to buy electric vehicles. Moreover, there will be a combination of private and public charging stations in the country, despite the fact that infrastructure needs a lot of investment. At the same time, it is predicted that the number of hydrogen fuel charging stations will remain low.

Lithium Batteries will be the main power source for electric vehicles. The research has shown that this type of power source would be less costly and more reliable for drivers. Furthermore, battery efficiency will increase by 100%, especially in regard to Lithium-ion technology. At the same time, manufacturing plant efficiency for production of e-cars could increase by 20%. German car manufactures are continuously developing their production facilities for electric vehicles and batteries by investing in R&D of production plants.

Taking into account German consumer behavior, the scenario shows that the motivation for switching to electric vehicles will be strong enough. The incentives consider a profitable long-term price when purchasing an electric vehicle and less ongoing expenses, such as fuel and maintenance, in comparison to Internal Combustion Engine on charging a car. The standardization of norms concerning electric vehicles will also positively influence the development of E-Mobility in Germany. It creates another incentive for people to switch to electric vehicles because of high taxes for driving a gasoline powered car and using fossil power for charging a car. The scenario displays that strong immigration in Germany would not influence the demand for electric vehicles, and the population group aged 20-65 years would still buy electric cars or use services of car-sharing.

[87] Cf. Germany Trade & Invest (2015)

To sum it up, according to the most probable scenario, by 2035, German car holders will prefer electric vehicles, incentives by the government will be very attractive and therefore, it is very probable that the majority of new cars in Germany will be electric.

6.2 Scenario S-2 (Rank 2) – The Rise of the Hybrids

The authors were especially curious to find out what type of electric vehicle German consumers prefer, given that they are open to switching to battery powered cars.

Scenario two was chosen by the scenario software based on a consistency sum of 121 and a probability parameter of 62. The major difference to the scenario mentioned above is the preference of e-vehicle type. It is predicted that Hybrid Electric Vehicles will be the main preference of German consumers when it comes to the type of electric vehicle. The authors consider this to make sense since, in reality, it is most likely that the switch from gasoline powered cars to fully electric ones will be gradual.

The software based this outcome on various other predictions that vindicate the "rise of the hybrids" in comparison to other types of electric vehicles, such as FCEV. Lithium batteries will be the power unit of the future and therefore, charging stations will be broadly available all over Germany, being powered by a combination of renewable and fossil energy.

6.3 Scenario S-3 (Rank 3) – Did someone say Hydrogen?!

In some manifestations, the third scenario resembles scenario number one. The scenario software selected scenario three based on a consistency sum of 119 and a probability parameter of 61.

It is assumed that the smart grid will be implemented broadly in Germany until 2035. The same assumption is made for the battery charging infrastructure, which, according to scenario three, will be available broadly all over Germany. Nowadays, Hydrogen Fuel Cell charging stations are rare, as already mentioned in the previous part of this paper. However, for 2035, this scenario, in contrast to the other scenarios, predicts that that this will drastically change and a high number can be expected, due to big governmental investments as well as company investments. Also, the expected price reduction in the hydrogen fuel cell technology might be another reason for this potential development.

Based upon the mentioned assumptions, INKA 4 predicts that the Hydrogen Fuel Cell technology will play a more and more important role in future.

7 Discussion of Results and Disclaimer

The three selected scenarios portray the different possibilities on how electromobility could look like in Germany by 2035. The scenarios differ from each other in regards to the preference of the type of the electric vehicle, the number and type of available charging stations, and whether or not the government and politics will offer convincing enough financial and non-financial incentives to make it appealing to consumers to switch to electric cars.

Scenario planning is not a bulletproof discipline and that is also not the purpose of this academic paper. Rather, by using this technique, the authors intend to reveal connections between different areas of influence which, in return, show a spectrum of different forecasts for the future. The input factors used by the authors are based on currently available information and literature. Keeping this in mind, the projected results can be seen as valid estimations for future developments.

8 Conclusion

After extensive research, the authors were able to identify six areas of influence with a total of fourteen descriptors.

As the results of the three most probable INKA 4 scenarios have shown, it is very likely that Germany will make a huge step towards electromobility until 2035. According to the offered predictions, a strong development towards lithium batteries can be assumed, as well as a fast integration of the electric charging infrastructures, factors that are both incredible important for a changing the demand for electric cars. However, the ambitious goals of the German government for 2020 which were mentioned before might not be reached in time. Nevertheless, the results of the scenarios show that the strategy of implementing E-mobility in Germany could be successful. Advantages for e-car holders such as incentives as well as other benefits could have a great impact on the future development of electromobility in Germany. Nevertheless, Germany may not completely be seen as an independent market, since the influence of other countries is very high for an export champion like Germany. Foreign governmental decisions may highly influence the German market by unexpected decisions which could lead to more disruptive developments than it can be predicted today.

So what does this mean for Germany in regard to E-Mobility? Which Scenario is the right one? At this point, the authors believe it is important to mention and to stress the fact that the aim of scenario planning is not to predict the future without errors. Rather, it should be seen as an opportunity to take current events and information into consideration in order to give recommendations for the future. By analyzing the three given scenarios, state institutions, manufacturers and other parties involved are able to draw conclusions in order to develop appropriate strategies for the future. By taking the findings into consideration, they are able to react more quickly to the fast paced business environment and can adjust to upcoming realities concerning the implementation of electromobility in Germany in a better way than their competitors.

That being said, having had limited knowledge on electromobility and scenario planning, deciding on the different descriptors constituted a major challenge. Many descriptors depicted situations that were too similar to each other and therefore, the researchers were required to restart the process several times until they obtained the desired data quality and satisfying scenario results.

Taking all of this into consideration, the findings of this scientific paper should therefore be seen as guiding suggestions that lead involved parties in the right direction. It is important to adjust the input factors and to take into consideration the latest developments in this industry to ensure the validity of scenario planning.

9 Annex

9.1 Differences within the scenarios – 1st trial (16.01.2018)

Number of different projections

	S-12	S-11	S-18	S-13	S-10	S-14	S-16	S-17	S-15	S-3	S-2	S-1	S-4	S-7	S-9	S-8	S-6	S-5
Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CS	68	68	68	68	68	68	68	68	68	47	47	47	47	47	47	47	47	47
CA	1,89	1,89	1,89	1,89	1,89	1,89	1,89	1,89	1,89	1,31	1,31	1,31	1,31	1,31	1,31	1,31	1,31	1,31
PP	45	51	46	46	45	52	46	52	46	42	48	42	43	43	42	48	42	48
S-12		1	1	2	1	2	2	2	1	3	4	4	5	5	4	5	4	5
S-11	1		2	2	1	1	2	1	2	4	3	4	5	5	5	4	5	4
S-18	1	2		2	2	2	1	1	1	4	5	5	5	4	3	4	4	5
S-13	2	2	2		1	1	1	2	1	5	5	4	3	4	5	5	4	4
S-10	1	1	2	1		2	1	2	2	4	4	3	4	4	5	5	5	5
S-14	2	1	2	1	2		2	1	1	5	4	5	4	5	5	4	4	3
S-16	2	2	1	1	1	2		1	2	5	5	4	4	3	4	4	5	5
S-17	2	1	1	2	2	1	1		2	5	4	5	5	4	4	3	5	4
S-15	1	2	1	1	2	1	2	2		4	5	5	4	5	4	5	3	4
S-3	3	4	4	5	4	5	5	5	4		1	1	2	2	1	2	1	2
S-2	4	3	5	5	4	4	5	4	5	1		1	2	2	2	1	2	1
S-1	4	4	5	4	3	5	4	5	5	1	1		1	1	2	2	2	2
S-4	5	5	5	3	4	4	4	5	4	2	2	1		1	2	2	1	1
S-7	5	5	4	4	4	5	3	4	5	2	2	1	1		1	1	2	2
S-9	4	5	3	5	5	5	4	4	4	1	2	2	2	1		1	1	2
S-8	5	4	4	5	5	4	4	3	5	2	1	2	2	1	1		2	1
S-6	4	5	4	4	5	4	5	5	3	1	2	2	1	2	1	2		1
S-5	5	4	5	4	5	3	5	4	4	2	1	2	1	2	2	1	1	

CS:	Consistency Sum:
CA:	Consistency Average:
PP:	Probability parameter:

Overview of the projections

Szenario:	S-12	S-11	S-18	S-13	S-10	S-14	S-16	S-17	S-15	S-3	S-2	S-1	S-4	S-7	S-9	S-8	S-6	S-5
Rank:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Consistency Sum:	68	68	68	68	68	68	68	68	68	47	47	47	47	47	47	47	47	47
Consistency Average:	1,89	1,89	1,89	1,89	1,89	1,89	1,89	1,89	1,89	1,31	1,31	1,31	1,31	1,31	1,31	1,31	1,31	1,31
Probability parameter:	45	51	46	46	45	52	46	52	46	42	48	42	43	43	42	48	42	48
Deskriptoren:																		
1.1 Charging Infrastructure	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
2.1 Distribution of charging stations ...	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c
3.1 Electric Grid	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
4.1 R&D of Batteries	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
5.1 Improvement of manufacturing pl...	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
6.1 Power Units	a	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b	b	b
7.1 German consumer behavior regard..	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
8.1 Preference E-Vehicle types in Germ..	a	a	a	a	a	a	a	a	a	c	c	c	c	c	c	c	c	c
9.1 Energy Sources	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c
10.1 Government and Politics	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
11.1 Demographic Change	b	a	b	c	c	a	c	a	b	b	a	c	c	c	b	a	b	a
12.1 Cost related to electric vehicle	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
13.1 Competitors	b	b	b	b	b	b	b	b	b	a	a	a	a	a	a	a	a	a
14.1 Disruptive event (disaster)	c	c	b	a	c	a	b	b	a	c	c	c	a	b	b	b	a	a
15.1 Disruptive event (positive)	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a

Consistency matrix

		1.1	2.1	3.1	4.1	5.1	6.1	7.1	8.1	9.1	10.1	11.1	12.1	13.1	14.1	15.1
		a b c	a b c	a b c	a b c	a b c	a b	a b	a b c	a b c	a b	a b c	a b	a b	a b c d	a b c
1.1 Charging Infrastructure	a Broadly available all over Germany		1 1 2	3 2 0	1 1 1	1 1 1	0 0	-1 3	1 1 1	0 0 0	2 -1	0 0 0	2 -1	-1 2	0 0 0 0	0 0 0
	b Only in urban environments		1 1 2	1 1 1	1 1 1	1 1 1	0 0	0 3	1 2 1	0 0 0	0 0	0 0 0	1 -1	0 1	0 0 0 0	0 0 0
	c Status like today		-3 2 0	1 1 1	1 1 1	1 1 1	0 0	0 -1	-1 2 -1	0 0 0	-1 2	0 0 0	-1 2	2 -1	0 0 0 0	0 0 0
2.1 Distribution of charging stations ...	a only private	1 1 -3		0 0 0	0 0 0	0 0 0	1 -2	-1 1	1 1 -2	0 0 0	1 -1	0 0 0	1 -1	0 0	0 0 0 0	0 0 0
	b only public	1 1 2		0 0 0	0 0 0	0 0 0	1 2	-1 1	1 1 1	0 0 0	1 -1	0 0 0	1 -1	0 0	0 0 0 0	0 0 0
	c combination of both	2 2 0		0 0 0	0 0 0	0 0 0	1 1	-2 2	1 1 1	0 0 0	1 -1	0 0 0	1 -1	0 0	0 0 0 0	0 0 0
3.1 Electric Grid	a implemented all over germany	3 1 1	0 0 0		0 0 0	0 0 0	0 0	0 0	0 0 0	-1 -1 2	0 0	0 0 0	0 0	0 0	0 0 0 0	0 0 0
	b implemented just in big cities	2 1 1	0 0 0		0 0 0	0 0 0	0 0	0 0	0 0 0	-1 -1 2	0 0	0 0 0	0 0	0 0	0 0 0 0	0 0 0
	c status like today	0 1 1	0 0 0		0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0	0 0 0	0 0	0 0	0 0 0 0	0 0 0
4.1 R&D of Batteries	a battery efficiency increases 100%	1 1 1	0 0 0	0 0 0		0 0 0	2 2	-2 2	1 1 1	0 0 0	0 0	0 0 0	1 1	-2 3	0 0 0 0	0 0 0
	b stays the same	1 1 1	0 0 0	0 0 0		0 0 0	0 0	2 -1	0 0 0	0 0 0	0 0	0 0 0	0 0	0 0	0 0 0 0	0 0 0
	c battery efficiency increases 50%	1 1 1	0 0 0	0 0 0		0 0 0	1 1	-1 1	1 1 1	0 0 0	0 0	0 0 0	1 1	-1 2	0 0 0 0	0 0 0
5.1 Improvement of manufacturing pl...	a efficiency increases by 30%	1 1 1	0 0 0	0 0 0	0 0 0		0 0	-1 1	0 0 0	0 0 0	0 0	0 0 0	1 -1	-1 2	0 0 0 0	0 0 0
	b efficiency increases by 50%	1 1 1	0 0 0	0 0 0	0 0 0		0 0	-2 2	0 0 0	0 0 0	0 0	0 0 0	2 -2	-2 3	0 0 0 0	0 0 0
	c stays the same	1 1 1	0 0 0	0 0 0	0 0 0		0 0	0 -1	0 0 0	0 0 0	0 0	0 0 0	-1 1	1 -1	0 0 0 0	0 0 0
6.1 Power Units	a Lithium Battery	0 0 0	1 1 1	0 0 0	2 0 1	0 0 0		-1 2	3 2 -2	0 0 0	0 0	0 0 0	2 -1	-2 3	0 0 0 0	0 0 0
	b Hydrogen Fuel Cell	0 0 0	-2 2 1	0 0 0	2 0 1	0 0 0		-1 2	-1 2 3	0 0 0	0 0	0 0 0	2 -1	2 -2	0 0 0 0	0 0 0
7.1 German consumer behavior regard...	a Internal Combustion Engine	-1 0 0	-1 -1 -2	0 0 0	-2 2 -1	-1 -2 0	-1 -1		-2 1 -2	0 0 0	-2 2	0 0 0	0 0	1 -1	0 0 0 0	0 0 0
	b Battery powered electric cars	3 3 -1	1 1 2	0 0 0	2 -1 1	1 2 -1	2 2		2 2 2	0 0 0	2 -1	0 0 0	0 0	-1 1	0 0 0 0	0 0 0
8.1 Preference E-Vehicle types in Germ...	a BEV	1 1 -1	1 1 1	0 0 0	1 0 1	0 0 0	3 -1	-2 2		0 0 0	2 -1	0 0 0	2 -1	0 0	0 0 0 0	0 0 0
	b HEV	1 2 2	1 1 1	0 0 0	1 0 1	0 0 0	2 2	1 2		0 0 0	2 -1	0 0 0	2 -1	0 0	0 0 0 0	0 0 0
	c FCEV	1 1 -1	-2 1 1	0 0 0	1 0 1	0 0 0	-2 3	-2 2		0 0 0	2 -1	0 0 0	2 -1	0 0	0 0 0 0	0 0 0
9.1 Energy Sources	a only fossil power	0 0 0	0 0 0	-1 -1 0	0 0 0	0 0 0	0 0	0 0	0 0 0		0 0	0 0 0	0 0	0 0	0 0 0 0	0 0 0
	b only renewable energy	0 0 0	0 0 0	-1 -1 0	0 0 0	0 0 0	0 0	0 0	0 0 0		0 0	0 0 0	0 0	0 0	0 0 0 0	0 0 0
	c combination of both	0 0 0	0 0 0	2 2 0	0 0 0	0 0 0	0 0	0 0	0 0 0		0 0	0 0 0	0 0	0 0	0 0 0 0	0 0 0
10.1 Government and Politics	a special tax on ICE and money incen...	2 0 -1	1 1 1	0 0 0	0 0 0	0 0 0	0 0	-2 2	2 2 2	0 0 0		0 0 0	2 -1	-1 2	0 0 0 0	0 0 0
	b no tax on ICE and no tax incentive o...	-1 0 2	-1 -1 -1	0 0 0	0 0 0	0 0 0	0 0	2 -1	-1 -1 -1	0 0 0		0 0 0	-1 2	1 -1	0 0 0 0	0 0 0
11.1 Demographic Change	a population gets older	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0		0 0	0 0	0 0 0 0	0 0 0
	b population gets younger	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0		0 0	0 0	0 0 0 0	0 0 0
	c population stays the same	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0		0 0	0 0	0 0 0 0	0 0 0
12.1 Cost related to electric vehicle	a electric vehicle is cheaper than ICE	2 1 -1	1 1 1	0 0 0	1 0 1	1 2 -1	2 2	0 0	2 2 2	0 0 0	2 -1	0 0 0		-1 1	0 0 0 0	0 0 0
	b electric vehicle is more expensive th...	-1 -1 2	-1 -1 -1	0 0 0	1 0 1	-1 -2 1	-1 -1	0 0	-1 -1 -1	0 0 0	-1 2	0 0 0		1 -1	0 0 0 0	0 0 0
13.1 Competitors	a Tesla fails	-1 0 2	0 0 0	0 0 0	-2 0 -1	-1 -2 1	-2 2	1 -1	0 0 0	0 0 0	-1 1	0 0 0	-1 1		0 0 0 0	0 0 0
	b Tesla succeeds	2 1 -1	0 0 0	0 0 0	3 0 2	2 3 -1	3 -2	-1 1	0 0 0	0 0 0	2 -1	0 0 0	1 -1		0 0 0 0	0 0 0
14.1 Disruptive event (disaster)	a atomic war	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0	0 0 0	0 0	0 0		3 -3 -3
	b nuclear disaster	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0	0 0 0	0 0	0 0		3 -3 -3
	c Meteoroid	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0	0 0 0	0 0	0 0		3 -3 -3
	d no disaster	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0	0 0 0	0 0	0 0		0 0 0
15.1 Disruptive event (positive)	a no more mineral oil as resource	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0	0 0 0	0 0	0 0	3 3 3 0	
	b government will ban ICE completely...	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0	0 0 0	0 0	0 0	-3 -3 -3 0	
	c no event	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	0 0 0	0 0	0 0 0	0 0	0 0	-3 -3 -3 0	

9.2 Differences within the Scenarios – 2nd try (27.04.2018)

Number of different projections

	S-110	S-109	S-104	S-103	S-101	S-102	S-108	S-106	S-107	S-99	S-100	S-105	S-97	S-98
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
CS	123	121	119	118	100	100	97	85	83	75	72	57	53	53
CA	1,84	1,81	1,75	1,74	1,52	1,49	1,47	1,29	1,26	1,12	1,07	0,88	0,82	0,80
PP	61	62	61	62	55	59	59	63	63	63	63	60	56	60
S-110		1	1	2	3	2	1	2	1	3	2	2	4	3
S-109	1		2	1	3	2	1	1	2	2	3	2	4	3
S-104	1	2		1	2	1	2	3	2	2	1	3	3	2
S-103	2	1	1		2	1	2	2	3	1	2	3	3	2
S-101	3	3	2	2		1	2	4	4	3	3	3	1	2
S-102	2	2	1	1	1		1	3	3	2	2	2	2	1
S-108	1	1	2	2	2	1		2	2	3	3	1	3	2
S-106	2	1	3	2	4	3	2		1	1	2	1	3	2
S-107	1	2	2	3	4	3	2	1		2	1	1	3	2
S-99	3	2	2	1	3	2	3	1	2		1	2	2	1
S-100	2	3	1	2	3	2	3	2	1	1		2	2	1
S-105	2	2	3	3	3	2	1	1	1	2	2		2	1
S-97	4	4	3	3	1	2	3	3	3	2	2	2		1
S-98	3	3	2	2	2	1	2	2	2	1	1	1	1	

CS:	Consistency Sum:
CA:	Consistency Average:
PP:	Probability parameter:

Overview of the projections

Szenario:	S-110	S-109	S-104	S-103	S-101	S-102	S-108	S-106	S-107	S-99	S-100	S-105	S-97	S-98
Rank:	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Consistency Sum:	123	121	119	118	100	100	97	85	83	75	72	57	53	53
Consistency Average:	1,84	1,81	1,75	1,74	1,52	1,49	1,47	1,29	1,26	1,12	1,07	0,88	0,82	0,80
Probability parameter:	61	62	61	62	55	59	59	63	63	63	63	60	56	60
Deskriptoren:														
1.1 Electric Grid	a	a	a	a	a	a	a	a	a	a	a	a	a	a
1.2 Battery Charging station availabili...	a	a	a	a	b	a	a	a	a	a	a	a	b	a
1.3 Hydrogen Fuel Cell Charging stat...	b	b	a	a	a	a	b	b	b	a	a	b	a	a
1.4 Accessibility of charging stations ...	a	a	a	a	a	a	a	a	a	a	a	a	a	a
2.1 Power Units	a	a	a	a	a	a	a	a	a	a	a	a	a	a
2.2 R&D of batteries	a	a	a	a	a	a	a	a	a	a	a	a	a	a
3.1 German Consumer behavior regar...	b	b	b	b	b	b	b	a	a	a	a	a	a	a
3.2 Preference of E-Vehicle types in G...	a	b	a	b	c	c	c	b	a	b	a	c	c	c
3.3 Demographic Change	a	a	a	a	a	a	a	a	a	a	a	a	a	a
4.1 Governments and Politics	a	a	a	a	a	a	a	a	a	a	a	a	a	a
5.1 Improvement of manufacturing pl...	b	b	b	b	b	b	b	b	b	b	b	b	b	b
5.2 Influence of norms on developme...	a	a	a	a	a	a	a	a	a	a	a	a	a	a
5.3 Source of power for charging stat...	b	b	b	b	b	b	b	b	b	b	b	b	b	b
6.1 Cost related to electric vehicle	a	a	a	a	a	a	a	a	a	a	a	a	a	a

Consistency matrix

		1.1 a	1.1 b	1.2 a	1.2 b	1.3 a	1.3 b	1.4 a	1.4 b	2.1 a	2.1 b	2.2 a	2.2 b	3.1 a	3.1 b	3.2 a	3.2 b	3.2 c	3.3 a	3.3 b	4.1 a	4.1 b	5.1 a	5.1 b	5.2 a	5.2 b	5.3 a	5.3 b	6.1 a	6.1 b
1.1 Electric Grid	a Smart Grid implemented broadly in ...			1	0	0	0	2	1	2	0	0	0	0	2	2	2	0	0	0	0	0	1	1	0	0	1	2	1	-1
	b Implemented just in big cities			0	0	0	0	2	1	1	0	0	0	0	2	1	1	0	0	0	0	0	1	1	0	0	1	2	1	-1
1.2 Battery Charging station availabili...	a Broadly available in Germany	1	0			-2	2	3	2	3	-2	2	1	-1	2	3	3	-2	0	-1	2	-2	1	1	2	-1	1	1	2	-1
	b Only in urban environments	0	0			-1	1	2	1	3	-2	2	1	-1	2	2	2	-1	0	-1	2	-2	1	1	2	-1	1	1	2	-1
1.3 Hydrogen Fuel Cell Charging stat...	a High number of hydrogen charging...	0	0	-2	-1			1	3	-3	3	-2	-1	-2	3	-3	-1	3	0	-2	2	-2	1	1	2	-2	1	1	2	-2
	b low number of hydrogen fuel cell ch..	0	0	2	1			1	-2	2	-2	2	1	1	-1	-2	-1	-3	0	2	1	-1	0	0	-1	1	1	1	1	1
1.4 Accessibility of charging stations ...	a Public and private battery charging ...	2	2	3	2	1	1			3	-3	2	1	-2	3	3	3	-3	1	-2	3	-2	1	2	2	-2	0	0	2	-2
	b HFC and Battery charging stations...	1	1	2	1	3	-2			1	-2	0	0	-3	3	-3	-3	3	0	-3	2	-3	1	1	2	-2	0	0	2	-2
2.1 Power Units	a Lithium Battery	2	1	3	3	-3	2	3	1			2	2	-3	3	3	2	-3	1	-1	2	-2	1	1	2	-1	0	0	2	-1
	b Hydrogen Fuel Cell	0	0	-2	-2	3	-2	-3	-2			-3	-3	-3	3	-3	-2	3	1	-1	2	-2	1	1	2	-1	0	0	2	-1
2.2 R&D of batteries	a Battery efficiency increases 100%	0	0	2	2	-2	2	2	0	2	-3			-2	3	3	3	-3	0	-1	2	-2	1	1	2	-1	0	0	3	-2
	b Battery efficiency increases by 30%	0	0	1	1	-1	1	1	0	2	-3			-1	2	2	2	-3	0	-1	2	-1	1	1	2	-1	0	0	2	-2
3.1 German Consumer behavior regar...	a Majority of car fleet will still be powe..	0	0	-1	-1	-2	1	-2	-3	-3	-3	-2	-1			-3	1	-3	0	2	-2	2	-1	-2	-2	2	0	0	-2	2
	b Majority of car fleet will be Electric c...	2	2	2	2	3	-1	3	3	3	3	3	2			2	2	2	0	-2	2	-2	1	2	2	-1	0	0	2	-1
3.2 Preference of E-Vehicle types in G...	a BEV	2	1	3	2	-3	-2	3	-3	3	-3	3	2	-3	2				0	-1	3	-2	1	2	2	-1	0	0	3	-2
	b HEV	2	1	3	2	-1	-1	3	-3	2	-2	3	2	1	2				0	-1	2	-2	1	2	2	-1	0	0	2	-1
	c FCEV	0	0	-2	-1	3	-3	-3	3	-3	3	-3	-3	-3	2				0	-1	3	-2	1	2	2	-1	0	0	3	-2
3.3 Demographic Change	a stronger immigration, DC will not in..	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0			1	0	0	0	0	0	0	0	0	0
	b DC will decrease demand for EV	0	0	-1	-1	-2	2	-2	-3	-1	-1	-1	-1	2	-2	-1	-1	-1			0	1	0	0	0	1	0	0	-1	1
4.1 Governments and Politics	a Incentives convincing enough to sw..	0	0	2	2	2	1	3	2	2	2	2	2	-2	2	3	2	3	1	0			1	1	2	-1	0	0	2	-1
	b incentives not strong enough to sw..	0	0	-2	-2	-2	-1	-2	-3	-2	-2	-2	-1	2	-2	-2	-2	-2	0	1			0	0	-1	1	0	0	-1	2
5.1 Improvement of manufacturing pl...	a Efficiency increases by 10%	1	1	1	1	1	0	1	1	1	1	1	1	-1	1	1	1	1	0	0	1	0			2	-1	0	0	1	-1
	b Efficiency increases by 20%	1	1	1	1	1	0	2	1	1	1	1	1	-2	2	2	2	2	0	0	1	0			2	-1	0	0	2	-2
5.2 Influence of norms on developme...	a standardization influence EV positiv..	0	0	2	2	2	-1	2	2	2	2	2	2	-2	2	2	2	2	0	0	2	-1	2	2			0	0	2	-2
	b standardization will negatively influ...	0	0	-1	-1	-2	1	-2	-2	-1	-1	-1	-1	2	-1	-1	-1	-1	0	1	-1	1	-1	-1			0	0	-2	2
5.3 Source of power for charging stat...	a only renewable energy for charging...	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0
	b combination of renewable and foss...	2	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0
6.1 Cost related to electric vehicle	a EV will be cheaper than ICE	1	1	2	2	2	1	2	2	2	2	3	2	-2	2	3	2	3	0	-1	2	-1	1	2	2	-2	0	0		
	b EV will be more expensive	-1	-1	-1	-1	-2	1	-2	-2	-1	-1	-2	-2	2	-1	-2	-1	-2	0	1	-1	2	-1	-2	-2	2	0	0		

9.3 List of final descriptors

Descriptor name: Electric Grid

Area of influence: Infrastructure

Current situation: A “Smart Grid” is broadly defined as an energy network that integrates the consumption and feed-in patterns of all market participants connected to it. It ensures an economically efficient, sustainable supply system with low losses and high availability by combining traditional ways of generating energy (coal fired and nuclear energy plants) with renewable sources. More than 30% of electricity is already generated through renewable sources. There is a need for a system that recognizes and distributes energy according to demand.

Specification A:

- **Name:** Smart Grid implemented broadly in Germany (10.000 people and more)

- **Description:** It is predicted that in 2050, 80% of electricity consumption will come from renewable energy sources. In regard to that development, as a first step, Germany passed its *"Act on the Digitization of the Energy Transition"* in July 2016, which will result in a nationwide deployment of smart meters as well as an investment of $23.6bn in smart grid infrastructure.
- **Reason:** The drastic increase in energy generation through renewable energies is going to intensify the pressure on Germany to invest in network development and the modernization of the electric grid system since – at times – renewables-based electricity already exceeds the transportation capacity of most networks.
- **Probability:** 55%

Specification B:

- **Name:** implemented just in big cities (Population >300.000)
- **Description:** Despite much discussion about the smart grid, the development has been slower than expected.
- **Reason:** Mainly three factors are slowing down the pace of development: Lack of clear regulatory framework and incentives, absence of significant consumer demand and segment-specific issues.
- **Probability:** 45%

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Descriptor name: Power Units

Area of influence: R&D, Innovation and Technology

Current Situation: A variety of different types of batteries and power units exist on the market but the two biggest and most promising contesters for "clean" energy sources for cars in the future are Lithium Batteries and Hydrogen Fuel Cells. Experts agree that there are pros and cons for both innovations and while Tesla is the pioneer for Lithium Batteries in electric cars, a lot of other car manufactures including Toyota, Honda, Hyundai, GM, VW and Mercedes are mainly focusing on Hydrogen Fuel Cells.

Specification A:

- **Name:** Lithium Battery
- **Description:** Hydrogen Fuel Cells and Lithium Batteries may be able to co-exist in the radical change that is E-Mobility, but experts agree that the lack

of supporting infrastructure, the costs and safety issues and most importantly, the fact that hydrogen is hard to capture and store, makes Fuel Cells highly unsuitable for consumer and small vehicles.

- **Reason:** In contrast to Lithium Batteries, which are highly suited for consumer vehicles, hydrogen would only make sense where high-capacity electric cars are already making the most sense, which is in a controlled, standardized environment (e.g. delivery trucks and city busses).
- **Probability:** 60%

Specification B:

- **Name:** Hydrogen Fuel cell
- **Description:** Despite some obvious downsides, Hydrogen Fuel Cells have two crucial advantages over current Lithium Batteries; they recharge within minutes and have 200x the energy density of a standard lithium battery, meaning the consumer gets to drive for a longer range without having to stop. Proponents believe drives will demand a similar convenience when petrol and diesel cars are outlawed and Hydrogen Fuel Cells would offer them exactly that.
- **Reason:** The longer ranger and quicker charging ability are the two main factors why a significant amount of big car manufacturers choose Fuel Cells as the energy source for/of the future. Additionally, some experts think that the capacity of lithium-ion cells is almost at its peak and it will not be able to yield enough further improvements to replace the internal combustion engine; there will only be small future gains in price and performance.
- **Probability:** 40%
-

Sources:

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Descriptor name: German consumer behavior regarding cars

Area of influence: Society

Current situation: In 2017, the market share of EV was about 1.5% in Germany. Bloomberg´s New Energy Finance´s annual long-term forecast of the world´s electric vehicle market predicts an extreme increase of EV over the coming years; mainly driven by five underlying factors.

Specification A:

- **Name:** Majority of car fleet will still be powered by Internal Combustion Engine
- **Description:** Bloomberg´s New Energy Finance report suggests that even though 54% of new car sales will be EV by 2040, "only" 33% of the total global car fleet will be electric by then, meaning that 2/3rd of all of the cars on the road will still be powered by ICE.
- **Reason:** Despite the clear tendency in consumer behavior towards EV, it will most likely take more than 10-20 years before the majority of ICE vehicles will be replaced by EV. The fiscal and monetary incentives need to continue to increase in order to offer customer a real inducement to switch to EV – apart from ecological reasons.
- **Probability:** 60%

Specification B:

- **Name:** Majority of car fleet will be Electric cars
- **Description:** Bloomberg´s analysis shows five underlying factors that are expected to drive increased EV adoption over the coming years – short term regulatory support in the EU market, falling lithium-ion battery prices, increased EV commitments from auto markets, growing consumer acceptance as a result of competitively priced EVs across all vehicle classes and the increasing role of car sharing and autonomous driving. Additionally, more than 50% of all new cars sold in 2040 will be EV.
- **Reason:** By 2029, most EV will become price competitive on an unsubsidized basis with comparable ICE vehicles. In addition, a combination of fines for ICE and special money and tax incentives on BEV will put severe pressure on traditional ICE vehicles and will make it extremely attractive for consumers to consider buying an electric vehicle. Bloomberg predicts autonomous vehicles to replace human driving cars starting in 2030 which will impact vehicles sales and, by 2040, 80% of all autonomous vehicles to be electric due to lower operating costs
- **Probability:** 40%

Sources:

- Bloomberg. (2018). *Bloomberg New Energy Finance 2018*. Abgerufen am 2018. Jun 2018 von Electric Vehicle Outlook 2018: https://about.bnef.com/electric-vehicle-outlook/

Descriptor name: Government and Politics

Area of influence: Politics

Current situation: There are already a variety of tax/money incentives and positive regulations on BEV that go hand in hand with special tax /fines on internal combustion engine vehicles.

Specification A

- **Name:** Tax / Money incentives and regulations will be convincing enough for consumers to switch from ICE to EV
- **Description:** The government and private institutions rely on two things to persuade consumers to switch to electric vehicles – tax and money incentives as well as regulatory advantages. The German government is offering a buyer's premium of 4.000€, the promise to not have to pay motor vehicle tax as well as a variety of road traffic advantages for electric cars, such as special parking spots, the suspension of restricted entry asses and special traffic lanes as well as the use of bus lanes. In addition to that, the government is "punishing" drives of ICE vehicles by putting a fine on petrol and diesel cars as well as to increase the tax on mineral oil.
- **Reason:** Since the purchase price of electric vehicles is currently still higher than the one for comparable internal combustion engine vehicles, there is a need to offer additional incentives and benefits to persuade consumers to switch to BEV.
- **Probability:** 60%

Specification B:

- **Name:** Benefits of incentives and regulations will not be strong / convincing enough to persuade consumers to switch to BEV
- **Description:** Anyone buying an electric car now will continue to be tax-free in the future and should benefit from special parking, possible use of bus lanes and other advantages. Despite this as well as the high buyer´s premium, the car costs per kilometer are still higher than in comparable vehicles with internal combustion engines.
- **Reason:** Because of the high initial purchase price, electric vehicle are not profitable just yet. Moreover, because of their limited range, the electricity cost advantages are not yet decisive. Last but not least, certain regulations, es-

pecially road traffic measures, are just theoretical ideas and are not implemented nationwide yet. Consumers need to see a real benefit, on daily basis, that will make them consider to switch to BEV.

- **Probability:** 40%

Sources:

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Descriptors name: R&D of batteries

Area of influence: R&D, Innovation and Technology

Current situation: E-vehicles do not approximate yet to petrol cars in terms of range and filling speed. An E-Golf for example reaches a range from 282 km compared to a golf with petrol engine which is able to reach distances from 1000 km up to 1163 km (diesel). However, Tesla is already able to offer a range of 400 km with the Model S.

Also, charging of batteries is time consuming. An e-golf needs at least 50 minutes to charge if there is the possibility of a high-speed charging station with 43 kw/h. (4566 high-speed charging stations in Germany currently available – They are the most common ones right now.)

Specification A

- **Name:** Battery efficiency increases 100%
- **Description:** Increasing battery efficiency especially in Lithium-ion technology in terms of "energy density, power density, the life cycle and the cost per kWh."
- **Reason:** The Lithium-ion technology is considered as one of the most promising way to store energy in the near future, due to their low environmental impact as well as their long service live. According to researches by Bloomberg, the demand for Lithium-ion batteries will drastically increase. 21GWh were demanded in 2016. Experts predict a demand up to 1,300 GWh for 2030. Tesla is currently investing high amounts in lithium-ion batteries. It is expected to build a battery which is twice as powerful as today. Due to promising studies which forecast a double improvement of the range efficiency, thanks to new materials, as well as an important cost reduction, experts predict a breakthrough in this technology in the near future.
- **Probability:** 60%

Specification B

- **Name:** Battery efficiency increases by 30%
- **Description:** A 100% battery increase due to new studies as well as to new materials and an expected breakthrough is not possible.
- **Reason:** If a breakthrough with new technologies is not possible and the lithium-ion battery increases the efficiency like in the past, a 30% for 2035 increase is expected, as studies have shown, that lithium-ion batteries increased the efficiency by 10% in 8 years from 2008 till 2016.
- **Probability:** 40%

Sources

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Descriptor name: Improvement of manufacturing plans

Area of influence: Industry

Current situation: Today the main challenge for the e-vehicle production is the core of every e-vehicle: The battery. Due to automatization in the car production process, companies are able to continuously produce more productive and efficient. Robots together with artificial intelligence are used, to reduce costs. In the German automobile industry one person costs around 40 Euro an hour, compared to a robot which only costs 3 to 6 Euro.

The number of robots which is used in the manufacturing process, grows significantly. From 2005 to 2015 the number of industrial robots used in Germany could be doubled to in total 240.000 robots. The German car manufacturer Daimer for example uses robots in their manufacturing plant in Untertürkheim to install heavy hybrid batteries. For the near future it is expected to increase the production process again due to a real cooperation between human and robots.

Specification A

- **Name:** Efficiency increases by 10%
- **Description:** Efficiency of car manufacturing increases by 10% until 2035.
- **Reason:** According to a study from the Boston Consulting Group, the automobile industry worldwide will increase the efficiency, due to the consequences

of Industry 4.0, to 6-9% until 2025. By expecting continuous growth rates the efficiency and productivity might reach at least a rate of 15-20% by 2035. The growth in sales rate will according to Boston Consulting Group increase 22% by 2025. This specification will assume the less positive assumption of the Boston Consulting group with a 15% increase of the productivity until 2035.

- **Probability: 30%**

Specification B

- **Name:** Efficiency increases by 20%
- **Description:** Efficiency of car manufacturing increases by 20% until 2035.
- **Reason:** According to the previously mentioned study of the Boston Consulting Group, this specification will assume the more positive assumption of an efficiency increase around 20% until 2035.
- **Probability:** 70%

Sources

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Descriptor name: Preference E-Vehicle types in Germany

Area of influence: Society

Current situation: The automotive industry in Germany currently uses different types of e-vehicles. The main 3 different types are battery electric vehicles, hybrid electric vehicles and fuel cell vehicles. Due to the goal of a CO_2 emission reduction, the German "Bundesrat" did pass a resolution to prohibit the sale of ICEV by 2030.

Specification A

- **Name:** BEV 40%
- **Description:** Battery electric vehicles will play an important role in 2035.
- **Reason:** According to Statista BEV will play an important role as it is expected, that 20% of the new car registrations in Europe will be fully electric by 2030. By assuming, that this forecast for Europe will also apply for the German automobile Industry means, that it is expected, that out of all electric vehicle types around 30 % will be fully BEV by 2035. Especially due to the infrastructure for BEV which is currently growing. According to the International Energy Agency (IEA) there has been a 73% cost reduction in the last 7 years for batteries.
- **Probability:** 40%

Specification B

- **Name:** HEV 50%
- **Description:** Hybrids and plug in hybrids will play the most important role in 2035.
- **Reason:** According to Statista hybrids as well as plug-in-hybrids will together make up around 46% of all new registrations in 2030 and 70% out of all electric car types.
- **Probability:** 50%

Specification C

- **Name:** FCEV 10%
- **Description:** Hydrogen Fuel cell vehicles
- **Reason:** Even though hydrogen vehicles do have a significant advantage compared to battery electric vehicles in terms of faster charging times (only a few minutes), the recharging infrastructure is significantly better for BEV nowadays (charging times lasts hours). The missing infrastructure for FCEV is one of the reasons why experts predict this technology not to be significant in the near future. However, according to the IEA a technology learning rate of between 0,78 and 0,85 is forecasted as well as a 22% and 15% cost reduction with "each doubling of cumulative production".
  Daimler, Linde, OMV, Shell und Total as well as other partners created the Joint Venture H_2 MOBILITY Deutschland GmbH & Co. KG. The goal is to set up together at least 400 hydrogen tanks in Germany until 2023. According to a scenario study to "Roland Berger" hydrogen fuel cells might play an important role in the longer future. Scenario B from Roland Berger predict a significant cost reduction in this technology. As a consequence, it is expected to produce an amount of 5 million units which might be 5% of the global share market in 2025. An 80% reduction of the todays fuel cell system cost is predicted under several conditions. If this important development continues a 10% market share could probably be expected in 2035.
- **Probability:** 10%

Sources:

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Descriptor: Influence of Norms on development of E-mobility

Area of influence: Industry

Current situation: To ensure user-friendliness as well as according to security reasons, international standards plus norms are defined for the charging infrastructure. It should be ensured, that charging for every electric vehicle can be done without difficulties at any charging point. The Combined Charging System (CCS) is a system which is already uniform in Europe as well as in the United states. The goal of the "Charging Interface Initiative e.V." will be to establish the CCS as a worldwide standard for all kind of battery electric vehicles.

Also, the ISO 12405 defines uniform testing to be able to estimate for Lithium-Ion batteries performance, efficiency and life-time period.

Specification A:

- **Name:** Norms and standardizations will influence E-mobility positively until 2035
- **Description:** Norms and regulations will lead to a faster development of E-mobility until 2035.
- **Reason:** According to the "Plattform of Electrombility" in Germany as well as the DIN Norm association, norms have an important positive impact on the development of the electromobility in Germany and worldwide. Standardization will increase the attractiveness for electromobility worldwide. A drastic

cost reduction in this field is also expected due to standardization. Customers will more likely buy an electric car if they can be sure, that they can charge their care without problems wherever they travel to. Standardized safety regulations for Lithium-ion batteries will also lead to a greater acceptance in this technology.

- **Probability:** 80%

Specification B:

- **Name:** Norms and standardizations will influence electromobility negatively until 2035
- **Description:** Norms and regulations will lead to a slower development of electromobility until 2035
- **Reason:** Due to further investments for car manufacturers in order to be able to fulfil national and international requirements, standards and norms, companies in this field might have disadvantages.
- **Probability:** 20%

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- Nationale Plattform Elektromobilität. (2017). *Norms & Standards.* Abgerufen am 10. Jun 2018 von Nationale Plattform Elektromobilität: http://nationale-plattform-elektromobilitaet.de/en/the-topics/norms-standards/#tabs

Descriptor name: Demographic Change

Area of influence: Society

Current situation: According to the study of the DLR institute for traffic research in Germany, which has been analyzed 3.111 people in Germany who either earn a BEV or a Hybrid, the typical electric car holder shows the following characteristics: Electric car holders in Germany tend to be well-educated and have an average age of 51. Most of these owners live in provincial or rural areas. Only one fifths of the e-car holders live in bigger cities with more than 100.000 habitants.

On the other hand, **electric car sharing** is more used by younger people from an **average age of 39** according to the “Frauenhofer” Institute for System and Innovation

Research. E-car sharing users tend to be **high educated employed people in a smaller household**. They live mainly in central residential areas and have no car, but rather use several offers of public transportation.

However, experts predict a demographic change which will lead in general to an older generation in future due to less birth rates, emigration as well as the mortality rate. According to the Federal Statistical Office today 60% of the German population is between 20 and 65 years old. in 2035 only 53% will most likely be in this age group.

The Federal Statistical Office forecasts a trend of the demographic change in Germany with the so called 13. coordinated population projection until 2060. In this protection 11 different two different variants are available. This paper will concentrate on the first two. Variant 1 predicts a weaker-, variant 2 a stronger immigration.

Specification A

- **Name:** Variant 2: stronger immigration - the demographic change will not influence the demand for electric cars
- **Description:** In 2035, the German population will buy e-vehicles even if they are older.
- **Reason:** According to Variant 2 of the 13. coordination population projection a decrease of the German population of 2 Million by 2035 is expected, as well as a 6,5% decrease of the population aged between 20 and 65. The amount of the population younger than 20 will slightly decrease and the amount of people from 65-79 will increase by 5,5%.
  As in this variant the decrease of the population is due to stronger immigration "only" 2 million and most of the population will still be in the age group of 20 to 65 in 2035, or older (according to the "Statistische Bundesamt Germany") it is most likely, that the total amount of people who could buy an electric car will stay around the same.
- **Probability:** 70%

Specification B

- **Name:** Variant 1 – weaker immigration - The demographic change will decrease the demand for e-vehicles.
- **Description:** In 2035, the German population will decrease the demand for e-vehicles by 10%.
- **Reason:**
  According to Variant 1 the German population will decrease by 4,3 Million people in 2035. This is a nearly 6% decrease. The distribution of the different age groups only differentiates slightly from variant 2. However, due to the strong decrease of the population in variant 1, due to weaker immigration, a 10% reduction of e-vehicle demands will be assumed.
- **Probability:** 30%

References:

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- Statistisches Bundesamt. (2018). *13. koordinierte Bevölkerungsvorausberechnung nach Bundesländern*. Abgerufen am 10. Jun 2018 von Statistisches Bundesamt: https://service.destatis.de/laenderpyramiden/

Descriptor name: Cost related to Electric Vehicle

Area of influence: Finance

Current situation: Currently, people in Germany still tend to buy ICE not only because it is more comfortable to find a charging station, but also because the purchase costs of BEV or Hybrids are still much more expensive today. According to the "Kraftfahrt-Bundesamt" out of in total 3.351.607 new registers vehicles in 2016 were 1.746.308 petrol cars, 1.539.596 diesel, 47.996 hybrids and 11.410 e-vehicles. According to Handelsbalatt 2017, today the purchase cost of a e-golf is 35.900 Euro, a golf with diesel engine 30.000 Euro and a golf with petrol engine just 27.250 Euro. The so called "Umweltprämie" from 4.000 Euro for a e-golf does reduce the purchasing cost but in the end an e-golf is still above other alternatives. Even though the running cost for e-vehicles are lower due to tax reduction as well as lower charging costs for electricity, the live cycle costs for an e-vehicle will be higher as ICE vehicles up until 5 years after the purchasing.

Specification A

- **Name:** Electric vehicle is 30% cheaper than ICE
- **Description:** The life time cost of electric vehicles will be in general cheaper than the life time costs of ICE vehicles in 2035.
- **Reason:** According to Bloomberg New Energy Finance analysts the total cost of ownership, which includes the purchase price as well as running costs of battery-only cars, will be less than the cost for internal combustion engines in 2022. From 2010 till 2016 the cost for lithium-ion batteries dropped by 65% and reached $350 kWh. According to the study of Bloomberg it is expected to lower the cost of lithium-ion batteries again to only $120 per kWh by 2030.

According to the federal ministry of environment and natural support Germany, the purchasing cost of BEV as well as PHEV will be still higher by 2030, but due to much lower charging cost for e-vehicles (which will be for a BEV 3,91 Euro per 100 km for a middle size vehicle compared to an ICE which will cost 7,94 Euro per 100km) it will be cheaper in total to own an electric car in 2035.
According to the forecast of the studies it is predicted, that e-vehicles will be cheaper than ICE vehicles by 2035 with a very high probability.

- **Probability:** 60%

Specification B

- **Name:** Electric vehicle is 20% more expensive that ICE
- **Description:** The life time cost of electric vehicles will be in general cheaper than the life time costs of ICE vehicles in 2035.
- **Reason:** If a breakthrough in the BEV technology as expected is not possible, due to learning curves, as well as governmental regulations and governmental promotions, a cost reduction of at least 10% can be still expected.
- **Probability:** 40%

References:

- Statista. (2017). *Elektromobilität.* (Statista, Hrsg.) Abgerufen am 11. Jun 2018 von Statista-Dossier zur Elektromobilität: https://de.statista.com/statistik/studie/id/6547/dokument/elektromobilitaet/

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- Kraft-fahrt Bundesamt. (2018). *Neuzulassungen von Pkw in den Jahren 2007 bis 2016 nach ausgewählten Kraftstoffarten*. Abgerufen am 10. Jun 2018 von Kraft-fahrt Bundesamt: https://www.kba.de/DE/Statistik/Fahrzeuge/Neuzulassungen/Umwelt/n_umwelt_z.html

Descriptor name: Battery Charging station availability

Area of influence: Infrastructure

Current situation: For today there are about 4138 charging stations all over Germany according to Bundesnetzagentur (15 January 2018). "Electric Mobility in Pilot Regions" program funded by the Federal Ministry of Transport, Building and Urban Development the realization and building of charging points. Germany works out pilot projects to increase the number of charging stations with a purpose of bringing the production of electric cars to further level.

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- **Name:** Battery charging stations available broadly in Germany
- **Description:** The number of electric cars in Germany is highly dependent on charging infrastructure. If the charging battery stations will be broadly available all over Germany, it is assumed that the average distance between stations will be 20 km.
- **Reason:** According to Bundesnetzagentur's research, existing charging stations are available in big German cities such as Stuttgart, Hamburg, Berlin, Dresden, München and in the largest metropolitan region Rhein-Ruhr with over 11 million inhabitants. Federal Ministry of Transport and Digital Infrastructure reports that European Commission approved to invest 300 million Euro in charging infrastructure, so Germany has started to install charging posts at all motorway stations and plans to spend again 300 million Euro for installing further 15.000 charging stations in the country.

- **Probability:** 80%

Specification B:

- **Name:** Battery charging stations only in urban environments
- **Description**: Since the lithium batteries stations are broadly available in big cities of Germany today, it is assumed that the charging infrastructure will be also developed in smaller cities, so battery charging stations will be available only in urban environments (More than 50.000 people).
- **Reason:** According to Bundesnetzagentur's research, the charging stations in Germany are available only in big urban areas for today. There are no possibilities yet to charge an eclectic car outside the city. The company Sortimo (SME) from Germany plans to build the largest charging station in the country along A8 highway in the industrial area in Bavarian-Swabia, between Ulm and Augsburg. The planned first charging station would allow drivers to recharge a car in a fast way. However, the development will start again in one region in Germany, and it will take more years to implement the plan all over the country.
- **Probability:** 20%

References:

- Bundesnetzagentur. (2018). *Ladesäulenkarte*. Abgerufen am 10. Jun 2018 von Bundesnetzagentur: https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/HandelundVertrieb/Ladesaeulenkarte/Ladesaeulenkarte_node.html

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- Ayre, J. (13. Sep 2017). *World's Largest Charging Station To Open In 2018 In Germany*. Abgerufen am 10. Jun 2018 von Clean Technica: https://cleantechnica.com/2017/09/13/company-planning-worlds-largest-ev-fast-charging-station-along-a8-germany/

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- Voelcker, J. (21. Feb 2018). *Germany's hydrogen stations exceed US; California beats Japan on density*. Abgerufen am 10. Jun 2018 von Green Car Reports: https://www.greencarreports.com/news/1115396_germanys-hydrogen-stations-exceed-us-california-beats-japan-on-density

Descriptor: Hydrogen Fuel Cell Charging Stations

Area of influence: Infrastructure

Current situation: Today the number of hydrogen fuel stations in Germany exceeds the number in United States. According to research, there are 45 hydrogen fueling stations that are available for a public (21 February, 2018). Germany has the highest rate of increase in hydrogen fueling stations in 2017.

Specification A:

- **Name:** High number of hydrogen charging stations
- **Description**: Hydrogen fueling is also a way to use clean and renewable energy, so it could be proposed that such kind of charging stations will be highly demanded as battery stations.
- **Reason:** Germany added 24 operational hydrogen fuel cell charging stations during one year in 2016. It is known that hydrogen fuel also reduces CO_2 emission as it harnessed with water and natural gas. The report made by "Institut für Elektrochemische Verfahrenstechnik" says that electric charging and hydrogen fueling need pretty the same investment. Despite the fact that electric charging has higher efficiency, hydrogen charging suits better for long distance way and heavy transport. Therefore, the conclusion is that both charging variants could be used.
- **Probability:** 50%

Specification B:

- **Name:** Low number of hydrogen charging stations

- **Description**: It is predicted that hydrogen fuel cell charging stations will be less used than battery stations due to less efficiency and negative experts' opinion.
- **Reason:** Despite the fact that the number of existing hydrogen fuel cell charging stations is increasing, it is still small. It is also difficult to fill up HFC; The experts report that fuel cells wear out in a fast way and it is hard to regenerate a car again. Besides, it is not easy to make a hydrogen for use as a fuel and distribute it with low losses. Despite the fact that the number of existing hydrogen fuel cell charging stations is increasing, it is still small.
- **Probability:** 50%

References:

- Shahan, Z. (17. Jun 2016). *Why hydrogen fuel cell cars are not competitive — from a hydrogen fuel cell expert*. Abgerufen am 10. Jun 2018 von Energy Post: http://energypost.eu/hydrogen-fuel-cell-cars-competitive-hydrogen-fuel-cell-expert/

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Descriptor name: Accessibility of charging stations in Germany

Area of influence: Infrastructure

Current situation: In 2011 the highest quantity of charging stations are provided in public places in Rhein-Ruhr and Stuttgart areas; the private stations are mostly placed in Bremen/Oldenburg, Hamburg and Rhein-Ruhr areas. In comparison to 2011, the number of charging stations has increased in 2018. Germany plans to develop a concept of enhancing charging stations to encourage the public to use new mobility concepts and making EVs a more attractive purchase.

Specification A:

- **Name:** Public and private battery charging stations
- **Description:** Despite the fact that to install charging stations in public places is costly, it is assumed that in Germany there will be a combination of private and public charging stations in order to increase sales and use of eclectic vehicles in the country (government owned, shopping centers, motorway service stations).
- **Reason:** Despite the fact that private charging locations are more available, 15% of public place is still could exist for lithium stations. For people it is convenient to recharge their cars not only at home and working place, but also in parking places, while they make shopping or just spend a time in a city. However, public charging stations need a lot of investment. Germany would spend 140 million Euro (based on 24,000 Euro per station) between 2017-2020. According to studies, consumers would like to charge their vehicles in public places for free.
- **Probability:** 40%

Specification B:

- **Name:** Hydrogen fuel cell charging stations and battery stations (public and private)
- **Description:** Due to different experts' opinions in the automotive industry, there is a probability that Germany will have the combination of hydrogen fuel cell charging stations and battery stations.
- **Reason:** Hydrogen fuel charging stations could be used in addition to battery stations as they provide more mileage than batteries and fuel cells could not wear out so quickly as batteries. Besides, change in charging infrastructure from diesel and gas is not so significant and does not cause C02 emissions. At

the same time, The German Federal Government has invested 1 billion EUR for hydrogen and fuel cell technology research and development over a ten-year period. However, specialists think that the use of hydrogen is a bad decision.

- **Probability:** 60%

References:

- Nationale Plattform Elektromobilität . (Nov 2015). *Charging Infrastructure for Electric Vehicles in Germany Progress Report and Recommendations 2015.* Abgerufen am 10. Jun 2018 von Nationale Plattform Elektromobilität : http://nationale-plattform-elektromobilitaet.de/fileadmin/user_upload/Redaktion/AG3_Statusbericht_LIS_2015_engl_klein_bf.pdf

- Shahan, Z. (17. Jun 2016). *Why hydrogen fuel cell cars are not competitive — from a hydrogen fuel cell expert*. Abgerufen am 10. Jun 2018 von Energy Post: http://energypost.eu/hydrogen-fuel-cell-cars-competitive-hydrogen-fuel-cell-expert/

- Germany Trade & Investment. (2015). *Electromobility in Germany: Vision 2020 and Beyond.* Abgerufen am 10. Jun 2018 von Germany Trade & Investment: https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Brochures/Industries/electromobility-in-germany-vision-2020-and-beyond-en.pdf?v=3)

Descriptor name: Source of power for charging stations in Germany

Area of Influence: Industry

Current situation: As electric vehicles raise their popularity in Germany, the solution of power source for charging stations is still not certain. For today most of the cars in Germany are charged at fuel stations with diesel and gas; and there are also power stations for charging eclectic batteries. The question for today is the following: what power source for charging stations would be used in Germany by 2025?

Specification A:

- **Name:** Renewable energy at charging stations
- **Description:** As the main idea of promotion and development of electromobility is to reduce CO_2 emission, the question about using renewable energy is the power source for charging stations is also important and topical. The most part of the research has shown that charging stations in Germany are planned to be powered by only renewable energy in the future, but not in the nearly future.
- **Reason:** In terms of legislation connected with power from renewable energy, Germany plans to increase a share of 40 to 45 percent by 2025. The Energy Concept in Germany considers the development of «Smart Grid» that saves climate by using renewable energy (wind, solar, water,..). In addition to it, in the previous research about charging stations it was found out that Sortimo company plans to build the largest and fastest charging stations in Germany along A8 highway in Bavarian-Swabian area. The company announced that electricity will be sourced by 100% renewable energy.
- **Probability:** 10%

Specification B:

- **Name:** Electricity supply with renewable and fossil power (combination)
- **Description:** One of the main goals of electromobility is to use renewable energy sources, however, it is difficult to switch completely from fossil power sources to 100% renewable sources, so it is predicted that charging stations would be powered by renewable and fossil power in the nearly future.
- **Reason:** According to overview of German standardization and its current target concerning supply of electricity for charging stations in Germany, the country plans to use renewable energy source. However, research about energy source in Germany has shown that the country plans to use only 80% of renewable energy by 2050, not 100%. It leads to a conclusion that electricity for charging stations could be also supplied with a fossil power. The information sources were limited, further research is needed.
- **Probability:** 90%

References:

- Ayre, J. (13. Sep 2017). *World's Largest Charging Station To Open In 2018 In Germany*. Abgerufen am 10. Jun 2018 von Clean Technica: https://cleantechnica.com/2017/09/13/company-planning-worlds-largest-ev-fast-charging-station-along-a8-germany/

- Germany Trade & Investment. (2015). *Electromobility in Germany: Vision 2020 and Beyond.* Abgerufen am 10. Jun 2018 von Germany Trade & Investment: https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Brochures/Industries/electromobility-in-germany-vision-2020-and-beyond-en.pdf?v=3)

Descriptor: Influence of Norms on development of E-mobility

Area of influence: Industry

Current situation: To ensure user-friendliness as well as according to security reasons, international standards plus norms are defined for the charging infrastructure. It should be ensured, that charging for every electric vehicle can be done without difficulties at any charging point. The Combined Charging System (CCS) is a system which is already uniform in Europe as well as in the United states. The goal of the "Charging Interface Initiative e.V." will be to establish the CCS as a worldwide standard for all kind of battery electric vehicles.

Also, the ISO 12405 defines uniform testing to be able to estimate for Lithium-Ion batteries performance, efficiency and life-time period.

Specification A:

- **Name:** Norms and standardizations will influence E-mobility positively until 2035
- **Description:** Norms and regulations will lead to a faster development of E-mobility until 2035.
- **Reason:** According to the "Plattform of Electrombility" in Germany as well as the DIN Norm association, norms have an important positive impact on the

development of the electromobility in Germany and worldwide. Standardization will increase the attractiveness for electromobility worldwide. A drastic cost reduction in this field is also expected due to standardization. Customers will more likely buy an electric car if they can be sure, that they can charge their care without problems wherever they travel to. Standardized safety regulations for Lithium-ion batteries will also lead to a greater acceptance in this technology.

- **Probability:** 80%

Specification B:

- **Name:** Norms and standardizations will influence electromobility negatively until 2035
- **Description:** Norms and regulations will lead to a slower development of electromobility until 2035
- **Reason:** Due to further investments for car manufacturers in order to be able to fulfil national and international requirements, standards and norms, companies in this field might have disadvantages.
- **Probability:** 20%

References:

- Nationale Plattform Elektromobilität. (2017). *Norms & Standards.* Abgerufen am 10. Jun 2018 von Nationale Plattform Elektromobilität: http://nationale-plattform-elektromobilitaet.de/en/the-topics/norms-standards/#tabs

Descriptor name: Demographic Change

Area of influence: Society

Current situation: According to the study of the DLR institute for traffic research in Germany, which has been analyzed 3.111 people in Germany who either earn a BEV or a Hybrid, the typical electric car holder shows the following characteristics: **Electric car holders in Germany tend to be well-educated and have an average age of 51. Most of these owners live in provincial or rural areas. Only one fifths of the e-car holders live in bigger cities with more than 100.000 habitants.**

On the other hand, **electric car sharing** is more used by younger people from an **average age of 39** according to the “Frauenhofer” Institute for System and Innovation Research. E-car sharing users tend to be **high educated employed people in a smaller household**. They live mainly in central residential areas and have no car, but rather use several offers of public transportation.

However, experts predict a demographic change which will lead in general to an older generation in future due to less birth rates, emigration as well as the mortality rate. According to the Federal Statistical Office today 60% of the German population is between 20 and 65 years old. in 2035 only 53% will most likely be in this age group.

The Federal Statistical Office forecasts a trend of the demographic change in Germany with the so called 13. coordinated population projection until 2060. In this protection 11 different two different variants are available. This paper will concentrate on the first two. Variant 1 predicts a weaker-, variant 2 a stronger immigration.

Specification A

- **Name:** Variant 2: stronger immigration - the demographic change will not influence the demand for electric cars
- **Description:** In 2035, the German population will buy e-vehicles even if they are older.
- **Reason:** According to Variant 2 of the 13. coordination population projection a decrease of the German population of 2 Million by 2035 is expected, as well as a 6,5% decrease of the population aged between 20 and 65. The amount of the population younger than 20 will slightly decrease and the amount of people from 65-79 will increase by 5,5%.
  As in this variant the decrease of the population is due to stronger immigration “only” 2 million and most of the population will still be in the age group of 20 to 65 in 2035, or older (according to the “Statistische Bundesamt Germany”) it is most likely, that the total amount of people who could buy an electric car will stay around the same.
- **Probability:** 70%

Specification B

- **Name:** Variant 1 – weaker immigration - The demographic change will decrease the demand for e-vehicles.
- **Description:** In 2035, the German population will decrease the demand for e-vehicles by 10%.
- **Reason:**
  According to Variant 1 the German population will decrease by 4,3 Million people in 2035. This is a nearly 6% decrease. The distribution of the different age groups only differentiates slightly from variant 2. However, due to the strong decrease of the population in variant 1, due to weaker immigration, a 10% reduction of e-vehicle demands will be assumed.
- **Probability:** 30%

References:

- DLR Presse-Portal. (26. May 2015). *DLR wertet größte und umfangreichste Studie über Erstnutzer von Elektroautos aus*. Abgerufen am 10. Jun 2018 von DLR Presse-Portal: http://www.dlr.de/dlr/presse/desktopdefault.aspx/tabid-10172/213_read-13726/year-all/#/gallery/14080

- Bundeszentrale fur Politische Bildung. (2018). *Demografischer Wandel*. Abgerufen am 10. Jun 2018 von Bundeszentrale fur Politische Bildung: http://www.bpb.de/politik/innenpolitik/demografischer-wandel/

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Descriptor name: Cost related to Electric Vehicle

Area of influence: Finance

Current situation: Currently, people in Germany still tend to buy ICE not only because it is more comfortable to find a charging station, but also because the purchase costs of BEV or Hybrids are still much more expensive today.

According to the "Kraftfahrt-Bundesamt" out of in total 3.351.607 new registers vehicles in 2016 were 1.746.308 petrol cars, 1.539.596 diesel, 47.996 hybrids and 11.410 e-vehicles. According to Handelsbalatt 2017, today the purchase cost of a e-golf is 35.900 Euro, a golf with diesel engine 30.000 Euro and a golf with petrol engine just 27.250 Euro. The so called "Umweltprämie" from 4.000 Euro for a e-golf does reduce the purchasing cost but in the end an e-golf is still above other alternatives. Even though the running cost for e-vehicles are lower due to tax reduction as well as lower charging costs for electricity, the live cycle costs for an e-vehicle will be higher as ICE vehicles up until 5 years after the purchasing.

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According to the forecast of the studies it is predicted, that e-vehicles will be cheaper than ICE vehicles by 2035 with a very high probability.

- **Probability:** 60%

Specification B

- **Name:** Electric vehicle is 20% more expensive that ICE
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- **Reason:** If a breakthrough in the BEV technology as expected is not possible, due to learning curves, as well as governmental regulations and governmental promotions, a cost reduction of at least 10% can be still expected.
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- **Probability:** 80%

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- **Name:** Battery charging stations only in urban environments
- **Description**: Since the lithium batteries stations are broadly available in big cities of Germany today, it is assumed that the charging infrastructure will be

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- **Probability:** 20%

References:

- Bundesnetzagentur. (2018). *Ladesäulenkarte*. Abgerufen am 10. Jun 2018 von Bundesnetzagentur: https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/HandelundVertrieb/Ladesaeulenkarte/Ladesaeulenkarte_node.html

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- **Name:** High number of hydrogen charging stations
- **Description**: Hydrogen fueling is also a way to use clean and renewable energy, so it could be proposed that such kind of charging stations will be highly demanded as battery stations.
- **Reason:** Germany added 24 operational hydrogen fuel cell charging stations during one year in 2016. It is known that hydrogen fuel also reduces CO_2 emission as it harnessed with water and natural gas. The report made by Institut für Elektrochemische Verfahrenstechnik says that electric charging and hydrogen fueling need pretty the same investment. Despite the fact that electric charging has higher efficiency, hydrogen charging suits better for long distance way and heavy transport. Therefore, the conclusion is that both charging variants could be used.
- **Probability:** 50%

Specification B:

- **Name:** Low number of hydrogen charging stations
- **Description**: It is predicted that hydrogen fuel cell charging stations will be less used than battery stations due to less efficiency and negative experts' opinion.
- **Reason:** Despite the fact that the number of existing hydrogen fuel cell charging stations is increasing, it is still small. It is also difficult to fill up HFC; The experts report that fuel cells wear out in a fast way and it is hard to regenerate

a car again. Besides, it is not easy to make a hydrogen for use as a fuel and distribute it with low losses. Despite the fact that the number of existing hydrogen fuel cell charging stations is increasing, it is still small.

- **Probability:** 50%

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Descriptor name: Accessibility of charging stations in Germany

Area of influence: Infrastructure

Current situation: In 2011 the highest quantity of charging stations are provided in public places in Rhein-Ruhr and Stuttgart areas; the private stations are mostly placed in Bremen/Oldenburg, Hamburg and Rhein-Ruhr areas. In comparison to 2011, the number of charging stations has increased in 2018. Germany plans to develop a concept of enhancing charging stations to encourage the public to use new mobility concepts and making EVs a more attractive purchase.

Specification A:

- **Name:** Public and private battery charging stations

- **Description:** Despite the fact that to install charging stations in public places is costly, it is assumed that in Germany there will be a combination of private and public charging stations in order to increase sales and use of eclectic vehicles in the country (government owned, shopping centers, motorway service stations).
- **Reason:** Despite the fact that private charging locations are more available, 15% of public place is still could exist for lithium stations. For people it is convenient to recharge their cars not only at home and working place, but also in parking places, while they make shopping or just spend a time in a city. However, public charging stations need a lot of investment. Germany would spend 140 million Euro (based on 24,000 Euro per station) between 2017-2020. According to studies, consumers would like to charge their vehicles in public places for free.
- **Probability:** 40%

Specification B:

- **Name:** Hydrogen fuel cell charging stations and battery stations (public and private)
- **Description:** Due to different experts' opinions in the automotive industry, there is a probability that Germany will have the combination of hydrogen fuel cell charging stations and battery stations.
- **Reason:** Hydrogen fuel charging stations could be used in addition to battery stations as they provide more mileage than batteries and fuel cells could not wear out so quickly as batteries. Besides, change in charging infrastructure from diesel and gas is not so significant and does not cause C02 emissions. At the same time, The German Federal Government has invested 1 billion EUR for hydrogen and fuel cell technology research and development over a ten-year period. However, specialists think that the use of hydrogen is a bad decision.
- **Probability:** 60%

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Descriptor name: Source of power for charging stations in Germany

Area of Influence: Industry

Current situation: As electric vehicles raise their popularity in Germany, the solution of power source for charging stations is still not certain. For today most of the cars in Germany are charged at fuel stations with diesel and gas; and there are also power stations for charging eclectic batteries. The question for today is the following: what power source for charging stations would be used in Germany by 2025?

Specification A:

- **Name:** Renewable energy at charging stations
- **Description:** As the main idea of promotion and development of electromobility is to reduce CO_2 emission, the question about using renewable energy is the power source for charging stations is also important and topical. The most part of the research has shown that charging stations in Germany are planned

to be powered by only renewable energy in the future, but not in the nearly future.

- **Reason:** In terms of legislation connected with power from renewable energy, Germany plans to increase a share of 40 to 45 percent by 2025. The Energy Concept in Germany considers the development of «Smart Grid» that saves climate by using renewable energy (wind, solar, water,..). In addition to it, in the previous research about charging stations it was found out that Sortimo company plans to build the largest and fastest charging stations in Germany along A8 highway in Bavarian-Swabian area. The company announced that electricity will be sourced by 100% renewable energy.
- **Probability:** 10%

Specification B:

- **Name:** Electricity supply with renewable and fossil power (combination)
- **Description:** One of the main goals of electromobility is to use renewable energy sources, however, it is difficult to switch completely from fossil power sources to 100% renewable sources, so it is predicted that charging stations would be powered by renewable and fossil power in the nearly future.
- **Reason:** According to overview of German standardization and its current target concerning supply of electricity for charging stations in Germany, the country plans to use renewable energy source. However, research about energy source in Germany has shown that the country plans to use only 80% of renewable energy by 2050, not 100%. It leads to a conclusion that electricity for charging stations could be also supplied with a fossil power. The information sources were limited, further research is needed.
- **Probability:** 90%

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