Status quo and perspectives of the electromobility in Germany and the USA

Austrian Marshall Plan Foundation

Tim Klenner

Home: University of Applied Sciences Kufstein Tirol
Supervisor: Prof. (FH) Dr. Claudia Van der Vorst

Host: York College of Pennsylvania
Supervisor: Prof. Donald J. Hake II

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Tim Klenner	
Student´s name	Student´s signature
1710642077	Rosenheim, 08.01.2020
Matriculation number	Rosenheim, date

Contents

List of figures

List of tables

Abstract

This research study is based on a survey, to project possible future scenarios for the development and success of electric vehicles, with a close look at battery electric cars.

Climate Change is a highly discussed topic this decade and therefore every solution attached to it becomes controversial. Everybody has an opinion on electric cars and, whether it is bad or good, most people have a reasoning behind it. The approach to shift transportation to electric vehicles is one of the most common concepts.

After the basic definitions of electric cars and their drivetrain, as well as two similar alternative-fuel-powered engines, the main part of the thesis revolves around the survey and its results. The most interesting questions were picked and broken down in exact numbers. Where helpful, the sample groups were divided even further than nationality. For example, by filtering only younger, or wealthier parts of the sample. To be as unbiased as possible, every possible bias, like members of a Porsche forum participate in the German survey, was stated and explained in the beginning and then considered, when the results are being analyzed. Participants of the survey in both the US and Germany have been asked the same questions.

Three questions from the US-survey were analyzed in this research study, to see how their mindset about electric cars is built and how much they believe in electric vehicles as the future of mobility.

Those questions were:

- What kind of car are you driving?
- Are you considering buying an electric vehicle (again)?
- What are the current advantages of EVs in comparison to gasoline-powered cars?

The same three questions were also analyzed for the German part of the study, but additionally, a fourth one was interpreted, because most German participants did not answer the second question positively:

- Why do you/do you not want to buy an electric vehicle in the future?

American participants seem to be more open minded, looking at the future of cars. They had a higher ratio of people believing in electric vehicles than Germany (89% to 54%). This could be a result of the more developed infrastructure of charging stations and a stronger industry of electric vehicles, with leading companies like Tesla and Rivian.

German participants have a reasoning behind being closer minded, since a huge part of their economy is built around gasoline-powered car manufacturers. In case the industry turns around through the disruptive innovation, which EVs can definitely be, VW, Daimler and BMW have to adapt fast enough to have a chance to keep their market shares.

Young participants' strong belief in electric cars will open up opportunities for manufacturers of electric vehicles in both countries.

1. Introduction

The upcoming generation has to handle a huge obstacle: Climate change. Scientists all over the world have proven that it is real and even though there is still a big minority that believes it is fake, it cannot be ignored. To stop the earth from heating up more every year, humans have to cut emissions and with every new year there are new solutions coming up and countries start acting fast:
The European Union (EU) released their future plans to seal a ban on throwaway plastic in March 2019. These laws will affect every country inside the EU. Later the same year, Germany announced to ban plastic bags in August and the law passed one month later[1].

This has just been one of many approaches to stop climate change and although it may seem like one does not affect the phenomenon, adding up cuts by putting effort into several approaches will be the final solution.

One of the most controversial decisions that humanity has to face in the near future is whether they will stick to their traditional mobility, including flying, that is almost exclusively powered by gas, or switch to an alternative. Mobility and industry are some of the main sectors, producing CO_2. Therefore, if successfully developed, electric cars could be a way to reduce emissions by massive amounts. By just looking at the facts on the surface, this alternative seems to be the only reasonable path to pick, but by digging further into the topic, electric cars have disadvantages as well.

1.1. Problem

This decade has been defining for several industrial and technological evolutions. In most of those cases, you can see an exponential progress and growth of the market. Therefore, the population has to adapt to and accept the technology in order to make it become successful. Electric cars have been in the market for over a decade now and although they promise to be cleaner than gasoline powered cars, they still only have a small percentage of market share and can barely be seen on the streets.

It is problematic, that electric vehicles are neither fully rejected nor accepted by the public, still both sides argue with facts and numbers. Is this the result of electric vehicles failing in many other categories, where gasoline-powered cars have always been dominant and which customers now take for granted? Is the development of a new branch in the car industry just a phase? Or do people simply ignore the fact that this new technology could be a clean way for the future?

[1] cf. The Local, 2019

1.2. Objectives

The goal of this study is to determine how fast adoption and acceptance of electric vehicles is spread and how those affect the future. Projections are going to be made, how the industry of car-manufacturing will change, dependent on different values. Since there might be differences between countries, two major nations of car manufacturing will be compared to each other: The United States of America and Germany. After stating general facts about electric vehicles to clarify any superficial knowledge and misunderstandings, this thesis will display the reputation of electric vehicles, specifically electric cars, and point out differences and similarities between Germans and Americans regarding their adoption and acceptance of this technology. Moreover, the study will differentiate between various perceptions of the development by American- and German car manufacturers.

1.3. Structure

Looking at the manufacturers and numbers of sales from the two countries, it should be possible to create a general view of the certain opinions of electric cars. Creating a survey for both Germans and Americans will help to analyze if those opinions comply with the truth. The survey will also simplify the differentiation between the US and Germany, by creating one form for each country and splitting participants into different groups according to their country of residence.

Both parties have been asked the same questions, but they have been slightly adjusted to the certain region. The survey contained specifics about electric vehicles and a second part to gather information about the participants' demographics.

The research study analyzes the survey and independent opinions and compares the results collected from Germans and German data to those coming from Americans and their data.

Derived hypothesis:

What are the status quo and perspectives of electro mobility in the United States of America and Germany and what are the differences and similarities between their states of acceptance and adoption?

2. Basic explanation of the electric drivetrain

Electric vehicles have a drivetrain that features three major components: The battery is used to generate energy which is then transformed from direct current (DC) to alternating current (AC) by the inverter and then converted into power and circular movement by the electric motor, which transfers that circulation to the wheels. If you want to compare it to a combustion engine, the battery replaces the gasoline, which is normally used to generate energy. The motor then converts the gasoline into movement inside the cylinders, so the electric motor could be compared to the gasoline-powered engine. Having a huge battery in the car creates an advantage, because it allows the manufacturer to insert technological features into the car that get powered by that electrical energy, without any conversion from mechanical energy.

2.1. Definition of the battery design

The battery is essential to power an electric vehicle, because it is used to generate electrical energy from chemical energy. Basically, every power provider in any new electronic device nowadays is a lithium ion battery, because they have the least disadvantages. They offer a higher energy density, resulting in more power, lower weight and smaller size, than the nickel batteries we used to use. Different materials for the electrodes and the electrolyte solution cause different battery attributes. Using different materials results in dissimilar chemical reactions which affect how the battery works, how much energy it is capable of storing and it causes different voltages.

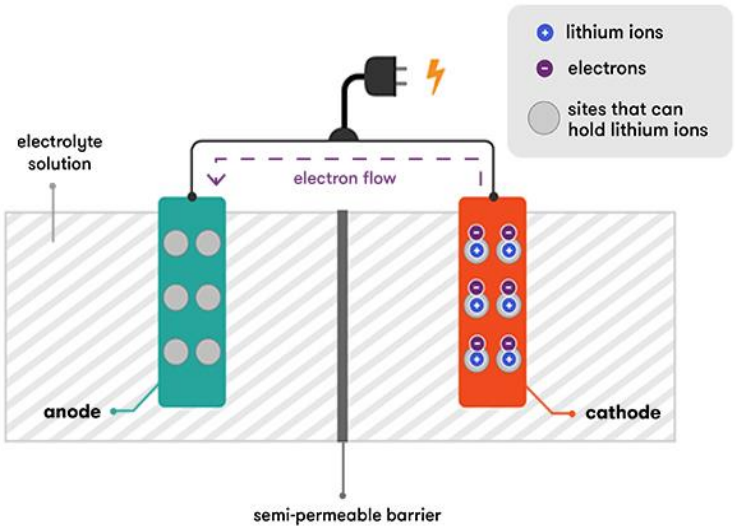

Figure 1: chemical process of a lithium ion battery[2]

[2] Bhatt, 2016

The lithium ion battery has two electrodes, called the cathode and the anode. Depending on the status of usage (either charging or discharging), each electrode can be either the cathode or the anode, if the correct chemical term needs to be used. The definitions during the state of discharging are common, therefore the anode equals the negative electrode while the cathode represents the positive electrode.
The image shows a fully charged battery. For this reason, the anode is negatively charged, while the cathode is positive. Using the electronic device causes an oxidation, the lithium atoms separate the electrons, so they flow over the metal towards the anode. After giving away their electrons, the lithium atoms turn into lithium ions and they start to get transported through the semi-permeable barrier to the anode by the electrolyte solution. That barrier works as a filter that lets lithium ions pass while it keeps the two sides of electrolyte solution apart from each other to prevent a short circuit. The ion then binds to the metal oxide at the anode, causing a reduction. The reduction then creates positively charged particles that can take up the electrons.
This reaction could theoretically run until nearly all of the lithium molecules are gone. In reverse, by charging the electronic device, the oxidation takes place at the metal oxide, creating a reduction on the right side until most lithium ions bind back at their starting position. No battery can ever be fully charged or discharged, because the "empty" electrode would implode.

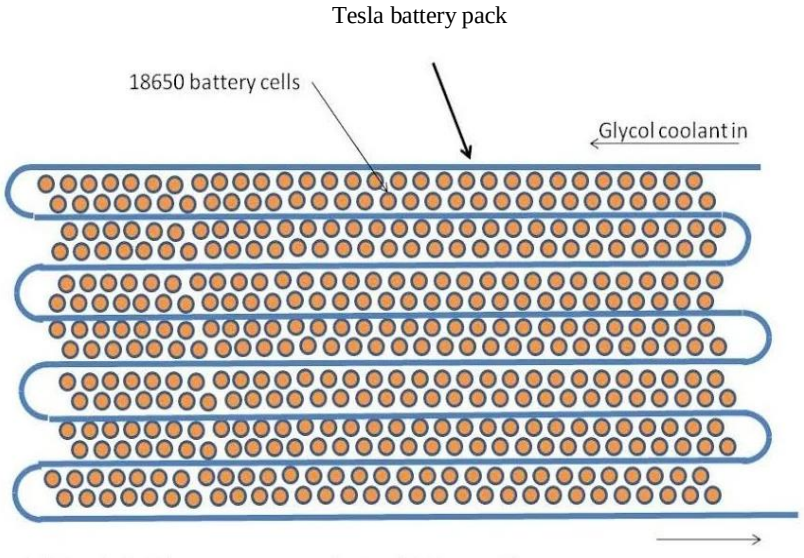

Figure 2: Tesla Model S battery pack[3]

Tesla was the first electric car company to see an advantage in wiring more smaller batteries over less bigger ones, because of the more effective cooling system. The smaller cells distribute temperature very evenly and by using the coolant the way Tesla does, every single battery is cooled. This reduces the overall temperature of the battery pack, resulting in a long span of lifetime and a safer car.

[3] Arcus, 2018

The Tesla Model S uses 16 modules[4], wired in series, each containing six groups, also wired in series, of 74 18650 battery cells per row, which are wired in parallel. Overall this adds up to a stunning 7.104 cells in a Tesla Model S[5].
For their new models, the Model 3 and Y, they improved their source of power. They cut the 16 modules down to just four big ones, two of those consist of 23 groups, while the other ones contain 25 groups. One group equals 46 single batteries, adding up to 4.416 cells in the pack. By implementing the more powerful 2170 cells instead, they achieved a similar range with less battery weight.[6]

2.2. Definition of the inverter

The battery creates direct current that cannot be used to create continuously spinning circular power. Instead, altering current is needed, which is the reason why an inverter is included into every new electronic device powered by a standard lithium ion battery.

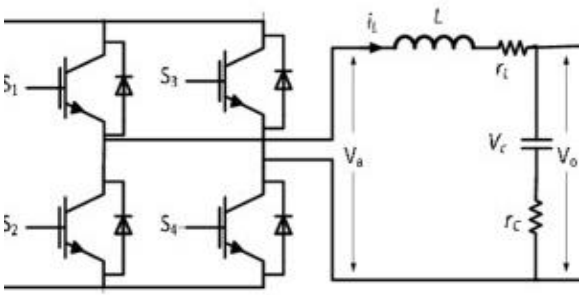

Figure 3: scheme of a DC-AC inverter[7]

First of all, it is important to connect switches two and three, as well as one and four with a 'not' connection, to prevent the circuit from a short circuit. Then you alternate the circuit between two different states, close one and two and you have a closed circuit with current flowing through the load and closing three and four will result in a closed circuit, too, but with the opposite current flow.

This is how a square wave alternating current is produced from direct current.
By adjusting the time between opening and closing the switches as well as adjusting which switches open/close at what time, you can create two square wave alternating curves, starting with a positive alternating curve that closes rarely, then more often until the climax, from where on it begins to close fewer times again, at one point, it switches to the negative alternating curve (different switches) and the same cycle repeat here. The average of the curve can be seen as an approximation to the alternating wave that the electric motor needs to function. By adjusting the alternating square curves and the intervals in between, it is possible to give a close approach to the actual alternating wave.[8]

[4] cf. Musk, 2013
[5] cf. Lambert, 2016
[6] cf. Arcus, 2018
[7] Techsaagar, 2019
[8] cf. Woodford, 2019

2.3. Definition of the induction motor

An induction motor consists of two major parts: the stator and the rotor. This study is looking at the alternating current motor, which has its stator on the outside and it is used to create a rotating magnetic field. You can basically describe it as a ring of electromagnets. Inside the stator is the rotor, a cage built up from parallel bars, connected by two discs at each end and more discs laying inside. When alternating current flows through the stator, it creates the magnetic field that is rotating around the stator. This magnetic field is used to force the rotor to rotate, creating the energy needed to power a car and while the internal combustion engine needs to convert the horizontal movement of the cylinders into a rotation, an electric motor directly outputs a rotating movement. Since the rotor can rotate up to 18000 times a minute, there is no gearbox needed for an electric car.[9] Also, the fact that the motor can simply spin backwards prevents the need of a reverse gear.

2.4. Definition of the basic control software

Every electric vehicle comes with several software features, some are necessary, some just add to the less negative environmental footprint or other aspects of the car.

The Battery Management System (BMS) is definitely mandatory in the long run, because it keeps the battery alive as long as possible. To achieve that it has to work on several aspects to preserve the capacity of a battery. The following tricks definitely increase a battery's life span.
As pointed out earlier, a battery cannot be fully charged or discharged, because the electrodes would collapse. The Battery Management System is responsible for that not to happen. The charging- and discharging current have to be surveilled, too. They have to decrease when the battery comes close to the points when the BMS shuts the charging or discharging completely down, that is why your phone always needs so long to charge the last 10%.

The Control Unit is also a mandatory part of the car, but not just in the long run. No car could drive without the control unit, because it is used to let different car parts communicate with each other. In gasoline powered cars, you have up to 70 smaller electronic control units, but Tesla revolutionized the principle and only uses one control unit in their new Tesla Model 3.

The Traction Control System (TCS) is known for a very long time now and basically every car built during the last 20 years has to have it. But again, Tesla managed to find a way to make it smarter and

[9] cf. Patrick, 2011

improve some aspects. Instead of using the common no slip differential that has a lot of parts and therefore a lot of mechanics that break easily, Tesla used the simpler open differential. To prevent over- and under-steering, they connected the brakes to the stability control. Since those brakes act electrically, single ones can be activated. When the driver loses control over his vehicle, the software activates the necessary brakes and the Tesla will come to a stop, without using an expensive, complicated Traction Control System.

> *"Model S Traction Control is designed to ensure maximum contact between the road and the tires. Whether you are accelerating off the line, zooming along the winding roads of the Rockies or find yourself in a Gulf Coast rainstorm, Traction Control prevents loss of traction and maintains control. Stability Control reacts in moments of under-steer or over-steer by reducing torque and applying the brakes to individual wheels for enhanced control when cornering."* [10]

The last feature that Tesla became famous for is Regenerative Braking. A lot of people refer to the Model 3 as a one-pedal car, because as soon as you let go of the gas pedal, the car will start to break on its own. This may seem like an invention to make driving easier, but it is so much more. Cars have a lot of kinetic energy and by using the brakes in normal cars, you waste it by creating heat. These regenerative brakes provide the possibility to convert it back into electrical energy. So basically, every time the car does not accelerate, it charges.[11]

[10] N.U., 2014
[11] cf. Toll, 2018.

3. Alternative-fuel competitors

The internal combustion engine will not be the future of cars, due to finite amount of resources and the climate change. Battery electric vehicles could be one solution, but only in case they can develop batteries to be more efficient than they are right now. Tesla creates batteries and cars that have a better energy footprint than gasoline powered vehicles in the long run[12], but other battery electric car manufacturers produce at a higher level of emissions, without the solar powered Gigafactories. But lithium might become one of the most powerful and expensive resources soon, so researchers should keep looking for other options. Still, electric vehicles include different types of power creation than batteries and two variants already have prototypes or production cars on the market. The most common alternative today are hydrogen fuel cells and they seem promising, but they also need development to figure out their exact capabilities. Methanol fuel cells were just discovered and open up a completely new way to power engines.

3.1. Definition of hydrogen fuel-cells

The hydrogen fuel cell is being used in several cars already, for example the Toyota Mirai, with 6000 units sold in California only, since its introduction in 2015.[13]

The debate about this form of energy production is similar to the one about electric motors. Although it is environmentally more friendly than the internal combustion engine, hydrogen by itself is not found in the nature, so it has to be produced in a chemical process that splits up water in hydrogen and oxygen, or as a by-product in the exploitation of natural gas or oil. Those outcomes may seem harmless, but in order to gain the energy from merging the two parts again, the energy has to be invested into the endothermic chemical reaction to split them up.[14] Also, hydrogen can only be filled into the car's tank as either a -200-degree Celsius fluid or as gas. Because of the fluid's temperature, producers are building the vehicles to be refilled with gas, although this has a big disadvantage itself: the whole infrastructure has to be built, because refueling is specialized on fluids so far.

Another factor that is used against hydrogen fuel cells is the emission of NOx, a by-product that is produced, because normal air is used to merge with the hydrogen that is stored in the car and the air is not just oxygen.[15]

[12] cf. Alvarez, 2019
[13] cf. Resnick, 2019
[14] cf. D'Allegro, 2019
[15] cf. Sorokanich, 2018

3.2. Definition of methanol fuel-cells

There is not a lot of information available about the methanol fuel cell, because the only vehicle ever introduction with this kind of drive concept is the 2020 Gumpert Nathalie, a car that was introduced in 2018. Most of the leaked information has come from the manufacturer itself.

The fuel cell works similar to the hydrogen powered cell, but instead of refueling gas, which would require a new infrastructure, the cell benefits from running on a fluid, so new refill stations could theoretically be built over night with available knowledge and technology. Basically, this electrical motor is fueled by pure alcohol, which is split in CO2 and hydrogen by heating it up to 300 to 400 degrees Celsius. The hydrogen is then used to power the fuel cell in the same way as the conventional hydrogen fuel cell does.[16]

Still, a new technology always has its flaws: Although the Nathalie has a range of 800 kilometers at 80 km/h, the process of splitting hydrogen from alcohol creates carbon dioxide as a by-product, and that is the most common reason why drives switch away from combustion engines. And after all the research that was done to be able to launch their first vehicle with this drive, Gumpert will charge an expensive fee for buying one of their vehicles: The car will start at 300.000-500.000 Euros.

[16] cf. Wagner, 2018

4. Status of electric vehicles

This and the following chapters are mainly based on the results of the survey about electric vehicles and their acceptance and adoption. There were a few biases in the study, simply because there is no way to avoid all of them.

Barely any participants from the US were neither college students, professors nor their family members, resulting in a sample that exceeds the knowledge of an average American. Therefore, a high rate of acceptance and good knowledge is expected.

In Germany, a greater variety of people was reached. The results were by a lot of students, friends and family members. Also, the survey was posted in a Porsche-forum. The 50-70 votes coming from there may have a huge impact in the German results, because they provide of third of the sample. Good knowledge is expected from them, but as the opposite of the US-bias, they might not accept electric vehicles at all, since Porsche has a history of great internal combustion engines.

4.1. Status of electric vehicles in the United States

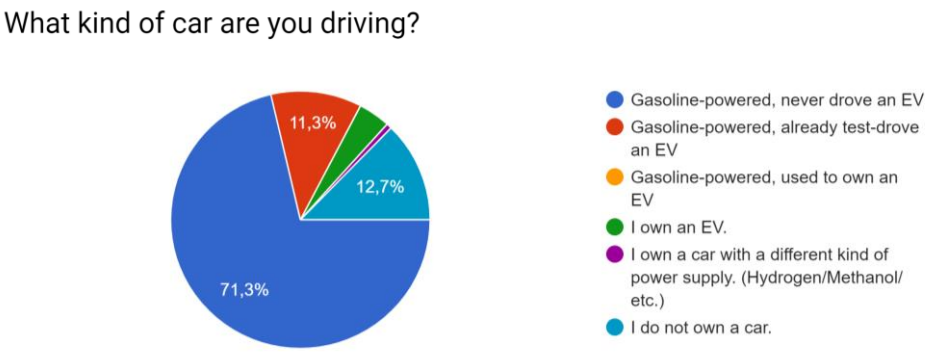

Table 1: US-survey: What kind of car are you driving?[17]

In the USA, nearly three quarters of the 150 participants never tried driving an electric vehicle (107; 71%), while only 8 participants own an EV or a differently powered vehicle (equals 5%). As pictured, none of the people that used to drive an electric vehicle switched back to a gasoline powered vehicle. Also, it is noticeable that a huge part of the population in America does not have a car (19, 13%). Three of these people are above the age of 25 and that only four have a better income than 15.000 $ a year might be a result of 14 being students. All of the people below the age of 25 do believe in the future of electric cars, so some of them might buy one for themselves as soon as they can afford it.

[17] Klenner, 2019

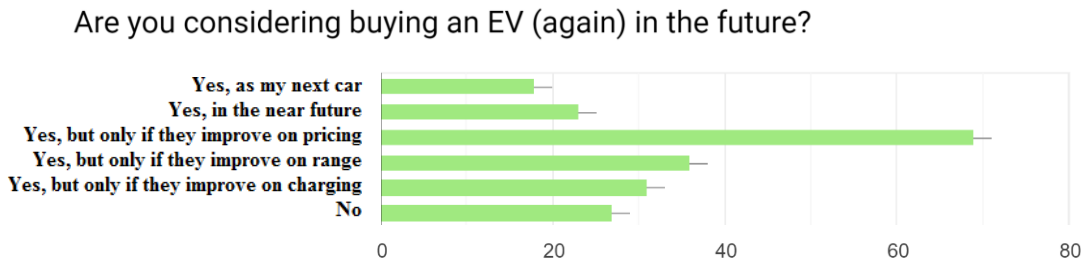

Table 2: US-survey: Are you considering buying an EV (again)?[18]

Americans struggle with the pricing of electric cars (69; 46%), since gasoline powered cars tend to be very cheap in the US. Tesla's large batteries seem to affect the feeling about range positively, since it was only stated 36 times (equals 24%). The good infrastructure of Tesla Superchargers might also have an impact on the low number of participants worrying about recharging (31; 21%). Only 27 people stated that they will not buy an electric car in the future (equals 18%). Individual answers tend to show that people are undecided and wait for the future progress.

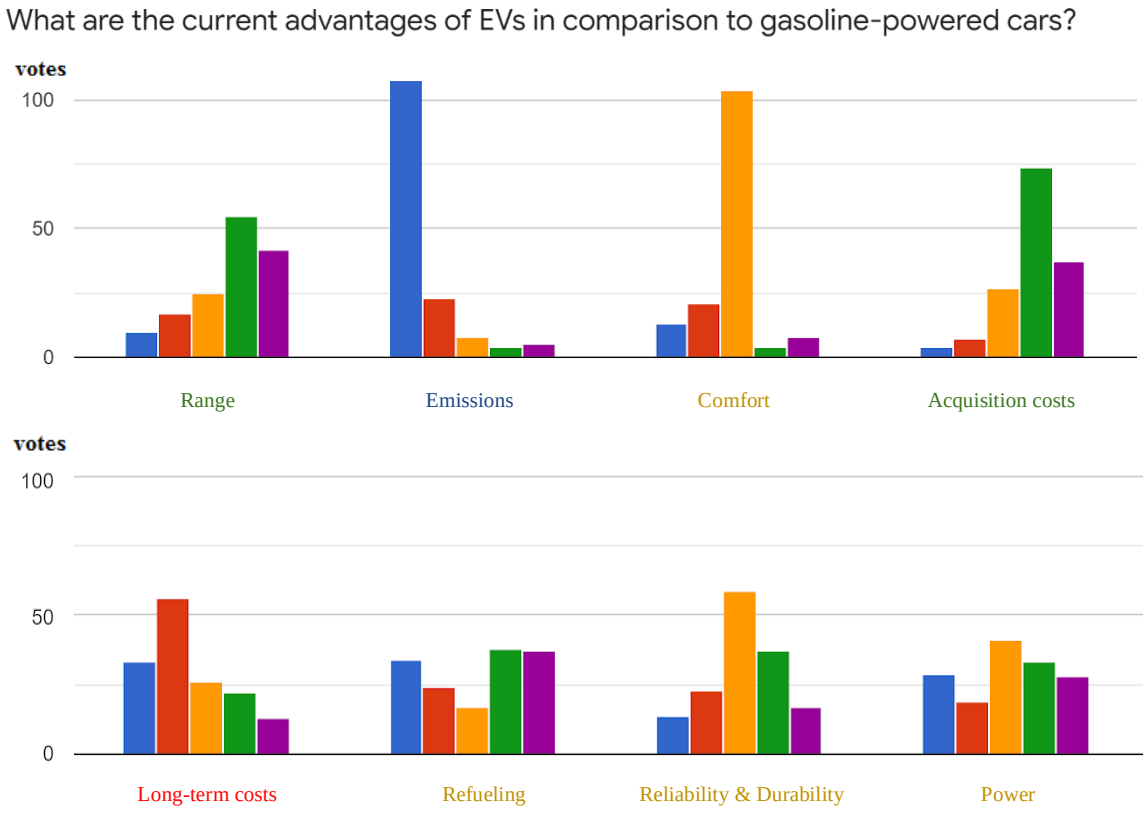

Table 3: US-survey: What are the advantages of EVs compared to gasoline-powered cars?[19]

[18] Klenner, 2019
[19] Klenner, 2019

This part addresses the comparison of electric vehicles to gasoline powered cars. The left bar (blue) represents a strong advantage for electric vehicles, the right bar (purple) represents a strong advantage for gasoline powered cars. Red and green are slight advantages for the certain side and yellow stands for equality.

“Range” shows a diagram that is slightly shifted towards the right. It shows a very accurate picture considering this is about the state of technology right now. Gasoline-powered cars to have a longer range but being able to recharge your car at home and having the full range available at any point is a huge advantage for electric cars.

“Emissions” shows a picture of the optimal future for electric vehicles. Tesla might have a strong advantage already, but no other manufacturer can keep up with their low emissions so far, because none of them have factories, solely powered by renewable energies, such as solar. Mining for the battery resources, building the battery and car, and also generating the energy to power the motor, and while the advantage for electric vehicles already exists, they still create a lot of emissions.

Not a lot of people considered the reduced noise and vibrations and self-driving abilities when they said “comfort” is equal. Anyways, it does not generate a huge advantage. The accurate diagram should still be shifted more towards the left. Not being forced to refuel every 800 kilometers can be considered a factor of comfort, too, but so can driving 800 kilometers at one time without having to take a lunch break.

“Long-term costs” show a diagram that gives a slight advantage to electric cars. Charging at public stations is not cheap, but less expensive than gas. Most owners charge overnight at home, which makes it even cheaper. Also, fewer maintenances due to no mechanical damage make electric cars cheaper in this sector. Therefore, the diagram should be shifted further to the left. Long-term costs are probably the biggest advantage of electric vehicles right now and as more manufacturers and therefore more engineers and mechanics acknowledge electric drivetrains, maintenance prices will decrease in the future.

“Acquisition costs” displays a left-skewed diagram, with the peak at the slight advantage towards the gasoline powered cars. This is accurate, considering there are some electric cars that can compete with the pricing of their gasoline powered competition, but most electric vehicles are still more expensive than their gasoline powered competition. This is the diagram most likely to shift towards the left in the future, basing the prediction on information from the past.

Considering that charging your vehicle is cheaper than refueling it with gasoline already gives an advantage towards electric cars. But also, you have less maintenances, because there is less mechanical damage and less parts in general in an electric vehicle. Therefore, a further shift to the left is accurate.

"Refueling" polarizes opinions. Half of the participants gave the advantage to electric cars, because it is cheaper, you can do it at home and as long as you charge every night and do not drive long distances, you will never have to refuel in public again. The other half prefers gasoline powered cars, because they have to refuel less due to a bigger range and you save time by quick refuels on long distance drives. This point will polarize consumers even more in the future, since faster charging times damage batteries and people, who mostly use their car for long distance rides will continue to see an advantage in internal combustion engines, while people that use their vehicle for short distance rides only will experience an increasing advantage with rising range as a result of further developed batteries.

The advantage is given to the gasoline powered cars, when it comes to "reliability and durability", but it is very close. Most people think it is equals, but electric cars do have a very slight advantage. Less mechanical parts result in a better reliability and the Model 3 proved itself to be reliable. Additionally, Tesla predicts the it to run 800.000 kilometers before you have to change the battery. And as soon as you have done that, you basically have a new motor.

"Power" is slightly shifted towards the right, giving the advantage to gasoline powered cars. This is not a surprising result, since the United States have always been famous for powerful, gasoline powered muscle cars. To stay with American manufacturers, Ford has built an electric F-150 pick-up prototype, the production vehicle is announced for 2021[20]. In a video they show the vehicle towing a train, which was loaded with normal F-150 cars with a weight of over a million pounds (more than 450 tons), to demonstrate the power of electric engines.

[20] cf. Blanco, 2019

4.2. Status of electric vehicles in Germany

The new Porsche Taycan could have an effect the Porsche forum votes, but it did not seem to have a huge impact on Porsche fans: Many results that seem to come from a forum member cover the disadvantages only and a lot of superficial knowledge can be found, stating facts that were true years ago, but not anymore, like the high emissions and low range of the Nissan Leaf.

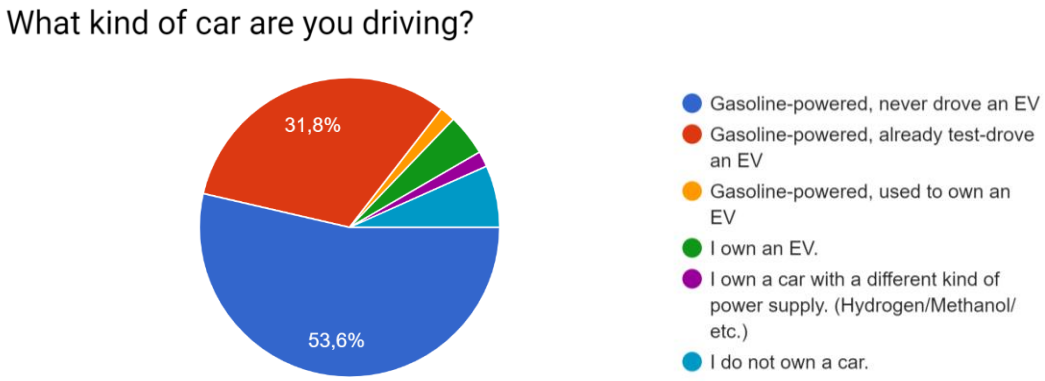

Table 4: Germany-survey: What kind of car are you driving?[21]

When asked about their current vehicle, German participants stated that more than 53% have never drove an EV and only 11 out of the 179 people own one (equals 6,2%), split in 8 battery electric vehicles (green) and 3 cars with other alternative engines. That is less than the people, who do not own a car (12; 6,7%). In Germany, all twelve participants stated that their income is lower than 15.000€, which classifies them in the lowest income bracket. Eleven of those people are below the age of 25 and only one person did not state student, or unemployed as their employment status, while all but two believe in the future of electric cars. Therefore, they simply do not have a chance to own an electric car yet.

[21] Klenner, 2019

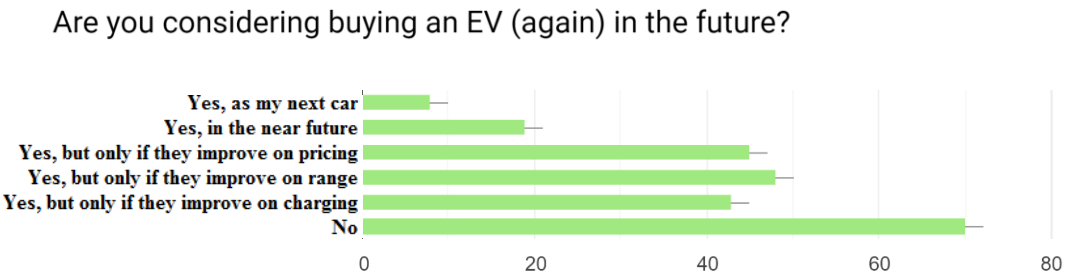

Table 5: Germany-survey: Are you considering buying an EV (again)?[22]

Many Germans do want to buy an electric car in the future. Including the people that used the 'other'-option to state their reason, 76 out of the 179 participants stated 'no' as a reason (equals 42%). Driving an electric car makes a difference as it seems, but not a huge one. Only 21 out of the 58 that already drove an electric car (equals 36%), said they do not want to buy one soon. By filtering all participants that either own or used to own an electric car, everyone (14 out of 14) agrees on buying another one in the future.

The optional question why Germans do/ do not want to buy an electric vehicle gives a lot of different reasons. Most of the 24 people that stated 'yes', want to drive an environmentally friendly vehicle, to work against the climate change (11; 46%). Two other reasons that were given multiple times are the fit into city-traffic, short distance rides (4; 17%) and the fast acceleration (3; 13%). 'No' was answered 55 times, mainly because they believe in hydrogen fuel cells or they question the environmental assessment (27, 49%). This reason has a root, because Germany still runs on one third lignite- and charcoal-powered energy[23]. Many participants did not need a car (7; 13%). Range seems to be a problem, too (8; 15%) and emotions and sound were more important than expected (7; 13%), most likely because of the Porsche forum members.

[22] Klenner, 2019
[23] cf. AP University College, 2019

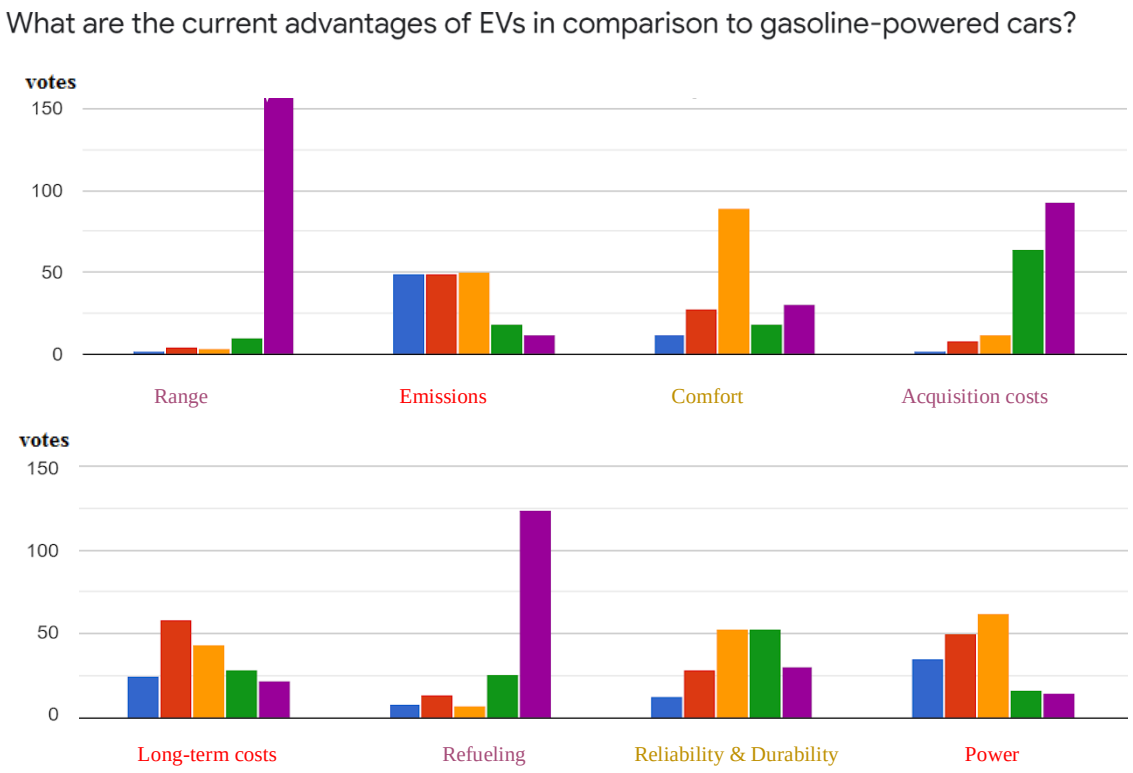

Table 6: Germany-survey: What are the advantages of EVs compared to gasoline-powered cars?[24]

The bars and colors represent the same advantages as in the US-part of the survey.

“Range” is a one-sided result, but it should not be depicted shifted so far to the right. Today’s electric cars can have a range of more than 500 kilometers, which is way less than their gasoline powered competition. But because they can be recharged at home overnight, this range can be available every morning, without being forced to head to a gas station first.

“Emissions” are displayed in a suitable diagram. There is definitely an advantage for electric vehicles but as of today and especially in Germany, it is not necessarily a strong one. The energy they use to recharge is not fully green and the circumstances under which most manufacturers build the cars show the early production phase of electric cars. Tesla is the only company, producing electric vehicles with so few emissions that a blue vote is appropriate. The average of all electric manufacturers would currently be red. Giving gasoline-powered cars the advantage is questionable, since pretty much every electric vehicle has lower emissions after their lifespan.

[24] Klenner, 2019

“Comfort” is a balanced diagram. The small purple peak might be Porsche enthusiasts that love the sound of their cars, especially since all of the 31 votes come from people that are 45 years or older and have a good income. For most people, noise and vibration is still considered a disadvantage and also refueling on short distance drives is not seen as comfortable.

“Acquisition costs” show a left-skewed diagram, which is a good representation. Tesla’s Model 3 is a big competitor to premium manufacturers, such as BMW or Mercedes. The Performance option by Tesla is available for about 60.000 €, while you pay 67.000 € for the BMW M3 and nearly 80.000 € for a new Mercedes C63 AMG, which is not even their top model of the C-Class. Still, the Tesla Model 3 is basically the only electric car that can compete with the prices of gasoline powered cars; therefore, the advantage should be given to cars with an internal combustion engine.

“Long-term costs” can be interpreted the same way as in the previous chapter. The diagrams are close to being exact matches and long-term costs are similar in the US and Germany.

“Refueling” is shifted to the right. In Germany, the infrastructure to recharge a car is not as great as in the States, especially California, or European countries, like the Netherlands or Norway, which is why the advantage goes towards gasoline powered vehicles. But if the car is charged overnight every day and it does not need to be used for longer trips, there is no need to visit any public charging station at all. So, if the owner charges smart, the electric car has a time- and cost-advantage. The actual shape should be polarized, as it is in the US version, but with a shift to the right.

“Reliability and durability” are basically balanced, with a slight shift to the right. This might result from the assumption that owners have a lot of trouble finding dealerships or mechanics when their car breaks. Still, electric cars have a lot fewer mechanical parts, therefore less parts, that can be damaged. Tesla had their problems with reliability, but they improved to be equally good as competitive companies that produce gasoline powered cars. The durability has not fully been tested yet, but Tesla states that Model 3s can reach over 800.000 kilometers before they lose the first 20% of their battery capacity.

Surprisingly and completely different to the US answers, “power” is very slightly shifted to the left, but it is still equal in general. With hyper cars like the VW I.D. R (680 horsepower, holds the track record at Pikes Peak Hill Climb and the Goodwood Festival Of Speed) or the Rimac Concept Two (1915 horsepower), there is already electric competition all the way at the top of the best high-performance cars and the technology has almost exclusively been developed and used for the recent decade. The manufacturer Rivian has planned to launch two fully electric cars to the broad public next year: a truck and a pick-up, both with 754 horsepower and 4 electric engines.

5. Determine differences

This chapter compares the results of the previous chapters. It analyses how German mindsets differentiate from American ones and what the reasons are, that most likely affect those differences. In the following, acceptance and adoption in both countries are summed up and interpreted and the perception of manufacturers are being compared. The results of this study is being set out and explained. Since the thesis is about adoption and acceptance, which cannot be compared in one number, the outcome mainly revolves around opinions of basic people and also professionals and experts.
These opinions have been compared to factual numbers to analyze the level of bias in the study and get a picture of different mindsets by different samples: e.g. old and young people or wealthy versus impoverished people.

5.1. Differences in acceptance & adoption of electric vehicles

Tesla has a huge impact on people's mindsets, because they are the ones, leading this innovation. Most participants seem to have accepted electric vehicles already, but the debate between battery electric vehicles and hydrogen fuel cell powered cars is clearly depicted in the survey and this study. In Germany, you see a bigger demand for hydrogen fuel cells, maybe because energy is generated through coal a lot, which keeps battery electric cars from being much cleaner than gasoline powered ones. It affected the adoption of electric cars that the States did only have one successful electric car before Tesla, the Prius. While in Europe and Germany, Nissan and other manufacturers launched a few cars, that had bad range, bad reliability and durability, looked bad, or summed up generated a really bad reputation on electric vehicles. This made it look like that is the standard of their capability and it just was not good enough to impress the general public. A lot of people still seem to have that picture in mind, when they look at modern electric vehicles, although they have developed and improved a lot.
Tesla being located in your country results in a more developed recharging infrastructure, because they built and are still building Superchargers all over the world, but mainly in the US. Surprisingly, Europe and especially the western part, consisting of France, Britain and Germany, have a higher density of Superchargers than a big part of the US. But by comparing the populous areas for Superchargers in Europe, like the Netherlands, to those in America, especially the Northeast and California, it is obvious that the US still has a lead in the development of infrastructure. The following graphs show the number of Superchargers in North America (blue), Europe (black), and the Asia Pacific area (green). Especially since the second third of 2017, the blue line continues to build its lead to Europe and Asia every year. As of January 1st, 2020, there are 861 of Tesla's charging stations in the Northern part of America, 505 can be found in Europe, and 396 have been built in Asia.

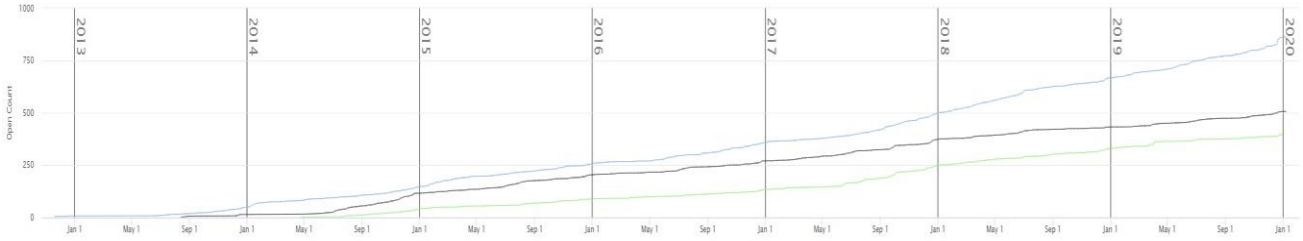

Figure 4: Open Superchargers by region[25]

By taking a look at the younger participants, you can see a huge wave of positivism towards electric vehicles. Considering all people below the age of 35 as young, only 21 do not think electric vehicles can be successful, while 136 do. Many of them might look at the climate change, because it is probably the biggest threat to humanity at this point and the youth has to solve this major problem. Electric cars might not be completely clean, but Tesla shows how their emissions can be better, even if you still use coal-powered energy to recharge. Looking at the participants above the age of 34, the two results for Germany and the USA are very different. In Germany, you have 64 people who do think that electric cars are the future, while 73 think differently. Even if you consider the Porsche forum answers, this would still be an even comparison. In America, all these answers were given by educated people with at least a bachelor's degree. Out of the 26 people that fit into the scheme only two did answer 'No', when asked if electric vehicles are the future. The first option why the results were so different was the state of education, but more than 80% of the German answers came from people with at least a bachelor's degree. Therefore, this displays a result that points in the same direction as the latest aspect. The worse acceptance of German people suffers under the consequences of having the worse infrastructure and more expensive costs. According to this analysis, electric cars are more likely to be successful in the US than in Germany.

There is a strong acceptance of electric cars by actual owners. In Germany, only three people switched back to a gasoline car, while in America, no one did. Experiencing is a good way to convince people about the advantages of electric cars. Also, there are very few owners, who regret buying an electric vehicle. By just talking to them about cars or anything related, they will somehow lead the conversation to the advantages of electric cars and how much they enjoy it and most of them always keep track with the development of the industry of electric vehicles.

[25] supercharge.info, 2019

5.2. Differences in the perception of manufacturers

Germany has always been a car nation, with three of the four biggest companies being car companies (Volkswagen AG, Daimler AG, BMW). But it is not only about the internal combustion engine anymore, as it used to be for over 100 years and the big companies could face a dangerous threat. Sales are already decreasing for competition of the Tesla Model 3, and they need to react.

Tesla's disruptive innovation was successful up until now. They came out of nowhere and now they are the leading company in one of this decade's biggest innovations. And it is not just that, their cars include a lot more innovations, like self-driving ability, the software updates, that just gave every Model 3 a few more horsepower, and the minimalistic design with the huge touchscreen. And that is just a fraction of what they came up with.

When Porsche released the Taycan and had a promising lap on the Nürburgring, it seemed like someone had finally caught up to Tesla and then a few days later Tesla announces a three-motor powered Tesla Model S and breaks the Porsche's lap time. It nearly seems like Tesla is playing with its competition, because they want them to catch up. Elon Musk acts like he's challenging other manufacturers, so the innovation will succeed, without focusing at his own profits, but at what he could achieve.

Volkswagen is turning their whole brand into a manufacturer of electric vehicles in the next decades, which is by far the most radical reaction to Tesla's innovation. They are helping to build up an infrastructure of charging stations over Germany and announced several electric cars for the future in the year 2019.

Other manufacturers do not react like that. Audi launched the e-Tron SUV this year, and they predicted that one third of all new Audi models in going to be electric by 2025 (including hybrids). Mercedes is going to launch the EQC in 2020 and they have not announced anything else in the direction of electric engines. What they have done is building a prototype car, called the Mercedes ESF, featuring a variety of innovations, like a screen in the rear window or a drone that sets up the warning triangle in case of an accident. This opens up more paths to go, with building knowledge about electric cars while continuing with their usual production. BMW just announced that they are going to build a huge factory in Dingolfing, Germany to expand their production of electric cars. They want to launch the i4 and the iX3 in 2021, both with numbers that would be promising right now, but looking at what happened the last two years, a 600-kilometer range will not be very impressive by then. These three giants of German car manufacturing are taking steps towards the production of electric vehicles, but they continue to keep the option to pass on the development at any point by continuously releasing more gasoline powered vehicles.

6. Summary and next steps

Looking at the past, you can see how slowly the development started with just a few companies actually researching about and building electric cars. But in the past five years, many new companies have been founded, and they are working towards a future for electric cars: car manufacturers, battery manufacturers, battery recycling specialists, or mechanics for electric cars. More and more start-ups are reaching milestones and companies like Polestar, Byton or Rivian are launching very promising cars. Meanwhile, companies that usually focus on mobile electronic devices work on or even present concepts of cars to the public, like Apple[26] or Sony[27].

This is the typical development of a disruptive innovation, led by Tesla. They started by selling high-priced cars to a niche market, with the Model S and Model X, and made their way to an affordable, but qualitative Model 3. The answer to the first part of the derived hypothesis will be decided by the success of electric cars, which is based on their future developments. If successful, this kind of innovation can go in two directions for existing companies: Either they disrupt themselves, by killing their main product line to make space for the new product or they stick to their origins and go bankrupt, by losing profit due to customers choosing the innovative product over theirs. So, in both ways, it will be a high-stake evolution for companies. But if the innovation turns out to be a failure, killing the main product line does also damage the company whereas sticking to the original product would probably gain them more market share, because competitors might invest into the innovation and lose their focus, just to lose shares.

The history has shown how startups and newcomers succeeded by disrupting industries and outdoing existing companies, examples being Apple and Nokia, Netflix and Blockbuster, or Kodak being destroyed by several competitors producing digital cameras. The three companies that were disrupted, had the majority of shares of their market, yet two of these do not exist anymore and the last one lost a huge part of its share and importance. They all missed to adjust to, or simply did not have trust in the development of their technology, which lead to a catastrophe for them. But in the year 2020, major companies have the knowledge to prevent themselves from failing in their market in case of a disruptive innovation. If the battery development continues to bring up more advantages and companies keep on building new infrastructure, the acceptance will rise further. Being asked, if the participants would consider buying an electric car, more than 270 votes showed an interest in electric cars, once they either get cheaper, have a bigger range or once the charging infrastructure will see improvement.

[26] cf. Painter, 2019
[27] cf. Beresford, 2020

To answer the derived hypothesis, it has to be split into the status quo and perspectives. Similarities and differences are displayed in either of those sectors.

The status quo of electro mobility in the United States of America and Germany makes it a controversial topic. American citizens struggle a lot with the acceptance, even when having the better infrastructure to recharge batteries and the average price to recharge is lower than in Germany, at public charging stations and at home. Both the USA and Germany have a lot of city traffic, a good application for electric vehicles. The leading manufacturer, Tesla, is selling their cars cheaper in the US than in Germany, because of customs and taxes. But the US is a huge country, therefore people are used to having long distance rides, for which the batteries are just not ready yet. German participants have less faith in the industry of electric cars, probably because electric cars' state of art is further developed in the US than in Germany and the German industry is built on companies that manufacture cars with an internal combustion engine. A lot of Germans seem to be afraid of a change that could heavily affect their economic status and life. This is holding back the progress, because start-ups tend to be created in a country with good acceptance and existing companies only make little effort to develop electric cars. A breakthrough in America is more likely to happen than in Germany, based on the number of successful manufacturers and the acceptance.

The perspectives of electro mobility in the United States of America and Germany show a good potential of acceptance by young people. They believe in the success of electric vehicles. Over 85% stated this, by answering the question "Do you think electric vehicles will be successful in the future?" with yes. A similarity between both nations can be drawn here, since the percentages were very equal. Otherwise, a big difference can be observed, when looking at older people. In America, more than 90% believe in electric vehicles. Meanwhile, in Germany, less than half of the answers were positive. In both countries, participants were similarly educated, but the results were not similar. The conservativity of older participants is an obstacle in the path of electric vehicles, but the positive reaction of younger people opens up opportunities in the future.

In the future, there will be a change in acceptance and adoption of alternative-fueled cars, because the need for oil and gas in getting bigger and more expensive, and a solution has to be found against climate change. The main question is, which kinds of power supply and engine will be successful. With only three different systems available right now, there is not much of a choice, especially since all of them are electric and both fuel cells are powered by hydrogen. Battery electric vehicles have a lot of advantages, those being long-term costs, low emissions, and comfort. Owners of electric cars will tell you that even recharging is more advantageous than in a gasoline car, as soon as you get used to it, because by charging every night, there is no need to visit a gas station again until you plan a longer trip.

Especially German car manufacturers have to keep up with Tesla and other new and upcoming companies in this sector. They need to focus their production more on electric vehicles, in case the innovation is successful, even if it loses them profits at first, because the German industry is mainly built up on their companies and a failure of those will result in bad consequences for the whole industry, economy, and country. The way of approaching the innovation will be a highly discussed topic, both in public and in research papers, and every company will provide their own solution and way to go. These approaches are possible areas for future research.

But there is still a long way to go, until battery electric cars will be fully accepted by the population. The Porsche forum was not completely wrong, because emissions have to get lower, because this is the attitude that will give electric vehicles the decisive advantage over gasoline powered vehicles. Additionally, range has to expand, charging- and repairing-infrastructure has to be built and acquisition costs have to be lowered, so they become equal to the ones of gasoline-powered cars. The broad majority has to get taught about the current state of electric cars and other electric vehicles, because a lot of superficial knowledge can be found that may have been true five years ago, but has changed since then, due to the fast development of batteries. Tesla shows how to do it with their fully solar powered Gigafactories. That requires a lot of investment and although a lot of manufacturers already participate in the development and some announced their future being electric engines only, the minds have to change, so the industry can change, too.

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