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A Comparison of Electric Vehicles and Conventional Automobiles:

Costs and Quality Perspective

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Abstract:

This report covers the research area of electric vehicles dedicated for personal transportation and its relevant market including the necessary to know background information about the topic.

Since the newly developed car market area of e-mobility has not experienced a long presence on the global personal vehicle market, the report is focusing on the research of current situation for the buyers and the less and more favorable conditions in different countries.

The core of the report is a comparative research of BEV, PHEV and conventional types of vehicles with their real market costs situation of spring 2017.

The three mentioned propulsion systems vehicles are put into test and finally delivering the true cost to own of each particular one, while considering their propulsion system related quality features as well.

Ongoing, the researched assumptions are later on put into test in the form of a questionnaire focusing on finding out about the awareness of electric vehicles among the publicity nowadays.

The final statement that is going to be approved or rejected is the electric vehicles as the future of the global car market.

Language:	English
Key words:	electric vehicles, battery electric vehicles, plug-in hybrid vehicles, conventional vehicles, global car market

Table of Contents

1. Introduction 1

1.1 Aim 1

1.2 Research question 1

1.3 Limitations 1

2. Background 2

2.1 History of electric cars 2

2.1.1 1830s - 1890 2

2.1.2 1890s - 1935 3

2.1.3 1935 – 1990 3

2.1.4 1990s - Today 4

2.2 Worldwide electricity and fuel prices 5

2.2.1 Electricity prices 5

2.2.2 Gasoline and diesel prices 7

2.3 Advantages and challenges for electric automobiles 9

2.3.1 Advantages of electric motor cars over combustion engine vehicles 9

2.3.2 Barriers and challenges for EVs 11

2.4 EV Buying Options in 2017 12

2.4.1 Battery Electric Vehicle (BEV) 12

2.4.2 Hybrid Electric Vehicle (HEV) 12

2.4.3 Plug-In Hybrid Electric Vehicle (PHEV) 14

2.5 Electric vehicle subventions and incentives 15

2.5.1 Direct subsidies 15

2.5.2 Fiscal incentives 16

2.5.3 Fuel-costs savings 17

2.6 EVs' worldwide market share 18

3. Methodology 20

3.1 Data 21

3.1.1 Introduction of the objects of the comparative research 21
3.2 Quantitative factors – Total Cost of Ownership (TCO) 24
3.2.1 Purchase costs 25
3.2.2 Maintenance and service costs 28
3.2.3 Fuel costs 30
3.2.4 Depreciation costs 33
3.2.5 TCO bottom line 35
3.3 Qualitative factors comparison 38
3.3.1 Quality and materials 39
3.3.2 Pleasure of ride 41
3.3.3 Everyday-usage experience 42
3.3.4 Qualitative factors bottom line 44
4. Results 45
4.1 C – Segment 45
4.2 F – Segment 46
4.3 Survey 47
4.3.1 1st question 48
4.3.2 2nd question 49
4.3.3 3rd question 49
4.3.4 4th question 49
4.3.5 5th question 50
4.3.6 6th question 50
4.3.7 7th question 51
4.3.8 8th question 51
4.3.9 9th question 52
4.3.10 10th question 52
5. Discussion 53
6. Conclusion 54

7. Works Cited 56

8. Appendix – survey 59

1. Introduction

1.1 Aim

The automobile market in the world of 2017 offers more buying options than in any year before, meaning different sizes, styles, quality and luxury levels or performance. The era is, however, special in another optional area, namely the vehicle's type of fuel. The classical, conventional gasoline and diesel-powered cars are no longer the only consumer's options, while picking up a car on the market and the electricity is more in the game than ever before.

It is certainly a nice gesture from an environmental perspective to decide for an eco-friendly driving machine, however, how expensive does it become to drive sustainably is another question. The consumers have the option of choosing fully electric zero tail-pipe emission vehicles, hybrid or even plug-in hybrid cars. Each mentioned one has then its own bright side, but there are dark sides as well.

This thesis sets as its aim to find out, what the real costs of owning an electric vehicle are, considering a wide spectrum of influencing factors typical for any car, but also considering different situations in different countries. The thesis should function as a guide for any consumer considering to buy an electric vehicle and should equip him or her with all necessary information about this type of transportation, its benefits and disadvantages and mainly the expected costs and related quality parameters linked with owning an electric vehicle over a conventional car. The thesis then compares the alternatives of buying a certain fully electric personal vehicle, a hybrid / plug-in hybrid and the conventional vehicle.

1.2 Research question

"What are the total costs of ownership of an electric vehicle over a conventional automobile and how is their consumer usage experience in everyday traffic situations? Is then the electric vehicle in terms of these factors the future?"

1.3 Limitations

This research is going to be limited to a comparison of only three propulsion technologies, namely the battery electric vehicle (BEV), plug-in hybrid electric vehicle (PHEV) and the internal combustion engine vehicle (ICE). Each mentioned category will be limited to the comparison of objects from two given car segments, the small family vehicle segment and full size luxury vehicle segment. In certain situations, where it appears useful for the research, two different local markets are going to be considered.

2. Background

2.1 History of electric cars

2.1.1 1830s - 1890

The first cornerstone in the evolution of electric vehicles was set already in the very beginning of the entire car industry itself. Already in the 1830s, the scientists and engineers came up with a series of different breakthroughs in the technology of electrically powered vehicles. In this time, there were several innovations from countries like the Netherlands, Hungary and the United States, who invented the first small-scale models of electric vehicles. The very first functioning electric vehicle was developed d around 1832 by the British inventor Robert Anderson (Matulka, 2014). However, this particular one still stood far behind the term of a practical vehicle.

The first electric vehicle in the United Sates was introduced in the end of 19th century by the inventor William Morrison in Iowa and the general interest was growing. Until the end of the century and still in the beginning of the next one, horses remained the main mode of transportation. However, in terms of personal vehicles, three distinct propulsion technologies emerged, namely the gasoline, steam and electrically powered. The steam engine did not find very practical usage in personal vehicles, because its extensive start-up times, especially in cold winter months. It took up to 45 minutes and the fact of refilling the water in the tank was another range-limiting factor. The range factor was already much better managed with the gasoline powered internal combustion engine. Anyway, the driver here was still forced to change gears while driving, which made the vehicle much harder to operate and the vehicle's engine needed to be started by a hand crank.

2.1.2 1890s - 1935

The electric engine on the other hand, did not face any of these above-mentioned struggles. The electrically powered cars held the significant advantage of easy operation in the beginning of the 20th century and became therefore in addition to other factors, popular t among the women. Compared with the gasoline engine, the next benefit was the non-polluting run of the engine and it became perfect for short distance town traffic. These facts had an effect on the market and the electric cars entered the new century with a 28% market coverage, in term of road-vehicles in the United States. (Curtis D. Anderson, 2010)

The innovators of this time obviously took notice of this and in the year 1891, the well-known founder of a later successful company with the same name, Ferdinand Porsche introduced his car model P1. This particular model was the company’s first car ever and was electrically driven. In 1914, Thomas Edison and Henry Ford met up to cooperate on the development of a low-cost electric vehicle for wide masses, which unfortunately for the electric car, did not work out that well. (Strohl, 2010)

The first mass-produced car possessing an internal combustion engine, the Ford Model T, came into the way of the electric car already in 1908. It represented a very affordable automobile suited for the wide mass, with a price tag of 650 USD, whereas the electric roadsters from that time had an almost triple price tag of 1750 USD. Moreover, in 1912 the electric starter was developed, which made the great disadvantage of the hand crank disappear and boosted the sales of gasoline-powered cars. The biggest developments on the market, seen mainly in the United States, were the falling prices of gasoline and the growing network of gas stations around the country in the 1920s. Electricity, on the other hand, was still not accessible in most of the rural areas at that time and finally around 1935, the electric cars were ultimately beaten by the combustion-engine cars and disappeared for a long time from the market. (Matulka, 2014)

2.1.3 1935 – 1990

For the following 30 years, the domination of the combustion engines leads to not developing electric motor technology and overall, focus was on the combustion one. The cheap prices of oil and continued focus on advancing combustion technology left the electric one in the dark.

In 1970, the Clean Air Act was established, which put the responsibility on any American state to meet certain air quality goals. Later in the 1970s, the world prices started soaring and the oil resources were finally starting to be considered as limited. In the United States, oil prices? peaked in 1973 with the Arab oil embargo and focus was redirected towards lowering the dependence on foreign oil resources and looking for homegrown resources of oil. Only three years later, the government agreed on the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, with the aim to research alternative fuel possibilities. (Matulka, 2014)

Following a similar oil price situation and development in Europe, France established their so-called “PREDIT” program to foster the acceleration of the electric vehicle RD&D in 1976 as well. (Curtis D. Anderson, 2010)

In this era, two companies happened to dominate the really small but existing electric car market. The first and more successful one was a Florida based producer, Sebring-Vanguard, which produced over 2,000 "CitiCars" in the 1970s. The second one was an even less popular model by Alcar Corporation. The CityCar remained the most sold electric car in the United States until the appearance of Tesla Roadster in 2006. As an example from the car scene in Europe, the German car manufacturer BMW tried its luck during the Olympic Games in Munich in 1972, where they introduced their 1602 E model. This car was powered by a 42-horsepower, fully electric engine, with the range of 37 miles on single charging. However, besides its usage during the Olympic Games, the car with its electric motor never reached mass production. (Thompson, 2015) Until the beginning of the 1990s, there was little enthusiasm for electric vehicles

2.1.4 1990s - Today

Thanks to the passage of the 1990 Clean Air Act Amendment and the 1992 Energy Policy Act, plus the regulations on transportation emissions in California, the interest for electric vehicles in the United States rose. The Air Resource Board in California required the car producers to introduce and sell a zero-emission car in order to place themselves on the market of the state. (Curtis D. Anderson, 2010)

General motors revealed in this time its EV1 model, being first of its kind by the company. It became the most sold electric vehicle on the American market and the first one from its era, produced by a major automaker. Its main contribution in terms of electric cars is that it for the first time caused public excitement and enthusiasm for electric vehicles. It became a pioneer vehicle in its segment and during its initial year in production in 1996, it already sold 1117 units. General Motors, however, was not able to turn its electric car profitable for the company and they made it disappear from the market in 2001. (Brown, 2016)

Another cornerstone and a response from the Japanese market was when Toyota introduced its Prius in 1997. It was the world's first mass produced hybrid electric vehicle and worldwide sales started in 2000. It became the bestselling hybrid car of the first decade of the 21st century.

In 2006, a new start- up company emerged in the Silicon Valley, calling themselves Tesla Motors, with their initial car, a fully electric model Tesla Roadster. Because of their limited resources, the car was based on the already existing platform of another carmaker, the Lotus Elise. The financial situation of the company changed dramatically, when the American Energy Department provided Tesla Motors with a loan of 465$ million, which the company was able to fully repay already in 2013. The money was dedicated to the building of their giga-factory that made Tesla the biggest car manufacturer in California. (Matulka, 2014)

Due to Tesla's great success, the electrically powered vehicles inspired other major automakers, so that in 2010 Chevrolet presents its hybrid model Volt and Nissan its all-electric car, the Leaf. In 2013, BMW introduced their fully electric vehicle i3 and hybrid i8. The mainstream trend of EVs in the latest years happens to be the plug-in hybrid technology, installed in every major car producers' model.

2.2 Worldwide electricity and fuel prices

Since the prices of both electricity and fossil fuels differ tremendously within continents, countries or even regions, the impact on the final expenditure dedicated to the fuel costs of any car owner differs. Therefore, the local prices of both kWh and a liter of gas or diesel, as the more traditional cars fuels, should be considered.

2.2.1 Electricity prices

The price of electricity usually involves the costs for building, financing, maintaining and operating the power plants or electricity grid in the particular location. For the profit-oriented energy providers, their profit margin logically plays another role in the pricing. (U.S.

Department of Energy, 2016) However, the key factors affecting the final price of electricity tend to be the costs of the fuels from which the plant produces the energy and the maintenance and operating costs of the power plants and their transmission and distribution system. Other major factors affecting the price are weather conditions. The hydropower plants can benefit from snow or rain in the production of electricity or, on the other hand, suffer in the dry and hot months. The biggest energy demand usually takes place in summer, because of cooling in the hot months. Local legislative regulations are an influencer as well, since the prices of some regions can be regulated by the public sector. (U.S. Department of Energy, 2016)

Another factor influencing the final price of kWh is the type of customer. The highest rate is usually paid by the residential consumer, followed by the commercial one, paying slightly less and finally the industrial, paying as a rule the lowest rate per kWh. The reason for that is that they use much higher amounts of electricity, which can be delivered at higher voltages, so that the supply is more efficient and less expensive. (U.S. Department of Energy, 2016)

Finally, another price influencer is the location of the end consumer. The availability of power plants and fuels, local costs and local price regulation have a major effect on the final price. Observing the real life numbers from Europe in *Figure 1* the kWh is relatively expensive in Italy, Germany and the UK, moving between 15.7 and 14.16 USD cents. On the other hand, countries with cold climates, for example Canada, Finland or Sweden, enjoy more affordable electric energy , with less than half the price, moving between 7,23 and 5,34 USD cents.

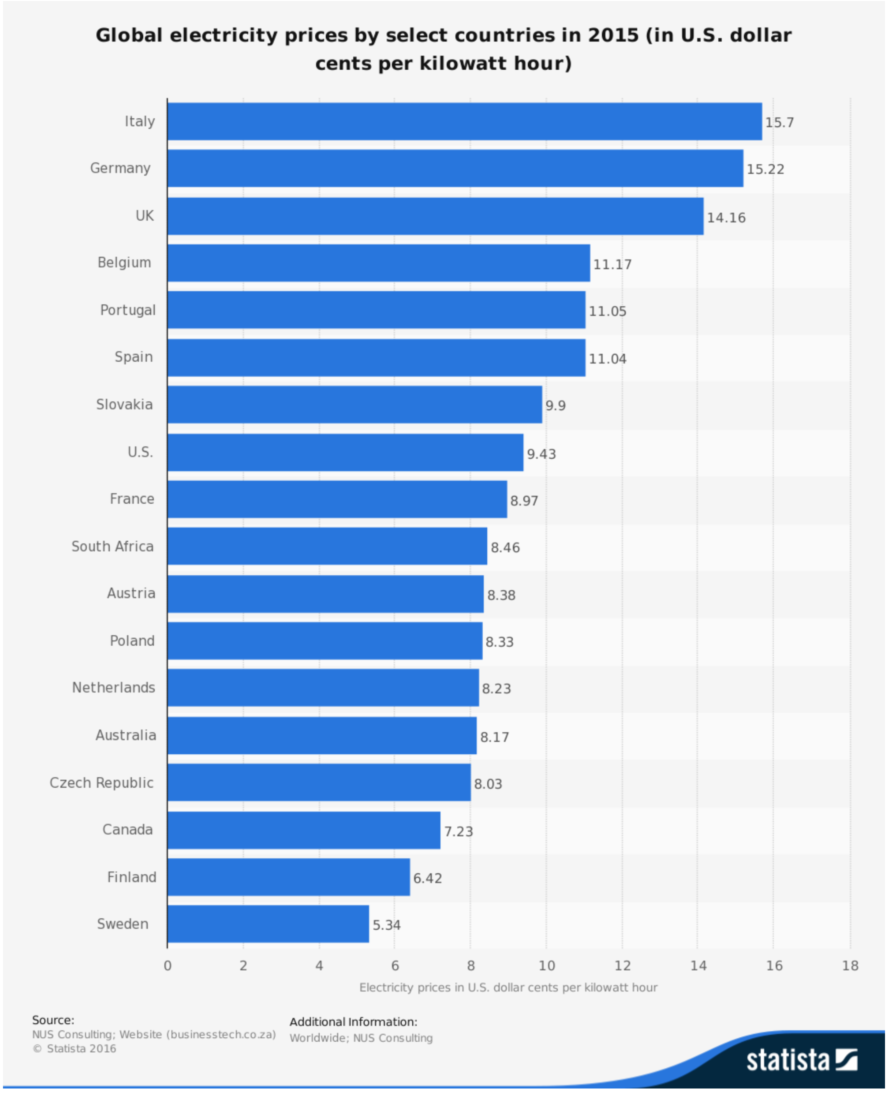


Figure 1: Global electricity prices in selected countries 2015

2.2.2 Gasoline and diesel prices

In terms of gasoline used for personal vehicles, there is a difference based on the octane level, which marks the fuel's quality. The cheapest is the regular gas, followed by midgrade and premium gas, with the in the same order ongoing price level.

If we move to the core price composition of oil, we face four main components. The biggest influencer tends to be the crude oil cost. The international crude oil supply is generally coordinated by the Organization of the Petroleum Exporting Countries (OPEC). It is an intergovernmental organization consisting of 13 crude oil exporting countries, which all together control around 2/3 of the Earth's proven oil reserves. The next influencers on the retail prices of gas are later on the added governmental tax, refining costs and profits, marketing and distribution, as well as the profit margins of the oil companies providing the retail sell. (U.S. Department of Energy, 2016)

The overall tendency on the local markets is in most of the cases, that the richer countries, indicating higher average income, have higher gasoline prices than those with lower average income per capita. However, we find exceptions like the USA (0, 67 USD per liter), where we find one of the cheapest gasoline retail prices throughout the globe, regardless of the developed economy of the country,. Another two developed economies, namely Canada (0, 93$ per liter) and Australia (1, 03$ per liter) show a similar trend, where gas appears to be affordable compared with the local average income. Moving towards Europe, countries like the Netherlands, Italy, Sweden or Portugal indicate more than doubled gas retail price, moving between 1, 7 and 1, 62 USD per liter. On the other hand, the cheapest final gas retail prices in Europe we find in countries like Austria, Czech Republic or Poland, where people in February 2017 paid between 1,28 and 1,17 USD per liter.

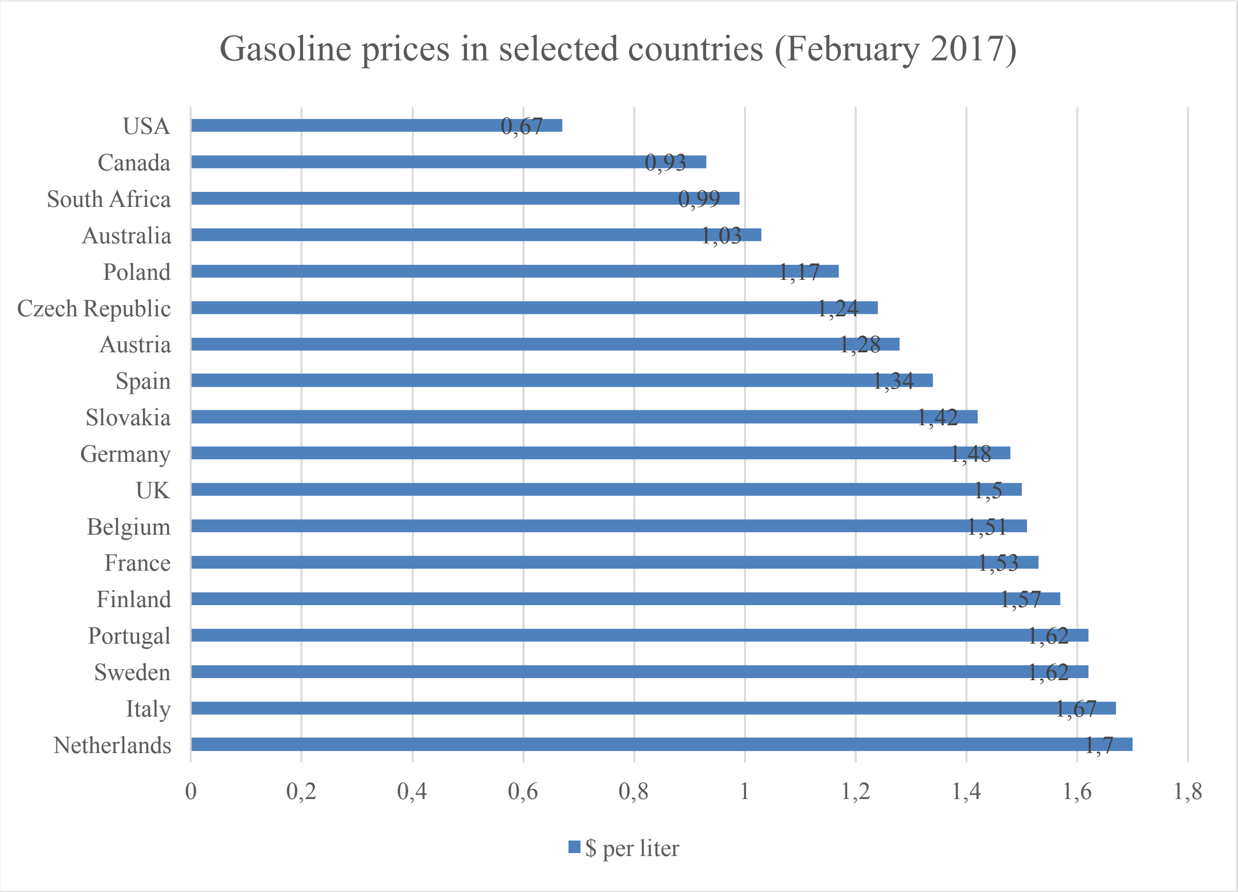


Figure 2: Gasoline prices in selected countries (February 2017), source: GlobalPetrolPrices.com

More or less, we find the same situation regarding the factors affecting the retail price of the diesel fuel. The retail price of diesel is then as a rule similar to the countries' gasoline price, with the exception that it might be up to $0, 2 lower and there is a strong correlation regarding their price fluctuations. The reason for it is the price of the same main component needed for their production, namely the crude oil mentioned before. It is usually not common to have a higher diesel price than gasoline price, however, in some American states it is actually the case.

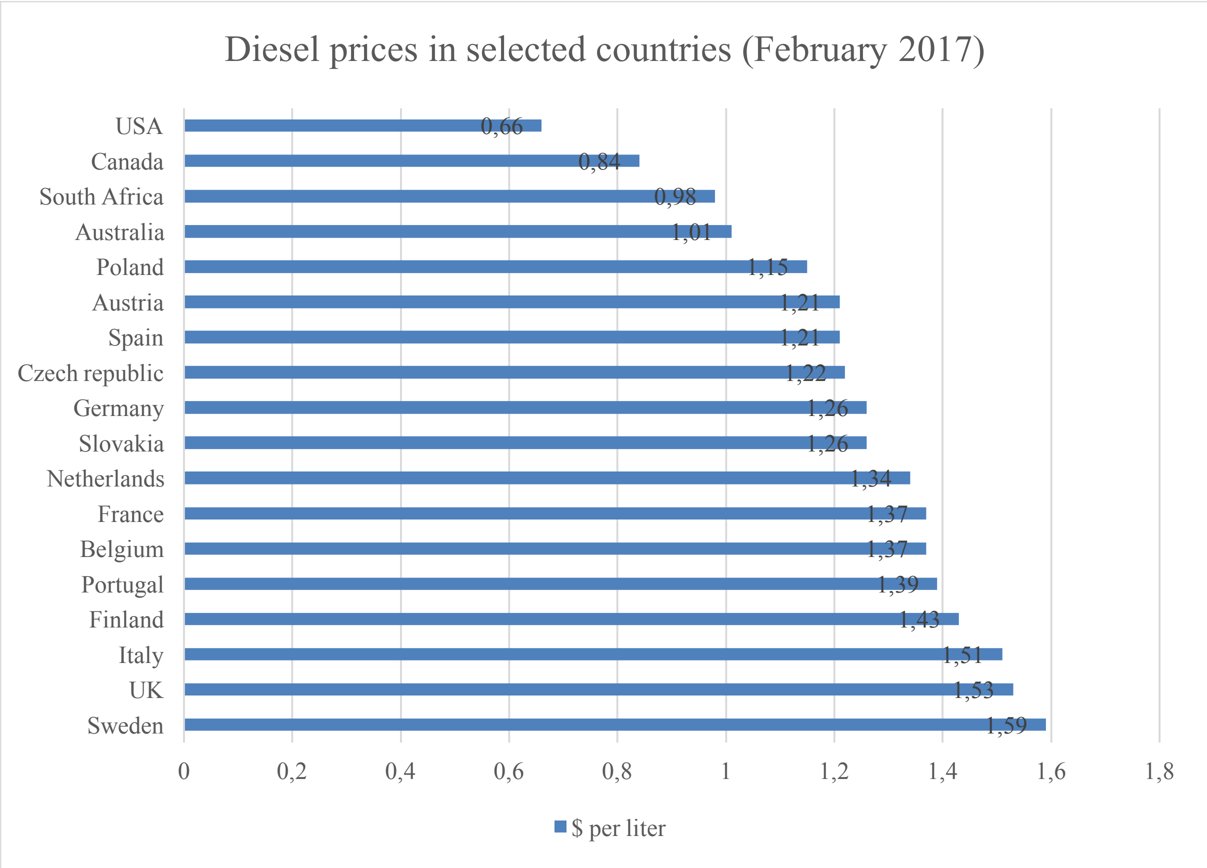


Figure 3: Diesel prices in selected countries (February 2017), source: GlobalPetrolPrices.com

2.3 Advantages and challenges for electric automobiles

2.3.1 Advantages of electric motor cars over combustion engine vehicles

The most obvious advantage of any electric car over combustion engine car is its zero tail pipe emissions, which is an unquestionable fact. However, the electric energy used for the propelling of the engine still needs to be produced somewhere to supply its consumption. Thus, the EVs only shift the air pollution up on its production stream towards the electricity plants, which in most of the cases still use fossil fuels for their production. As an impact of this is then anyway the positive fact, that the air polluting process now moves to the nonurban areas and the agglomerations profit from locally lower emissions and the and pollutants harmful to the health, which go hand in hand (i.e. CO, NOx, THC, NMHC). (Adolfo Perujo, 2011) The emissions produced by the power plants are far easier to manage in a unified form at the plants, producing the energy with much higher carbon dioxide efficiency, than in the case of huge amounts of single cars in the daily traffic. Another fact is the reduction of noise caused by the traffic, since the EV's motor running is significantly quieter, thanks to the missing exhaust. (Adolfo Perujo, 2011)

Another major advantage of any type of fully electrically powered vehicle is a significantly lower consumption cost. Moreover, the price and consumption of kWh of EVs represent a significant difference of the consumption of any gasoline or diesel car.

Moving on, the electric engine entirely misses the transmission with the clutch and consists of just very few moving particles, unlike the combustion engine. Therefore, there is no need for change of any type of oil, coolant, water or start sparks of the engine. This fact has a consumer-friendly aspect of less wear out of the engine components, going hand in hand with lower maintenance costs, dedicated to the service of the vehicle. (Jha, 2013) The electric cars are usually enhanced with the system of regenerative engine braking, when the foot is removed from the gas pedal. This process eventually prolongs the lifetime of the braking pads and simultaneously recharges the batteries while braking.

The average efficiency of today's combustion engines, namely the way how effectively it operates with the consumed fuels, is between 25% and 35%. The electric engines, on the other hand, have more than triple the amount of efficiency,. at least 90%. (Boxwell, 2014)

The next positive impact of the missing transmission and the overall nature of the electric unit is its instant torque, offering maximum power from the standstill, whereas a combustion engine can only achieve this at high speed. (Boxwell, 2014) The power delivery is extremely smooth and achievable at any moment of the drive, making it a security element in case of possible fast response needed in traffic situations, such as overtaking.

Finally yet importantly, the buy of any new EV is in many countries subsidized by the government, stimulating the public interest to purchase the EVs over the conventional automobiles in order to reduce the country's dependency on foreign oil. This is usually the case for the fully electric BEVs, but subsidizing hybrid cars might be considered as well in many destinations.

2.3.2 Barriers and challenges for EVs

2.3.2.1 Range and batteries

The major barrier for buying any EV is the range of a single charge of the car, which is much lower than for any fully tanked conventional automobile. The vast majority of the EV market nowadays, are only able to travel from 80 to 160 km on a single charge (with the Tesla, however, up to 500km, but becoming very pricy). (Boxwell, 2014) This could be considered sufficient as a daily range for most of the population, however, it is still incomparable with the range of any combustion engine vehicle. Those normally achieve 500km on a single tank, without being limited by the charging station network and being able to refill their tank at any gas station. For any regularly long-distance travelling driver, the limited range might present a problem.

Continuing the talk about the range of EVs, it markedly decreases while driving on the highway at speeds higher than 130km/h, at which the car needs more power. However, cruising up to the speed of 110km/h, the EVs usually still manage well without any significant range drops. (Boxwell, 2014)

2.3.2.2 Charging

When somebody owns an electric car, his/her basic need is to have the possibility to charge it conveniently, in order to calm down his/her worries. In case of shorter distances around the town, for journeys to the work place, grocery stores or schools, the usual car range is most of the time sufficient for one day.

A majority of the EV owners (95%) usually charge their cars' batteries during the night, when they are not using the car,. (Boxwell, 2014) Anyway, not all the members of the population have the luxury of parking in a garage, where they can simply plug in their vehicle. Many people park their cars in the street and they would have to be lucky to have any public charging point in their living area. (Erjavec, 2012)

The next problem occurs for trips that are longer than the one charge range of the vehicle. In this case, the customers are forced to rely on the charging points' network. Although the number of charging stations is increasing, it is still incomparable with the convenience of the gas stations and their geographical density. The charging time is another issue, which might be solved with the so-called rapid chargers, adding to the vehicle's range within less than an hour. However, their occurrence is rather rare today. (Erjavec, 2012)

2.3.2.3 Purchase price

Finally, there is the question of the purchase price of any electric car, which is generally speaking much higher than any other conventional market product from given class and quality segment. The main reason for electric cars being so expensive is mainly their battery price, where we face nowadays the price of 350 USD per 1 kWh of its capacity. (Wesoff, 2016) Speaking of the purchase price of any EV, let us observe it through the example of fully battery electric Chevrolet Bolt, where the battery capacity is 60 kWh and its selling price is around 37.495 USD in the US. Given the above-mentioned price of 1 kWh, we face a battery price of 21.000 USD, which is more than half of the final selling price. (Edelstein, 2017) This fact makes it difficult for the automakers to satisfy their profit margin, while trying to offer an affordable car and that is why the electric cars are more expensive than competing conventional vehicles.

2.4 EV Buying Options in 2017

We identify three main types of electric vehicles, regarding the extent to which their operating is dedicated to the use of electricity as the source of energy.

2.4.1 Battery Electric Vehicle (BEV)

Cars carrying the name of BEV are solely powered by electricity and therefore possess no internal combustion engine; therefore they are referred to as the only zero tail pipe emission type. In case of recharging, they have to be plugged into the electric power grid. Vehicles of this type are not equipped with gearboxes, because of their solely electric drive train. Regenerative braking as a way of charging is included in the technology. (Smith, 2014) Typical examples of BEVs are any type of Tesla’s products, like the Model S or Model X in the high-end luxurious car segment. The more affordable alternatives might be the Chevrolet Bolt, Ford Focus Electric, Hyundai Ioniq or the Volkswagen’s E-Golf. From the low-cost segment, we encounter the Mitsubishi i-MiEV or Smart Electric Drive, for example.

2.4.2 Hybrid Electric Vehicle (HEV)

Hybrid electric cars are powered by both an electric plus an internal combustion engine; the second one powered by either gasoline or diesel. The internal combustion engine is dominant and the electric motor serves only as a supplement. The car is therefore equipped with a smaller battery, and the combustion engine combined with the energy stemming from the regenerative braking provide the power for it. Unlike the BEVs, this battery cannot be recharged via a battery outlet, because its capacity is small and the hybrid cars are not equipped with such a plug. The purpose of hybrid electric vehicles is to achieve a better fuel economy and better car efficiency. (Smith, 2014) The electric motor minimizes idling and improves the vehicle's ability to stop and go, which is particularly useful in the city traffic. Moreover, the electric motor assists or fully donates the vehicle's acceleration and the low-speed driving. (Boxwell, 2014) Another major advantage of the HEVs over the BEVs is, due to the addition of the combustion engine, the much higher range of the vehicle, when the batteries of the electric engine run out of power. Below, we identify three main types of HEVs.

1) The parallel hybrid car is the first type, which uses the internal combustion engine and the electric engine simultaneously to power the car. This means that both types can fully put the vehicle's wheels into motion. (Boxwell, 2014) Examples of such hybrid vehicles are for instance the Toyota Prius or all different Lexus hybrid models.

2) The second type of HEV is the so-called series hybrid vehicle. The car is again equipped with both electric and internal combustion engines. However, in this case the combustion engine itself alone cannot put the vehicle into motion, because its function here is solely to generate energy, when the vehicle's battery runs out of it. (Boxwell, 2014) Therefore, the combustion engine carries the name and has the function of a certain range extender. The examples of series hybrid vehicles are the American Chevrolet Volt and its European version Opel/Vauxhall Ampera or the BMW i3 equipped with Rex (above referred range extender). All of these, however, apply to the category of Plug-In Hybrid Vehicles as well.

3) The third type of HEV is the so-called twin drain vehicle. The principle is that each drive axle is powered differently, one by the combustion and the second by an electric engine. The internal combustion engine powered drive axle includes the gearbox, whereas the second drive axle, the electric engine powered one, has no gearbox. (Boxwell, 2014) The electric and conventional drive are kept entirely separate from each other and the car can switch between them, or both can be used simultaneously. The examples of twin train HEVs are Volvo V60 hybrid or their XC90 hybrid, as

well as all hybrid vehicles offered by Peugeot or Citroen. However, some of them already belong to the next category.

2.4.3 Plug-In Hybrid Electric Vehicle (PHEV)

Same as the HEV, the plug-in hybrid vehicles are equipped with both electric and combustion engine. The major difference is the way of charging, where besides the regenerative braking and energy coming from the combustion engine, the batteries can be charged from the power grid through the vehicle's plug. For this reason, the vehicle's batteries are significantly bigger and can provide a purely electric drive for several kilometers. After their discharge, the combustion engine comes into place. This fact makes the PHEV particularly useful for longer journeys, without the need to recharge the batteries. (Smith, 2014)

On the other hand, the automobile is useful in the city traffic, where the vehicle runs in the fully electric regime and produces zero tailpipe emissions and thus does not make the air pollution in the cities any worse. These facts represent an attractive option on the changing automobile market, while offering the advantages of both, the electric and combustion engine worlds. (Boxwell, 2014)

However, even the plug-in hybrid vehicles include some negative aspects, such as. the over-dimensioned complexity of a vehicle possessing two completely different propulsion units. This complexity brings then possibly higher maintenance costs.

In the more affordable price segment, we deal with PHEVs like Chevy Volt, as the world's most sold PHEV, Ford models like C-Max Energi or Fusion Energi or Hyundai Sonata Plug-In Hybrid. Plug-In Hybrids have become particularly interesting for the traditional automakers in the upper-mid class in the recent years, therefore we find on the market models like Audi A3 e-Tron, BMW 330e or Mercedes-Benz C350 Plug-In Hybrid. PHEVs are, however, no rarity among the high-end luxurious car segment, with Porsche presenting their Cayenne and Panamera 4 E-Hybrid or even the Mercedes-Benz with the S550 Plug-in Hybrid. The potential of an enhancement of the conventional combustion engine by the additional use of the advantages of the electric engine became notably interesting for exotic hyper carmakers, like the McLaren with their P1 or Porsche with 918 Spyder, all equipped with an electric plug besides their fuel tank.

2.5 Electric vehicle subventions and incentives

The governments of different countries globally attempt to stimulate the market demand for any form of electric vehicles, with the intention to popularize the EV sales and minimize the routinely higher selling price of these. Notwithstanding, the extent to which this attempt is fostered differs dramatically. In some countries, the buyers of any electrically rechargeable vehicles enjoy the incentives mainly consisting of tax reductions or exemptions and in other ones, the much higher monetary valued support in the form of bonus payments and premiums. (European Automobile Manufacturers Association, 2016)

Universally, we can differentiate between three main sorts of incentives for electric vehicles, intended to increase their sales volume. These are presented below.

2.5.1 Direct subsidies

The first ones are the direct subsidies, which could be understood as a one-time bonus upon the purchase of a new EV. Nevertheless, this type of subsidy is nowadays still not widespread and only potential buyers in a few countries can take advantage of such a direct subsidy. Iin Europe, France has a very favorable position in this matter, as their residents receive up to 7.000 EUR in form of a one-time bonus for vehicles emitting less than 20 g/km of CO2. There is nonetheless the condition that the total amount of the incentive cannot exceed 30% of the vehicle's purchase price, including the value added tax. For the vehicles producing between 21 and 50 g/km of CO2, the incentive is5.000 EUR. (Peter Mock, 2014)

In the United Kingdom, the government is as well pretty generous to the EV buyers, with slightly less strict conditions than the government of France. The incentive for purchasing a vehicle that emits less than 75 g CO2/km is25% of the purchase price, however, limited to the maximum of 5.000 GBP (about 5.800 EUR). (Peter Mock, 2014) The next EV-friendly government is Sweden, where inhabitants receive a premium of 40,000 SEK (about 4,000 EUR) for cars with zero CO2 emissions, meaning only the purely electric vehicles and 20,000 SEK (about 2,000 EUR) for cars with CO2 emissions between 1 and 50 g/km, as in the case of any PHEV. (European Automobile Manufacturers Association, 2016)

Leaving Europe and moving to the United States, the federal government grants a one-time bonus in the form of a tax credit up to the amount of 7.500 USD (about 3.900 EUR), depending on the vehicle's battery capacity.. In the US, however, the citizens enjoy the pleasure of direct subsidies from their particular state as well, adding another incentive to the federal one. Taking the state of California as an example, their citizens receive another 2,500 USD (about 1.800 EUR) in the form of a one-time bonus payment for purchases of fully electric vehicles and 1.500 USD (about 1.100 EUR) in case of plug-in hybrids . (Peter Mock, 2014)

In Asia, the electric car trend is encouraged by local governments as well. In Japan there is a generous incentive of 850.000 JPY (about 6.300 EUR) for the purchases of BEVs and PHEVs (Peter Mock, 2014). In China, they follow the similar model with a one-time bonus between 35.000 and 60.000 RMB (about 4.200 and 7.200 EUR) for their citizens as an incentive for buying any BEV, depending on the particular vehicle's battery range. The PHEVs are considered in the Chinese EV incentive program as well; more precisely it represents 35.000 RMB (about 4.200 EUR) for PHEVs with battery range of at least 50 km or higher. (Peter Mock, 2014)

2.5.2 Fiscal incentives

The second type of incentives stimulating the local market demand for electric vehicles in specific countries are the so-called fiscal incentives, which include a reduced purchase and/or annual tax for EVs. There are three main categories of these tax breaks (presented below).

1) The first type of fiscal incentive is value added tax or VAT on the purchase price of any EV, which can globally differ roughly from 5% to 25% of the base price on any newly bought vehicle. Norway should be mentioned in this case, as it represents the only country in the world that excludes the VAT from the buyers of any fully electric BEV . This, however, does not apply for the PHEVs. In all other counties, VAT for any electric car is actually higher than for the competing conventional automobile from the given segment, due to their higher base price. (Peter Mock, 2014)

2) The second tax break is the so-called one-time purchase or registration tax, which is charged in many markets on top of the VAT on the purchase price of the vehicle. However, some governments exclude the owners of the EVs of paying this as an incentive for buying EVs. This is the case, under certain conditions, in countries like the Netherlands, where vehicles producing less than 95 g/km of CO2 in case of gas vehicles or 88 g/km for diesel cars, are exempt from the registration tax. One of the highest car registration taxes is paid in the Nordic countries, namely in Norway and

Denmark. Here the buyers of an EV enjoy the pleasure of the registration tax break as well. (Peter Mock, 2014)

3) In some countries, the local governments additionally charge their vehicle owners an annual circulation ownership tax on a yearly basis. Some markets are trying to take advantage of incenting the market by putting exemptions on this type of tax in the case of an EV. Germany for instance is granting a 10-year annual circulation tax break for their citizens, buying a particular electric car. In the Netherlands, this exemption exists as well for any vehicle producing less than 50 g/km of CO2. (European Automobile Manufacturers Association, 2016)

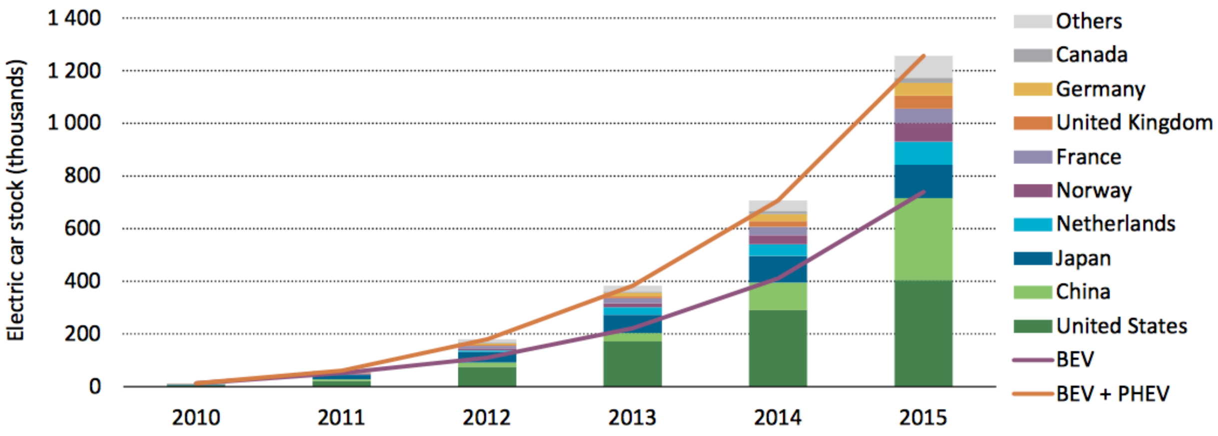
2.5.3 Fuel-costs savings

The fuels-costs savings represents another type of incentive for the buyers of electric cars, however, they are not directly granted by the governments anymore. These happen due to the electricity prices being lower than fossil fuel prices, because of lower taxation and/or lower energy costs, as well due to the higher efficiency of EVs. This incentive might be particularly interesting for consumers with high yearly mileage, while getting the maximal advantage of the EV's efficiency. Countries with expensive gasoline and diesel also benefit from this, as the EVs' electric propulsion speaks for a compelling change in terms of fuel costs.

A 100 km trip performed by an EV corresponds roughly with 20 – 25% of costs of travelling by a car powered by a conventional engine in most European countries. In the United States, with much lower fossil fuel prices, we face the margin of about 50% diminished fuel costs. (International Energy Agency, 2016)

2.6 EVs' worldwide market share

Figure 1 • Evolution of the global electric car stock, 2010-15



Note: the EV stock shown here is primarily estimated on the basis of cumulative sales since 2005.

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2016), IHS Polk (2014), MarkLines (2016), ACEA (2016a), EEA (2015) and IA-HEV (2015).

Figure 4: Evolution of the Global EV Market 2010-15, source: International Energy Agency, 2016

The electric vehicle segment is a relatively newly developed market, which in brighter scope started at the beginning of the current decade. Interestingly, the share of the BEVs is slightly ahead of the PHEVs. In 2009, the multi-government policy forum called EVI, consisting of 16 world's leading EV car stock governments, was established with the common challenge to spread 20 million of electric cars on the common territory by 2020. (International Energy Agency, 2016)

Between 2014 and 2015, there were over 550.000 EVs sold globally, which stands for an overall increase of 70% within one year. The decreasing production costs of electric vehicles, mainly the decreasing battery prices in combination with increased one-charge range, the national incentive programs of several governments and the other obvious benefits of e-mobility led to their late deployment. In 2015, the electric vehicle stock finally exceeded the threshold of one million electric vehicles on the roads worldwide and by the end of the same year, the final number landed at 1,26 million vehicles. (International Energy Agency, 2016)

Table 6 ● Electric car stock (BEV and PHEV) by country, 2005-15 (thousands)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Canada							0.52	2.60	5.71	10.78	18.45
China						1.43	6.50	16.40	31.74	104.91	312.29
France	0.01	0.01	0.01	0.01	0.11	0.30	2.93	9.25	18.88	31.50	54.29
Germany	0.02	0.02	0.02	0.09	0.10	0.25	2.34	6.13	13.25	26.03	49.22
India				0.37	0.53	0.88	1.33	2.76	3.13	4.02	6.02
Italy	0.53	0.53	0.53	0.60	0.60	0.64	0.76	1.42	2.47	3.99	6.13
Japan					1.08	3.52	16.14	40.58	69.46	101.74	126.40
Korea						0.06	0.34	0.85	1.45	1.52	4.33
Netherlands				0.01	0.15	0.27	1.14	6.26	28.67	43.76	87.53
Norway				0.25	0.39	0.79	2.80	7.21	15.42	35.21	70.82
Portugal						0.02	0.22	0.32	0.53	0.82	2.00
South Africa									0.03	0.05	0.29
Spain						0.07	0.65	1.20	2.21	3.66	5.95
Sweden		0.12	0.13	0.13	0.16	0.19	0.37	1.25	2.65	7.09	14.53
United Kingdom					0.19	0.29	1.37	3.78	7.28	21.86	49.67
United States	1.12	1.12	1.12	2.58	2.58	3.77	21.50	74.74	171.44	290.22	404.09
Others*							1.73	4.48	8.76	19.59	44.89
Total	1.67	1.78	1.79	4.04	5.89	12.48	60.65	179.23	383.09	706.77	1 256.90

Figure 5: EV Stock by Country 2005-15, source: International Energy Agency, 2016

The two major markets with respect to the on-road present EVs are by far China and the United States. For the first time in 2015, China took over the global electric car leadership and outperformed the United States in terms of newly registered electric vehicles. However, the United States still possesses the biggest EV stock globally with more than 404.000 cars on their roads, whereas China occupied the second position with slightly above 312.000 EVs in their local traffic. (Figure 5) The third position, being fairly far behind, is then held by the Japanese with about 126.000 electric cars. These three countries represent the only ones in the world with more than 100.000 EVs in 2015. Other significant e-mobility enthusiastic countries are finally stemming from Europe. In the third (fourth?) position in 2015 was the Netherlands, followed by Norway, France, United Kingdom and Germany. (*Figure 5*) These altogether eight main electric car markets in 2015 account for 90% of global EV sales. Strong correlations of these statistics can be observed with the countries' national electric car incentive programs, meaning the high EV stock correlating with generous local incentive policies. (International Energy Agency, 2016) All mentioned countries enjoy a form of either a direct subsidy or a fiscal incentive for buying an EV on their territory.

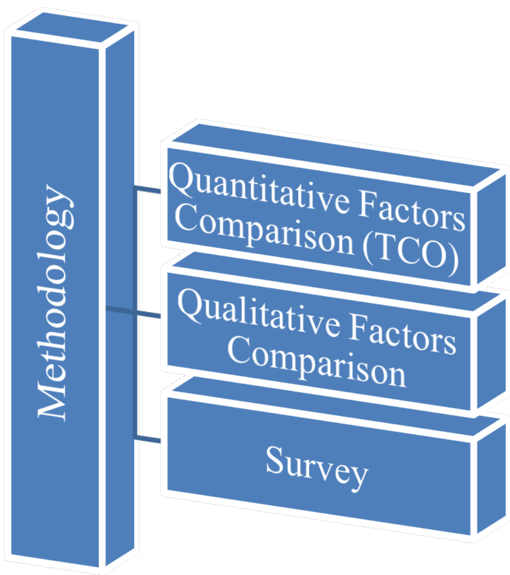
3. Methodology

The purpose and core aim of this thesis is to observe, analyze and finally compare different buying options of three personal vehicle categories. These are the battery electric vehicles, plug-in hybrid vehicles and finally the conventional cars. The research model is later on considering both quantitative and qualitative distinctness and typical features of each of these vehicle categories.

Since the world's car market covers a huge diversity of segments and price levels, the thesis is acknowledging not only one, but two of them in order to create a more versatile research approach. Therefore, the thesis takes into consideration the C-Segment European standard car category (also known as small family car segment), as the more affordable choice, alongside with the F-Segment in terms of the European car standards, also known as the full-size luxury automobiles, with regularly a double or triple price tag. However, within this comparative research, the chosen vehicle models will be treated equally, with the common limitation of the very similar purchase price among all of the three models in the same market segment.

Given the three researched car categories distinguished by their propulsion system and the two market segments, we face six different car models.

Last step of the thesis's methodology is going to be the thesis survey, aiming for determining the public understanding and awareness of electric vehicle market in Spring 2017 by a panel of selected respondents.



3.1 Data

The research is referring to the comparison of BEV, PHEV and ICE (internal combustion engine) types of vehicles, where the main concerns cover the costs dimensions and the quantitative differences between them. The purchase prices, maintenance costs, costs of fuel consumption and loss value after 3 years present the comparison model summarized as the total cost of ownership (TCO). This one is going to be performed for each single of the six, for the research selected, automobiles.

Since the costs and monetary factors are not the buyer's only criteria and he or she may have other needs besides personal transportation, the research also includes the qualitative differences of the selected models; . namely the individual model's features of the pleasure of the ride, experience of its daily usage and last but not least, every participating vehicle model's overall elaboration quality and used materials.

Finally, to increase the informative value of the research itself, the public perception of the electric vehicles is going to be put into test, with the aim of recognizing the consumers' knowledge of and overall interest for the electric vehicles in the world of 2017. For this purpose, an online questionnaire will be filled out by random members of the society. The results will represent the general tendencies among the consumers in terms of buying behavior within the car purchase process.

3.1.1 Introduction of the objects of the comparative research

The research matrix indicates six particular car models as the basis for further analysis and comparison. This was performed respecting the two previously mentioned criteria, namely their propulsion system and given car segment within the same retail price level. All of these are the latest offers of each given car manufacturer on the car market in spring 2017.

	Battery Electric EVs	**Plug-In Hybrid EVs**	**ICE vehicles**
C - segment Small family vehicle	*Ford Focus Electric*	*Audi A3 e-tron*	*Volkswagen Golf GTI*

F - segment Full-size luxury vehicle	*Tesla Model S 90D*	*Porsche Panamera 4 E-Hybrid*	*BMW 550i Gran Coupé xDrive*

3.1.1.1 C-segment

The C-segment objects, small family compact cars, commonly belong to the lower medium car segment and present every year the major market share of the newly registered cars in most markets, amounting up to almost a third of the market for newly registered cars. (Martin Campestrini, 2011)

Three similarly priced 5-door hatchbacks within the small family vehicle segment were selected. Although they possess similar attributes within their retail price and car segment, the propulsion system is their major distinction. All of them are very typical examples within their segment with a solid market position, making them familiar for the end consumers from everyday traffic situations. They have been present on the market for a long time and therefore address a selected target group very precisely.

The very first member of the research, given the compact car segment, is the American Ford Focus Electric. We refer to it as the electric sibling, except for its propulsion system, of the otherwise identical conventional Ford Focus model. It is a BEV, which means that the vehicle is propelled solely by the electric engine. The car producer himself states on his website, that its 35 kWh battery is capable of 162 km (115 miles) on its 100% charge and the electric engine itself is capable of 107 kW (143 HP) with the torque of 250 Nm with its solely front wheel drive system. Since we address the EV here, it is equipped with the 1-gear automatic gearbox. (Ford, 2017)

The PHEV competitor for Ford Focus Electric and the second member selected for the comparative research is model A3 in the version e-tron from the factory of the major German car producer Audi. Since we face here a plug-in hybrid vehicle, according to the car manufacturer's web page, it is propelled by the Audi's 1.4 TFSI 4-cylinder gas engine with the cubic volume of 1.395 cm^3 in combination with an electric engine. Together they serve the performance of 150 kW (204 HP), which is achievable at the torque of 350 Nm. The Audi's A3 e-tron battery has the capacity of 8,8 kWh and serves for a purely electric ride of up to 31 miles (50 km). Further, the car is a front-wheel drive and comes standardly with Audi's automatic 6-speed S-tronic gearbox. (Audi, 2017)

Finally, the conventional competitor for the BEV Ford Focus Electric and the PHEV Audi A3 e-tron within the compact car segment is the Volkswagen with its Golf GTI model, another major German manufacturer.. Since it is the conventional car model intended for the research, solely a 4-cylinder gasoline motor propels this particular model with the cubic capacity of 1984 cm3. The maximal performance is 169 kW (230 PS), which is achievable by the torque of 350 Nm. Moreover, the vehicle is equipped with Volkswagen's automatic 6-speed double-clutch DSG gearbox and the car is a front wheel drive. (Volkswagen, 2017)

3.1.1.2 F-segment

Next I will examine the F car segment, specified as full size luxury vehicles. The research is going to consider another three class-specific models with a a similar price level. All representatives are four-door fastback sedans with a similar body style and silhouette. Unlike the examples of the C-segment, these selected car models have a shorter presence on the market, starting around the half of the 00s decade.

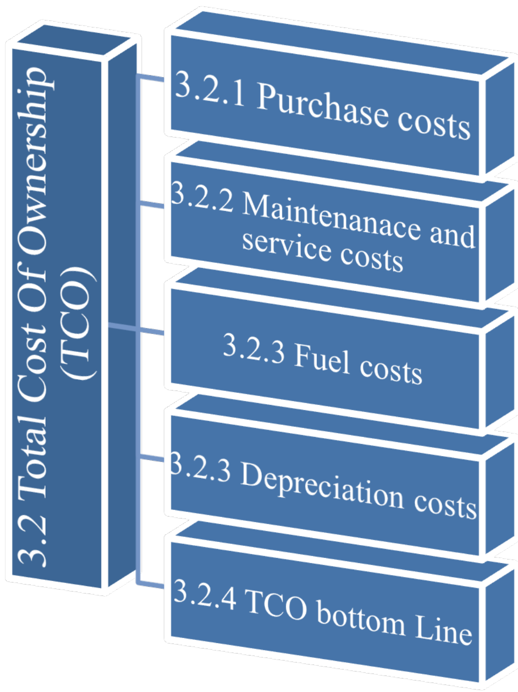
Since we face the luxury car segment, the expectations of the given vehicles are understandably much higher than in the previously discussed segment. The manufacturers' standards are considered as challenging, taking into attention the nearly tripled price tag compared with the previous case. Comfort, quality materials and high engine performance, as well as the extensive space dimensions are standard here. However, except all of these similarities, there occurs to be one major disparity among the three models. The different propulsion system of each single one, bringing hand in hand a significant amount of other vehicle's related features, as well as the different ride and usage experience.

The first model of the F segment is by many people observed as a pioneer and game changer in terms of personal vehicles and stems from a Californian manufacturer's plant, the battery electric Tesla Model S 90D. It made its debut as the first luxury car model in terms of its propulsion system. As the model's name states, it is equipped with a 90 kWh battery, which is, given to the car producer's website, capable of 557 km (294 miles) for a single full charge. This particular BEV is propelled by two electric engines located on each of its axles, serving a performance of 356 kW (518 PS) and therefore logically equipped with the four-wheel drive system. The mentioned performance is then achievable at the torque of 658 Nm. (Tesla, 2017)

The second examined vehicle within the luxury car segment is also a representative for the plug-in hybrid vehicle from another major car manufacturer. The Porsche Panamera 4 E-Hybrid is the electric sibling of the same looking conventional model from the car producer. The Panamera 4 E-hybrid is powered by the combination of a 6-cylinder gasoline engine with the cubic volume of 2.894 cm³ and an electric motor, which together achieve the performance of 340 kW (462 PS) at the torque of 700 Nm. The vehicle's battery pack has the capacity of 14,1 kWh and serves the possible purely electric range of 50 km (31 miles). Further, the vehicle is as standard equipped with the four-wheel drive system and Porsche's PDK 8-speed automatic gearbox. (Porsche, 2016)

Last but not least, the conventional model from another German luxury car producer BMW, namely its class BMW 650i xDrive Gran Coupé, is examined. Its V8-cylinder gasoline engine with the cubic capacity of 4395 cm³, as its single propulsion system, delivers the performance of 330 kW (450 PS), which is achievable at the torque of 650 Nm. The four-wheel drive system xDrive comes as standard with BMW's 8-speed sport automatic transmission Steptronic. (BMW, 2017)

3.2 Quantitative factors – Total Cost of Ownership (TCO)



As mentioned in the previous chapters, the main aim of the research is the determining and comparison of the total cost of ownership in the timeframe of three years from the initial buy of the particular vehicle, given to its segment and more importantly its propulsion system.

Total cost of ownership is an accounting method used for determining the costs of an asset in the long run; this means covering besides its purchase price, its operating costs for a certain usage period. (Reed, 2014) Such a TCO analysis consists of a variety of factors, however, for this thesis, mainly those parameters where the different costs of the three propulsion systems stand out the most are going to be considered.

Therefore, four indicators have been selected as the main measures for this comparison . These are the initial purchase price of the given automobile, followed by the estimated maintenance and service costs for a period of three years and the estimated fuel costs for the same period. The fourth indicator of the total cost of ownership considered within this comparative research is the loss of value of the specific vehicles after the three years of personal usage and the average market price on the market after this period.

The insurance and financing expenditures are going to be neglected within this comparative research. The reason for the non-consideration of these secondary cost influencers is, that within their price segment, we face the same cost levels and therefore they are not compatible for the comparison itself. Meaning that their cost level is not related to their propulsion system.

The German market will primarily be used as a reference for comparing prices and costs, as the major European country regarding the car industry with the biggest market volume in terms of sold vehicles on the continent. Later on it will be compared with the market of the United States, specifically the state of California. The following prices include the German value-added-tax (VAT) of 19% and the Californian sales tax of 7,5 %.

3.2.1 Purchase costs

The purchase price comparison of the different car models within different propulsion systems and car segments is, as previously declared, focused on the German market as the major European car market, along with the state of California (CA) as the overseas market.

The situation in Germany in terms of different price aspects is not complicated. The reason for this is that, there are no direct subsidies for neither BEVs nor PHEVs as mentioned in chapter 2.5 regarding national incentives. Therefore, next to the retail price the price includes solely the local value added tax, which is 19 % for the whole territory

In order to follow the manufacturer's suggested retail price (MSRP) for a given vehicle in California in the United States, the local sales tax of approximately 7,5% of the car's purchase price has to be considered. On the other hand, the federal American tax credit of 7.500 USD for buying of a BEV and battery's capacity related tax credit for PHEVs are considered. The second one is delivered thanks to the American governmental webpage fueleconomy.gov. Moreover, as mentioned in chapter 2.5, the additional Californian state rebate of 2.500 USD for the purchase of a BEV and the rebate of 1.500 USD for PHEVs are considered as well.

3.2.1.1 C - Segment

	BEV *Ford Focus Electric*	**PHEV** *Audi A3 e-tron*	**ICE** *Volkswagen Golf GTI*
German MSRP 2017 (incl. 19% VAT)	34.900 EUR	36.900 EUR	33.800 EUR
American MSRP 2017	29.120 USD	38.900 USD	29.915 USD
+ 7,5% sales tax (California)	+ 2.184 USD	+ 2.917,50 USD	+ 2.243,60 USD
- federal tax credit	- 7.500 USD	- 4.502 USD	not eligible
- state rebate (CA)	- 2.500 USD	- 1.500 USD	not eligible
= final purchase price	21.304 USD (20.026 EUR)	35.815,50 USD (33.668 EUR)	32.158,60 USD (30.230 EUR)

When comparing the final purchase prices of the three different car models of the C-segment, within the three propulsion categories, the PHEV Audi A3 e-tron appears to be the least affordable option out of the three given automobiles in both the German and Californian markets. The Ford Focus Electric is a 2.000 EUR and the Golf GTI more than 3.000 EUR cheaper alternative for the German consumer.

An overall tendency of cheaper purchase prices of all given automobiles on the Californian market can be recognized however, the Ford Focus Electric stands out the most being more than 40% cheaper than in Germany, due to the generous incentive systems of both the federal American government and the state of California. For the two other models of Audi and Volkswagen, the purchase price is lower by only circa 3.000 EUR, which does not represent that significant a difference,.

3.2.1.2 F – Segment

	BEV *Tesla Model S 90D*	**PHEV** *Porsche Panamera 4 E-Hybrid*	**ICE** *BMW 550i Gran Coupé xDrive*
German MSRP 2017 (incl. 19% VAT)	110.920 EUR	109.219 EUR	98.200 EUR
American MSRP 2017	94.000 USD	99.600 USD	94.200 USD
+ 7,5% sales tax (California)	+ 7.050 USD	+7.470 USD	+7.065 USD
- federal tax credit	- 7.500 USD	-7.500 USD	not eligible
- state rebate (CA)	-2.500 USD	-1.500 USD	not eligible
= final purchase price	91.050 USD (85.589 EUR)	98.070 USD (92.188 EUR)	101.265 USD (95.192 EUR)

In the segment of the full size luxury automobiles, the conventional BMW 650i Gran Coupé xDrive is the cheapest alternative in terms of the purchase price of the three given models. The following PHEV from Porsche and BEV from Tesla are about more than 10.000 EUR more expensive.

The American market in California indicates again lower purchase prices by all three vehicles. The consumer here experiences quite the opposite ranking of the final purchase price, because the conventional BMW model is after final subsidies, next to the two competitors, the least affordable alternative regarding its final purchase price. The PHEV from the factory of Porsche is a bit more affordable, however, only by roughly 3.000 EUR. The most expensive one from the German market, namely the BEV from Tesla, is on the other hand the cheapest option of the compared models in California, being almost 10.000 EUR cheaper compared with the local price of the ICE BMW.

The 25.000 EUR final purchase price difference between Germany and California for the Tesla model, could be observed as a serious game changer.

3.2.2 Maintenance and service costs

In order to equally research the differences between the maintenance and service costs of the six given vehicles, the vehicle user platform Edmunds.com is going to be used, which indicates the rough yearly expenses of the vehicles in a period of up to 5 years, based on the different experience of the specific model's owners. As stated in the previous chapters, solely the usage period of 3 years is going to be used for this thesis

The car maintenance costs include the common operations linked with owning and using a vehicle for a longer period. To be specific, the most common maintenance costs are related to the change or refill of the vehicle's standard fluids, like the regular engine oil change, engine coolant or wiper fluid refill. Later on, there are other parts of the car that over time face a need for up keeping or renewal; such as the battery, start plugs or minor particles like the windshield wipers, the cabin air filter or the engine air filters. Another matter of the vehicle's regular maintenance process over a period of three years are its wheels, which need to be rotated, balanced and aligned after possible tire exchange. (Henry, 2013) Regular official service visits, demanded by the manufacturer in order to guarantee the car's warranty, are also included in the maintenance costs.

Since the prices of services in Germany and the United States are similar, the distinction between the prices of the two countries is going to be left out in this step of the cost comparison between the selected cars.

3.2.2.1 C-Segment

	BEV *Ford Focus Electric*	**PHEV** *Audi A3 e-tron*	**ICE** *Volkswagen Golf GTI*
Maintenance (3y)	1.073 EUR	2.974 EUR	1 884 EUR
Repairs (3y)	95 EUR	0 EUR	154 EUR
Total	1.174 EUR	2.974 EUR	2.038 EUR

In the comparison of the maintenance and repair costs s of the given automobiles within the compact car segment over the period of three years, the maintenance costs are much higher than the repairs. The reason for this might be the manufacturer's legally guaranteed warranty, usually covering a period of at least two years. This has the consequence of low repair expenditures for the consumer in the initial years of ownership. The regular maintenance of the vehicle is usually not granted within the base model price specification of the three given automobiles of this comparison and therefore the owner carries the befitting costs.

The most cost-demanding vehicle regarding maintenance and repairs of the C-segment is the PHEV from Audi, with an expected expenditure within a three-year ownership close to 3.000 EUR. The reason for this might be the complexity of the dual, ICE and electric engine and therefore a higher need of maintenance. It could also be linked with Audi's, as a premium car manufacturer, higher service costs in general over its rivals within this research. The ICE model from Volkswagen has the second position s with about a third lower maintenance and repair expenditures, and last but not least the Ford's EV rank third with very low estimated expenditure, just slightly over 1.000 EUR over three years of ownership. The cost efficiency of Ford is reasonable due to the less maintenance of the electric engine, consisting of only few moving particles and no need of changing of the engine fluids, as described more detailed in the previous chapter 2.3.1.

3.2.2.2 F – Segment

	BEV *Tesla Model S 90D*	**PHEV** *Porsche Panamera 4 E Hybrid*	**ICE** *BMW 650i Gran Coupé xDrive*
Maintenance (3y)	1.576 EUR	4.335 EUR	4.271 EUR
Repairs (3y)	0 EUR	3.385 EUR	2.850 EUR
Total	1.576 EUR	7.720 EUR	7.121 EUR

In the full size luxury vehicles' segment, we face a significant expected expenditures' difference between both the PHEV from Porsche, ICE vehicle from BMW compared with the BEV from Tesla.

The two first mentioned appear to be financially demanding, as both are scoring above 7.000 EUR in expected maintenance and repairs. However, the fact does not appear shocking, since both are products of luxury car manufacturers equipped with ICEs and with a price tag of more than 90.000 EUR on both the German and Californian markets. Compared to the three times higher purchase price of both the PHEV and ICE models from the C segment, the roughly tripled maintenance and repair costs appear reasonable.

The Tesla on the other hand, has rather similar expected maintenance and repair costs of around 1.500 EUR as the BEV from Ford within the small family car segment. This is due to the sole electric engine; same as in the previously described case of Ford. Such a low cost after three years of usage among such highly priced luxury vehicles is unique and understandably presents certain market advantages over its competitors.

3.2.3 Fuel costs

A major distinction between the three researched propulsion types of vehicles can be made based on their consumption properties. On the one hand, there is the usage of different fuels and on the other hand, we face different fuel consumption management for a particular type of engine.

In this chapter the consumption figures for each particular vehicle model will be studied, based on information from the manufacturers' websites. The combined consumption of both highway and city traffic will be considered. However, 15.000 km has been selected as as the average yearly mileage for this comparison. This specific distance accounts roughly for driving 41 km on average every single day of the year.

Multiplied with the combined consumption of every single researched model per 100 km the needed gasoline and electricity amount for the whole year is going to be determined. In order to transfer this amount into monetary value, the given liter of gasoline and kWh of electricity prices are going to be used for both the American and German market, as stated in the chapter 2.2. Because this research concerns the vehicles' usage period of three years, the annual fuel expenditure is going to be multiplied to correspond with this period.

3.2.3.1 C-Segment

	BEV *Ford Focus Electric*	**PHEV** *Audi A3 e-tron*	**ICE** *Volkswagen Golf GTI*
Consumption of gas or electricity	- 15,4 kWh/100km	1.7 l/100km 11.5 kWh/100km	6,4 l/100km -
Yearly consumption on 15.000 km	- 2310 kWh	255 l 1725 kWh	960 l -
Yearly fuel expenditure in Germany (1,39 EUR/l, 0,14 EUR/kWh)	- 323,40 EUR	354,45 EUR + 241,50 EUR = 595,95 EUR	1.334,40 EUR -
3-year fuel expenditure in Germany	970,20 EUR	1.787,85 EUR	4.003,20 EUR
Yearly fuel expenditure in California (0,63 EUR/l, 0,09 EUR/kWh)	- 207,90 EUR	160,65 EUR + 155,25 EUR = 315,90 EUR	604,80 EUR -
3-year fuel expenditure in California	623,70 EUR	947,70 EUR	1.814,40 EUR

Due to the huge price differences between the German and American markets of electricity and gasoline, where America indicates more than 45% cheaper retail price of gasoline and almost 65% cheaper electricity price, we face tremendous 3-year fuel costs differences on the two markets.

Within the C- segment of the selected vehicles, the BEV Ford is by far the cheapest alternative in terms of fuel expenses, followed by the PHEV from Audi, with about doubled fuel expenditure in Germany and about one third higher in California. Volkswagen's conventional vehicle has by far the highest fuel costs, with about four times bigger expenses in Germany and three times bigger expenses in California, both compared to the least costly BEV from Ford.

3.2.3.2 F – Segment

	BEV *Tesla Model S 90D*	**PHEV** *Porsche Panamera 4 E-hybrid*	**ICE** *BMW 650i Gran Coupé xDrive*
Consumption of gas or electricity	- 18 kWh/100km	2.5 l/100km 15,9 kWh/100km	9,4 l/100km -
Yearly consumption on 15.000 km	- 2700 kWh	375 l 2385 kWh	1.410 l -
Yearly fuel expenditure in Germany (1,39 EUR/l, 0,14 EUR/kWh)	- 378 EUR	521,25 EUR + 333,90 EUR = 855,15 EUR	1,959,90 EUR -
3-year fuel expenditure in Germany	1.134 EUR	2.565,45 EUR	5.879,70 EUR
Yearly fuel expenditure in California	- 243 EUR	236,25 EUR + 214,65 EUR	888,30 EUR -

(0,63 EUR/l, 0,09 EUR/kWh)		= 459,90 EUR	
3-year fuel expenditure in California	729 EUR	1.352,70 EUR	2.664,90 EUR

Logically we find the same ranking of the particular propulsion system within the luxury vehicle segment, in terms of the final fuel expenses on both the American and German markets. That means the BEV from Tesla has the lowest fuel consumption expenditures , followed by the Porsche PHEV whereas the conventional BMW has the least affordable fuel expenses .

However, given to the higher vehicles' performance in this price category, all the particular models indicate higher consumption hand in hand with higher fuel expenditures than their less powerful alternatives from the small family vehicle segment. There is not any major price difference in the framework of the electricity consuming BEV from Tesla, compared with the expenditures from Ford, nevertheless increasingly significant dissimilarities among PHEVs of Porsche and Audi, but mainly among conventional models of Volkswagen and BMW as well.

Comparing the local markets of Germany and California, the fuel expenditure of Tesla is about one third cheaper in California, for the Porsche it is about 50% cheaper, and the conventional BMW shows at the highest fuel price difference of about 65% lower fuel expenditure for the very same vehicle.

3.2.4 Depreciation costs

In the next step of the selected quantitative factors' comparison of the three propulsion system automobiles, the re-sale value is going to be compared after the final period of three whole years of usage, with the similar mileage of around 45.000 km (27.960 miles) for all of the six researched models. This amount corresponds with the average yearly mileage of 15.000 km, considered for the fuel costs calculation in the previous step. Later on, the resale price is going to be estimated based on the average three to five offers of the vehicles from the same production year 2014.

Due to the different initial purchase prices on the German and Californian market, focus is going to be put on the loss of value of the cars to represent a more reasonable and adjusted results. The server used for the estimation of the three-year resale value for Germany is Mobile.de and for California, Cars.com.

3.2.4.1 C –Segment

	BEV *Ford Focus Electric*	**PHEV** *Audi A3 e-tron*	**ICE** *Volkswagen Golf GTI*
Re-sale price Germany (3 years)	23.500 EUR	29.000 EUR	23.000 EUR
Loss value Germany	11.400 EUR (33%)	7.900 EUR (21%)	10.800 EUR (32%)
Re-sale price California (3 years)	12.100 EUR	No values	19.600 EUR
Loss value California	7.926 EUR (40%)	No values	12.558 EUR (42%)

The overall depreciation of the given car models on the American market is surprisingly higher than in the case of Germany, up to 10%difference between the initial purchase and three-year resale price. The most depreciation-resistant vehicle of the three cars in the small vehicle segments is the PHEV Audi, with only 21% of loss value after the usage of three years on the German market. This could, however, not be compared with the situation in the United States, because this model of Audi A3 e-tron did not reach the local market until 2016 and therefore there are no offers of a three-year-old model.

3.2.4.2 F-Segment

	BEV *Tesla Model S 90D*	**PHEV** *Porsche Panamera 4 E-Hybrid*	**ICE** *BMW 650i Gran Coupé xDrive*
Re-sale price Germany (3 years)	65.000 EUR	77.000 EUR	60.000 EUR
Loss value Germany	45.920 EUR (41%)	32.219 EUR (29%)	38.200 EUR (39%)
Re-sale price California (3 years)	55.900 EUR	54.000 EUR	51.900 EUR

Loss value California	29.700 EUR (35%)	38.188 EUR (41%)	43.292 EUR (45%)

Looking at the numbers for the resale value of the expensive full size luxury vehicles compared to the small family car segment, there is the general tendency of slightly higher depreciation.

In terms of the resale prices of the given vehicle after three years on the German market, the biggest value drop is for the BEV from Tesla and the conventional BMW with both about a 40% value reduction compared with the local purchase price. Surprisingly, similar as the small family car segment before, the PHEV model from Porsche is holding up most successfully regarding the preservation of the resale value, with the smallest price drop among the three vehicles at, just around 29%.

On the overseas market on the other hand, the very same vehicles perform rather differently in terms of the actual resale value. The lowest depreciation is experienced by the BEV model from Tesla, with roughly a 35% plunge compared with the initial local purchase price. PHEV from Porsche comes on second place with a drop of 31% in resale value and the last position is held by the conventional BMW, with a 45% resale price drop, indicating the biggest depreciation within this category in both markets.

In this step of the comparison of the total cost of ownership over a period of three years of usage, the final cost countdown of the four researched types of costs for every single of the six compared automobiles will be summarized.

3.2.5 TCO bottom line

3.2.5.1 C – Segment

	BEV *Ford Focus Electric*	**PHEV** *Audi A3 e-tron*	**ICE** *Volkswagen Golf GTI*
Purchase price in: Germany	 34.900 EUR	 36.900 EUR	 33.800 EUR

California	20.026 EUR	33.668 EUR	30.230 EUR
Maintenance and service costs	+ 1.174 EUR	+ 2.974 EUR	+ 2.038 EUR
Fuel costs:			
Germany	+ 970,20 EUR	+ 1.787,85 EUR	+ 4.003,20 EUR
California	+ 623,70 EUR	+ 947,70 EUR	+ 1.814,40 EUR
Re-sale value:			
Germany	- 23.500 EUR	- 29.000 EUR	- 23.000 EUR
California	- 12.100 EUR	no values	- 19.600 EUR
Final TCO:			
Germany	13.544,20 EUR	12.661,85 EUR	16.841,20 EUR
California	9.723,70 EUR	no values	14.482,40 EUR

As is portrayed in the table above, the total cost ranking for a 3-year-period is different in Germany and the state of California for the researched vehicle types in the C car segment.

In Germany, the PHEV Audi A3 e-tron had the lowest total cost of ownership given the selected cost parameters for this comparison, with the TCO of around 12.700 EUR. The BEV Ford Focus Electric came second within this segment with the TCO sum of about 13.500 EUR representing, together with Audi, the overall good result for the two EVs of this category, mainly because of their little depreciation. The ICE Volkswagen Golf GTI scored as the vehicle with the highest TCO sum of about 16.800 EUR.

On the Californian market, the re-sale value of the PHEV from Audi could not be estimated, due to the non-presence on the market in 2014, and therefore it was left out from the comparison. However, the BEV from Ford scored lowest with the costs of only 9.700 EUR over three years. As in Germany, the ICE vehicle from Volkswagen scored t highest within the small family car segment.

3.2.5.2 F – Segment

	BEV *Tesla Model S 90D*	**PHEV** *Porsche Panamera 4 E-Hybrid*	**ICE** *BMW 650i Gran Coupé xDrive*
Purchase price in:			
Germany	110.920 EUR	109.219 EUR	98.200 EUR
California	85.589 EUR	92.188 EUR	95.192 EUR
Maintenance and service costs	+ 1.576 EUR	+ 7.720 EUR	+ 7.121 EUR
Fuel costs:			
Germany	+ 1.134 EUR	+ 2.565,45 EUR	+ 5.879,70 EUR
California	+ 729 EUR	+ 1.352,70 EUR	+ 2.664,90 EUR
Re-sale value:			
Germany	- 65.000 EUR	- 77.000 EUR	- 60.000 EUR
California	- 55.900 EUR	- 54.000 EUR	- 51.900 EUR
Final TCO:			
Germany	48.630 EUR	42.504,45 EUR	51.200,70 EUR
California	31.994 EUR	47.260,70 EUR	53.077,90 EUR

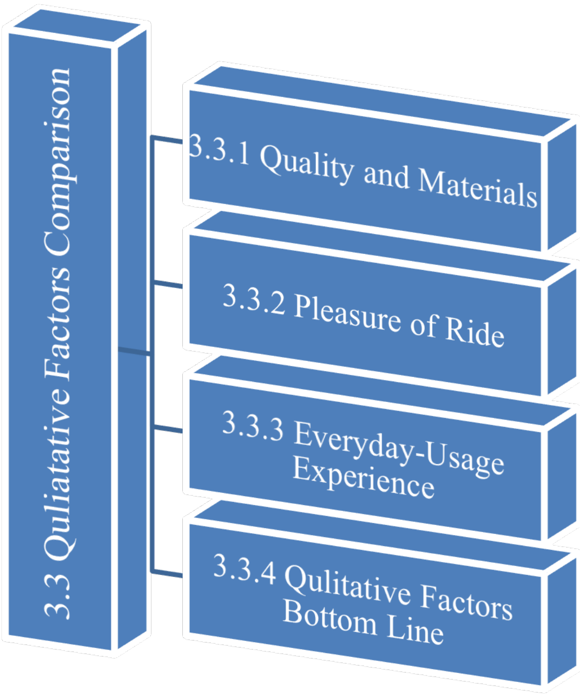
The TCO totals for the given full size luxury models of this comparative research are due to the at least three times higher purchase prices than their C-segment alternatives, almost proportionally at least three times bigger on both the German and Californian markets.

Observing the cost situation in Germany, the PHEV from Porsche is the cheapest alternative with the TCO of about 42.500 EUR over three years, followed by the BEV from Tesla as the second least expensive vehicle with about 48.600 EUR in costs. The conventional luxury model from German BMW is the most expensive vehicle to own with the estimated TCO of about 51.200 EUR after three years.

The TCO comparison in California differs slightly from the situation in Germany. The BEV from Tesla showed the overall lowest TCO of just about 32.000 EUR, within both German and Californian markets in this segment. The PHEV from Porsche ranked second with a much higher final sum of around 47.000 EUR and the BMW with an expected amount of 53.000 EUR in terms of TCO was the far most expensive.

Concluding, the four EVs, either of the BEV or the PHEV type, represent the best scoring alternatives in terms of the quantitative factors of this comparative research among both researched car segments.

3.3 Qualitative factors comparison



Since the different types of vehicles go hand in hand with different values in terms of costs of owning these vehicles, their cost side is not the only point of comparison for the final consumer. The everyday driver wants to know more besides the cost figures and therefore certain qualitative factors of the particular vehicles should as well be taken into consideration.

Each car brand with their particular production model has its unique quality, material but as well driving pleasure specifications. Taken into account the specific distinction of the different propulsion systems within this comparative research, the everyday-usage experience of all the concerned models is going to be considered as well.

Therefore, in terms of this comparison, different qualitative features will be taken into account besides the quantitative factors (particularly TCO) of the given vehicles. The comparison will concern three different categories within the qualitative factors, firstly the quality and materials, followed by the pleasure of ride and last but not least, the final everyday-usage experience.

Important to note is that unlike the primary data based comparison of the previous chapter *3.2. Quantitative Factors – Total Cost of Ownership*, this specific comparison is based on personal impression of the writer himself and therefore should be observed in a more subjective manner.

3.3.1 Quality and materials

The first qualitative concern of the comparison is the particular quality of workmanship and used materials, which might be observed as the first and most superficial qualitative distinction of the different car models.

This particular factor is very much related to the vehicle's manufacturer and therefore we are facing a brand related distinction. The particular propulsion system does not have any significant role in the quality and materials of the given vehicle. However, the car segment is much related to this topic and the particular expectations for both concerned C and F car segment differ substantially.

The six vehicles are therefore going to be compared within their own segment, in the same way as was done in the previous comparison. Each vehicle is going to be rated on the scale from 1 to 3, with the 1 being the worst quality and materials and the 3 the best one. 1 stands for below average, 2 for average and the 3 for above average score.

3.3.1.1 C – Segment

	BEV *Ford Focus Electric*	**PHEV** *Audi A3 e-tron*	**ICE** *Volkswagen Golf GTI*
Quality and material rating	2 (average)	3 (above average)	3 (above average)

Since the American Ford does not belong to the luxurious car manufacturers, it ended up with the rating 2, because of its usage of cheap plastics in the interior and overall not very outstanding quality of craftsmanship of American car manufacturers. Anyhow, it is still classified as average, because many other mainly Asian car producers have still even worse quality and materials.

Both models from Audi and Volkswagen on the other hand receives higher rank regarding the quality of craftsmanship and used materials, with the score of 3 points, regarded as above average. Both particular models stem from the plants of the two brands of the German car concern Volkswagen and due to the similar price tag, they show similarities in terms of this comparison category. Going more into specifics, we face less usage of cheap plastics and even alcantara or leather parts in the cabin.

3.3.1.2 F-segment

	BEV *Tesla Model S 90D*	**PHEV** *Porsche Panamera 4 E-Hybrid*	**ICE** *BMW 650i Gran Coupé xDrive*
Quality and material rating	1 (under average)	3 (above average)	3 (above average)

Within the luxury car segment, the expectations regarding the quality of craftsmanship and used materials rise a lot compared with the previous segment, which is understandable considering the at least tripled purchase price. Therefore, this particular segment comparison is much stricter.

The Tesla, being again the American car, indicates some lack of quality of craftsmanship and in the used materials and as a result receives the score 1, below average. In the basic version without any additional extras, the buyer does not receive any leather seats and the overall impression of the cabin does not seem that premium for this price, if we compare it to its competitors.

Same as for the small family car segment, the German car manufacturers, Porsche and BMW in this case, score an above average rating concerning the quality and materials. The Panamera, however, offers in its basic model only partially leather seats, whereas BMW's 6 series comes with leather as standard.

3.3.2 Pleasure of ride

In the second step of the qualitative factors comparison, the overall pleasure of the ride between the given car models is going to be evaluated and. That means that the vehicle's typical riding specifics are going to be taken into consideration. Since this category is besides the car brands specific for the particular propulsion system feature, the same ranking as in the previous chapter is going to be used, namely the scale from 1 (below average) to 3 (above average).

3.3.2.1 C – Segment

	BEV *Ford Focus Electric*	**PHEV** *Audi A3 e-tron*	**ICE** *Volkswagen Golf GTI*
Pleasure of ride	1 (under average)	2 (average)	3 (above average)

Since the Ford's mainly efficiently oriented electric engine is not really powerful and its acceleration is not anyhow outstanding compared with its competitors, in the comparison category it scores as below average and with the lowest score of all three models. The PHEV from Audi is placed as average with its performance of 204 HP and the VW's sportive tuned Golf GTI with its 230 HP scores the highest with above average performance and most responsive handling.

3.3.2.2 F – Segment

	BEV *Tesla Model S 90D*	**PHEV** *Porsche Panamera 4 E-Hybrid*	**ICE** *BMW 650i Gran Coupé xDrive*
Pleasure of ride	3 (above average)	3 (above average)	3 (above average)

Since all the selected automobiles of the full size luxury segment are due to their high purchase price and tough competition significantly driver-oriented, it is difficult to mark one's riding features as worse than the others. All of the compared models of the segment serve a four-wheel drive system offering a safe and secure driving experience, while being propelled by high performance engines starting at 450 HP, all capable of the acceleration from 0 to 100 km/h between 4 and 5 seconds.

Overall, each one of the three models selected for the full size luxury fastback category is rewarded with an above average and therefore highest ranking in terms of the pleasure of ride.

3.3.3 Everyday-usage experience

The final qualitative feature of the six for the comparison selected car models concerns their everyday-usage experience and, as such, is strongly related to the particular propulsion system of each one. The typical ownership and driving experience linked with riding every of these automobiles is going to be focused on.

3.3.3.1 C – Segment

	BEV *Ford Focus Electric*	**PHEV** *Audi A3 e-tron*	**ICE** *Volkswagen Golf GTI*
Everyday-usage experience	1 (under average)	3 (above average)	2 (average)

Within this parameter, the BEV from Ford faces a strong disadvantage over its competitors due to the single propulsion system of the electric engine, which obviously needs to be charged. This fact makes it very difficult for drivers not living in the immediate distance to any public charger or equipped garage. Moreover, if we consider the necessity to charge on any further distance than 160 km, it makes the BEV appear inconvenient. However, the bright side of the everyday-usage of the BEV from Ford might be the silent and calm electric engine running, especially in the hectic city traffic. Anyhow, due to the poor density of charging infrastructure in most countries nowadays, the Ford ends up with an below average rating, in terms of its everyday-usage experience.

The totally opposite example is the conventional model from Volkswagen, which is capable of a long range due to the size of the conventional fuel tank that can be refilled at any gas station, the density of which is in every country very convenient. The only disadvantage might be the louder running of the conventional engine and therefore the Golf GTI scores an average rating regarding the everyday-usage experience.

The PHEV from Audi offers the best of both worlds, in terms of the everyday-usage experience , due to its wider range because of the possession of the ICE, that comes into game after the vehicle's battery runs out of electricity. The electric engine on the other hand provides the fluent, calm and silent driving experience in everyday city traffic or on any other shorter distances. For these reasons, the A3 e-tron scores an above average rating here and represents the winner in this category within the small family car segment.

3.3.3.2 F – Segment

	BEV *Tesla Model S 90D*	**PHEV** *Porsche Panamera 4 E-Hybrid*	**ICE** *BMW 650i Gran Coupé xDrive*
Everyday-usage experience	2 (average)	3 (above average)	2 (average)

The ranking of the BEV from Tesla indicates an improvement in terms of everyday-usage experience from its equivalent from the small family car segment, due to the with any conventional car comparable range. The silent engine running later on can be mentioned as another positive aspect. However, the inconvenient charging unit finally positions the Model S with an average rating within this category.

The selected conventional model from BMW performs very similarly, due to its propulsion system and the usage experience features mentioned by its conventional equivalent from the C – segment. Therefore, the 650i Gran Coupé xDrive scores identically, average 2,

Finally, no major changes occur for the PHEV model from the F car segment from the workshop of Porsche, compared to its equivalent propulsion system model from the small family car category. Due to the same advantages of the possession of both conventional and electric engines, the Panamera 4 E-Hybrid scores above average regarding everyday-usage experience.

3.3.4 Qualitative factors bottom line

3.3.4.1 C – Segment

	BEV *Ford Focus Electric*	**PHEV** *Audi A3 e-tron*	**ICE** *Volkswagen Golf GTI*
Quality and materials	2 (average)	3 (above average)	3 (above average)
Pleasure of ride	1 (under average)	2 (average)	3 (above average)
Everyday-usage experience	1 (under average)	3 (above average)	2 (average)
Final rating	1,33	2,67	2,67

The final ratings within the qualitative factors of the three compared vehicles are dominated by the ICE from Volkswagen and the PHEV from Audi, where due to their contradictory advantages and disadvantages both scored a final rating of 2,67, that can be understood as an above average evaluation. The BEV from Ford scored far behind the first two mentioned models and ends with a 1,33 rating, equivalent to a below average qualitative factors' score.

3.3.4.2 F – Segment

	BEV *Tesla Model S 90D*	**PHEV** *Porsche Panamera 4 E-Hybrid*	**ICE** *BMW 650i Gran Coupé xDrive*
Quality and materials	1 (under average)	3 (above average)	3 (above average)
Pleasure of ride	3 (above average)	3 (above average)	3 (above average)
Everyday-usage experience	2 (under average)	3 (above average)	2 (above average)
Final rating	2,00	3,00	2,67

In terms of the comparison of the vehicle-specific qualitative factors among the selected full size luxury car models, the overall winner was the PHEV from Porsche scoring with the best possible grade in all categories. The conventional BMW came second, due to a worse rating in the everyday-usage experience (2,67), which can however still be observed as an above average rating. Finally, the BEV from Tesla, which indicated a serious lack in the category quality and materials compared with its competitors, as well as a minor lack in the everyday-usage experience, was ranked last. The Models S for that reasons scored a rating of 2,00, classified as average.

4. Results

In this chapter, the results from the previous methodical chapters are going to be highlighted in a unified form and from these a particular final statement and result will be issued. For this purpose, the results from both the quantitative and qualitative comparative research are going to be considered. The previous distinction between the two given car segments is going to be respected, after which a conclusion is going to be derived.

The two compared units will be the total cost of ownership after the usage of the vehicle for three years, as well as the particular vehicles' qualitative features (both researched in detail in the chapters 3.2 and 3.3).

The results from the quantitative and qualitative features' comparison will be finally compared with the results of an online questionnaire, focusing on understanding the public perception of electric vehicles nowadays.

4.1 C – Segment

	BEV *Ford Focus Electric*	**PHEV** *Audi A3 e-tron*	**ICE** *Golf GTI*
Final TCO in Germany California	 13.544,20 EUR 9.723,70 EUR	 12.661,85 EUR no values	 16.841,20 EUR 14.482,40 EUR
Final qualitative score	1,33 (below average)	2,67 (above average)	2,67 (above average)

Considering the price situation on the German market within the small family vehicle segment, the PHEV Audi A3 e -tron scored the lowest score in terms of TCO, combined with an above average qualitative features' score . These two facts make this Audi the final winner of this research in Germany within C – car segment.

The ICE vehicle Volkswagen GTI achieved the second rank on the German market , costing on the one hand about more than 4.000 EUR more than Audi, offering on the other hand the very same qualitative features' score of above average.

Even though the BEV Ford Focus Electric is about more than 3.000 EUR cheaper than the Golf GTI, in terms of the 3-year TCO, its qualitative factors' score is below average. For this purpose, we observe the Focus Electric as the loser within its segment in Germany.

Because of the non-presence of the PHEV Audi A3 e-tron until the year 2016 in the United States, this car could not be considered on the Californian market in the research. Consequently, from the comparative research on the overseas market remains the duel between the conventional Golf GTI and BEV Focus Electric. In spite of the much higher score of the Golf GTI with regards to the qualitative research, the Focus Electric outperforms the first mentioned one with a TCO of about 5.000 EUR (33%), mainly due to the generous local incentive politics). This fact makes the BEV the final winner on the Californian market within this research.

4.2 F – Segment

	BEV *Tesla Model S 90D*	**PHEV** *Porsche Panamera 4 E-Hybrid*	**ICE** *BMW 650i Gran Coupé xDrive*
Final TCO in			
Germany	48.630 EUR	42.504,45 EUR	51.200,70 EUR
California	31.994 EUR	47.260,70 EUR	53.077,90 EUR
Final qualitative score	2,00 (average)	3,00 (above average)	2,67 (above average)

Same as in the small family car category, considering the German market price situation again the PHEV from the workshop of Porsche represents the best deal from this category's vehicles, due to the lowest TCO and overall excellent qualitative features score . The Panamera 4 E-Hybrid is therefore the overall winner of the F- segment on the German market.

In the duel between the BEV from Tesla and ICE car from BMW it is harder to distinguish the winner, because of their very similar TCO scores, differing only by the Model S 90D being 3.000 EUR cheaper . Nevertheless, after the consideration of both models' qualitative features, the conventional BMW 650i Gran Coupé xDrive outperforms the Tesla Model S 90D with its above average rating. Therefore, the conventional BMW has the second position and leaves the BEV Tesla behind in Germany, as the loser in terms of this research.

Following the Californian price situation, the BEV model from Tesla is the absolute winner, again due to the generous local incentive politics for EVs, with a TCO score of about 15.000 EUR less than the PHEV from Porsche and even about 21.000 EUR cheaper than the conventional BMW. These cost differences make the Tesla, even besides the notwithstanding average qualitative features' score, the final winner of this research in California.

The PHEV from Porsche comes second in California, due to its about 6.000 EUR lower TCO in combination with its excellent qualitative features' ranking. The conventional model from BMW on the other hand comes out as the loser, due to its highest TCO score and slightly lower, but still above average rated score of qualitative features.

4.3 Survey

It appears clear that there is market potential for electric vehicle, since both researched personal vehicle segments on the German and Californian markets from the previous chapters *3.2 Quantitative Factors – Total Cost of Ownership* and *3.3 Qualitative Factors Comparison* were dominated by the plug-in hybrid technology vehicles, namely the Audi A3 e-tron and Porsche Panamera 4 E-Hybrid, or even the battery electric vehicle Tesla Model S 90D. However, in reality it is still not common to face that many electric vehicles in regular everyday traffic in the majority of any cities.

In order to find out, how the new EV trend on the automobile market is perceived by the public, particularly individual persons, the next part of this research sets as its aim to find out more about this matter.

For this purpose, an online questionnaire was constructed, consisting of ten different questions concerning various topics touched throughout the processing of this thesis and perceptions of electric vehicles nowadays. Each particular question offered from two to five multiple-choice answers, of which only one could be chosen and the respondent was left without the option to skip any of the questions.

The questions for the questionnaire are related to the so far performed and researched topics from the chapters of this thesis. Therefore, these facts are going to be compared with the answers from the panel of respondents.

The answers to this survey were collected through two main channels, the first one being the social media, in particular Facebook student groups and the second and more influential one, direct emails to the students of the University of Applied Science Novia in Finnish cities Turku, Vaasa and Raseborg. Important to mention is that the respondents' panel represented mainly the perception and awareness of students younger than 25 years of age and not quite that much covering the older population.

The survey was open from the 3rd of March 2017 until the 1st of April 2017 on a web platform designed for online questionnaires called SurveyMonkey.com. This one offered an URL link for easy and versatile sharing of the online questionnaire among different participants. Both main response sources led then, in the end, to a total number of 164 respondents. The complete version of the survey with its results is located in chapter *8. Appendix* of this thesis.

4.3.1 1st question

The very first question aimed at categorization of the respondents, namely the age group of each single participant.

The majority, 82% of the respondents were between 18 and 25 years of age, which is understandable due to the selected source channels consisting mainly of students. The second most represented age group was between 26 and 35 years of age, solely 16%. The least represented age group was between 36 and 50 years of age with only 2%.

4.3.2 2nd question

The second question was asking the respondent about his or her previous driving experience in any EV, covering both PHEVs and BEVs and had the purpose of determining whether there is an overall favorable possibility to try the EVs out.

The result indicated that the vast majority (88%) had no experience whatsoever of driving an EV,. Only 12% had driven an EV.

This fact indicates the overall new character of the particular market and resulting non-ubiquity of electric vehicles nowadays. As a conclusion, the public is therefore not sufficiently offered the possibility to try out the feeling of an EV ride.

4.3.3 3rd question

The third question in the questionnaire concerned the awareness of different EV models on the current market. This question is interconnected with the chapter *2.4 EV buying options in 2017* and *3.1 Data*. From these listed, it was experienced that the current market offer is pretty rich and serving a variety of buying options.

The majority (60%) of the participants marked here as their choice the answer of knowing between 1 and 3 different EV models on the current market. 15% answered that they were aware of 6 EV models or more.13% gave the answer of knowing 0 current EV models and last but not least, 12 % of the respondents can think of 4 to 5 electric car market offers.

The conclusion of this is then that the public awareness of the EV models among the respondents is quite little, due to a 60% majority of respondents knowing only 1 to 3 models. Considering the fact that almost every major car manufacturer nowadays includes in their product portfolio at least one EV model, the public awareness of the market remains not fully discovered, also considering that solely 15% of respondents can think of at least 6 different EV models.

4.3.4 4th question

The next, fourth question concerned the awareness of the maintenance and service costs of the EVs, which was in detail discussed in the chapter *2.3.1 Advantages of electric motor cars over combustion engine vehicles*. From that, one clear advantage was the obvious benefit of low maintenance needed, mainly in the case of BEVs.

Proceeding to the outcomes of this question, 45% of the respondents answered that they would link the EVs with low maintenance and service costs, 37% marked the answer “I don’t know” and only 18% would not link the EVs with the low particular costs.

The conclusion of this answer leads to the assumption, that the obvious advantage of low maintenance and service costs is publicly a rather well known fact. However, only represented by less than the majority of respondents (45%), who are skilled about this particular advantage of electric vehicles. Therefore, there are certain reservations regarding how well the public knows the benefits of e-mobility, a message that should be delivered more clearly.

4.3.5 5th question

The 5th question concerned the perception of the EV retail purchase prices, as described in the chapter *3.2.1 Purchase costs,* observing this situation on both the Californian and German markets. The results from this chapter were that the EVs appear at least in Germany as representing the European market, rather more expensive than competing conventional models, due to the poor incentive policies.

The vast majority (58% of respondents) observes the current EV market offers as not affordable, 25% do not know and only 17% think of them as affordable.

The electric vehicles are nowadays observed rather as luxury goods among the public, which is also a fact in reality. The conventional cars can still be purchased cheaper, at least if we focus on the price situation in Europe, where the respondents stem from.

4.3.6 6th question

Proceeding to the sixth question of the survey, it inquired about the participants’ consideration of the environmental impact when selecting vehicle. This question was linked with the chapter *2.3.1 Advantages of electric motor cars over combustion engine vehicles*, where the advantage of zero local tail-pipe emissions of EVs was determined and therefore their beneficial environmental impact.

Whereas a slight majority (53%) considers the environmental impact of their personal transportation type, 37% do not consider this particular one at all and 10% remained indecisive.

After observing these figures, it can be stated that the environmental impact plays a certain role in the personal vehicle selection process among a fragment of the asked public. This particular benefit of EVs could thus speak in favor for them for the majority of asked individuals, considering the environmental impact in their personal vehicle selection process.

4.3.7 7th question

In the seventh question, the respondents were asked if they have considered or would consider an EV in their selection process of a new vehicle. Therefore, it represents a connection to the chapter *3. Methodology,* which compares the three personal vehicle-buying options given their different propulsion system.

The respondent panel answered this question later on, with 50% considering the EV throughout their car selection process, 39% stated the exact opposite and 11% remained indecisive in this question.

The result of this question indicates therefore a certain openness for the EV by the public nowadays, due to 50% admitting the consideration of an EV in their buying decision process. An interest for EVs nowadays is therefore obvious.

4.3.8 8th question

The eight question tried to determine the biggest concern of the respondents regarding purchasing an electric vehicle and gave the them a choice of five answers. This question is therefore narrowly linked with the chapter *2.3.2 Barriers and challenges for EVs,* discussing the suggested problems while using an EV for personal transportation.

The responses were divided among many different answers here, but the higher purchase price still represented the biggest concern their with 35% of votes. The second biggest concern was the poor situation of charging infrastructure in the respondents' living area with 31% and the third biggest concern was the lower one-charge range with 16% of votes. 10% stated their concern to be other than the survey's options and named here reasons like battery performance in colder climates or maintenance in general. Only 8% indicated no concerns when purchasing an electric vehicle.

The outcome of these answers indicates the higher initial purchase price as the main concern by more than a third of there spondents. Nevertheless, the purchase price is not the only concern of owning an EV and battery related problems of this type of personal transportation still stand out as well.

4.3.9 9th question

The ninth question of the survey follows up on the previous one and asks the participant about the final fact that would convince him or her to purchase any EV. For this reason, we can relate this inquiry, same as in the question before, to the chapter *2.3.2 Barriers and challenges for EVs.*

For almost the half of respondents (48%), the ultimate game changer would be amore affordable initial purchase price. 23% replied a more convenient charging infrastructure in their living area () and 12% chose the option “other than optional ones” (). The statements in the last category were too heterogeneous, making it impossible to sum up the most common other reason. 6% then stated that none of the optional answers would convince them to buy an EV.

The responds again confirmed the fact, that the major concern of EVs is their purchase price, perceived as not that affordable and that the respondents might feel more addressed if the EV market experienced some major price reductions. This would therefore be a major reason for seeing more EVs in today’s traffic.

4.3.10 10th question

The very last part of the questionnaire was a general question, namely if the respondents consider the EVs as the future of the global car industry. 75% chose “yes” as their answer, 19% remained without any opinion here and 6% chose “no” as their answer.

These results showed the overall potential of the EVs besides other conventional cars among the public and fostered the overall answer for the research question of this thesis. The EV car market as a newly developing area has the potential for growth in upcoming years and it might with time present serious competition to the, over 100 years remaining, mainstream conventional car industry.

5. Discussion

The thesis once and for all clarified the real figures of owning six different, either BEV or PHEV or ICE, car models within the price conditions of one European and one American market in early 2017.

Since this thesis set as its aim to find out the real consumer experience of owning an EV within today's price conditions, the six given car models were put into real test. The comparison of certain prices is, however, due to the tremendous amount of local markets too excessive and had to be limited to only two markets. To present as real and useful a picture as possible, two major automobile markets on the two continents were considered, namely one in Europe and one in North America, both with the highest local sales volumes within the continental territory.

The car models' selection for the comparative research was performed based on the two mentioned car segments, in order to cover at least two different target groups of consumers interested in distinguished quality features of their automobiles. The first one, the small family vehicle segment, with the highest percentage of sales volume was chosen as it represents the most comprehensive segment on the personal vehicle markets. The second car class targeted the higher-end consumer aiming for full size luxury vehicle. The competing models within the same class were naturally focused on similar space dimensions, performance but a comparable purchase price as well, in order to create the fairest comparison conditions for each single model. The aim was to underline the differences linked with the possession of given propulsion systems.

The economy of owning the three propulsion system car models was divided into four major parameters, namely the purchase costs, maintenance and service costs, fuel costs and finally, their depreciation costs. All mentioned categories were examined in a most detailed manner, including the local incentive and tax policies as well as real local brand-new and used market figures. These were the vehicles' typical features, which indicated the different cost situation between the three propulsion systems in a most distinguished manner. Insurance costs has been neglected, however, because of same prices within the same car segment and class and they are anyhow not relevant to the specific type of vehicle's propulsion system. Therefore, the insurance cost comparison was for this comparative research observed as rather incompatible.

Since the consumer's vehicle selection process does not only cover the cost side of the automobiles, the chosen models were put into test regarding their unique qualitative features in the next step as well. In this step three different comparison dimensions were considered. Namely, the overall built quality and used materials along with the vehicle's offer of pleasure on ride with its typical driving features and finally the final consumer's expected everyday usage experience. This one was based mainly on the to the propulsion system's typical secondary features and everyday activities. These three comparison categories aimed to cover most of the heterogeneous vehicles' qualitative features, as a supplementary essence to the previously researched cost situation.

In order to make this thesis more comprehensive, its last step was to reflect the public awareness of the relatively newly developed EV market. The online survey set as its aim to reflect the perception of the EVs within a fragment of today's society and resulted in finding answers on a variety of related topics. The main message delivered from the survey was an overall openness of the people towards the electric vehicles, however, struggling mainly due to the higher purchase prices compared with the conventional competitors.

6. Conclusion

The aim of this thesis was in the beginning said to be the enhancement of the typical buyer's decision process of a new vehicle for his personal transportation in the in recent years newly developed market area of electric vehicles. The electric engine mechanism suitable for personal transportation is, however, a long existing technology, which stood at the very beginning of the car industry itself, as could be read in the very first chapter. Since the public awareness about different advantages, but barriers as well, of this type of transportation is unfortunately rather little, due to the short market presence, the thesis focused on enlightening the situation in many diverse topic areas. Nevertheless, the introduction still left hanging in the air the question, what is in the reality going to be the future of the e-mobility in general in the upcoming years or decades.

In chapter number two was described the necessary background information speaking for the positive and negative factors and different situations all over the globe in terms of the electric personal transportation. This part of the research indicated the particular more or less favorable countries for the usage of EVs in their traffic, mainly regarding heterogeneous cost situations and public incentives. From the local market conditions resulted then the overall distribution of the EVs among single countries, indicating higher EV car stocks on the soil of territories with generous incentive policies.

The methodical third part of the thesis focused on putting the background information about the topic into real life practice. Following this aim, different propulsion technologies used within the market models of 2017 were compared based on their owning costs, on two markets and among two segments, continuing with the comparison of their individual quality properties and propulsion system related features. From this, we experienced the favorable situation mainly for the PHEVs in the majority of the cases, no matter within which of the researched markets or segments. These indicated for the consumer interesting local price situations and other EV related benefits, compared with the in the research included ICE technology vehicles.

Further, the thesis' survey put into test the public awareness of the electric vehicle market and indicated interestingly the overall openness for this newly developed car market among a majority of respondents. However, interest is limited by the struggles of its current time, namely the current charging infrastructure situation and more importantly, slightly higher purchase prices than their competing conventional models.

Thesis question:

"What are the total costs of ownership of an electric vehicle over a conventional automobile and how is their consumer usage experience in everyday traffic situations? Is then the electric vehicle in terms of these factors the future?"

Concluding, in order to find out the answer to the question stated in the introduction of the thesis, if the electric vehicles are the future of the global car market, throughout the thesis the beneficial potential of the EVs in general was experienced and confirmed. The PHEV or BEV models ranked usually as winners against their conventional competitors at full length of the diverse comparison categories. This fact was later on confirmed by the majority of participants of the thesis's survey itself, where exactly three thirds were in favor of this hypothesis, indicating that they consider it as the future of the global car industry.

Finally, my personal suggestion for other specialists in terms of any further research covering the area of e-mobility and the usage of electric vehicles for personal traffic would concern the research of future developments of the EV market. Since this thesis indicated the profitability of owning a certain type of an EV and their lucrative proposition for the current market, the question that appears is to which extent exactly are they going to be spread in the upcoming years and how long is it going to take the EVs to represent a substantial share of the car stock in particular countries. Obviously taking into consideration upcoming incentive programs in new countries and other for them more or less favorable local conditions.

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8. Appendix – survey

1) Age group:
   a) 18- 25 (82.00%)
   b) 26-35 (16.00%)
   c) 36-50 (2.00%)
   d) 51 onwards (0.00%)
2) Have you ever driven an electric vehicle? (Battery electric, Plug-In Hybrid)
   a) Yes (12%)
   b) No (88%)
3) How many EV models from current market can you think of?
   a) 0 (13.00%)
   b) 1-3 (60.00%)
   c) 4-5 (12.00%)
   d) 6 onwards (15.00%)
4) Would you consider the EVs linked with low maintenance and service costs?
   a) Yes (45%)
   b) No (18%)
   c) I don't know (37%)
5) Do you perceive the current EV market offers as affordable?
   a) Yes (17%)
   b) No (58%)
   c) I don't know (25%)
6) Do you consider the environmental impact of the car while selecting your personal vehicle?
   a) Yes (53%)
   b) No (37%)
   c) I don't know (10%)

7) Would you consider / have you considered an EV within your new car selection process?

   a) Yes (50%)
   b) No (39%)
   c) I don't know (11%)

8) What would be your biggest concern while purchasing an EV?

   a) Higher purchase price (35%)
   b) Poor situation of the charging infrastructure in your area (31%)
   c) Limited one-charge range (16%)
   d) None of these (8%)
   e) Other (10%)

9) Which fact would convince you to buy an EV as your next car?

   a) Affordable purchase price (48%)
   b) Convenient charging infrastructure in your area (23%)
   c) Sufficient one-charge range (11%)
   d) None of these (6%)
   e) Other (12%)

10) Do you consider the EVs as the future of the global car industry?

   a) Yes (75%)
   b) No (6%)
   c) I don't know (19%)