UNIVERSITY OF LJUBLJANA
FACULTY OF ECONOMICS

TEAM MASTER'S THESIS

# ANALYSIS OF EUROPEAN MARKET DEMAND FOR ELECTRICAL VEHICLES

Ljubljana, March 2018

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# AUTHORSHIP STATEMENT

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## LIST OF ABBREVIATIONS

**USA** – United States of America
**EU** – European Union
**OEM** – Original equipment manufacturers
**EEC** – European Economic Community
**R&D** – Research and Development
**CRM** – Customer relationship management
**SUV** – Sport utility vehicle
**GDP** – Gross domestic product
**EC** – European Commission
**EFTA** – The European Free Trade Association
**UN** – United Nations
**EV** – Electric vehicles
**BEV** – Battery electric vehicles
**PHEV** – Plug-in hybrid vehicles
**IEA** – International Energy Agency
**EVI** – Electric Vehicles Initiative
**ICEV** – Internal combustion engine vehicle
**REEV** – Range-extended electric vehicles
**$CO_2$** – Carbon dioxide
**CAGR** – Compound annual growth rate
**UK** – United Kingdom
**VW** – Volkswagen
**AFV** – Alternative fuel vehicle
**LPGV** – Liquefied petroleum gas vehicles
**NGV** – Natural gas vehicles
**GHG** – Greenhouse gases
**DECC** – The Department of Energy and Climate Change
**LCO** – Lithium Cobalt Oxide
**LMO** – Lithium Manganese Oxide
**NMC** – Lithium Nickel Manganese Cobalt Oxide
**LFP** – Lithium Iron Phosphate
**NCA** – Lithium Nickel Cobalt Aluminum Oxide
**LTO** – Lithium Titanate
**AC** –Alternating current
**DC** – Direct current

# INTRODUCTION

The European Union's (hereinafter: EU) growth in the last years together with government support policies, falling battery costs and economies of scale are guiding the EU car market to, in less than two decades, a scenario were all new cars sold will be 100% electric vehicles (hereinafter: EV). By reaching 50% of the market in 2029, 50 million EV units are expected to be sold (Yang, 2010). These numbers are supported by myriad subsidy programs, including tax incentives and financing supports to auto manufacturers, grants for research and development, construction of support facilities, incentives for car purchases, and government procurement programs (Ichinohe & Endo, 2006; Doucette & McCulloch, 2011).

EU economic transformation over the past years, since 2009 public debt crisis, has being extraordinary even though creating opposite economic situations between Southern Europe and Central and Northern Europe: a higher unemployment rate and public debt in the Mediterranean countries, and a lower unemployment rate with higher Gross domestic product (hereinafter: GDP) growth rate in the Eastern and in Northern member countries. In 2015, public debt in the European Union was 85% of GDP, with disparities between the lowest rate, Estonia with 9.7%, and the highest, Greece with 176% (Srivastava, Annabathina & Kamalasadan, 2010).

Despite the growing disparate between the EU countries, if considered as a single country, EU is still the second largest economy in the world in nominal terms and according to purchasing power parity. The EU's GDP was estimated to be €16.5 trillion (nominal) in 2016 according to the International Monetary Fund, representing 22.8% of nominal global GDP. The euro is used by 19 of its 28 members and in six other European countries, officially or de facto, is the second largest reserve currency as well as the second most traded currency in the world after the United States dollar (Aristovnik & Čeč, 2010).

The International Monetary Fund recently raised its growth forecasts for the Eurozone for 2017 and 2018. Business confidence in Europe, as measured by Eurostat's economic-sentiment index, is at its highest point in over a decade. Unemployment stands at 7.7%, its lowest level since 2008. Since mid-2015, output in the continent has expanded by 2% per year—faster than United States' 1.7% yearly growth rate over the same period.

In the described EU economy, the analyze of the vehicle market in previous years shows that EU countries have already adopted some plans in order to stimulate domestic demand for electric vehicles, but results were not satisfactory. Some sceptics say that EU is not yet ready for the EV expansion, while others predict that in a few years it will become one of the biggest EV markets in the globe. Who is right?

Many companies are trying to assess EU further growth of the EVs in order to seize the opportunity in the emerging market. The biggest challenges for these firms entering the EU market are its size, heterogeneity, dynamism, as well as socio-cultural and institutional differences. We have to take into account that there are huge differences between countries inside EU. The Southern Europe countries are far less developed than the Central and Northern ones, and differences between rural and urban areas are still considerable. All these differences are also reflected in the EV market.

The main purpose of this thesis is to gain an in-depth and comprehensive understanding of the EU EV market, researching the relationships between current and future sales, EV technologies, governmental polices and end-user impressions, deploying an overall analyze of the EU EV market potential and further development possibilities. Throughout the analysis of market trends, as well as EV manufactures, we try to find out what is the potential of the market now and the upcoming future. The focus of our attention will be on (1) analyzing European current automotive industry; (2) challenges and opportunities for the EV industry inside EU and globally; (3) how EVs technology will affect EU's EV market demand in the next decades; (4) analysis of available sources and literature; (5) end-user research conducted via questionnaire applying online survey, in-depth interviews with experts from electric automotive industry and EV test-drives. The research questions are: Which factors will most influence the future demand for battery electric vehicles? In what way will these factors influence the demand for battery electric vehicles?

The theoretical part of the thesis will be based on the review and subsequent analysis of the academic and professional literature on the relevant topics and concepts. The majority of sources and literature for the thesis were found on academic web-databases (e.g. Proquest Direct, Emerald, Science Direct, Sage). Qualitative and quantitative research will be firstly based on an online survey, focusing on customers commuting habits and vehicle buying decision factors, secondly semi-structured in-depth interviews where survey results were further debated. The third part of qualitative research are field interviews done at the EV test drive event and the final forth analysis include our own EV test drive experiences.

In the first chapter of the thesis, we present the main characteristics of the European automotive industry as a whole and EV overview of the EV industry, where we introduce general information about the global market and key trends related to EVs.  In the second chapter, we provide theory and key concepts of EV technologies from the technical and economic points of view that are relevant to the scope of our thesis. In the third chapter, we analyze data collected through our research work including the four already described data collecting approaches. Based on the information gathered through the market analysis we end our master thesis with the fourth and final chapter, listing the upcoming challenges for carmakers in the EU EV market, accompanied by required resources and capabilities needed for implementation.

# 1 EUROPEAN PASSENGER VEHICLE MARKET

European battery electric vehicle market is the main topic of this thesis, where it is described past and future demand for this type of vehicle, its competitor models and factors influencing this demand. In order to gain a base point to analyze the future demand for battery electric vehicles demand, we need first to recognize the importance of the automotive industry in Europe and understand the past development of this market.

This chapter starts with classification of vehicle types, where common automobile categories and acronyms are displayed and market analyses, were sales of each vehicle type is shown during the years.

## 1.1 Classification of electric vehicle types

Electric vehicles (EVs) are an imaginative impetus innovation that can diminish ozone harming substance outflows from the vehicle divisions and additionally local pollution emanations (Chan, 2007; Bradley & Frank, 2009). Right now, most automobiles worldwide are fueled by internal combustion engines (ICEVs), while EVs are completely or halfway controlled by electric engines. Here, we will use the expression "EV" for plug-in electric vehicles, i.e. automobiles that store the electric energy for drive in a battery that can be charged again by means of an outside power supply (Chau, Wong, & Chan, 1999). Along these lines, EVs in the accompanying battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and range-extended electric vehicles (REEVs).

EVs were initially imagined over 150 years prior, however the automobile market has stayed ruled by ICEV models. A few endeavors to re-acquaint EVs to the main markets after the oil-value stuns in the 1970s fizzled (Chan, 2007). Nonetheless, the circumstance today is singular once with continually rising fuel costs and expanding natural awareness mindfulness.

### 1.1.1 The different types of electric vehicles

Buyers have many options between a several distinct sorts of hybrids, pure battery electric vehicles and vehicles powered by fuel cells. In any case, understanding the essential contrasts between these innovations, and their focal points and drawbacks, is not generally clear for customers. Auto-makers by now utilize five primary kinds of EV technical possibilities. These technologies change in the path the on-board power battery, recharge possibilities and the way the inward electric engine and petrol engine work together. The blend between battery capacities, charging options and technology complexity provides end users with a big selection of choices in regards to automobile ranges, refueling choices and cost. The accompanying segments depict every one of the principle electric vehicle and hybrid technology innovation available, how they work, and their related points of interest and weaknesses. Traditional vehicles utilize non-renewable energy sources (e.g. petroleum or diesel) to control an internal combustion motor. While driving, they create noise and fumes outflows (pollution). Customary vehicles are wasteful, just around 18 to 25 % of the energy accessible from the fuel that is utilized to move it on the streets. Such automobiles have been mass-delivered for over a century, and a generous helpful framework including vehicle assembling, repair and refueling stations has as needed be been produced (European Environment Agency, 2016).

### 1.1.2 Hybrid electric vehicles (HEVs)

HEVs have been commercially available for more than 15 years. They combine an internal combustion engine and an electric motor that assists the conventional engine during, for example, vehicle acceleration. The battery of an HEV cannot be charged from the grid but is typically charged during regenerative braking or while the vehicle is coasting. As an HEV is predominantly powered by its conventional engine, hybridization can be regarded as a technology added to conventional vehicles with the aim of increasing fuel efficiency, reducing pollutant and CO emissions, rather than being an entirely separate type of vehicle.

HEVs typically have lower fuel consumption and exhaust emissions than conventional technologies. The more sophisticated the hybrid system, the greater the potential to lower emissions. Many different types and models of HEVs exist, ranging from 'micro-HEVs', whose only fuel-saving feature is regenerative braking and where the electric engine on its own is not capable of powering the vehicle, through to 'full HEVs', which are able to drive small distances in electric-only mode. The ways in which the conventional engine and electric motor are joined can also differ across different HEV models. Parallel hybrids employ an electric motor and a combustion engine that are connected so they power the vehicle together. Series-parallel hybrids, or power-split hybrids, combine power from the conventional and electric motors to drive the wheels but, unlike a parallel hybrid, these vehicles can be driven from the battery alone, although typically only at low speeds for short distances. Their configuration can allow the vehicle to be powered 100 % from the conventional engine, 100 % from the electric motor or in any intermediate ratio, e.g. 30 % electric motor and 70 % combustion engine. Batteries for hybrids, both plug-in and nonplug-in, tend to be more expensive than the ones for battery electric vehicles in terms of price per kWh. This higher price is mainly because hybrid vehicles require greater power-to-energy performance. Indicative electric driving range: 0–10 km (European Environment Agency, 2016).

### 1.1.3 Plug-in hybrid electric vehicles (PHEVs)

PHEVs are fueled by an electric engine and an ICE intended to work either together or independently. The on-board battery can be charged from the electric matrix, and the ICE backings the electric engine when higher working force is required or when the battery's condition of charge is low. The electric driving range is littler than BEVs, as the batteries have a tendency to have littler sizes. The batteries can have less capacity stockpiling limit since they depend less on electrical power alone to control the automobile. The battery limit in PHEVs is composed more for short outings in the city or driving, for instance, than for long time trips. In any case, with respect to REEVs, the ignition motor permits an any longer general driving reach possibility. Batteries for PHEVs have a tendency to be costlier than for BEVs as far as cost per kWh. This higher cost is predominantly in light of the fact that PHEVs require greater power-to-energy performance. The ecological effect of PHEVs relies upon their operation mode. Running only in the electric engine brings about zero pollution discharges however depending just on the customary motor can prompt fuel utilization and outflow levels equivalent to or higher than those of traditional vehicles of a comparable size, on the grounds that the extra batteries increment the vehicle mass. Also, with respect to BEVs, the general ecological execution of PHEVs depends incredibly on the offer of renewables in the electrical power grid matrix. PHEVs can be monetarily alluring for drivers if the power utilized is less expensive than the petroleum or diesel that would have generally been utilized. Demonstrative electric driving range: 20– 85 km. (European Environment Agency, 2016; Kelly, MacDonald, & Keoleianm, 2012).

### 1.1.4 Range-extended electric vehicles (REEVs)

REEVs have a serial hybrid arrangement in which their ICE has no immediate connect to the wheels. Rather the ICE goes about as a power generator and is utilized to power the electric engine or energize the battery when it is low. The on-board battery can likewise be charged from the network. The electric engine is in this manner exclusively in charge of straightforwardly driving the vehicle. One preferred standpoint of REEVs is that the regular motor can be little, as it is required just when the vehicle surpasses its electric driving extent. This diminishes the vehicle's weight. Concerning a PHEV, a REEV over comes the issue of a small driving extent range related with BEVs on the grounds that it can be powered at ordinary filling stations. Characteristic electric driving range: 70– 145 km (European Environment Agency, 2016).

### 1.1.5 Fuel cell electric vehicles (FCEVs)

FCEVs are likewise totally moved by electricity power. For this situation, the electricity is not put away in a huge battery framework yet is rather given by a fuel cell 'stack' with the utilization of hydrogen from an on-board tank joined with oxygen extracted from the air. The principle points of interest of FCEVs over BEVs are their longer range and quicker refueling, like those of a traditional vehicle. On account of the present size and weight of power module stacks, FCEVs are more qualified for medium-sized to vast vehicles and longer trips. Power module stack innovation is in a prior phase of advancement than the advances portrayed above and few models of FCEVs are as of now economically accessible. Facilitate innovative advancement is required for FCEVs to enhance their toughness, bring down the expenses and set up a hydrogen powering framework, including independent stations or pumps for hydrogen. Demonstrative electric driving reach: 160–500 km (European Environment Agency, 2016).

### 1.1.6 Battery electric vehicles (BEVs)

BEVs models are the principle focal point of this work. They are fueled exclusively by an electric engine, utilizing electrical power put in an on-board battery. The battery must be routinely charged, normally by connecting to the vehicle to a charging station associated toward the nearby power network. BEVs have the most elevated energy efficiency of all automobile drive frameworks, regularly around 80 % or a greater amount of the energy put away in the battery into movement. The electric engine is especially productive, and regenerative braking gives advance proficiency charge. Regenerative slowing mechanisms help keep the battery in an electric vehicle charged, by changing over into power a great part of the energy that would regularly be lost as warmth through conventional braking. There are no fumes discharges while driving a battery electric vehicle. This enhances cities air quality. The best advantages for nature happen when BEVs are fueled by power from sustainable sources. In any case, there are fewer outflows notwithstanding when power originates from the normal blend of renewables and petroleum derivatives utilized now in Europe (European Environment Agency, 2016). In the EU-28, near 30 % of power was delivered from renewables in 2014 (Eurostat, 2018). BEVs, in any case, still have to some degree restricted driving range contrasted with regular automobiles and normally require quite a while to revive the on-board batteries. BEVs have a tendency to have extensive batteries to amplify the vitality stockpiling limit and thus permit longer driving reaches. These huge batteries for the most part cost more than those utilized as a part of hybrids. Be that as it may, battery costs per kilowatt-hour (kWh) have a tendency to be more affordable for BEVs. Demonstrative electric driving range: 80– 400 km.

## 1.2 Automotive market overview

The automotive market is an extensive variety of organizations and associations engaged with the plan, improvement, assembling, promoting, and selling of engine vehicles, some of them are called automakers. It is one of the world's most vital economic divisions by income.

The European auto industry market is evaluated in the upcoming parts by its performance over the years, its volume and segments.

### 1.2.1 Market analysis

Europe is home of 302 automobile manufactures production plants and vehicle assembly lines spread across 26 countries. These EU plants produce 19.2 million trucks, buses, vans and cars per year that are internally consumed and exported worldwide providing €90 billion trade surplus and the turnover sustaining 6.8% of EU's GDP. Counting only the EU15 countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom), the automotive industry account for €396 billion in tax contributions. All this provided economic growth has a ripple effect that boost an array of other business (supply chain, aftermarket companies, rental companies). From all EU workforce, 5.7% (12.6 million) workers are employed in the automotive sector and the 3.3 million direct jobs in automotive manufacturing speak for 11% of total EU manufacturing positions.

Surpassing the €50 billion figure in 2016, automobile industry's research and development (R&D) investments are the biggest from the private sector in Europe, registering more than 8 thousand patents in the European Patent Office. European automobile industry is a global player providing high standard goods what contributes to the consumer's opinion that the majority of 'Made in Europe' products are high quality.

European countries perform a leading role regarding car efficiency and clean production. The volume of water, energy used, carbon dioxide ($CO_2$), and waste produced during vehicles manufacturing are between the lowest in the world. Cars, trucks, buses and vans made in Europe are the quietest, cleanest and safest.

Recent improvements in the macroeconomic situation in most of the European countries helped European's new vehicles market to sustain its growth path started in 2015 and peaked in 2016 also in 2017, once the final sales numbers are computed. This good performance of the market as a whole can be attributed to a couple of factors. Adjust in the stimulus regulations in Italy and Spain, both big internal European markets, the development of Polish and Czech markets and by the matter that, accounting for 54.3% of European market, United Kingdom (UK), France and Germany faced expanding interest for new cars due to credit low cost and increased consumer trust.

Germany, UK and France are leading the European trend of increase in sales to corporate buyers, that now account for the largest share of new sales, and the increase in sales of large passenger cars like sport utility vehicles (SUVs) while sales of diesel cars are declining.

The European new cars market had total revenues of $459.146.5m (€371.956.88m) in 2016, representing a compound annual growth rate (CAGR) of 4.1% between 2012 and 2016. In comparison, the German and UK markets grew with CAGRs of 4% and 4.9% respectively, over the same period, to reach respective values of $113.783.1m (€92.176.26m) and $74.474.6m (€60.332.25m) in 2016.

Market consumption volume increased with a CAGR of 1.7% between 2012 and 2016, to reach a total of 16.574.9 thousand units in 2016. The market's volume is expected to rise to

20.630.1 thousand units by the end of 2021, representing a CAGR of 4.5% for the 2016-2021 period.

The performance of the market is forecast to accelerate, with an anticipated CAGR of 5.4% for the five-year period 2016 - 2021, which is expected to drive the market to a value of $596.340.6m (€483.098.50m) by the end of 2021. Comparatively, the German market will increase with a CAGR of 4%, and the UK market will decline with a CARC of -0.6%, over the same period, to reach respective values of $138.288.7m (€112.028.37m) and $72.365.6m (€58.623.73m) in 2021 (Marketline, 2017).

The uncertainty regarding Brexit outcomes could bring the European market to a slight deceleration on growth rates. Even though the current improvement in the macroeconomic conditions in Europe are driving the sales up, they could be not strong enough to sustain the growth once the repressed demand reaches saturation.

### 1.2.2 Market Volume

New passenger cars sales worldwide reached almost 70 million units in 2016, with China (21.1 million units), Europe (14.6 million units), and United States (7.7 million units) as largest markets. Diesel powered cars represent 65% of the new passenger cars sold in Europe in this period, 12% in India and 6% in South Korea. Japan represents 60% of new hybrid car sales worldwide in 2016 and more than 40% of total global production of electric cars is located in China (ICCT, 2017).

The EU new car registrations number reached 14.6 million in 2016 (Table 1), which is almost the same levels registered in the years 2001–2007, showing that the EU market had completely recovered from the 2009-2011 crisis. 2011 was the year with the lowest sales (13.1 million units) hitting particularly hard the Southern European markets, like Spain, where the number of new vehicles in 2012 represented less than half of any one year from 2001 to 2007. Nevertheless, 2014, 2015 and 2016 figures are increasing for Spain, Italy and other Southern European countries (ICCT, 2017).

*Table 1: European countries by number of new passenger vehicle registrations in 2016*

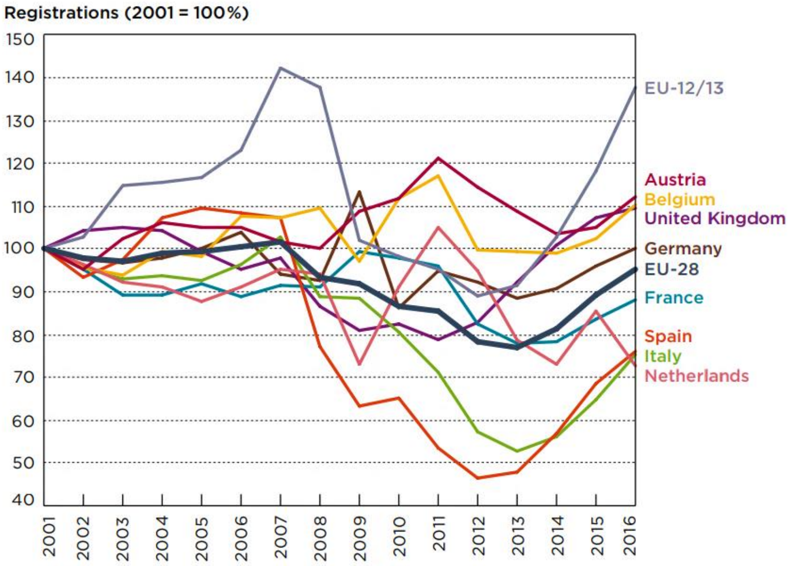
| **Country** | **Number of new passenger car registrations (2016)** |
|---|---:|
| Austria | 329.604 |
| Belgium | 539.519 |
| Bulgaria | 26.370 |
| Croatia | 43.015 |
| Czech Republic | 259.693 |
| Denmark | 222.927 |
| Estonia | 22.429 |
| Finland | 118.986 |
| France | 2.015.177 |

| | |
|---|---|
| Germany | 3.351.607 |
| Greece | 78.873 |
| Hungary | 96.552 |
| Ireland | 146.603 |
| Italy | 1.824.968 |
| Lithuania | 20.320 |
| Luxembourg | 50.561 |
| Netherlands | 382.825 |
| Poland | 416.123 |
| Portugal | 207.330 |
| Romania | 94.924 |
| Slovakia | 88.163 |
| Slovenia | 63.674 |
| Spain | 1.147.007 |
| Sweden | 372.318 |
| United Kingdom | 2.692.786 |
| European Union | 14.641.356 |
| Iceland | 18.442 |
| Norway | 154.603 |
| Switzerland | 317.318 |
| EU + EFTA | 15.131.719 |

*Source: ICCT, 2017*

Even though new sales have faced a drop in the 2006-2008 period, German new vehicles sales faced a rise in 2009 due a government scrappage scheme (the government encouragement of their citizens to purchase a new vehicle and scrap an old one that they have owned for more than 12 months, therefor the name, "scrappage scheme") and since then increased again to approximately 3.4 million vehicles per year, figuring as the largest market on Europe, with 23% overall share. Spain, in other hand, registered fewer than half new vehicles in 2012 when compared with years 2001-2007. Nevertheless, sales in Spain and Italy are facing an upward trend since 2014 (Figure 1).

*Figure 1: Registrations 2001-2016 by country*

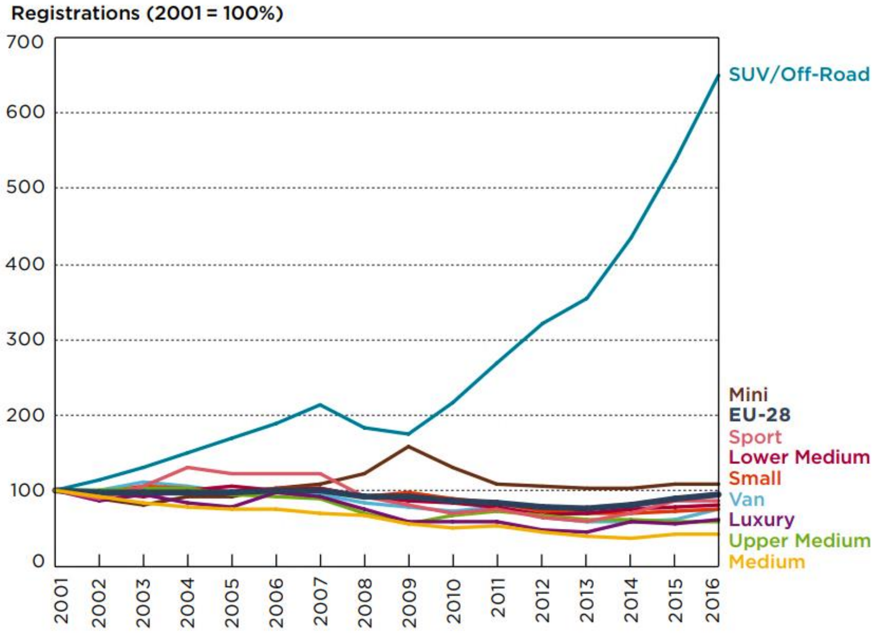



*Source: ICCT, 2017*

### 1.2.3 Market share of the passenger vehicle type and segments

The best-selling car model in Europe is the Volkswagen (VW) Golf, accounting for about 4% of all new vehicles sales in the EU in 2016. By a wide margin the most grounded development in vehicle deals occurred in the SUV segment. Over 3 million new autos in 2015 were SUVs, or around three-fold the number of 10 years prior. (Figure 2) BEVs are not strongly represented in the SUV market.

*Figure 2: Registrations 2001-2016 by model type*



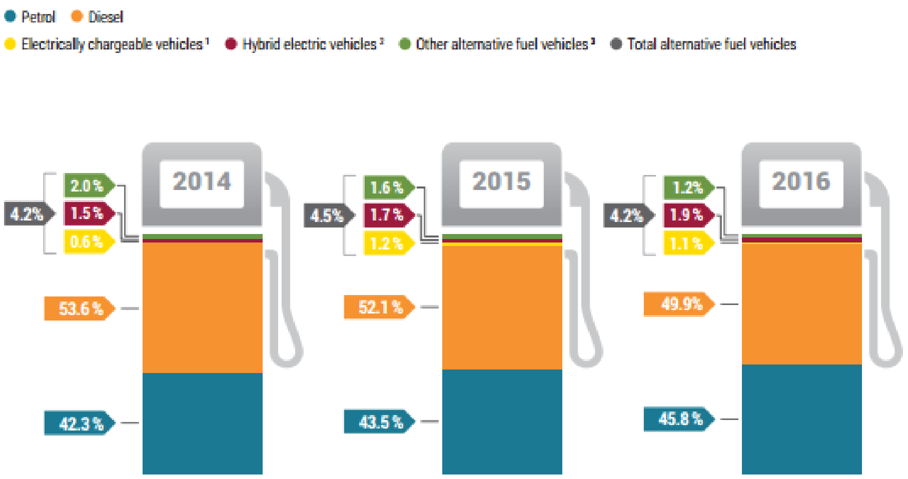
*Source: ICCT, 2017*

The outcome of the VW Dieselgate scandal was that sales of new diesel cars dropped significantly. In the period of 2011–2012, more than half of new passenger cars sales in the EU were diesel cars, an all-time high. After 2012 diesel's market share slowly decreased to 49% in 2016, although diesel shares vary largely by EU country. France, for example, used to have a diesel market share notably higher than the EU average and this market share dropped from 77% in 2008 to 52% in 2016. Another interesting example is Germany, where the diesel market share stood around 48% over the past five years but is now shows strong signs of decline towards the end of 2016, reaching the 38% mark in August 2017. Italy is the only major European passenger car market that has not seen a decline in diesel shares since 2015 (ICCT, 2017).

Currently gasoline and diesel motors are still the main drivers of Europeans new cars. Hybrid-electric vehicles represented 1.8% of the new EU car sales in 2016, having a noticeable increase in Spain where the market share jumped from 1.8 % in 2015 to 2.7% in 2016. This increase put Spain near Netherlands level (2.9%), the EU's most popular market for hybrid-electric car sales.

Plug-in hybrid (PHEV) and battery electric vehicles (BEV) kept the same level of registrations in 2016 as the previous years, around 1% of EU market share. Netherlands remains in the leadership for electric vehicle market within the EU, having 6% of new cars sold in 2016 being electric despite the fact that the share of electric vehicles declined substantially compared to the previous year because reduction on tax incentives for electric vehicles in the Netherlands.

*Figure 3: New passenger cars in the EU15 by fuel type*




*Source: ICCT, 2017*

With a 35.1% grow in comparison to the same period of 2016, the fourth quarter of 2017 demand for alternative fuel vehicles (AFVs) in EU continued to show its upward tendency (Table 2). In the last quarter of 2017, 227.378 AFVs where register, representing 6.7% of total passenger car sales and another 1.9% of all cars registered in EU where electrically-chargeable vehicles.

*Table 2: Europe vehicle registration by country*

| **Countries** | **Q4 2017** | **Q4 2016** | **% Change** | **Q1-Q4 2017** | **Q1-Q4 2016** | **% Change** |
|---|---|---|---|---|---|---|
| Austria | 3691 | 2447 | 50.8 | 14161 | 9028 | 56.9 |
| Belgium | 6.902 | 5.075 | 36.0 | 29.543 | 20.775 | 42.2 |
| Bulgaria | 483 | 267 | 80.9 | 1.301 | 593 | 119.4 |
| Czech Republic | 1.905 | 1.462 | 30.3 | 7.223 | 5.090 | 41.9 |
| Denmark | 2.248 | 2.234 | 0.6 | 8.490 | 8.737 | -2.8 |
| Estonia | 245 | 200 | 22.5 | 1.271 | 825 | 54.1 |
| Finland | 2.836 | 1.575 | 80.1 | 12.003 | 6.285 | 91.0 |
| France | 31.223 | 23.405 | 33.4 | 108.318 | 81.639 | 32.7 |
| Germany | 35.734 | 20.215 | 76.8 | 117.989 | 65.706 | 79.6 |
| Greece | 951 | 454 | 109.5 | 2.906 | 1.881 | 54.5 |
| Hungary | 1.470 | 649 | 126.5 | 4.765 | 2.057 | 131.6 |
| Ireland | 163 | 49 | 232.7 | 5.383 | 3.260 | 65.1 |
| Italy | 57.983 | 44.373 | 30.7 | 230.010 | 185.553 | 24.0 |
| Latvia | 153 | 148 | 3.4 | 492 | 408 | 20.6 |
| Lithuania | 229 | 118 | 94.1 | 767 | 465 | 64.9 |
| Netherlands | 8.305 | 19.533 | -57.5 | 30.891 | 35.430 | -12.8 |
| Poland | 7.772 | 5 | 55.7 | 28.015 | 17.131 | 63.5 |
| Portugal | 3.372 | 1.872 | 80.1 | 10.530 | 6.076 | 73.3 |
| Romania | 661 | 456 | 45.0 | 2.227 | 1.163 | 91.5 |
| Slovakia | 814 | 280 | 190.7 | 2.905 | 913 | 218.2 |
| Slovenia | 497 | 206 | 141.3 | 1.843 | 865 | 113.1 |
| Spain | 20.097 | 10.534 | 90.8 | 67.916 | 36.221 | 87.5 |
| Sweden | 13.948 | 8.760 | 59.2 | 44.163 | 31.533 | 40.1 |
| United Kingdom | 25.696 | 18.948 | 35.6 | 119.821 | 88.891 | 34.8 |
| European Union | 227.378 | 168.251 | 35.1 | 852.933 | 610.525 | 39.7 |
| EU15 | 213.149 | 159.474 | 33.7 | 802.124 | 581.015 | 38.1 |
| EU (new members) | 14.229 | 8.777 | 62.1 | 50.809 | 29.510 | 72.2 |
| Norway | 24.052 | 15.738 | 52.8 | 82.853 | 62.171 | 33.3 |
| Switzerland | 5.277 | 4.151 | 27.1 | 17.569 | 15.020 | 17.0 |
| EFTA | 29.329 | 19.889 | 47.5 | 100.422 | 77.191 | 30.1 |
| EU + EFTA | 256.707 | 188.140 | 36.4 | 953.355 | 687.716 | 38.6 |
| EU15 + EFTA | 242.478 | 179.363 | 35.2 | 902.546 | 658.206 | 37.1 |

*Source: European Automobile Manufacturers Association, 2018*

EU market for liquefied petroleum gas vehicles (LPGV) and natural gas vehicles (NGV) have also faced growth, showing an increase of 27.3% also in the last quarter of 2017 (Table 3). In the same period the registration of battery electric and hybrid electric cars had a demand increase of 54.8% and 43.4% respectively. Plug-in hybrid vehicles had shown a more moderate growth of 15.0%.

*Table 3: EU market for liquefied petroleum gas and natural gas vehicles*

| **Countries** | **Q4 2017** | **Q4 2016** | **% Change** | **Q1-Q4 2017** | **Q1-Q4 2016** | **% Change** |
|---|---|---|---|---|---|---|
| Austria | 154 | 115 | 33.9 | 435 | 486 | -10.5 |
| Belgium | 688 | 426 | 61.5 | 2.673 | 2.290 | 16.7 |
| Bulgaria | - | - | | - | - | |
| Czech Republic | 1.045 | 931 | 12.2 | 4.090 | 3.349 | 22.1 |
| Denmark | 4 | 7 | -42.9 | 47 | 36 | 30.6 |
| Estonia | 3 | 0 | | 40 | 25 | 60.0 |
| Finland | 164 | 45 | 264.4 | 434 | 177 | 145.2 |
| France | 871 | 435 | 100.2 | 1.803 | 1.489 | 21.1 |
| Germany | 2.890 | 1.585 | 82.3 | 8.136 | 6.247 | 30.2 |
| Greece | 145 | 54 | 168.5 | 359 | 293 | 22.5 |
| Hungary | 15 | 10 | 50.0 | 34 | 40 | -15.0 |
| Ireland | - | - | | - | - | |
| Italy | 39.253 | 33.432 | 17.4 | 161.785 | 145.494 | 11.2 |
| Latvia | 18 | 25 | -28.0 | 92 | 82 | 12.2 |
| Lithuania | - | - | | - | - | |
| Netherlands | 534 | 623 | -14.3 | 2.145 | 1.519 | 41.2 |
| Poland | 2.551 | 1.932 | 32.0 | 10.051 | 6.512 | 54.3 |
| Portugal | 534 | 343 | 55.7 | 1.756 | 1.027 | 71.0 |
| Romania | - | - | | - | - | |
| Slovakia | 176 | 109 | 61.5 | 760 | 491 | 54.8 |
| Slovenia | 56 | 58 | -3.4 | 382 | 298 | 28.2 |
| Spain | 2.224 | 307 | 624.4 | 4.918 | 1.670 | 194.5 |
| Sweden | 1.664 | 1.183 | 40.7 | 4.923 | 4.514 | 9.1 |
| United Kingdom | - | - | | - | - | |
| European Union | 52.989 | 41.620 | 27.3 | 204.863 | 176.039 | 16.4 |
| EU15 | 49.125 | 38.555 | 27.4 | 189.414 | 165.242 | 14.6 |
| EU (new members) | 3.864 | 3.065 | 26.1 | 15.449 | 10.797 | 43.1 |
| Norway | 37 | 0 | | 40 | 4 | 900.0 |
| Switzerland | 240 | 337 | -28.8 | 764 | 944 | -19.1 |
| EFTA | 277 | 337 | -17.8 | 804 | 948 | -15.2 |
| EU + EFTA | 53.266 | 41.957 | 27.0 | 205.667 | 176.987 | 16.2 |
| EU15 + EFTA | 49.402 | 38.892 | 27.0 | 190.218 | 166.190 | 14.5 |

*Source: European Automobile Manufacturers Association, 2018*

Analyzing specific important EU markets regarding alternative fuel vehicles sale, we can notice the growth of 90.8% in Spain, 76.8% in Germany, 35.6% in UK, 33.4% in France and 30.7% in Italy.

Summarizing, EU market registered 852.933 alternative fuel vehicles in 2017, an increase of 39.7% comparing to 2016. This growth was mainly driven by the hybrid electric vehicles +54.8%, electrically-chargeable vehicles +39.0% and other alternative fuels +16.4%. Besides facing this substantial growth, alternative fuel vehicles still represent a small percentage of the whole European Union market with only 5.7% of 2017 market share, with electrically-chargeable vehicles constituting 1.4% of total passenger car sales.

As the data shows, alternative fuels vehicles are facing rapidly growth and have still space to keep growing. We will focus our further analysis just on this important topic of further potential of the electric car market in Europe.

In the final quarter of 2017, interest for AFVs in the European Union kept on developing – EU comes about were 35.1% higher than in a similar period in 2016. The 227.378 alternatively-powered vehicles sold during the fourth quarter of 2017 represented 6.7% of aggregate auto deals, while electrically-chargeable vehicles represented 1.9% of all autos sold over the European Union.

Enrolments of BEV (54.8%) and HEV (43.3%) represented the most grounded development. Interest for plug-in hybrid autos kept on developing (+15.0%), though at a slower pace than in past quarters. The EU market for LPGV and NGV vehicles likewise finished the year firmly, with demand expanding by 27.3% in the final quarter of 2017.

Overall in 2017, 852.933 alternative fuel vehicles were sold in the EU, up 39.7% contrasted with 2016. This elevation was for the most part determined by the hybrid electric portion (+54.8%), followed by electrically-chargeable vehicles (+39.0%) and other alternative powered cars (+16.4%) that came back to development in the wake of losing ground in 2016. When taking a gander at their piece of the overall industry, alternative fuel vehicles still just assume a minor part in the European Union Market. Alternatively-powered autos represented 5.7% of the EU market in 2017, with electrically-chargeable vehicles constituting 1.4% of aggregate car deals (Table 4).

*Table 4: EU market for Alternatively-powered vehicles*

| **Countries** | **Q4 2017** | **Q4 2016** | **% Change** | **Q1-Q4 2017** | **Q1-Q4 2016** | **% Change** |
|---|---|---|---|---|---|---|
| Austria | 1.352 | 907 | 49.1 | 5.433 | 3.826 | 42.0 |
| Belgium | 666 | 508 | 31.1 | 2.709 | 2.054 | 31.9 |
| Bulgaria | 68 | 5 | 1260.0 | 68 | 5 | 1260.0 |
| Czech Republic | 73 | 70 | 4.3 | 307 | 200 | 53.5 |
| Denmark | 261 | 631 | -58.6 | 698 | 1.312 | -46.8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Estonia | 3 | 6 | -50.0 | 26 | 35 | -25.7 |
| Finland | 111 | 59 | 88.1 | 502 | 223 | 125.1 |
| France | 6.147 | 5.661 | 8.6 | 24.910 | 21.752 | 14.5 |
| Germany | 8.623 | 3.732 | 131.1 | 25.056 | 11.410 | 119.6 |
| Greece | 17 | 1 | 1.600.0 | 38 | 12 | 216.7 |
| Hungary | 310 | 51 | 507.8 | 749 | 172 | 335.5 |
| Ireland | 41 | 21 | 95.2 | 622 | 392 | 58.7 |
| Italy | 535 | 441 | 21.3 | 1.967 | 1.377 | 42.8 |
| Latvia | 7 | 5 | 40.0 | 39 | 22 | 77.3 |
| Lithuania | 15 | 11 | 36.4 | 52 | 64 | -18.8 |
| Netherlands | 3.244 | 1.308 | 148.0 | 9.897 | 4.268 | 131.9 |
| Poland | 176 | 39 | 351.3 | 439 | 108 | 306.5 |
| Portugal | 545 | 218 | 150.0 | 1.640 | 756 | 116.9 |
| Romania | 91 | 51 | 78.4 | 188 | 74 | 154.1 |
| Slovakia | 80 | 22 | 263.6 | 209 | 59 | 254.2 |
| Slovenia | 86 | 48 | 79.2 | 288 | 144 | 100.0 |
| Spain | 1.566 | 844 | 85.5 | 3.920 | 2.005 | 95.5 |
| Sweden | 908 | 904 | 0.4 | 4.217 | 2.945 | 43.2 |
| United Kingdom | 2.470 | 2.157 | 14.5 | 13.597 | 10.264 | 32.5 |
| European Union | 27.395 | 17.700 | 54.8 | 97.571 | 63.479 | 53.7 |
| EU15 | 26.486 | 17.392 | 52.3 | 95.206 | 62.596 | 52.1 |
| EU (new members) | 909 | 308 | 195.1 | 2.365 | 883 | 167.8 |
| Norway | 9.788 | 6.737 | 45.3 | 33.025 | 24.222 | 36.3 |
| Switzerland | 1.629 | 913 | 78.4 | 4.773 | 3.295 | 44.9 |
| EFTA | 11.417 | 7.650 | 49.2 | 37.798 | 27.517 | 37.4 |
| EU + EFTA | 38.812 | 25.350 | 53.1 | 135.369 | 90.996 | 48.8 |
| EU15 + EFTA | 37.903 | 25.042 | 51.4 | 133.004 | 90.113 | 47.6 |

*Source: European Automobile Manufacturers Association, 2018*

## 2 EUROPEAN BATTERY ELECTRIC VEHICLE MARKET

Overviewing the literature, we have found an immense number of academic articles, books, and research papers written on the electric vehicles topic, but few of them directly focus on the future market demand of EVs. This is a subject undergoing intense study because of its importance for the majority of the participants in the automotive industry and is, as such, inaccessible to the general public. We focus on the literature with particular emphasis on the factors influencing EV adoption, policy factors, technological and economic factors and customers buying decision factors.

## 2.1 Factors influencing the adoption of battery electric vehicles

The invention of the first electrical vehicle goes back in the year 1834. The lack of technology mostly connected to the poor quality of the battery and the fast development of the internal combustion vehicles stopped further developments until the 1970s, when the energy and oil crises once again stimulated the idea of EVs, but again without mass success (Chan, 2007; Propfe, Kreyenberg, Wind, & Schmid, 2013). Now in the 21st century a totally new concern, rising greenhouse gases (GHG) emissions, incentivized the attention on BEVs again, while their life cycle GHG emissions are lower than GHG emissions generated by ICEVs. One research done with analyzing electrical powered Nissan Leafs found out that during its lifetime GHG emissions present 71 to 91 percent of the lifetime GHG emissions of an ICEV with a proportional size engine (Bartolozzi, Rizzi & Frey, 2013; Hawkins, Singh, Majeau-Bettez, & Strømman, 2012; Hawkins, Gausen, Strømman, 2012).

A study done by International Energy Agency is showing that in the year 2015, 24% of global $CO_2$ emissions were generated from the transportation sector and their estimates are, that $CO_2$ emissions generated by vehicles will double till 2050 (International Energy Agency, 2017a). This is why technologies for "zero-emission" alternative powered vehicles as the BEVs are being incentivized by policymakers worldwide (Vassileva & Campillo, 2016). In almost all the reviewed literature it is predicted that policies on the GHG emissions and other transport related policies will play the main role in the future EV adoption. A research paper, written by Michael Wolinetz and Jonn Axsen (2015) categorized two different policies types for EVs, "demand-focused" and "supply focused" policies. Demand-focused policies are affecting directly the customers and are providing them subsidies, lowering road tolls, increasing taxation on petrol and diesel fuel and also by non-financial incentives as free parking spaces and driving on bus/taxi lanes. They define the second type "supply-focused" policies as those that are pushing vehicle producers and also fuel suppliers to develop market and sell BEVs. Examples of supply-focused policies are subsidies for R&D activities, standards on $CO_2$ level and other GHG regulations (Wolinetz & Axsen, 2015). In 2015, Norway was a country with highest BEV new market share in the world, accounting for 22%. And based on the Wolinetz and Axsen research, Norway's success was a clear result of their demand-focused policies.

The above-average success in the EV adoption in Norway is the reason it is studied in many research papers (Baure, 2018; Figenbaum, 2016; Holtsmark & Skonhoft, 2014). The research from B. Holtsmark& A. Skonhof (2014) is analyzing the Norwegian support and subsidy policy of electric cars and discovering if their strategy should be adopted by other countries. At the time of the paper was written, the Norwegian EV policies and regulations included: free parking on public places, EV owners did not have to pay most of the road tolls and some of the ferry connections, they were also allowed to use bus and collective traffic lanes, annual road tax, and motor vehicle tax was lower and additionally company car tax was 50% lower in comparison with the ICEVs and free charging was available on public founded charging stations. Their main conclusion was that Norwegian policies on the EVs should not be implemented by other countries and should even be ended by the Norwegian government as soon as possible. Their results from the study show that the policy incentives motivate families with higher income to buy a second car. On top of this, free parking spaces and possibilities to use bus lanes incentivized new EV owners to reduce the use of public transport and use EV for daily commutes to the city center. All of this is to be challenged and thought through if it is at the end actually missing the point which is the reduction of GHG emissions. Nevertheless, policies are pushing the adoption of EVs forward (Christensen, Wells, & Cipcigan, 2012).

By costing less and being relatively more effective compared to strong subsidies or registration tax rebates, demand-focused incentives tend to be more efficient. Nevertheless, demand-focused incentives could result in a rebound effect, once they reduce the marginal costs of driving an EV. Although, demand-focused incentives can deliver the message that the government is promoting car usage, what could not be the final goal (Langbroek, Franklin, & Susilo, 2015).

In order to reduce the gap between the wiliness of the consumer to acquire EVs and its cost, policy makers will have to drive people towards a more notable stage-of-change, for example, by delivering more information about both advantages and disadvantages of these cars, increasing the awareness about EVs, and making people more aware of their own patterns regarding daily commute. The difficult part is that not many policy incentives are needed to convince consumers to start using EVs, but these same incentives become less and less effectives and efficient once people active higher stages-of-change (Langbroek, Franklin, & Susilo, 2015; Sovacool & Hirsh, 2009).

Our research suggests that a minimum basic EV infrastructure could be more beneficial for the long-term adoption, still further research is needed to identify the precise levels of investment and this is beyond the scope of our thesis. As Harrison and Thiel (2016) noted "There is a correlation between EV uptake and infrastructure subsidies, but in our modelled scenarios it appears to be weaker than vehicle purchase subsidies or manufacturer fleet $CO_2$ targets. Our study results support the hypothesis that early EV adopters are less reliant on the provision of public charging infrastructure."

In order to provide policymakers a better understanding regarding the synergy between EV adoption and infrastructure, key policy points are featured below:

- Longstanding EV adoption is not a pure result of very high purchase subsidies only.
- In the short-term, subsidies are beneficial even in a scenario lacking other policies.
- Providing subsidies for longer periods do not make a significant impact after the initial market impulse, once further market growth needs to be backed by additional policies.

- The offer of purchase subsidies for EV before all technologies are accessible can bring a technology lock-in and constrain long-term maturation for newer technologies, due to the technology competition dynamics.

The literature on buyer's decision factors points out that one of the reasons for the lower demand for EVs in many countries is the higher initial costs (vehicle price) than the conventional ICE vehicles. Subsequent reasons are the "range anxiety", the perceived limited driving range of the EV vehicle when compare to an ICE counterpart, the time needed to charge the car battery and the lack of charging infrastructure when compared to the number of fuel stations available (Benysek & Jarnut, 2012). Nonetheless, a study performed in UK evaluating the charging behavior of EV owners found out that the early range anxiety tends to fade overtime once the knowledge and confidence is developed by the owners by driving for long periods (Vassileva & Campillo, 2016).

To analyze and recognize the most important driving forces that could explain the variables and the thought process of early EV adopters could help the development of better plans, policies and incentives to help increase its market adoption. (Vassileva & Campillo, 2016; Pearre, Kempton, Guensler, & Elango, 2011). Zubaryeva et al., compiled distinct criteria influencing the success of EVs market adoption:

- Demographic criteria (e.g. early adopters tend to have a high income, so wealthier countries will adopt EVs earlier).
- Environmental criteria (e.g. temperature variations).
- Energy criteria (e.g. including electricity mix; energy security).
- Transport criteria (e.g. market penetrations might be facilitated if it targets consumers interested in purchasing a second car).

As mentioned before, some of the big difficulties faced by EVs are the battery technology, its cost and the charging infrastructure. Another important barrier is the uncertainty associated with EV's sustainability and environmental performance. Some literature finds suggest that even though EV's environmental benefits and sustainability characteristics are considerable influencers on EV adoption, they are listed below cost and performance (Egbue & Long, 2011). Having potential consumers questioning the sustainability and "eco-friendliness" of EVs compared to ICE cars may indicate that consumers with high environmental awareness and values may have doubts if the purchase of an EV is beneficial to the environment. Accordingly, crucial measures need to be implemented to help the increase of EVs adoption, some of which are already being explored by some countries, including consumer education, more investment in the EV technology and infrastructure, battery swap programs and strong battery warranties.

Around year 2010, a lot of literature were analyzing the EV customers and searching for the characteristic of the EV early adopters. In 2013 study based on survey in the UK was conducted, researching demographic and attitudinal factors on the EVs adoption likelihood

(Schuitema, Anable, Skippon, & Kinnearc, 2013). EVs range problems and environmental-friendliness were found to be the two most influential factors. They consider social-demographic factors to be less important, however their assumption was that early adopter is a male with above average income. Additionally, the potential EV buyers would consider it as a second household vehicle. One other study also conducted in 2011, showed similar results (Hidrue, Parsons, Kempton, & Gardner, 2011). They found out that person willing to buy an EV would most likely be a man, between 30 and 50 years, living in a multi-person household and that has full-time job. Additionally, the results showed that early adopters were more likely to live outside big cities. Range anxiety was already mentioned as one of the main adoption barriers for EVs in the J. Anabel research. It is recognized also by other researchers (Egbue & Long, 2011; Hackbarth & Madlener, 2016). Test driving an EV is believed to be one of the solutions to the barrier (Franke & Krems, 2013). They believe that after testing EVs, customers would have fewer doubts and they would be faster convinced that EV range could meet their driving needs and by this improve one of the biggest adoption barriers.

## 2.2 Public support initiatives in the electric vehicle market

This subchapter will cover the adequacy, proficiency and practicality of public initiatives that urban areas may receive to stimulate the take-up and utilization of EVs. We recognize five featured classes: BEV environmental impact; the important part of BEVs in The Department of Energy and Climate Change (DECC) 2050 predictions; governmental arrangements possibilities to inactivate BEVs; an overall approach: public and private sectors working together for the advancement of BEVs and local government policies and subsidies for electrical vehicles (Bazaras and others, 2012).

### 2.2.1 Battery electrical vehicle environmental impact

In the media, on presentations and public relations material of manufacturers, BEVs, along with Fuel Cell Vehicles (FCVs), are often-times mentioned as “zero emission vehicles”. For example, Nissan Leaf is obviously presented as a zero emission vehicle on promotional pictures and on the one of car websites. In addition, the term itself is without any additional explanation or any restriction. In BMW UK’s advertisement campaign, one of its electric vehicles was described as a "zero CO when driving". However, the Advertisement Standard Authority is classifying this expression as a misleading. It disallowed all statements on BEV’s advertisements in the UK that would imply the production of no emissions (Advertising Standards Authority Ltd., 2013). These cases show the reasons for public misperception on BEV’s real impact on the environment.

The greenhouse harming substance emanation guidelines for many public institutions around the world heavily rely on BEVs, among different solutions, to diminish outflows coming from transportation. BEV is viewed as an innovation that can meet the CO decrease targets due to the nonattendance of tailpipe discharges, however the battery producing, its future scrapping, and the carbon production dues the electric power needed for its preparation must be considered in order to reduce the future possible deception that BEVs are zero-emission automobiles. The ecological effect of BEVs from beginning to end of life cycle has been studied in reports, yet the conclusions differ somewhat. The UK Department for Business Enterprise and Regulatory Reform and the Department for Transport (Björnsson & Karlsson, 2015) displayed a comparison of a Life Cycle Assessment (LCA) of BEVs and ICEVs. This report considers future outflows decrease because of electric power production and innovative upgrades of the vehicles by 2010, 2020 and 2030 for ten unique criteria. In 2010, BEVs scored were superior to ICEVs in environmental change affect, non-inexhaustible asset consumption and noise. They had superior scores than petrol engines however poor than diesel motor vehicles in oceanic eco-poisonous and photochemical oxidant arrangement, and superior to diesel yet poor than petrol for eutrophication. BEVs effects are worse for air acidification, water utilization, debris creation and human wellbeing. The conceivable future innovations outcomes and developments for BEVs until the point that 2030 are high, however the general outcomes for 2010 demonstrate that the decarbonization of the matrix is urgent to enhance the ecological effect of BEVs so it turns into a low-carbon innovative alternative (Andwari, Pesiridis, Rajoo, Martinez-Botas, & Esfahanian, 2017).

The percentage of the aggregate BEV affect because of the extraction of assets for the battery is expressed for every basis and is large, going in the vicinity of 12% and 87%. As indicated by another examination (Andy, 2017), half of BEV life cycle emanations originate from the lithium-ion battery creation and work. Contrasted with ICEVs, the discharges moved from activity to fuel creation, with a general decrease of 58% in emanations for each km. The ecological effect caused by the battery, estimated with Eco-marker 99, a LCA technique in light of Human Health, Ecosystems, and Resources model, is assessed at 15% of the aggregate. The effect of the extraction of lithium for the battery is below 2.3%, the bulk part of battery outflows starting from the supply of copper and aluminum. In Belgium, ozone harming substance discharges of BEVs, on an existence life cycle premise, were evaluated 78.27% lower than oil vehicle outflows. BEVs got superior scores over LPG, hybrids and oil vehicles in ozone depleting substance outflows, air acidification and human wellbeing. In addition, the future capability of BEV is higher as the presentation of renewables into the nation electrical power electrical network increments, what might enormously enhance BEV's outcomes. Be that as it may, diesel vehicles have not been examined in this paper. This conclusion differs from alternate studies, what might be expected to different study limits or a lower carbon density of the Belgium electric power matrix (Andwari, Pesiridis, Rajoo, Martinez-Botas, & Esfahanian, 2017).

Once the studies conclusions that have been depicted differ in their outcomes, the ecological effect of BEVs is as yet questionable; notwithstanding, it turns out to be certain that in numerous nations there is a need to decrease the carbon footprint of electricity for BEVs to bring down bad effect figures contrasted with new diesel ICEVs. Furthermore, it is important to contrast BEVs with new and future ICEVs. It is a typical error to contrast new BEVs with the normal ICEVs, as automobile producers have enhanced their efficiency and environmental effects and the right assessment must be between two new autos for the expected transportation evaluation in the future. Due to the assorted variety in electrical power matrix, BEV natural benefits are unequal between European nations. In any case, there is unanimity on the analyses that BEVs do enhance the air quality in urban territories, as a result of the nonattendance of tailpipes emanations, for example, nitrogen dioxide, sox and particulates (Investigation into the scope for the transport sector to switch to electric vehicles and plug-in hybrid vehicles. Also, the carbon footprint of the energy matrix is normally lower around night time (Andwari, Pesiridis, Rajoo, Martinez-Botas, & Esfahanian, 2017). The less receptive power plants, which work during the evening to give the base load, are likewise for the most part less carbon escalated (for example, nuclear energy plants) and the majority of the BEVs would be charged during the night period. The LCAs, which depend on the overall carbon footprint of electric power, marginally overestimate, accordingly, the environmental change effect of BEVs (Bellekom, Benders, Pelgröm, & Moll, 2012).

### 2.2.2 The role of battery electric vehicles in the Department of Energy and Climate Change 2050 pathways analysis

The UK has committed to an 80% reduction of its greenhouse gas emissions by 2050, relative to 1990 levels. DECC has developed a calculator which allows the selection of the intensity of the country's efforts across different fields and technologies, on a scale from 1 to 4. For each proposition, it displays information, including the consequences on UK GHG emissions up to 2050 and the percentage of imported primary energy. One of the parameters is "Domestic transport electrification" and is evaluated with the percentage of kilometers driven with different technologies, in 2050. Table 4 describes the assumptions made for each level of effort in this field. It illustrates the important role of BEVs in DECC's analysis. The 2050 Web Tool provides example pathways presented by scientists and institutions such as National Grid, Friends of the Earth, Campaign for Protection of Rural England, and Energy Technology Institute. Even if those pathways have very different origins, they all are favorable to domestic transport electrification, as four of the six examples advise a Level 4 effort and two a Level 3 in that field. When faced with having to make a trade-off between different solutions to improve energy security and GHG emissions reduction, electrification of domestic transport is an effort that a majority is willing to make. It is much less controversial than wind turbines or nuclear energy, for instance. However, this remains a theoretical acceptance, different from a consumer's acceptance, because it is made from the point of view of policymakers facing a choice to meet a target (Andwari, Pesiridis, Rajoo, Martinez-Botas, & Esfahanian, 2017).

Nevertheless, the political acceptance allows the implementation of policies to facilitate the adoption of BEVs.

### 2.2.3 Policy options to develop battery electric vehicles

Keeping in mind the end goal to decrease $CO_2$ outflows from light vehicles, strategies have been executed in Europe to advance low carbon vehicles adoption. It can be viewed as an approach to give an incentive to the nonappearance of tailpipe discharges. In a 2009 report assessing the effective approaches for cleaner automobiles and in view of a writing study, it has been reasoned that for the accomplishment of policies goals and consider any potential side effect of a solitary measure, they should be composed as a whole unified set of actions and not independently. Emanations control, car acquisition and fuel taxes charges, integrated with training, education, data and standards on market promoting and labelling, can push the share of vehicles to a more efficient fleet. It expresses that governmental approaches can influence customer practices. It must be taken in consideration that this report did not consider the strategies related with electric vehicles specifically; however, the greater part of the measures is common for all vehicles (Zhang, Mclellan, Tezuka, & Ishihara, 2013; Andwari, Pesiridis, Rajoo, Martinez-Botas, & Esfahanian, 2017). The fundamental measures which could help the advancement of BEVs, are depicted below and can be gathered in five classifications: emanations regulations, data information and user instruction, diminishment of capital and running expenses, and improvement of the charging framework (Yang, 2010).

Discharge emanation directives as the Euro standard an EU enactment forces strict breaking points on contaminations outflows of light vehicles, for example, carbon monoxides, particulates, nitrogen oxides and hydrocarbon. Different levels have been defined: Euro 6 norms are as of now in application. These controls concern diesel, petrol and natural gas automobiles. Higher regulations could presumably lessen the difference in introductory cost amongst ICE and BEV.

The offer of data information and user educational programs to the general society is another key instrument for BEV improvement. Vehicles discharge emanation levels are given by producers and showed in the car stores; in any case, this is insufficient by itself to drive the client to the BEV choice given its high introductory monetary cost. The life cycle monetary value and cost must be obviously disclosed to clients with the goal that they can be less reliant on the underlying expense of the automobile in their selection of vehicles and take pollution emanations as an essential factor. Labelling and getting a clear promoting campaign must stress out the measures that decrease the cost of the automobile over the live cycle. Lastly, the absence of confidence of purchasers on security and range must be handled. It could be possible through high-perceivability trials, for example, taxi fleets, precise data on the performance of BEVs, and a presentation in governmental fleets (Andwari, Pesiridis, Rajoo, Martinez-Botas, & Esfahanian, 2017).

As clients frequently neglect to assess the cost of ownership for automobiles over a lifetime, it is viewed as important to give stimulus at the purchase. It should be possible with auto allows and expenses or discounts frameworks in view of outflows, at time of the vehicle acquisition. In the UK, the Plug-In Car Grant has been executed since January 2011. This innovation unbiased approach targets ultra-low (tailpipe) outflows autos, including BEVs. The grant got by the purchaser of a qualifying automobile is of 25% of the cost of the vehicle, up to a most extreme of £5000 (Andwari, Pesiridis, Rajoo, Martinez-Botas, & Esfahanian, 2017). In 2008, this sort of measure was executed in France, Spain, Belgium and Sweden, EVs were exempted from enrollment impose in Greece, the Netherlands, Denmark, Ireland and Norway.

Road tax reduction is another apparatus that can be utilized for BEV adoption improvement. In some European nations, automobiles proprietors must pay a yearly fee to utilize their vehicle and the sum relies upon the CO discharges of the vehicle. By bringing down these fees for BEVs, it is conceivable to expand the engaging quality of those vehicles. In 2008 EVs were exempted from road taxes in Norway, Denmark and Greece (Andwari, Pesiridis, Rajoo, Martinez-Botas, & Esfahanian, 2017).

Fuel tax collection. An expansion of the tax assessment on diesel and petroleum would positively affect BEVs by correlation. Another option to fuel tax assessment is a fee for every determined kilometer, contingent upon the auto outflows, or per gram of CO produced (which is proportional).

Local governmental arrangements: restriction for the access of certain urban areas and decreasing of the parking slots. With a specific end goal to lessen the clog or to enhance air quality, numerous European urban communities have actualized Urban Access Restrictions plans. These can bring about an aggregate ban of a few classifications of vehicles in downtown areas or street estimating and permits. BEVs are exempted more often than not from these restricted traffic zones and can flow without permission. It is the situation in Bologna, Hannover, Verona, Munich, Stuttgart, Oslo, Poitiers, Krakow, Modena and London, for example. In Rome and Florence, BEVs get a half rebate contrasted with Euro 5 vehicles. It is all the more imperative than BEVs are focusing on chiefly urban clients: this fee exception can represent for a good number of buyers as a critical reserve fund. Parking prices decreases or exclusions is a measure executed locally, in a few regions. Contingent upon the propensities of the drivers, it can likewise speak to an essential preferred standpoint for a few clients. Such measures have been done in Norway, Denmark, Italy, Greece, and in the UK. Special parking spaces, with charge focuses, could likewise be executed (Andwari, Pesiridis, Rajoo, Martinez-Botas, & Esfahanian, 2017).

The expansion of public charging station framework for BEVs is additionally an essential factor, yet its development represents a vital venture investment, being a "chicken and egg" circumstance, as private financial specialists companies would like to put resources into a system if the demand exists and the drivers would consider purchasing BEV once the charging system matrix has been assembled. This is the reason it can be important to make motivating policies for the production of the charging framework in the public areas, or even to provide the charging stations directly. This measure is one of those prompted by the IEA.

### 2.2.4 An integrated approach: public private partnerships for the development of battery electrical vehicles

It is critical that a big part of partners engaged with BEV advancement incorporate their roadmaps and work intelligently on answers for the complicated issues that right now back off the improvements of BEV. One interesting concept is the one created by the Green eMotion venture, a Public Private Partnership bolstered by the EU. Started in 2011, its point is to advance electromobility by integrating innovation in European test areas, conveying an increase in the innovation for the technology. This venture has 24 million euros from the EU and is planned for 4-year where the total spending plans can reach 42 million euros. 42 associated institutions are included in the project, from different European nations yet in addition of different segments: companies like, for example, Alstom, Better Place, Bosch, IBM, SAP and Siemens, players as, for example, EDF, Endesa and Enel, the EV automakers BMW, Daimler, Micro-Vett, Nissan and Renault and European districts (Roma, Copenhagen, Barcelona and Berlin and more), ten research institutions and colleges crosswise over Europe and EV Technology Institutions (Danish Technological Institute, FKA, TUV Nord). This venture has two objectives, and none of them can be completed without this association crosswise over countries and different parts. Having standards that all instantiations would follow would be crucial, which is considered as "the key factor for a quick and cost efficient European rollout of energy power", and in addition the improvement of common European procedures, norms and IT arrangements. The second one is to widen the size of EV tests from nearby examinations to European system matrix. Charging stations inside the testing areas is intended to increment to 14.000 spots, for the most part in Berlin, Barcelona, Madrid and Malaga. This is relied upon to offer the field test required for a change of the EV innovation. This European co-association of partners is important to over-come a portion of the hindrances toward the improvement of BEV: the standards to be impose to the charging matrix, for instance, is important to diminish its costs, and huge scale tests will permit the identification of purchasers' wants and struggles. It could encourage associations amongst companies and produce economies of scale. The contacts amongst enterprises and research organizations will convey subsidizing to the establishments and additionally encouraging advances to the businesses and it would enable coordinate studies in EV. Coordinated effort on a worldwide scale is more difficult however possibly all the more fulfilling. The IEA planned to assume a part in the co-appointment of the efforts in its guide, for the most part in arranging, the preparing of workshops, information gathering, investigate system and examination, yet additionally by running joint test programs. The points of this activity are coordinated towards joint effort and data sharing, worldwide frameworks, for example, reusing matrix frameworks, standards for the foundation, writing about prescribed procedures to keep away from the reiteration of errors, and identification and help to the nations identified as first adopters (Andwari, Pesiridis, Rajoo, Martinez-Botas, & Esfahanian, 2017).

#### 2.2.5 Local Government policies and subsidies for electrical vehicles

Additionally, the placement of EVs is correlated to incentives as: tax rebates, subsidies and many other indirect and direct financial assistance conditions. A powerful tool for expanding EVs market is the collection of taxes on ICEVs that will provide abatement for EVs. This is what Norway is currently doing, once due to the high ICEVs tax and EVs tax rebate, purchase and maintenance costs for EVs are lower than ICEVs. Base on that, it's not by chance that the Norwegian EV's market is facing growth, making Norway the leading country in the EU by relative number of EVs (Weeda, 2012). Even with large and costly incentives for EV's acquisition, the quantity of EVs in plenty of EU countries is still low.

The EV30@30 campaign, initiated at the Eighth Clean Energy Ministerial in 2017, reclassified the Electric Vehicles Initiative (EVI) country members desires by defining the aggregate optimistic objectives for all EVI members of a 30% market share for EV in the aggregate of all passenger vehicles, light commercial vehicles, trucks and buses by 2030.

Not all European countries are members of the EVI, yet the greatest ones are. EVI tallies today with ten nations (Canada, China, France, Germany, Japan, Netherlands, Norway, Sweden, UK and United States of America (USA)), speaking for the vast majority of the worldwide EV stock and including the biggest and most quickly developing EV markets around the world.

The EV30@30 incorporates a list of executing activities at accomplishing this objective as per the needs and projects created in each EVI nation. These activities include:

- Supporting the implementation of charging stations and tracking it progress.
- Arousing public and private segments commitments for EV take-up in organizations and companies' fleets.
- The scale-up of research, including approach adequacy examination, data and experience sharing, and production capacity increasing.
- Building up the Global EV Pilot City program, a worldwide cooperative program went for encouraging the trading of experiences and the replication on best practices for the advancement of EVs in urban areas.
- Customer awareness campaigns.

According to the European Commission for Energy, Climate Change and Environment proposals for post-2020 $CO_2$ targets for cars and vans, the average emissions of the EU fleet of new vehicles in 2030 will have to be 30% lower than in 2021 and the same reduction for vans fleet must be seen in 2030. In order to guarantee that the reductions occur as early as possible, the goal for 2025 for cars and vans are 15% lower emissions than in 2021 (https://ec.europa.eu).

Aiming to ensure the transition from the current stage for the future framework, the proposal also includes the already established EU fleet emission goals for 2020/2021 of 95 g $CO_2$/km for passenger cars and 147 g $CO_2$/km for light commercial vehicles, both of which are based on the New European Driving Cycle test procedure.

We assume that this proposal from the European Commission will push both European countries that are in the EVI and not in direction to an increase on BEVs market share as a key factor to achieve the expected emissions reductions.

Additional existing EU governmental incentives, regulations and normative acts linked to the transport sector and alternative energy sources are summarized in Appendix 2.

## 2.3 Original equipment manufacturers future ambitions for battery electric vehicle

On the year of 2016 major declarations on the electric car deployment arrangement from main worldwide OEMs were made. These included declarations by Tesla, expecting to delivery no less than 1 million cars by 2020, or Volkswagen, which divulged an arrangement for a huge move towards the creation of electric powertrains and reported that no less than 30 electric models will enter the market by 2025 (Volkswagen, 2016). In the vicinity of 2015 and 2017, nine worldwide OEMs openly declared their readiness to make or essentially augment their electric model offer throughout the following five to ten years. In China, which represents 33% of the worldwide electric auto stock by 2025, many Chinese OEMs likewise declared huge electric vehicles production capacity scale-up plans. An outline of the considerable number of declarations that were followed in this appraisal is given in Table 5. Figure 4 gives an outline of electric auto delivery for the following 15 years. The figure pools together sign from a scope of various scenarios, including three IEA projections and the desire laid out in the Paris Declaration and assess them against goals set up by individual nations and declarations from major OEMs.

*Table 5: List of OEMs announcements on electric car ambitions, as of April 2017*

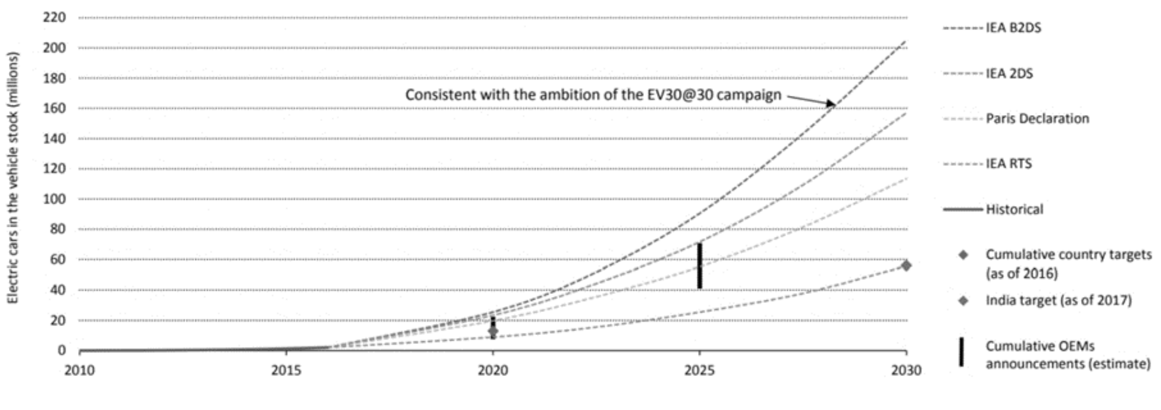
| OEM | Announcement |
|---|---|
| BMW | 0.1 million electric car sales in 2017 and 15-25% of the BMW group's sales by 2025 |

| | |
|---|---|
| Chevrolet (GM) | 30 thousand annual electric car sales by 2017 |
| Chinese OEMs | 4.52 million annual electric car sales by 2020 |
| Daimler | 0.1 million annual electric car sales by 2020 |
| Ford | 13 new EV models by 2020 |
| Honda | Two-thirds of the 2030 sales to be electrified vehicles (including hybrids, PHEVs, BEVs and FCEVs) |
| Renault-Nissan | 1.5 million cumulative sales of electric cars by 2020 |
| Tesla | 0.5 million annual electric car sales by 2018<br>1 million annual electric car sales by 2020 |
| Volkswagen | 2-3 million annual electric car sales by 2025 |
| Volvo | 1 million cumulative electric car sales by 2025 |

*Sources: International Energy Agency (2017b).*

The appraisal of OEM declarations as far as stock rise, as displayed in Figure 4, was created by considering aggregate sales goals at a given point in time, on the off chance that they were accessible, or computing them based on sales goals, accepting a linear improvement of sales development from start until the objective year (commonly 2020 or 2025). In situations where the objective year was 2020, the lower bound of the stock rise for 2025 was figured assuming consistent sales, while the higher bound was gotten from the utilization of RTS sales and stock rise to the accessible data on 2020. On account of China, the lower headed gauge for 2020 matches the 2 million yearly electric auto production capacity goal by 2020. The upper bound gauge mirrors the development in production capacity reported by the OEMs, considering a 66% capacity usage rate. By and large, representing the worldwide OEM declarations and targets, the electric auto stock originating from the OEM targets could extend between 9 million and 20 million by 2020.

*Figure 4: Deployment scenarios for the stock of electric cars to 2030*




*Sources: International Energy Agency (2017b).*

Acknowledging the declarations regarding 2025 and applying growth rates to goals reported to 2020, the OEM declarations could prompt 40-70 million electric autos by 2025.

The desired level coming from the OEM declarations evaluated here demonstrates a genuinely decent alignment with national goals to 2020. To 2025, the range assessed recommends that OEMs' aspirations exist in the range comparing to the Paris Declaration. Keeping in mind the end goal to see these aspirations appear, EV (and battery) production capacity limit needs to be incremented. The size of this task can be delineated by contrasting the battery limit augmentations required against latest developments: achieving the mid-point of the evaluated ranges for OEM declarations in 2025 would require the development of approximately ten battery manufacturing facilities with the production capacity of the Tesla Gigafactory.

## 2.4 Battery technology for electrical vehicles

Nevertheless, that EV market is growing every year, we could say that the market is still in the very beginning stage. Based on the research done by McKinsey consulting firm, we have today two segments of early adopters who already own electrical car. These two groups consists of the people who have higher incomes and people who are eco-friendly and high-tech mindset, both valuing “new” and “different” products (McKinsey & Company, 2017). For EVs to cross the chasm and become more mainstream, EV producers will have to find a way to resolve the main concerns that people have in order to consider buying an EV. As seen from many researches and discussions there are three biggest hurdles that are preventing the majority of people to adopt EVs: They are pricier than cars with internal combustion engine (ICE), “low” range is the second big thing and the third is charging time. Producers already did a lot on these tree topics. From 2010 to 2017, battery pack price fell roughly 86% from approximately $1000/kWh (€810.11/kWh) to $139/kWh (€112.60/kWh) (Richter, 2017; Andy, 2017). Despite that drop, the battery pack price still results in approximately 40% of the total cost of EV and represents the main reason why EVs are more expensive than ICE cars (the numbers are taken from the example of $38.000.00 (€30.780.00) electric Chevrolet Bolt of which the battery pack price is $15.734.29 (€12.746.42) (Lambert, 2016; Lambert, 2017). Significant improvements were also made in EV range. For example, Tesla Model S grew from 334 kilometers per charge in 2013 to 400 kilometers per charge in 2017. The increase is approximately 20%, mainly because of larger battery packs. Tesla Model S increased its battery pack from 60kWh in 2013 to 75kWh in 2017 (U.S. Department of Energy, n.d.). As for the third problem of EVs, long charging time have also been partly sorted by the fast charging systems, but this is more question of how fast the charging infrastructure will grow and not as much on the battery technology as it is for the first two. Focusing just on the above tree points it is obvious that the development of the battery will play a big role in the future adoption of electric vehicles.

### 2.4.1 Classification of batteries

As we have acknowledged before the batteries are the main part of an EV. Therefore, we will analyze which types and which key performance parameters of batteries are the most important in the moment and what are the predictions for the future.

There are two main battery types which are determent by their ability of being electrically recharged. The primary batteries also known as nonrechargeable batteries and secondary or rechargeable batteries. There are more types of secondary batteries from which the most common ones are lead acid, NiCd, NiMH, and Lithium-ion. For our analysis we will focus on the Lithium-ion batteries as they are the most commonly used in customer products (laptops, smartphones, and medical devices) and most importantly they are the main batteries used in EVs. There are more types of Lithium-ion batteries from which all of them have different advantages (BCG, 2009). To analyze different types of batteries we firstly need to know the key performances that are important for EV battery:

- Safety is one of the most important factors because of the possible damage to the people and equipment around it and additional this could result in turning a public opinion against the electric car industry for some time. The main concern is thermal runaway, which is a chemical condition in the battery where the heat inside the battery is generated faster than it can dissipates, which leads to a battery melting, gas release, acid spillage or even fire or explosion.
- Specific Energy or capacity is the characteristic which tells us how much energy can be stored in the battery per unit of mass. Higher the specific energy longer the car range.
- Specific Power or the ability to discharge a lot of power in short amount of time. For example, batteries for power tools have a high specific power, so they can handle high resistance but they also discharge relatively quickly so this means they have low specific energy. Therefore, for EVs you need a compromise between specific power and energy, so the car can have as long range as possible and at the same time sufficient power to drive with speeds high enough for the modern roads.
- Live span of a battery is measured in two ways, longevity and cycle life. Longevity represents how many years a battery can last before being unusual and “cycle life represents the number of times that battery can be fully charged and discharged before its capacity falls under 80% of its original capacity" (Peter, 2013). Live span is still somehow unknown because the newly used batteries are not on the market long enough to really have this numbers known. For now, Laboratory tests can be used as a rough number but in reality, the live span is not so much dependent on the design of a battery but on its usage. High/low temperatures, fast charging, fast discharging and other extremes have negative effect on the batteries live span.
- Operating range or the ability to be used in low and high temperatures. Normally the battery preforms the best in a room temperature. They can actually not be charged on the temperatures below freezing and they already do not work properly at lower temperatures as the cold slows the electrochemical reaction in the batteries. High

temperatures are also a problem for battery overheating and they shorten the life span. There are ways to optimize the battery for low or high temperatures, for example for low temperatures heaters and insulation is used and for high temperatures different electrolytes and materials are used to handle the heat. Bigger challenge is to design a battery which can handle both high and low temperatures which is important for vehicles and its represents additional cost for vehicle manufactures.

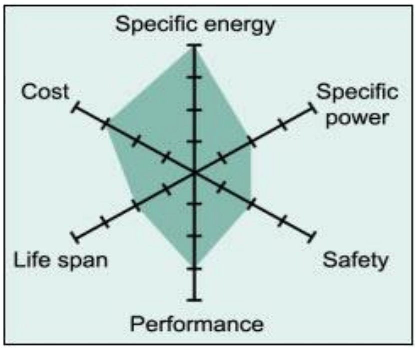
- Charging speed is also an important factor particularly in the eyes of potential customers. The technology for fast charging is already developed and more and more infrastructure is built every month, especially in big cities. But all the infrastructure and also additional coolers that are needed in the car for fast charging are increasing the cost of the EV which again makes it less desirable for the public.
- Price of the battery as the last key element of the battery but for sure not the less important one. As we have already mentioned in the paragraph above, there are a lot of improvements done in the battery industry to reduce the price but the costs still represent roughly 40% of the overall cost of the vehicle.

Understanding the key performances of an EV battery we can now continue whit the analysis of different Lithium-ion batteries to find the best one on the market today. We will look at the six most used ones on the market: Lithium Cobalt Oxide (LCO), Lithium Manganese Oxide (LMO), Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Iron Phosphate (LFP), Lithium Nickel Cobalt Aluminum Oxide (NCA) and Lithium Titanate (LTO) (Kay, 2018).

#### *2.4.1.1 Lithium Cobalt Oxide (LCO)*

These batteries are used in consumer electronics as smartphones, digital cameras and laptops because they have high specific energy. Even though they have great specific energy, they are not used for automotive industry. This is because of their relatively short life span, low specific power and low thermal stability which can further lead in overheating and present a potential safety risk for the EVs.

*Figure 5: Spider diagram for the Lithium Cobalt Oxide (LCO) battery*

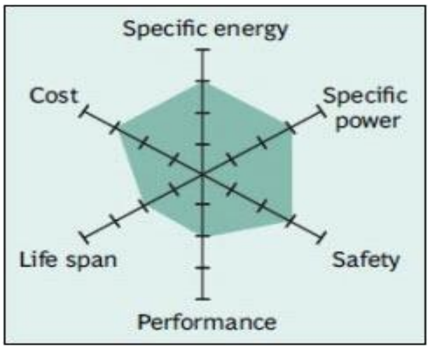



*Source: Buchmann, 2016.*

#### 2.4.1.2 Lithium Manganese Oxide (LMO)

The advantage of the LMO battery lays in its three-dimensional spinel design which lowers the internal resistance in the battery and improves high changes in current, consequently enables fast charging and fast high-power discharging. LMO batteries are therefore used for medical instruments, power tools and also hybrid and electric cars. Additionally, their spinel architecture makes it thermally stable and improves the safety but on the other side it lowers the cycle life and longevity.

*Figure 6: Spider diagram for the Lithium Cobalt Oxide (LCO) battery*

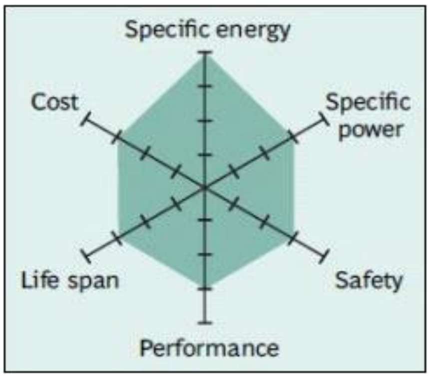



*Source: Buchmann, 2016.*

#### 2.4.1.3 Lithium Nickel Manganese Cobalt Oxide (NMC)

NMC batteries are nowadays widely used as they can be built economically, as their three active materials (nickel, magnesium and cobalt) can be used in different combinations and can be designed to suit specific requirements. Therefore, they have a wide range of usage from power tools, EVs, e-bikes and a lot more. The overall performance is satisfactory, moreover it has excellent specific energy performance and it has the lowest self-heating rate.

*Figure 7: Spider diagram for the Lithium Nickel Manganese Cobalt Oxide (NMC) battery*

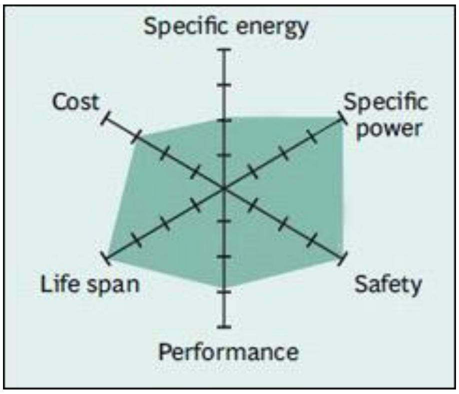



*Source: Buchmann, 2016.*

#### 2.4.1.4 Lithium Iron Phosphate (LFP)

The key benefits of the LFP batteries is up to 5 times longer cycle life compared to other Lithium-ion batteries, high specific power and are also very thermally stable which significantly increases its safety in terms of overheating and exploding. On the other side the specific energy is low in addition to high self-discharging makes it problematic with ageing. They are mainly used for electric bike and vehicles and also solar systems.

*Figure 8: Spider diagram for the Lithium Iron Phosphate (LFP) battery*

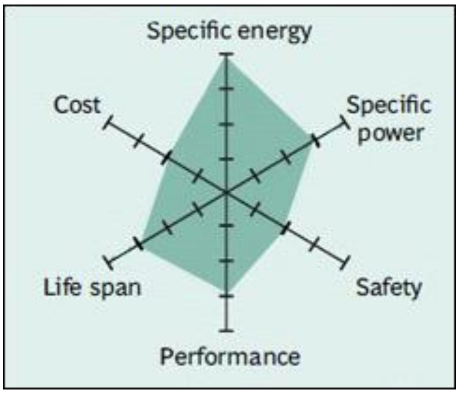



*Source: Buchmann, 2016.*

#### 2.4.1.5 Lithium Nickel Cobalt Aluminum Oxide (NCA)

As NMC also the NCA battery has high specific energy, good specific power and a long-life span makes it settable choice for EVs. On the contrary its high cost and low safety cancel out the good characteristics.

*Figure 9: Spider diagram for the Lithium Nickel Cobalt Aluminum Oxide (NCA) battery*

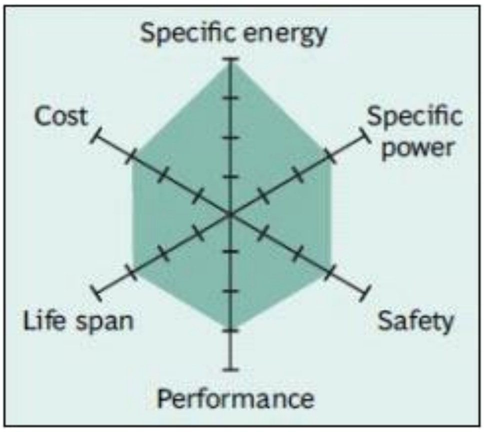



*Source: Buchmann, 2016.*

*2.4.1.6 Lithium Titanate Oxide (LTO)*

Li-Titanate batteries have similar spinel structure as LMO, resulting in one of the best fast charging times when compared to other Lithium-ion batteries. This battery preforms great in high discharging power and also its cycle life is one of the best. Obtaining a capacity of 80% at -30°C reflects its super low-temperature discharge. Crucial drawbacks are high price and low specific energy.

*Figure 10: Spider diagram for the Lithium Titanate Oxide (LTO) battery*




*Source: Buchmann, 2016.*

From the six main lithium battery types, clearly the best in terms of specific energy or in other words storing capacity is Li-aluminum (NCA). Beating nikel-maganese-colbat (NMC) and Li-cobalt battery (LCO) for approximately 20%. This advantage applies just for specific energy, if we look at the specific power and thermal stability they don't get on the first positions. Here Li-phosphate (LFP) and Li-manganese (LMO) are the leaders. Furthermore, we get the best result in terms of life spam and performance in cold temperatures, from Li-titanate (LTO) battery. It is evidently that non-off the battery type really stands out when analyzing all the main performance characteristics together. However, on the paper LTO battery has a promising performance characteristic for EV industry. The main problem is that the development of LTO is not far enough to be commercially adopted. Looking at the EV market, the top six most sold electric cars in Europe until November 2017 (Table 6) are using three different types: NMC, LMO and NCA battery.

*Table 6: Six most sold fully electric cars in Europe from January to November 2017 and their battery type*

| CAR COMPANY | MODEL | SALES (number of vehicles) from January to November 2017 | BATTERY TYPE |
|---|---|---|---|
| Renault | Zoe | 28,030 | NMC/LMO |
| BMW | i3 | 18,493 | LMO/NMC |
| Nissan | LEAF | 16,650 | NMC |
| Tesla | Model S | 12,916 | NCA |
| Volkswagen | e-Golf | 11,737 | NMC |
| Tesla | Model X | 10,517 | NCA |

*Source: Adapted from Lopes (n.d.).*

Renault and BMW with their best-selling models Zoe and i3 are both using a battery combination of NMC and LMO (Renault XX. For the first generation of the LEAF, Nissan was using LMO battery, but from 2017 on they are producing a new generation of LEAF with NMC battery. Both Nissan and VW are saying that NMC is a perfect choice as it has high specific capacity and its laminated cell structure enables the battery smaller size and weight (Blanco, 2014). Additionally, it results in better cooling performance, which means that there is no need for additional cooling system. Tesla on the other hand uses NCA batteries. As they say, the main advantage of this battery is its very little capacity loss over high mileage. The data that they collect from the lab test and also from their car buyers, shows that in most of their cars, the battery losses are just 5% of its capacity in the first 100.000 driven kilometers and that it should have 90% of original capacity after driving for approximately 240.000 kilometers. Although they have so good results with this type of battery they are investing heavily into the development of even higher energy dense and durable battery and they are already having some laboratory results with a new NMC battery that could retain approximately 95% of its original energy capacity after car driving for 480.000 kilometers. So, if also Tesla will start using their new generation NMC battery, all the top selling cars will be using this type of battery or at least a combination of it. (Garche, Karden, Moseley, & Rand, 2017; Lopes, n.d.).

### 2.4.2 Battery future developments

So as the demand for batteries grow rapidly and not just because of the car industry but also personal computers, mobile phones and the possibilities to store »green« energy produced by wind and solar power. The focused of the top battery producers is now on developing smaller and lighter battery that can store more energy and this does not mean just increasing the performance of lithium-ion battery but also finding a new alternative. There are little information about the development and performance results on new battery types. The manufacturers are not disclosing details about their discoveries as a new breakthrough could be a big game changer and would potentially result in a new market leader in this industry. However, there were still some promising discoveries published in 2017 that could lead further in to building a better battery (Deng, 2015; Miller, 2015).

In October 2017, Toshiba has announced the new generation of their lithium battery called SCiBTM. This anode material, titanium niobium oxide (version of LTO battery type) is prepared to achieve double the capacity of the anode compared to the other lithium-ion batteries currently on the market. Battery has a high energy density, rapid recharge and it exhibits low degradation even when it is charged and discharged at very low temperatures (-30°C). In a compact EV with 32kW/h battery pack, they realized 320km driving range with just 6 minutes of rapid recharge. Toshiba did these tests with a JC08 test cycle and the results were three times better that was possible with other lithium batteries. Director of Corporate Research & Development Center at Toshiba Corporation, said about the battery: "Rather than an incremental improvement, this is a game changing advance that will make a significant difference to the range and performance of EV. We will continue to improve the battery's performance and aim to put the next-generation SCiBTM into practical application in fiscal year 2019." (Toshiba Co., 2016).

One month after Toshiba, Samsung Advance Institute of Technology announced that they have synthesized a graphene ball. Samsung is saying that new batteries that will be using graphene will be able to charge faster and last longer. The numbers are showing up to 45% increase on the battery capacity and up to five-time increase in the charging speed compared by today's batteries. Based on their laboratory results graphene batter could be charged in just 12 minutes compared with current lithium-ion batteries that need approximately one hour too charge. Their research was focusing more into battery usage for mobile phones, but the graphene battery is showing a great potential also in the automotive industry as it can maintain stability up to 60 degrees Celsius. The technology sounds promising but as the scientists are caucus about the forecasts. A director at an IDTechEx, that Samsung has come to some interesting discovery but still thinks that the path to commercializing it will be hard and long. He said "The technology readiness level is still at the proof-of-concept to demonstrator stage. We often read about remarkable graphene-based results at these stages but only a few translate into commercial success stories.". The same opinion was stated from a Chief Technology Analyst of SK Securities. He had stated: "The key is who can commercialize the graphene-based battery technology first. It won't be easy to apply the minute processing technology for large-scale production of high-quality, electronics-grade graphene" (Son and others, 2017; Mu-Hyun, 2017; Jung, 2017).

As the most developments are related to improvements on lithium-ion battery, there are still some companies that are trying to develop something totally out of the box. One of these companies is AquaBattery with their 100% sustainable battery called The Blue Battery. This Dutch company has created a battery that is using only a mixture of water and table salt. Their battery runs at the atmospheric pressure and at room temperature so there are no chemical reactions happening during the chemical reactions inside the battery. Their aim is to get rid of the conventional batteries that are composed from a lot of toxic materials which are damaging our environment. Their battery had won the "circular economy" award but the anyway the development is still far away from being ready for commercial use (AquaBaterry Co., n. d.; Fildes, 2018).

The biggest critics of lithium-ion batteries are saying that lithium technology that was commercialized in 1991, is more or less "polished" to the perfection and that it will be really hard and costly to develop and achieve better performance out of it. It is mentioned that a totally new breakthrough with a different technology is needed to cause a real drastic improvement. The battery technology that is getting the most attention and is supposedly the closest to been commercialized is solid-state battery technology. In the beginning, a lot off small startups were interested and started the development of this type of technology and now more and more big automotive companies recognized its potential and started to be a part of it. There are a lot of plusses of the solid-state technology if we compare it to the conventional lithium-ion technology (Table 7) (Reisch, 2017; Lebedeva, Di Persio, Boon-Brett, 2016).

*Table 7: Comparison of solid-state and lithium-ion battery technology*

| **SOLID-STATE** | **LITHIUM-ION** |
|---|---|
| + Higher energy storage<br>+ Lighter<br>+ Nonflammable<br>+ Good performance at high temperatures<br>- Higher cost<br>- New technology | - Lower energy storage<br>- Heavier<br>- Flammable<br>- Decreased battery life at higher temperatures<br>+lower cost<br>+Proven technology |

*Source: Reisch (2017).*

The main difference of the two is that as the name indicates, solid-state battery uses solid electrodes and solid electrolytes instead of toxic and flammable liquid electrolytes used in modern lithium-ion battery. This characteristic enables the battery to be more energy dense and also more stable, which results in longer run-time per charge and also better stability at higher temperatures. Additionally, the removal of flammable electrolytes makes the battery safer and therefore even more desirable in the EV industry and car producers are every day more involved in the development of this technology (Solid Power Co., n.d.; Reisch, 2017).

Toyota was one of the first car brands that was talking about the potential of the solid-state technology used in vehicles. They stated their development of the solid-state battery already in June 2014 in their article “Invited Presentation: Innovative Batteries for Sustainable Mobility”. They had no mayor Breakthru yet achieved but have announced collaboration and join forces with Panasonic, which should supposedly speed up the process to commercialize the solid-state battery. Their projections are really optimistic, their aim is to bring the battery, commercially ready, on the market in year 2020 (Reisch, 2017; Kane, n.d.).

In April 2017 also, Hyundai decided to start the battle to develop EV compatible solid-state battery. The Korea Herald published: “Hyundai is developing solid-state batteries through its Namyang R&D Center’s battery precedence development team and it has secured a certain level of technology,”. They decided not to partner with some of their local battery producers like LG Chem or Samsung SDI, but to develop the new technology on their own. Additionally, the source from The Korea Herdal said that Hyundai will be able to expand the production of the solid-state battery till year 2025. This mean that they should have the finished design even couple of years before (Ji-hye, 2017; Jin, 2017).

Additionally, also BMW added itself to the growing list of automakers, seeing the future of EVs dependence of the solid-state battery. At the end of 2017 they have announced a partnership with company Solid Power. Solid Power is a spin-out company from the University of Colorado Boulder, established in 2012. They consider itself as a market-leader in the field of developing the next generation solid-state battery (Solid Power Co., n.d.; Reisch, 2017).

One of the latest news published by Green Car Congress is, that car maker Fisker filed a patent on solid-state battery technology. Fisker is claiming that this technology will enable 1-minute charging times which should be faster than filling up a gas tank. Furthermore, the single charge will enable ranges of more than 800 kilometers. Dr. Fabio Albano, vice president of battery systems at Fisker Inc. said: “This breakthrough marks the beginning of a new era in solid-state materials and manufacturing technologies. We are addressing all of the hurdles that solid-state batteries have encountered on the path to commercialization, such as performance in cold temperatures; the use of low cost and scalable manufacturing methods; and the ability to form bulk solid-state electrodes with significant thickness and high active material loadings. We are excited to build on this foundation and move the needle in energy storage.”. Their anticipations are, that the technology will be automotive production ready from 2023 on (Fisker Inc., 2017; Albano, 2017).

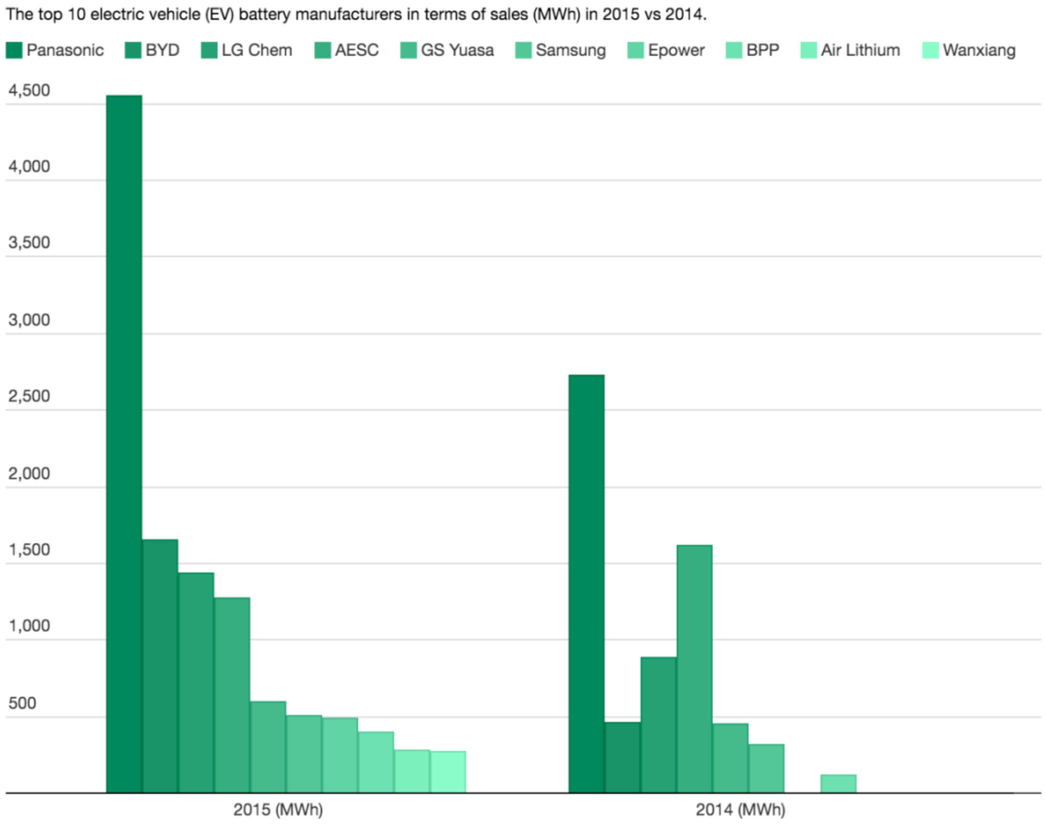
We see that a lot has been done in the year 2017 regarding the new battery technology. But there are no major new technologies foreseen for commercial use in the next two to five years. Nevertheless, the prices of present lithium-ion batteries are falling rapidly and are playing a big role in making the end price of the EV more and more competitive with a conventional internal combustion engine vehicle.

### 2.4.3 Battery demand and battery price projections

As already mentioned before the price of the battery will play a big role in the future adoption of EVs. This is why we will in this chapter look at the main battery producers analyze the present market share and their future plans and projections. At the end we will analyze the correlation between battery demand and battery price and try to determine how the battery price will affect the demand for EVs in Europe.

In the 1980s three important discoveries led the team managed by two Japan companies, Asahi Chemical and Akira Yoshino, to produce the first prototype of the lithium-ion battery in 1985. In 1991 Sony was then the first one to bring lithium-ion battery to the market and commercialized it. Since then Japan and South Korean companies were dominating this market. If we look at the top 10 battery producers in year 2014 and 2015 (Figure 11) and (Table 8) we can see, that China started to take the lead in this industry (Ayre, 2016). We can see that in 2015 a series of small Chinese battery suppliers appear in the bottom of the ranking: Epower, BPP, Air Lithium and Wanxiang. This small supplier together with BYD and AESC actually resulted in 36% market share in year 2015. However, the biggest producer was still Japanese company Panasonic, with approximately 40% market share. One of the reasons why Panasonic had the highest sales in 2015 is that they have a contract with Tesla, and the won the title of the most sold electric car in 2015 with their Tesla Model S.

*Figure 11: Top 10 EV Battery Producers (2015 vs 2014)*




*Source: Ayre (2016).*

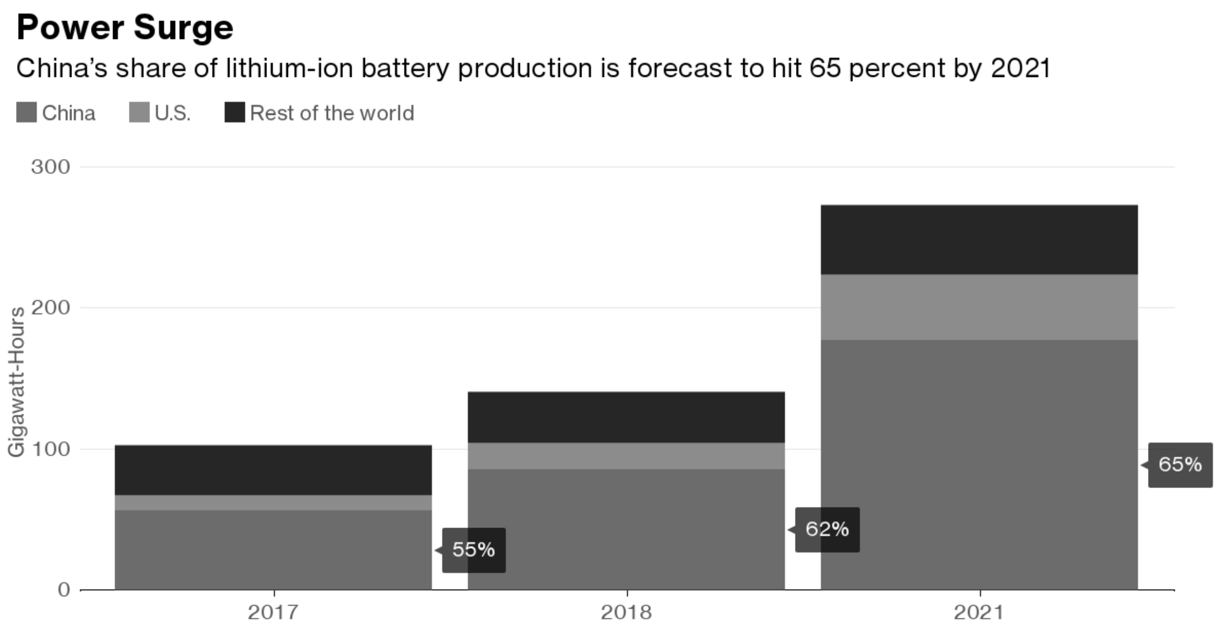
*Table 8: Comparison of solid-state and lithium-ion battery technology*

| **Battery Producer** | **2015 (MWh)** | **2014 (MWh)** | **% of 2015 Total** | **% of 2014 Total** |
|---|---|---|---|---|
| Panasonic | 4,552 | 2,726 | 40 | 41 |
| BYD | 1,652 | 461 | 14 | 7 |
| LG Chem | 1,432 | 886 | 13 | 13 |
| AESC | 1,272 | 1,620 | 11 | 25 |
| Mitsubishi/GS Yuasa | 600 | 451 | 5 | 7 |
| Samsung | 504 | 314 | 4 | 5 |
| Epower | 489 | NA | 4 | – |
| Beijing Pride Power | 397 | 121 | 3 | 2 |
| Air Lithium (Lyoyang) | 283 | NA | 2 | – |
| Wanxiang | 268 | NA | 2 | – |
| **TOTAL** | **11,449** | **6,579** | **100%** | **100%** |

*Source: Ayre, 2016*

Since 2015 China is just increasing their market share in the battery production industry. The biggest cause for this is their aggressive governmental policies and trying to restrict foreign rivals to enter their market. They started by making a tailor-made subsidy programs which have the specifications made just to fit Chinese battery producers. The growing battery demand in China lead to two foreigner's companies opening their plant in China. First was South Korea’s LG Chem and after also Korean company Samsung SDI. In 2016 Chinesewent even further, they have released a list of companies that were allowed to supply batteries in the country and not even one foreign company was on that list. At the end of 2016 the additional released guidelines that car battery manufacturers would need to have at least 8 GWH of production capacities inside China to be able to apply for subsidies. This target capacity could be only meet by two Chinesecompanies, BYD and CATL. Based on all the support that China is giving to their battery producers, the numbers are showing that they already have about 55% share of the lithium-ion battery production from the total of 103 gigawatt-hours market. Experts from this industry are forecasting that the demand for batteries will more than double in the next three to four years and China for sure does not want to miss this opportunity. In April 2017 Chinesegovernment called for companies to double their battery capacities for electric vehicles by 2020 and also encouraged them to invest in factories outside China. Looking at the Bloomberg New Energy Finance research, the forecasts are that China will hit 65 percent of the 273 gigawatt-hours market by 2021 and that the other 35% percent will be split between United State and rest of the world (Figure 12) (Novak, Muller, Santhanam & Hass, 1997; Brodd, 2001; Sanderson, Hancock, & Lewis, 2017; Ryan, 2017).

*Figure 12: Forecast of lithium-ion battery production by 2021*




*Source: Ryan (2017).*

One other research done by Financial Times is showing similar numbers. They are estimating that by 2020, 84% of the lithium-ion batteries will be produced in China and United States (Table 9).

*Table 9: Forecast of the companies lithium-ion battery production capacity by 2020*

| | **Capacity 2016 [GWh]** | **Extra capacity by 2020 [GWh]** |
|---|---|---|
| CATL (Ningde, China) | 5 | 45 |
| Tesla Motors/Panasonic (Nevada, US) | 0 | 35 |
| Lishen (Tianjin, China) | 3 | 17 |
| LG Chem (Ochang, S Korea) | 8 | 10 |
| BYD China (Shenzhen, China) | 3 | 9 |
| LG Chem (Nanjing, China) | 2 | 6 |
| LG Chem (Wroclaw, Poland) | 0 | 5 |
| Samsung SDI (Ulsan, S Korea) | 3 | 2 |
| Boston Power (Liyang, China) | 0 | 2 |
| Boston Power (Liyang, China) | 1 | 4 |
| Samsung SDI (Xian, China) | 2 | 2 |
| LG Chem (Michigan, USA) | 1 | 2 |
| CALB (Luoyang, China) | 1 | 2 |
| Panasonic Dalian (Dalian, China) | 0 | 3 |

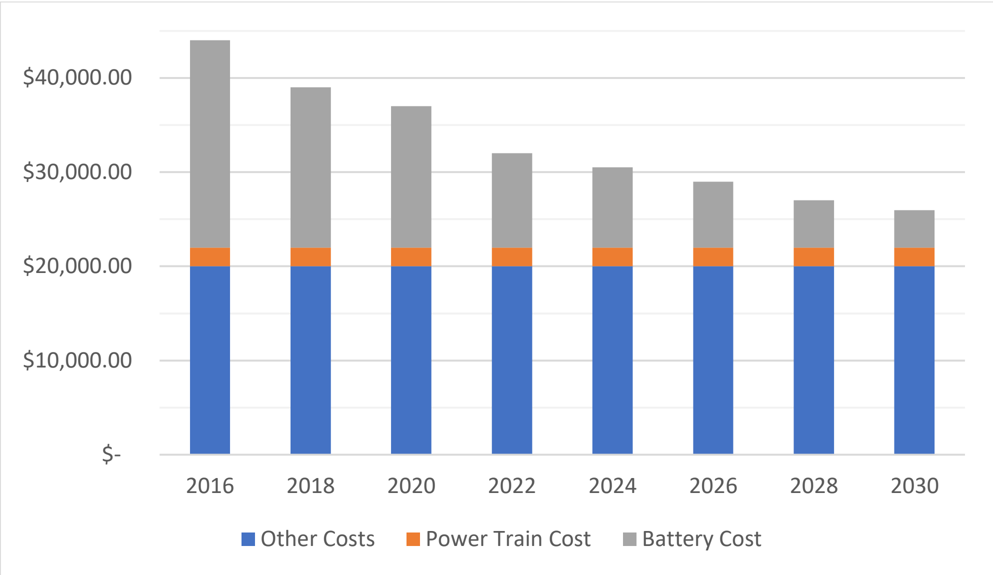
*Source: Sanderson, Hancock, & Lewis (2017).*

Everyone is talking about US and China, but where is Europe in this story? At present the market share of Europe is about 2.5 percent of the total market share. Europe is expecting to double the market share by 2021. As the battery capacity is expected to also double by 2021 this means that this means that Europe needs to increase the production for four times to reach the desired market share of 5 percent. There is already some investment planned for large-scale factories in Sweden, Hungary, Poland and Daimler's battery assembly plant in Germany. One of the biggest investments was made by Daimler. They have invested 500 million Euros in the new battery plant in Kamenz Germany. The productions should start operating in mid-2018, but Daimler has not disclosed the battery capacity of it. In October 2017 LG Chem announced to invest about 1.4 billion euros in to the new factory near city Wroclaw in Poland. They is just about 190 kilometers away from the German border and home of VW Group. They plan to produce up to 100.000 EV batteries annually in the new factory. To put it into perspective a small size EV needs around 25kWh battery pack which means that LG's production will be equivalent to about 2.5 GWh per year.

Additionally a Swedish company NorthVolt AB, run by a former Tesla executive, plan to raise 4 billion euros to invest in a lithium-ion battery factory that will be able to produce about 32 gigawatt-hours by year 2023, which is around 90% of the Tesla's Gigafactory target. In September 2017 Swiss engineering group ABB joined this project. Moreover, UK has decided to allocate almost 250 million pounds over the next four years for battery development (Ryan, 2017; Hirtenstein, 2017; Staff, 2017a; Staff, 2017b).

All the investments made in developing a better battery in combination with the economy of scale should result in a cheaper battery pack. This will be really important if the EV cars want to compete with commercial vehicles powered by fossil fuels. The average cost of the cars powered by fossil fuels is around 23.000 euros and is expected to rise to about 24.000 euros until 2025/2030. EVs to compete with this will need to rely on a 67 percent drop in battery price in next couple of years and it is estimated that will account for approximately 18% cost of the whole EV (Figure 13).

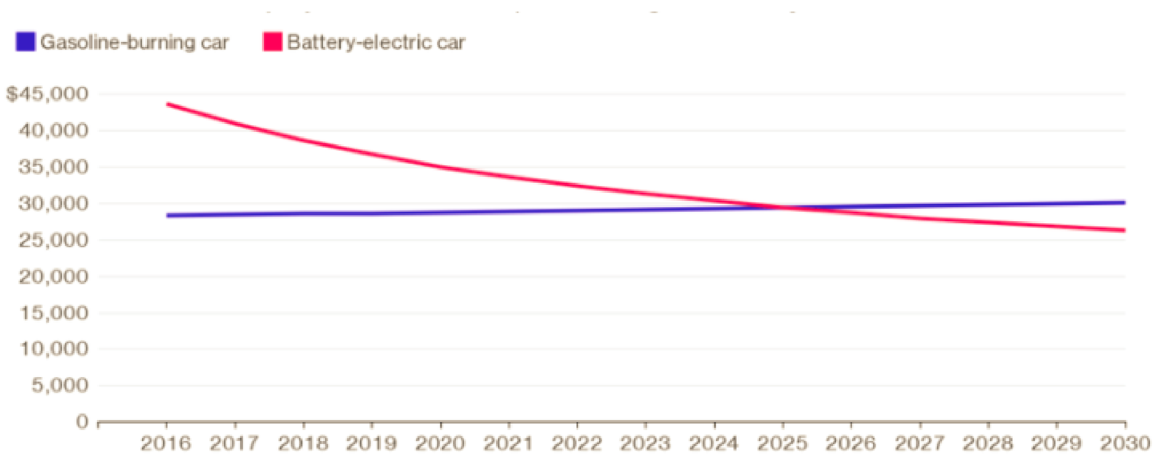
*Figure 13: Share of production costs of battery electrical vehicle*




*Source: Adapted from Sanderson, Hancock & Lewis (2017).*

Projections are that the price of battery pack will fall to around $156 (€126.38) a kilowatt-hour till 2021, compared to today's price at $273 (€221.16), this would be a 43 percent decrease. Which means that 67 percent decrease which is need will not yet be meat. More likely is that the prices of EVs will meet internal combustion engine car prices in year 2025 (Figure 14).

*Figure 14: Battery electrical vehicles prices estimation*




*Source: Sanderson, Hancock & Lewis (2017).*

## 2.5 Charging infrastructure in Europe

The restricted driving capacity of numerous electric vehicles implies that the sort of technology used to charge them, and the time duration it takes, are vital to the end-user. Just battery and fuel cell electric vehicles are absolutely dependent on the charging infrastructure; for hybrid cars, it isn't as crucial, as they likewise contain a customary ICE.

### 2.5.1 Electric vehicles charging options

There are three basic approaches to charge an electric vehicle: plug-in charging, battery swapping or wireless charging.

Plug-in charging is utilized by far most of current BEVs and PHEVs in Europe. Vehicles are physically linked with a charging point utilizing plugs and cables. Plug-in charging can be done wherever charging stations are situated: at houses, open roads or on business or private premises. Electric vehicles can, as a rule, be charged utilizing ordinary household plugs, yet this is slow since typical residential sockets give just a low electric current. It can thusly take around eight hours for a full charge. However, this can be very reasonable for charging during the night time. Quicker plug-in charging requires a specific framework. Nowadays, most public plug-in stations set up at cities, on local or national level offer just ordinary speed charging (European Environment Agency, 2016).

Battery swapping includes supplanting a utilized battery with a completely charged one at a dedicated swapping station. This offers a fast method for rapidly 'recharge' a vehicle. To date, no big suppliers in Europe offer battery swapping. Various obstacles have kept battery-swapping innovation from getting to be across the board, including the absence of electric vehicle models that support battery swapping, lack of standardized type and dimensions of the battery, and the high cost of building up the related charging and swapping framework (European Environment Agency, 2016).

Wireless charging, otherwise called induction charging, does not require a settled physical contact between the charging infrastructure and the vehicle. Rather, the framework makes a localized electromagnetic field encompassing a charging pad, which actuates when an electric vehicle with a compatible pad is situated above it. The wireless strategy at present works at just few pilot areas and is yet to be mass utilized. Cases of wireless charging pilot ventures are remote charging for buses at bus stations in Belgium, Germany, the Netherlands and the UK, and some pilot testing for drivers of EVs in Sweden (European Environment Agency, 2016).

There are different manners by which battery electric vehicles can be charged by means of plug-in charging. Four 'modes' of charging capabilities are usually accessible and each of them can include different mixes of energy level provided by the charging station (kW), sort of electric current utilized (alternating current (AC) or direct current (DC)), and plug types. As electrical power frameworks give AC, and batteries can store just DC, the power gave by the matrix to the electric vehicle initially should be changed over. The change should be possible either by an onboard AC/DC converter inside the EV or by a converter inside the charging point. Henceforth, AC charging is occasionally alluded to as 'onboard charging'. DC quick-charging stations have integrated converters, so the charging station itself changes AC power from the matrix into DC power for the EV. The power level of the charging source relies upon both the voltage and the top current of the power supply. This decides how rapidly a battery can be charged. The power level of charging stations extends broadly, from 3.3 kW to 120 kW. Lower power capabilities are common in private house charging stations (European Environment Agency, 2016).

- Mode 1 (slow charging): permits vehicle to charge utilizing typical regular building sockets and cables. It is ordinarily found in household or office structures. The ordinary charging power level is 2.3 kW. Regular building sockets give AC current.
- Mode 2 (slow or semi-fast charging): utilizes a non-specialized socket, but with a dedicated charging cable provided by the EV maker. A security gadget incorporated in the cable ensure protection to the electrical framework. AC current is provided.
- Mode 3 (slow, semi-fast or fast charging): utilizes a specialized socket and a special circuit to permit charging at higher power levels. The charging can occur via a box in the wall, generally utilized at private areas or at poles, regularly found out in open public areas. It utilizes devoted charging hardware to guarantee safe activity and gives AC current.
- Mode 4 (fast charging): in some cases alluded as 'off-board charging', conveys DC to the vehicle. An AC/DC converter is situated in the charging hardware, rather than inside the vehicle.

One drawback of high-power quick charging is that the higher currents imply that greater electricity is lost while charging, i.e. the efficiency is lower. In addition, quick charging can diminish battery lifetime, decreasing the quantity of charging cycles. Quick DC charging stations are likewise three times as costly to implement as a straightforward AC charger, therefore a large number of drivers are hesitant to put resources into the extra expenses. While some new electric vehicle models are sold with a DC charging point, others require the acquisition of an extra charging hardware (European Environment Agency, 2016). Electricity can circulate utilizing single-phase or three-phases frameworks. Residential units generally utilize single-phase power for lights and home appliances. It permits just a restricted power load. Business buildings generally utilize a three-phase framework, as it gives higher power.

*Table 10: Charging times to provide 100 km of battery electric vehicle driving*

| **Power, current, mode** | **Time** | **Location** |
|---|---|---|
| 120 kW<br>DC<br>(mode 4) | 10 minutes | Motorway service area or dedicated charging stations in urban areas<br>(future standard) |
| 50 kW<br>DC<br>(mode 4) | 20 - 30 minutes | Motorway service area or dedicated charging stations in urban areas<br>(current standard) |
| 22 kW<br>AC, three-phase<br>(mode 3) | 1 - 2 hours | Most public charging poles |
| 10 kW<br>AC, three-phase<br>(mode 3) | 2 - 3 hours | Household, workplace wall box |
| 10 kW<br>AC, three-phase<br>(mode 3) | 2 - 3 hours | Household, workplace wall box |
| 7.4 kW<br>AC, single-phase<br>(mode 1 or mode 2) | 3 - 4 hours | Public charging poles |
| 3.3 kW<br>AC, single-phase<br>(mode 1 or mode 2) | 6 - 8 hours | Household, workplace wall box |

*Source: European Environment Agency (2016).*

### 2.5.2 Electric vehicles charging locations

Numerous individuals assume that it is difficult to encounter charging stations for EVs however, the quantity of plug-in points has expanded quickly recently. More than 92 000 public charging stations are presently accessible crosswise over Europe. Charging stations for EVs are typically described by their level of openness for drivers. These classifications of charging stations are usually designed as private, semi-public and public.

Before-mentioned charging stations are found in houses and offices premises. They incorporate devoted charging boxes or usual building sockets. Home charging is a straightforward choice for EV proprietors since no membership or subscription costs are expected to get to the charging station. Private charging additionally happens when organizations introduce charging stations for use by representatives on office premises. Home charging normally has a tendency to be more typical in rural or provincial territories than in urban neighborhoods, as it needs that the vehicle proprietary to approach a private garage or have the capacity to plug the electric vehicle to a building socket. In urban communities, where vehicles are typically stopped on public lanes or in semi-public auto parks, it is harder to get to a private charging point (European Environment Agency, 2016).

These sorts of charging stations are arranged on private areas, yet can be reached by outside clients. Examples are charging stations situated in business auto parks, malls or recreation amenities buildings. Admittance to these charging stations is normally limited customers or clients. Business owners regularly view the charging stations as a complimentary service or a chance to publicity, so they don't charge clients for the power utilized. In different scenarios, the power utilized is incorporated into the client's parking bill, or in the usage price for car-sharing platforms. Most quick charging stations are semi-public and, as traditional gas stations, are based on private area yet open to every paying client.

Public charging stations are generally set close by highways parking spots or out in the public parking lots. Although private or semi-public charging stations frequently have wall boxes, the public framework in general offers standalone charging poles, eventually provided by the municipalities, but these municipalities are progressively appointing business suppliers to encourage the development and operation of public charging framework (European Environment Agency, 2016).

In a few urban areas, public charging stations offer are free for EV owners. Tesla likewise offers a system of quick charging stations crosswise over Europe for free for specific models. Such free charging stations are created to give an early motivator to drivers to buy EVs. In the more drawn out term, if EVs turn out to be more typical, free charging for EVs is probably going to vanish. An extensive variety of payment systems are utilized at charging stations. At public or semi-public ones, different payments and identification techniques are available. Clients are regularly identified via a smart-card and are in this manner charged for the real power utilized. This can imply that every EV driver needs to enroll and keep a few smart-cards from different providers in order to get access to an adequate number of charging stations. In different cases, power providers enlist specific cars and give each one a digital identification key. Enlisted cars are then recognized at charging stations without the need of the client's smart-card. This framework is known as 'plug and charge'. Other choices for client identification are telephone numbers, cell phone instant messages, 'smart cables' that have a SIM card, personal identification number numbers and also physical keys. Occasionally clients can pay straightforwardly at the charging station (with a bank card or money), or in combination with a proof of paying auto parking expenses. Both identification and payment should progressively be possible to do with smartphones applications. A few attempts were done to disentangle the range of different payment alternatives utilized in Europe (European Environment Agency, 2016). They expect to make an ever-more prominent number of charging stations accessible to all EV clients by shaping consortia of charging framework suppliers and encouraging 'eRoaming'. That gets rid of the requirement for proprietors to dependably hold a few smart-cards from different providers. At the EU level, the Alternative Fuels Infrastructure Directive 2014/94/EU made specially appointed access to charging stations obligatory and also requiring 'reasonable, easily and clearly comparable, transparent and non-discriminatory' prices (European Environment Agency, 2016; Fernandes, Frías, & Latorre, 2012).

### 2.5.3 Developing charging station infrastructure in Europe

What is the 'perfect' number of charging stations that ought to be accomplished in the EU, in what capacity would it be a good idea for them to be disseminated and on what course of time? All these inquiries depend on arrangements on future advancements in EV innovation and markets. EV market share will not show increment if the current charging stations framework stays static. Be that as it may, it additionally looks bad to extend charging stations altogether without knowing how individual transportation as a rule, and particularly the EV market, will look like later on. In a perfect world, both the automobile market and the infrastructure ought to develop at the same time. The Alternative Fuels Infrastructure Directive 2014/94/EU gives one gauge of the coveted extent of charging stations to EV numbers: no less than one public charging point for each 10 vehicles, continually considering new improvements in vehicle, battery and charging infrastructure innovation and accepting that most private electric vehicle proprietors have their own particular charging stations (European Environment Agency, 2016). The newly published European procedures for low-emission mobility additionally features the significance of freely accessible electric charging stations. To accomplish mass acknowledgment and arrangement of EVs, it perceives that charging and upkeep framework needs to wind up generally accessible all through Europe (European Environment Agency, 2016).

There are two broad ways to deal with working up charging framework. One includes building up a totally EV charging system first. The other is incremental development, in light of augmenting the infrastructure as EV owners requests increment after some time. On the off chance that adequate subsidizing is accessible, the first approach can help advance a quick take-up of EVs. In actuality, the incremental approach is more plausible, as public financing is regularly restricted and it can be hard to legitimize public interest in charging station without coordinating public requests. Be that as it may, without a huge charging network, drivers will delay the purchase of EVs. Other than the number and space arrangement, the sorts of charging stations to be made accessible to EV owners must be chosen. A few European studies have inferred that, in many situations, it is conceivable to guarantee regular mobility utilizing just normal EV charging overnight at home. Such direction is fundamentally streamlined. It centers around ordinary mobility in cities and slights long-distance trips. Customers stay worried that EVs have a restricted range. These worries can be alleviated by introducing infrastructure that charges vehicle batteries rapidly, to support long-distance trips (European Environment Agency, 2016; Tuttle, & Baldick, 2012).

There are a few downsides of quick charging and the advancement of quick charging infrastructure. Regular quick charging may decrease the battery's lifetime. Interestingly, regular and fragmented discharging and recharging utilizing regular home charging stations does not hurt the battery to a similar degree. Most makers admittedly guide their clients to running the battery between 10 % and 80 % charged. Additionally, the normal cost of a DC quick charging station is around three times as high as a typical AC charging station. Numerous BEVs, and particularly most PHEV models, as of now do not support quick charging, or they offer it just as a costly extra optional. For most drivers, slow charging is usually adequate, as most customer trips are short, so EVs more often than not come back to the charging station with a considerable amount of charge in the battery (European Environment Agency, 2016). For longer trips, notwithstanding, a framework system that can be utilized for ad hoc quick charging can help settle buyers worries about the restricted range of EVs.

In most European nations there are just a couple of thousand public charging stations, and they are usually slow charging stations. Such public charging stations are commonly introduced by public officials, utilities, EV makers or different organizations. In Europe, the Netherlands takes the lead with a system of more than 23.000 open charging stations in 2016. Other nations with extensive public charging station units are Germany (more than 14.000), France (more than 13.000), the UK (around 11.500) and Norway (around 7.600). On the other end of the list, with less than 40 charging stations are Bulgaria, Cyprus, Iceland, and Lithuania (European Environment Agency, 2016). A few nations are backing off the establishment of new public slow charging stations, with the focus moving to the development of quick charging stations. The EU built up the Trans-European Transport Network program to help the development and updating of transport infrastructure over the region. On infrastructure for EVs, the program has put resources into different projects including the pilot deployment of 115 high-power recharging stations on central European highways, to facilitate long-distance trips of EVs and advance sustainable mobility. Some while ago, recommendations were advanced to incorporate charging station target numbers for every EU Member State in the Alternative Fuels Infrastructure Directive 2014/94/EU. This would have brought about 8 million charging stations in the EU by 2020, with no less than 800.000 accessible to the overall population. In any case, these objectives were dropped amid the project discussions of the last text of the directive. Rather, governments were required to outline national action plans on charging stations framework and to introduce an 'appropriate number of electric recharging points accessible to the public' by the end of 2020 (European Environment Agency, 2016).

## 2.6 Industry analysis: Porter's five forces

### 2.6.1 Rivalry among existing competitors.

Typical representatives of this segment are the Europeans largest automakers, like VW, PSA and Renault. These giant conglomerates with almost a century of history in the automotive industry and wide production line ranging from heavy duty commercial vehicles to passage cars. All of them were listed on the Global Fortune 500 list and according to data available on their websites; each firm has sold more than 1.5 million units in 2016. Producers in this segment have rich automotive experiences and consider electric vehicle productions as one of their strategic directions. They have established “NEV subsidiaries”, where they develop and produce electric vehicles and have launched their own electric vehicle brands. The outsource of the developing and production of electric motors is more and more rare for these companies, that are prepared to produce electric motors in-house as soon as mass productions reaches critical point. Not only VW, but all the biggest EU automakers have enough financial power and capabilities to backward-integrate into electric motor production.

In comparison to the largest automotive producers, this segment mainly consists of private owned SMEs with lower scale operations. Instead of providing whole products ranges, these producers are more specialized, focusing on one or two core business (for example passenger cars and motorcycles). They have limited capital for investment, but are more efficient than the largest producers. These companies are more internationally oriented, with exports especially to Latin America and parts of Asia. In the electric vehicle business, they focus mainly on affordable smaller passenger cars and they do not have complete capacities for in-house production of core components (electric motors).

### 2.6.2 Bargaining power of buyers

Buyers can chose to outsource from a vast number of suppliers, who differentiate themselves in product characteristics, brand and supporting services, carrying out performance tests on trial electric vehicle series. Each electrical vehicle model has its own requirements regarding drive motors and suppliers have to provide motors based on buyer's technical specifications. However, once the cooperation is established, it tends to last for at least a few years.

We assess the bargaining power of buyers as moderate, with expectations to increase in the following years as a result of the increased number of suppliers, large quantities purchased and higher threat of backward integration from the largest players.

### 2.6.3 Threat of new entrants.

The investment requirements to establish a production company are high, as assembly lines and technological equipment need to be provided. Besides, products are the subject of patent property and fruit of R&D investments. Suppliers have to respect high automotive standards regarding safety and performance. These facts result in high barriers to entry. However, due to the early stage of the industry and relatively low quantities produced, manufactures cannot enjoy benefits from economies of scale yet. At the same time, the relationships between buyers and suppliers are not permanent yet (Camus, Farias, & Esteves, 2011). This leaves new entrants some possibility to enter the market. When the market of electric vehicles achieves mass production, higher quantities will enable existing manufactures to achieve economies of scale and reduce their costs, which will push potential new entrants out of the market. Established foreign producers are the most likely to enter the EU market.

Another scenario to be considered are the Chinese companies with strong capability of imitation. These firms may represent the biggest threat in the LSEV segment, where the price is the decisive factor. At the moment, the threat of new entrants is high, but we expect it to decline to moderate in the following years, as the market will mature and consolidate.

### 2.6.4 Threat of substitutes

If compared to traditional internal combustion engines vehicles, the purpose of electric motor in an EV is the same as the purpose of the engine in a traditional vehicle – it serves to run the vehicle. In case of a PHEV (plug-in hybrid vehicle), the vehicle is driven by a combination of both – combustion engine and an electric motor.

The electric drive motor serves for propulsion of an electric vehicle by converting electrical energy (coming from a battery) into mechanical energy. There are several types of electrical motors that can be used to drive an electric car, but most common is the permanent magnet synchronous motor. Despite many electric motor versions existing within the industry, there is no other substitute for an electric motor now, which makes the industry attractive from this point of view.

### 2.6.5 Bargaining power of suppliers

Electric motors are widely incorporated into electric vehicles, which is a rapidly growing market worldwide. Therefore, the increasing popularity of electric vehicles among consumers will likely stimulate the global electric motor market over the forecast period. As well, there is a rising demand for these motors from HVAC industry, as most HVAC appliances use electric motors for efficient operations.

According to Technavio's analysts forecast the global electric motors market (2015), about 11 key companies in EU can produce EV drive motors, of which 4 could deliver goods in volume for complete vehicle factories.

The growth in the electric drive motor market follows the growth in the EU EV market, as each vehicle needs at least one electric motor. If we assume a 100% annual growth of electric vehicle sales, then more or less the same growth is expected also in the electric motor market. Because of the growing market, there are many new entrants in the industry. The direct competition is coming from two directions:

- from domestic drive motor producers;
- from foreign global competitors.

Domestic producers are receiving strong support from the government, benefit from its policies and cooperation with university and institutes in R&D. As interpersonal networking is a common practice in EU everyday business, local suppliers are more likely to have the right connections within domestic EV automaker companies. Because of the expanding EV market, many foreign drive motor manufactures have established a subsidiary or a joint venture company in EU. While the local competitors' advantage is a strong relationship and cooperation with the government, foreign producers bring unique technologies, advanced products and R&D and powerful global brands.

According to the Technavio's analysts forecast (2015), the following 20 companies are the leading producers of permanent-magnet synchronous motors.

ABB is a global leader in power and automation technologies. Our solutions improve the efficiency, productivity and quality of our customers' operations while minimizing environmental impact. Innovation is at the forefront of what we do and many of the technologies that drive modern society were pioneered by ABB.

Allied Motion Technologies Inc. is a U.S. public company focused exclusively on serving the motion control market. It designs and manufactures motor and servo motion products for the Commercial, Industrial, and Aerospace and Defense markets. Allied Motion is growing both internally and through acquisition, and it is intend to be a leading worldwide supplier of technically advanced motion control products to our selected market segments.

AMETEK, Inc. is a leading global manufacturer of electronic instruments and electromechanical devices with 2015 sales of $4.0 billion (€3.24 billion). AMETEK has over 15000 employees at over 220 manufacturing locations around the world. Supporting those operations are more than 100 sales and service locations across the United States and in 30 other countries around the world.

ARC Systems, Inc. was founded in 1967 to provide the aerospace industry with a dependable source for high-precision motors and A.C. components. To meet the needs of this demanding market, ARC developed a unique team philosophy: to be a fully integrated, completely self-sufficient facility. Its products are incorporated in many different markets from Aerospace, Military and commercial. ARC is proud to say we have components on every ship in our fleet.

Founded in 1979, ASMO has devoted its technology to development and production of small motors for automobiles while putting up the slogan, "ASMO with Creation and Trust". As a result, ASMO's high quality products are trusted by the customers and have held the top-spot in sales and visibility when it comes to small motors for automobiles.

Baldor Electric Company is a leading marketer, designer and manufacturer of energy-saving industrial electric motors, mechanical power transmission products, and adjustable speed drives. The company was founded on the premise that a better motor is one that uses less electricity, a belief that stands true today.

Brook Crompton is a leading provider of electric motors for the global industrial market, with motor solutions that benefit a wide range of customers involved in numerous diverse markets. Our products are used in almost every industrial activity including water treatment, building services, chemicals/petrochemicals, general processing and manufacturing where they drive fans, pumps, compressors and conveyors amongst other things.

Through trusted brand names offer customers an unprecedented choice in selecting the right solution to match specific application requirements. Danaher Motion's growing family of leading motion control products and application expertise tells only half the story. With a worldwide service and support infrastructure, our field service engineers and support teams are available to assist whenever they are needed.

Emerson, based in St. Louis, Missouri (USA), is a global leader in bringing technology and engineering together to provide innovative solutions for customers in industrial, commercial and consumer markets around the world. The company is comprised of five business segments: Process Management, Industrial Automation, Network Power, Climate Technologies and Commercial & Residential Solutions. Sales in fiscal 2015 were US$22.5 billion (€18.23 billion).

Faulhaber is a leading supplier in the area of high precision miniature and micro drive systems. Faulhaber offers the most extensive range of miniature and micro drive technologies available from a single source worldwide. From high performance DC Motors, BLDC Motors, to Linear Motors, and Stepper Motors, each drive is designed to achieve maximum performance in minimum dimensions and weight. Matching precision gearheads, encoders, linear components and drive electronics are available to complete the system.

Founded in 1944, Franklin Electric has grown from a small motor manufacturing company into a leading global provider of complete water systems and fueling systems. Franklin Electric’s principal markets include clean water systems, water transfer and grey water systems, and fueling systems. Headquartered in Fort Wayne, Indiana, Franklin serves all corners of the world with more than 14 manufacturing and distribution facilities.

Since its founding in 1970, Huali has been a leading organization in the Chinese electric motor industry. More than 40 years of development, it is now a modern enterprise with its own production, distribution, R&D and customer service teams. Huali have become leaders not only in large and special electric motors, but also in high voltage, high efficiency and high quality motors. Our products includes about 11.000 varieties types in 40 major series.

Johnson Electric is the leader in motion subsystems. Our technology leadership, application expertise and global footprint make Johnson Electric the ideal partner for custom product development projects. Johnson Electric is committed to making our customers successful by providing product differentiation and supply chain excellence. For designers who demand performance leadership and assurance of supply, Johnson Electric is the safe choice. It serves many industries including Automotive, Building Automation, Home Technologies, Medical Devices, Power Tools and Lawn & Garden.

Maxon motor is the worldwide leading provider of high-precision drive systems up to 500 W. For the past 50 years, we have focused on customer-specific solutions, quality and innovation. Numerous companies from various industries count on drive systems of maxon motor for their mission-critical applications. Our drive systems can be found wherever precision and reliability have top priority.

Nidec is the world’s No.1 comprehensive motor manufacturer handling “everything that spins and moves”, miniature to gigantic. Aspiring to achieve still higher growth, each group company is enhancing its technical capabilities and competitive edge, while Nidec is positively striving in the area of M&A for companies that have highly-reputed engineering capabilities in motor-related fields.

Regal Beloit Corporation is a leading manufacturer of electric motors, mechanical and electrical motion controls and power generation products serving markets throughout the world. Regal offers a wide range of products that include electric motors and generators, gear reducers, electronic switchgear, bearings, couplings, gearing, drive components and conveyer systems. Regal products can be found in home furnaces, pumps, elevators, conveyors, X-ray machines, office equipment, power stations and thousands of other critical uses.

Rockwell Automation, Inc. (NYSE: ROK), the world's largest company dedicated to industrial automation and information, makes its customers more productive and the world more sustainable. Headquartered in Milwaukee, Wis., Rockwell Automation employs about 22.000 people serving customers in more than 80 countries.

Siemens AG (Berlin and Munich) is a global technology powerhouse that has stood for engineering excellence, innovation, quality, reliability and internationality for more than 165 years. The company is active in more than 200 countries, focusing on the areas of electrification, automation and digitalization. One of the world's largest producers of energy-efficient, resource-saving technologies, Siemens is No. 1 in offshore wind turbine construction, a leading supplier of combined cycle turbines for power generation, a major provider of power transmission solutions and a pioneer in infrastructure solutions as well as automation, drive and software solutions for industry.

TECO-Westinghouse Motor Company is a world leader in manufacturing electric motors and generators, with a broad selection ranging from ¼ hp to 100.000 hp. We are also a leader in supplying motor controls, and providing engineering services, genuine Westinghouse renewal parts and large motor repairs. Our company's products are used to drive pumps, fans, compressors, rolling mills, grinders, crushers, and a variety of other rugged applications. Headquartered in Round Rock, Texas, TECO-Westinghouse Motor Company serves the petrochemical, electric utility, pulp and paper, water/ wastewater treatment, air conditioning, marine, mining and metals industries.

Toshiba Corporation, a Fortune 500 company, channels world-class capabilities in advanced electronic and electrical product and systems into five strategic business domains: Energy & Infrastructure, Community Solutions, Healthcare Systems & Services, Electronic Devices & Components, and Lifestyles Products & Services. Guided by the principles of The Basic Commitment of the Toshiba Group, "Committed to People, Committed to the Future," Toshiba promotes global operations towards securing "Growth Through Creativity and Innovation," and is contributing to the achievement of a world in which people everywhere live in a safe, secure and comfortable society.

The industry is growing very fast, with many foreign competitors with established business in other world markets, entering in EU. Products are differentiated, with many electric motor versions available in the market, but permanent magnet synchronous motors are currently the most widely used in electric cars. Competitors are trying to optimize their product technical characteristics, providing higher power and torque, improved efficiency and better motor autonomy.

Many existing and potential competitors, high fixed costs and investment in innovation contribute to high rivalry among the competitors. However, expected market growth and product differentiation leave some space for the existing companies. We can assess rivalry among competitors as moderate to severe, with expectation to become even more intense in future years, due to an increased number of new entrants.

### 2.6.6 Overall industry attractiveness assessment

Table 11 summarizes the attractiveness of the EU electric drive motor industry for the current year (2018) and for the next 3 to 5 years. The EU electric drive motor industry, the same as the EV market, is starting to enter the growth phase. Competitors present in the market are domestic leading companies and foreign producers, who have already established business in other international markets. They compete in product differentiation, trying to improve their product's technical characteristics and performance. Buyers are still assessing them, trying to find reliable partners for the time when mass production starts. Increased demand for electric vehicles will allow new companies to enter in production of electric vehicles and in production of electrical drive motors. However, the intense competition in the upcoming years will allow only the most capable companies to triumph.

*Table 11: Overall EU electric drive motor industry attractiveness assessment*

| Determinant | **Industry attractiveness** | | | | | |
|---|---|---|---|---|---|---|
| | Current year | | | In 3-5 years | | |
| | Low | Medium | High | Low | Medium | High |
| Rivalry among existing competitors | | X | | X | | |
| Bargaining power of buyers | | X | | X | | |
| Threat of new entrants | X | | | | X | |
| Threats of substitutes | | | X | | | X |
| Bargaining power of suppliers | | | X | | | X |
| **Summary** | 1 | 2 | 2 | 2 | 1 | 2 |
| **Industry attractiveness** | **Medium-high attractiveness** | | | **Medium attractiveness** | | |

*Source: Konič (2015).*

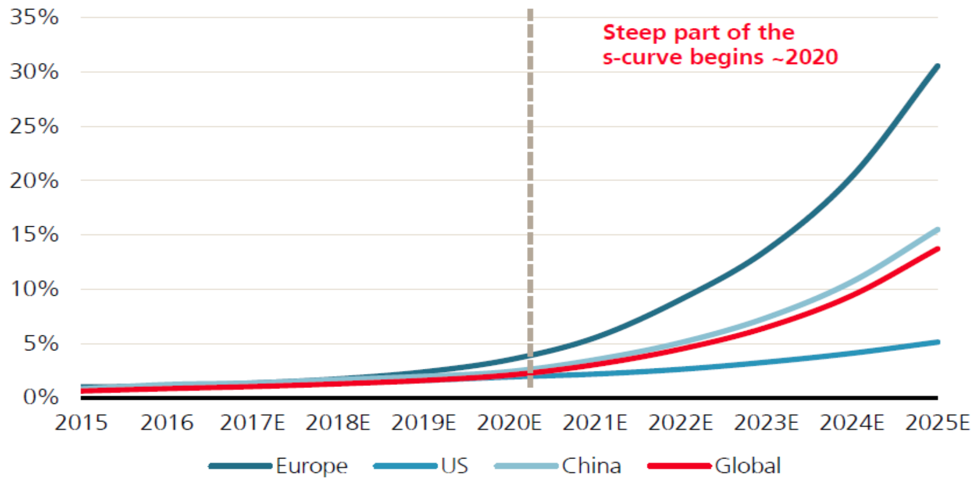
Now is the right moment to enter the industry, as benefits from economies of scale have not yet been achieved. Also, the relationships between buyers and suppliers are not fully established yet. Once the mass production starts, buyers bargaining power will increase due to large quantities purchased and the threat of backward integration. EV companies will probably produce in-house-only drive motors that are needed for large series electric vehicles, while for vehicles produced in small series, drive motors will still be outsourced.

## 2.7 Projections on the future demand for BEVs in Europe

As already mentioned we obtained the majority of sources and literature for the thesis from academic web-databases like ProQuest Direct, Emerald, Science Direct. However, finding literature about EV sales forecasts were more challenging to find. Mostly we could just find the forecasted sales numbers in reports and publications published by consulting companies (e.g. McKinsey & Company, The Boston Consulting Group, UBS...) and also reports published by financial news and information providers like Bloomberg.

One of the most optimistic forecast for EV sales in Europe, that we came across, was done by Swiss consulting company UBS. They are estimating that 30% of all new sold cars in Europe till 2025 will be EVs. The forecasts include both BEVs and PHEVs. Furthermore, they assume that in 2017 about 40% of all EVs sold were PHEVs and the rest was BEVs, but as BEVs are becoming more and more competitive, they expect the PHEV share to drop below 20 percent by 2025. Based on this, they expect that more than 24% of all new cars sold in EU will be BEVs (Figure 15).

*Figure 15: Forecasted percent of new sold electric vehicles in Europe, United States, China and Globally by 2025.*

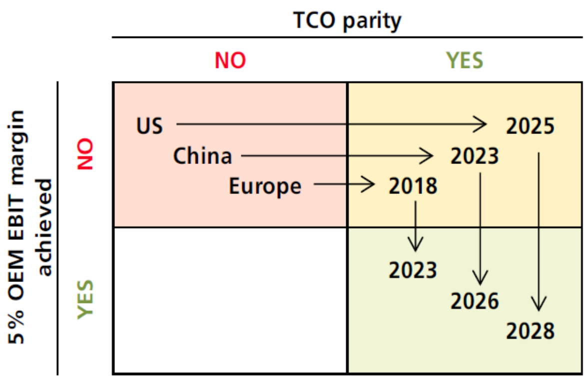



*Source: UBS (2017).*

The research was done by 39 of their analysts and it is based on the tear down cost of Chevy Bolt, which is one of the first cars with range over 320 kilometers. Their research shows that the total cost of ownership (TCO) of BEVs will meet TCO of ICEV already in 2018. Additionally, the true TCO parity (with term "true TCO" they refer to, purchase price excluding the governmentally subsidies and that the original equipment manufacturers (OEM) will make a 5% EBIT margin) will be reached in 2023 in Europe (Figure 16).

Their forecasted sales seem really high compared to the other analysis, and even their statement in the report says that the numbers appear aggressive. But they stated that based on their research, the numbers are not contradictive with the size of the investments that will be required in the electricity infrastructure, availability of raw materials and furthermore that they are in line with their finding from one of their customer survey results (UBS, 2017).

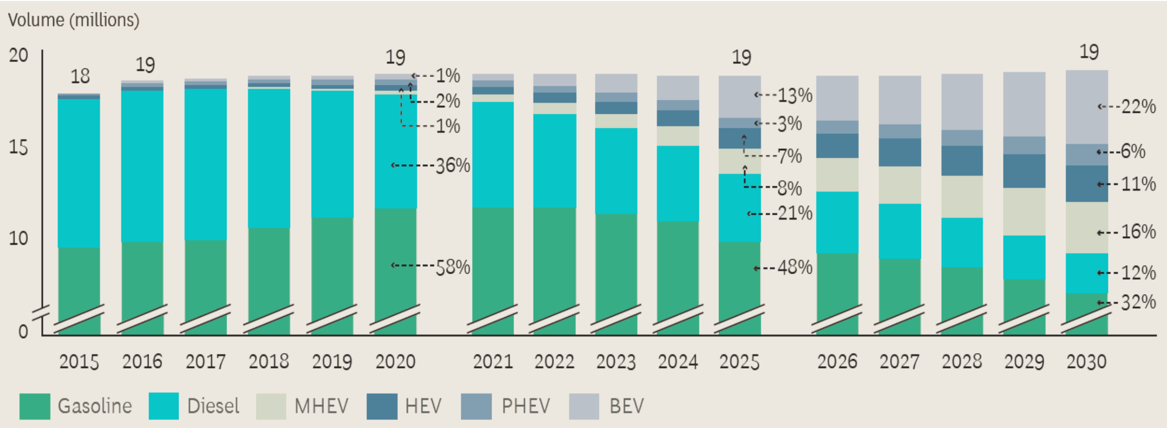
*Figure 16: Forecasted years when TCO of BEVs and ICEVs will meet (excluding subsidies on purchase price of the EV) with respect to the OEMs achieving 5% EBIT margin for US, China and Europe*




*Source: UBS: (2017).*

Furthermore, the three main factors, policies, EVs price and EV range will shape the future change towards electrified vehicles. They see the ICEVs to still have the biggest market share, they expect BEV share to rise for 1% in 2020 to 13% in 2025. After 2025 because of the progress in technology and economy of scale, the customers demand will push the EV sales up. Their expectations are that 22% of all new sold cars in Europe will be EVs (Figure 17). In 2030 they expect quite evenly divided market share between ICEVs (Gasoline and Diesel) accounting for 54% share and alternative powered vehicles accounting for 46% share (BCG, 2017).

*Figure 17: Projection of European market growth of new sold vehicles base on the engine type (in volume and percentage)*

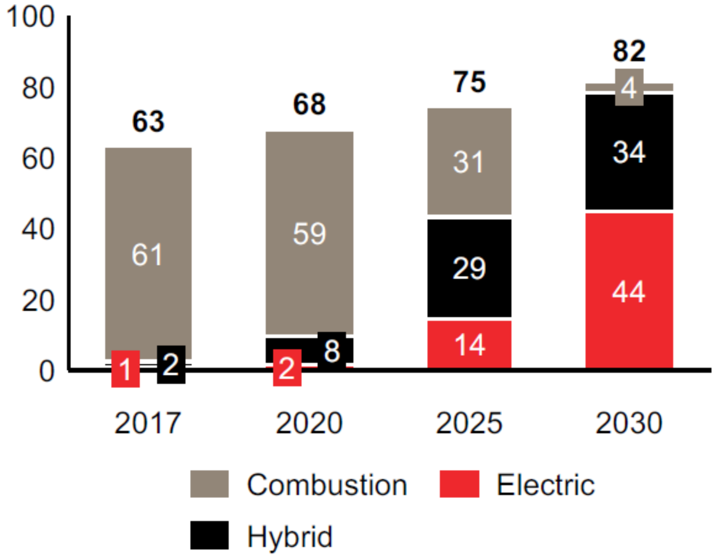



*Source: BCG (2017).*

Comparing the BCG and UBS estimations, we can see that UBS predictions are 5 years ahead of BCGs. The main difference observed in the two forecasts is in the prediction of TCO parity. By observing the methodology of the UBS research, we found out that 15 years' time of vehicle ownership was predicted when calculating TCO. Statistics about average ownership periods in European countries are hard to find, based on the European Automobile Manufacturers Association is the average ownership period in Belgium 5 years and in France 9 years (European Automobile Manufacturers Association, 2017). Although the data presents the ownership periods averages for just 2 European countries, the statistics in the same report shows, 10.7 years to be the average age of the passenger cars in EU. Moreover, the average ownership period must be lower than 10.7 years in EU accounting that part of the cars are bought second hand. By acknowledging this we think that UBS forecast is using to long ownership period, which results in their early TCO parity between BEVs and ICVs and has further effect on their high estimations of EVs market share in Europe by 2025.

One more future projection, presented by PWC (2017), concluded similar results as the Boston Consulting Group. They see the first strong push for BEVs after 2020, driven by the legislations and the second push after 2025 drive by the tipping point between BEVs and ICEVs in addition to more sufficient charging infrastructure. Their projection combines sales numbers for US, Europe and China. Their projection is that the number of new cars sold will grow from 63 million cars in year 2017 to 75 million cars in 2025 and 82 million cars in year 2030. Out of this, in 2025 already 14 million new sold cars will be electric (18.67%) and in 2030 already 44 million sales will be represented by electric vehicles, which represents 53.65% of market share (Figure 18).

*Figure 18: Projection of future sales numbers for US, Europe and China, based on their powertrain type (in millions)*




*Source: PWC (2017).*

Reviewing the literature, we found out that the predictions are quite different, as we see just from the before mentioned reports the BEVs market share was ranging from 13 to 30 percent in 2025 and from 22 to 53 percent in year 2030. All three reports were published in the year 2017 and even though the forecast is widely spread, we observed that all of them raised compare to the predictions published in two to three years before. For example, UBS stated that in their previous study, published in 2014, their estimation for Europe was 10% market share of new cars to be BEVs and PHEVs, which is 3 times lower compared to the latest one. In 2015 Goldman Sachs estimated the new vehicle sales of EVs to represent 22% market share in 2025, out of which BEVs would represent just one third, so just around 7 percent (Kooroshy, Bingham, Ibbotson, Simons, & Lee, 2015). So, it is obvious that BEV technology is developing faster that it was estimated couple of years ago, getting more attention and faster adoption.

## 2.8 European Union governmental support

Because of the relative strong governmental support (Table 12), almost every EU automotive company is making steps into EV production.

*Table 12: Incentives & Legislation in EU*

| **Countries** | **Purchase Subsidies** | **Registration Tax Benefits** | **Ownership Tax Benefits** | **Company Tax Benefits** | **VAT Benefits** | **Other Financial Benefits** | **Local Incentives** | **Infrastructure Incentives** |
|---|---|---|---|---|---|---|---|---|
| Austria | X | X | X | X | X | | X | |
| Belgium | X | X | X | X | | | | |
| Bulgaria | | | | | | | | |
| Croatia | | X | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cyprus | | X | X | | | | | |
| Czech Republic | | X | X | | | | | |
| Denmark | X | X | | X | | | X | X |
| Estonia | | | | | | | | |
| Finland | | X | X | | | | | |
| France | X | X | X | X | | | X | |
| Germany | X | | X | X | | X | X | |
| Greece | | X | X | | | X | | |
| Hungary | | X | X | X | | | X | |
| Ireland | | X | X | | X | | X | X |
| Iceland | | X | X | | X | | X | X |
| Italy | X | | X | | | | | X |
| Latvia | | X | X | | | | X | |
| Liechtenstein | X | | | | | | | |
| Lithuania | | X | | | | | X | |
| Luxembourg | X | | X | X | | | | |
| Malta | X | X | X | X | | | X | X |
| Netherlands | | X | X | X | | | | |
| Norway | | X | X | X | X | X | X | X |
| Poland | | | | | | | | |
| Portugal | X | X | X | X | | | X | |
| Romania | X | X | X | | | | | X |
| Slovakia | X | X | | | | | X | |
| Slovenia | X | X | X | | | | | |
| Spain | X | X | X | | | X | X | X |
| Sweden | X | | X | X | | | | |
| Switzerland | | | X | | | X | | |
| Turkey | | | | | X | | | |
| United Kingdom | X | X | X | X | | | X | X |

*Source: Konič (2015).*

The number of new entrants is increasing on a yearly basis, with LSEV producers achieving advanced automotive technology for some of their models and therefor becoming entitled to NEV subsidies (Gass, Schmidt, & Schmid, 2014) New players are entering into EV production also from other related industries – these are mainly battery suppliers who forward integrate into production of a complete vehicle (as for example BYD in China).

EU EV producers have different characteristics. In order to provide better understanding of potential buyers further information regarding each EU EV producer can be found in appendix. There we present producers' models, electric drive motors user and their strategies regarding the future. Data is taken from different sources, including company web-sites, where the forecasts regarding the future may sometimes be over-optimistic.

# 3 QUALITATIVE AND QUANTITATIVE RESEARCH OF THE MAIN FACTORS INFLUENCING THE ELECTRIC VEHICLE ADOPTION IN EUROPE AND THEIR EFFECT ON THE FUTURE DEMAND

## 3.1 Methodology

The main propose of this research is to find the main factors effecting the adoption of BEVs and to understand how this factor will influence on the future demand in Europe. Based on the literature review in the first part of the thesis, we discovered that first push for BEVs growth will be induced by the initiatives and legislations trying to affect reduction of GHG emissions. The success of the new European Commission proposal targets for reducing average new car $CO_2$ emissions till 2030, Clean Energy Ministerial's EV30@30 initiative targets and Paris declaration targets will be highly dependent on the increasing market share of electric vehicle.

Public policies will have an important and measurable effect on OEMs production plans, what will direct influence the EV situation on EU markets, but this policies are not all directed to the final client. We want to focus on customer decision factors for buying EVs and the evaluation of the literature revealed that early adopters were more environmentally aware people, a point that will still be an important factor for the future of the market. Other key drawbacks that were highlighted were purchase price and range. As the range for EVs have increased in the past few years and shows the tendency to keep improving in the foreseeable future, the weight of the "range anxiety" tends to be diminished in the upcoming future.

This brings us to our research questions:

- Which factors will most influence the future demand for battery electric vehicles?
- In what way will these factors influence the demand for battery electric vehicles?

The research questions were analyzed through both qualitative and quantitative research methods. The qualitative research is basically exploratory research used to gain understanding of the fundamental factors and motivations for the investigated issue. It gives the researchers knowledge and helps them to develop ideas for further qualitative research (Ereaut, 2002). Our primary qualitative research included semi-structured in-depth interviews with experts in the automotive industry and expert from electric power technology. Additionally, to gain even better understanding of the customers' needs and their buying decision factors we further conducted two field analyses. The field analysis was conducted on the BEV test drive marketing event held by one of the globally know car brands. On the event, which was going on for two weeks, we got a chance to interview a driving instructor, who had on average 40 test drives per day with random people who applied on the event. Additionally, we went on a test drive together with one of their participants and interviewed him after it. The second field analysis was done by test driving a battery electric vehicle for five days on our own. The test drive could lead to exaggerating some of the positive or negative factors of BEVs, so the aim was to get more insight on the BEVs and to get additional conformation to the observations concluded from the in-depth interviews.

The second quantitative part of the research was conducted with an online survey. We firstly collected the data by using a convenience or non-probability sampling method based on snow ball effect (Goodman, 2011). The survey, prepared with the internet survey platform 1KA, was spread on the social media platform Facebook add additionally asking the public to spread it to their friends. We also shared the survey trout e-mail, to our contact around Europe who were again encouraged to spread it to their family and friends. As we did not get enough respondents who own battery electrical vehicle we choose also an authority sampling method or also known as purposive sampling. We did this by sharing the hyperlink to the survey on selected automotive forums which specializes on electric vehicles. We further analyze the data collection in the qualitative research chapter.

## 3.2 Qualitative Research

### 3.2.1 In-depth Interviews

After we gathered data from the survey, we used some of the information to further explore the EV market. We conducted five in-depth interviews. Three participants are the experts from the automotive sector working for car brands whose car models are the top selling EVs in Europe. Their job titles are, Zero Emission Adriatic Manager, Sales director for Slovenia and the third one is Sales representative exclusively for electrical vehicles. Fourth interviewee is also from the automotive industry, but their brand at the moment sells just hybrid vehicles and will go on the market with their first fully electric vehicle at the end of year 2018, his job title is Sales director for Slovenia. The last one is R&D Manager at a globally recognized company in the field of electrotechnical equipment and partly collaborated with the project for planning the charging station infrastructure in Slovenia. The interviews were semi-structured and conducted face to face with the individuals. We thematically linked all the interviews together to investigate the enablers and barriers for EV adoption. The collected information's are reported below. In the first part we included just experts for the automotive field and after when we talk about the infrastructure we included also the interview with an expert in the field of electrotechnics.

We started with the general overview of the EV market in Slovenia and Europe, their look on the situation and on their current customers. All three car brands, that are already selling EVs, doubled and one almost tripled the number of EV sales from year 2016 to year 2017. However, this is just 2-3% of their sales, which is not enough for them to orient their focus on it. One of them said: “Research and marketing budgets are limited, so we do not use it on a segment which presents just 3% of our yearly sales. The data that we gathered are mostly responses from our current customers.”.  All of them told that there is small percent of private customers, the majority, around 70-80% are sold as company vehicles, to governmental institutions, municipalities and car sharing companies. For now, the majority of their private clients are buying the EV as their second car. One of the interviewee said: “Majority of our private clients buys EV as a second car, meaning that they already have petrol or diesel car in their household. But the EV serves as the main car, meaning that it is used for daily commutes and the ICEV becomes the second car, used for vacations and longer trips.”. But there are also one individualist who are proving that EV can be used as the only car in the household even though you do above average kilometers per day. Two companies have a client like this. The first one told us that they have a client who is an EV owner for two and a half years and did around 120.000 kilometers in this period. And the second one did more than 60.000 kilometers in one year and a half. By recalculating the numbers, this means that those two drivers are doing on average between 110 and 130 kilometers per day. Based on their conversation with these two EV owners, just the logic of filling the car on the petrol station needs to be changed, they claim that in the majority of their time and travel they visit the same places. This means that just in the beginning they needed to adopt and find the nearest charging stations which are near to their standard locations and get used to plug-in the car whenever they stop. Furthermore, in most days they need to charge the car just at the end of the day when you come home, because they do not use the full range of the car. If we look at the statistic from our survey, from where it is clear that around 90% of the people do less than 100 kilometers per day, means that above mentioned driving style would be suitable for all of them, under the condition that they have a possibility to charge the car at home.

Continuing with the future adoption of EVs, they all agree that this is a growing trend which they need to be a part of and it is an inevitable future. One respondent said: “This is not something that car companies would strive for, but the regulations on the level of the EU and also by cities itself are pushing us to do so.”. Getting a more defined answer, to what extend the electric vehicles will change the automotive market, was something we could not get from the interviewees. They mainly all agree, that before some new breakthrough will occur in the technology (mostly implying the batteries), they do not see a huge change in the sales numbers. Nobody sees any major changes in the next 5-7 years. One of them stated: “We almost reached the maximum performance from the lithium-ion batteries, which means that we will need some innovation on this field. But all the parts installed in a modern vehicle have to pass some extremely high requirements and to develop a new battery that firstly shows better performance as the current ones and most importantly pass all the necessary tests, get the required safety papers and at the end get commercially ready, can take minimum five years if not more.”. Mainly all agree that also before the prices will not drop for around 20%, the sales will not go up. One of them disagreed with the drop of the prices, he said: “The prices of the cars are everyday higher, so I don’t understand how people expect that will lower the price of our EV model in the future. What we need is a better battery. If EV could do 300 kilometers on one charge, we could easily increase the sales by 5 to 6 times, without any reduction to the price.”. Their car brand fits in to a more premium segment, where customers are not so price sensitive. Through the conversations it was not said directly but we got the filing and they were implying a bit to the fact that the prices are artificially plant so high. One said:” People are asking us: How can some small garage companies build an electric car that does more than 1000 kilometers on one charge, and the big companies like you are still struggling to reach even 300 kilometers?”, and he continued with the explanation: “You need to understand that, building a one custom car and palling a mass production for a car that will be sold globally are two totally different processes. We need to insure a fluent supply chain process, which means starting from signed long-term contract for raw materials, semi-product suppliers, equipment suppliers…, to having a durability tests made for each component of the car, even to the smallest button, insure all the safety regulations, and I can go on and on and on and I would still forget something. As the EVs are still relatively new technology, not all of that is jet prepared and optimized and ready for mass production. This means that the companies want a steady growth of the EV sales and not a big boom. And yes, if I could drop the price of an EV for even 10% more, the demand would increase so much that we could not deliver the cars to our customers this year as our capacities would be fulling.”. What they see is a constant growth of the EV segment and with it the charging infrastructure will grow organically together, just one thinks it will be a disruptive technology and when the prices fall, there will be a boom on the market, as it was with smart phones. And when this will happen, a lot of capital will be available to build the necessary infrastructure to keep up with the demand.

Talking about the infrastructure, we will at this point include also the fifth interviewee, the electrotechnics expert. He is not so optimistic about the fast growth of EVs. He said: “Everyone is saying that there is enough electric energy available even if we would all have electrical vehicles, which is actually through. But what is important for the charging infrastructure is not the energy capacity, but the electric power, and how much power can you deliver at one specific point.”. He explained that this would be a big problem in the cities, if we would for example like to provide charging stations to each street, each apartment building, this would mean, that we would need a new electric transformer station (Figure 19) on every couple of kilometers inside the city. He added that people do not even imagine how big would the wires need to be and the extend of the capital this would require.

He commented the recently build super charger station on one of the highway rest stations in Slovenia: “This is just marketing and throwing stones in people’s eyes, the superchargers at that station need 3 times more electric power as the whole petrol station and if all 10 charging stations would be plugged in to the cars at the same time, power break down would occur.”. So, he thinks we need to understand that our electric grid is not yet advances enough to support large amount of EVs, so he predicts that the growth of EV on the road will go in steps, meaning, EVs will overgrow the charging infrastructure, which will naturally slower the demand for new EVs down and increase the construction of the infrastructure and this process will repeat several times.

*Figure 19: Electric transformer station*

*Source: Vetrna energy HL s.r.o. (n.d.)*

Not as a part of our semi-structured interview questions, but we came with all of our participants, thorough the conversation to the question if individual cars will even be needed in the future. Everyone was unanimous that a big percent of people’s yearly revenue is spend for the car and that especially young ones are starting to reject the car ownership, and even fewer young people are getting the driver’s license. Someone stated: “I read a study, published by one of the known American Universities, which confirmed that year over year, fewer young people between the age 16 and 25 are getting driver’s licenses. And some of the main reasons stated in the study were economical, meaning that it is difficult for young to buy and maintain the car and secondly more and more of them live in big cities with sufficient public transport and new types of car sharing projects.”. They are focusing more of their resources towards understanding this trends that are disrupting the transportation sector than towards EV trends:” Based on some statistics, a car is on average parked more than 94% of the time. 94% of the time, do you know this!? When you hear this number, you know that evolution will not allow this to continue.", stead one of the interviewee and continued: "We, car manufacturers, will need to adopted to this and become more of a smart transport solution service that just car manufacturers If we will want to survive in the future."

### 3.2.2 Participation on a battery electric vehicle marketing event held by one of the globally know car brands

During one of the in-depth interviews, we were told that the company was at that very moment organizing a marketing event offering test drives with one of their fully electric car models. We grabbed the chance to gain additional data and negotiated participation in the event where we could interview one random participant and go with him on the test drive, plus talk to the driving instructors responsible at the event. The event was held in one of the largest business, shopping, entertainment, recreation and cultural centers in Slovenia, BTC City. The test model vehicle fit in the C segment or in other words medium segment cars (this segment includes car like Alfa Romeo Giulietta, Ford Focus, Opel Astra, Volkswagen Golf, Kia Cee'd) (https://en.wikipedia.org/wiki/C-segment). The purchase price of the car without any discount and subsidy is 40.295€. Which means that this EV costs approximately 43% more than the average price of passenger cars in EU-28 in 2016, which is 28.144€ (https://www.statista.com/statistics/425095/eu-car-sales-average-prices-in-by-country/). If we add the current subsidy for EV in Slovenia which is 7.500€, the test drive car selling price becomes just 17% higher than the average.

People could participate in a 20 minutes test drive with a fully electric car by registering in advance or by applying on the stand at the event. After we were declined by 3 people, we finally managed to find a person who allowed us to join the test drive and do a short interview after. The test drive tour included both city and highway ride. In the first part of the test, the instructor has explained the specifications of the car, additional equipment, safety features, car range… After is the first question from the participant was: "What is the price of the car?". This lead to further conversation connected to the costs, government subsidy, maintenance costs and real electric consumption of the car and determining the cost of the consumption for 100 driven kilometers. After the 20 minutes pass really quickly, we got a chance to find out about the experience of the participant. He enjoyed the test drive and said that after the first couple of minutes when he got used to the car, he really liked the quietness of the car and how smooth the ride is. He was also surprised with all the assistant technology that the car was offering and also about the performance of the car: "I didn't expect that the car accelerates so fast and that I was not scared to overtake other cars. I must say that I felt better driving this car than my diesel one and now it is even harder to wait for my new EV". The really interesting fact was, that he actually bought an electric car from one other car brand, four months before but this was his first test drive with EV. He preordered an EV from one other car brand which did not have jet the cars for tests as the production for the model did not even start at that time. We asked what was then the deciding factor for him to buy an EV if he actually didn't drive one. He said that one of his friends bought one and as she is mainly using the public charging station, where electricity is at the moment still free of charge, she has almost no operating costs. Based on this and the fact that he does around 80 kilometers per day he decided to buy an EV. He lives in a privet house so he has an option to also charge the car at home, but he plans to mostly use the public ones. For him this will be the only car in the household and that they excepted the fact that they will need to adapt their vacations or other longer-range trips according to the cars range and today infrastructure, or maybe just rent an ICEV for a couple of time per year.

After interviewing the participant, we have talked to the driving instructor, which had on average 40 test drives per day. We asked him what are the most common question that the participants have and what are the reactions after they finish with the EV test drive. He told us that for almost all the participant the first question is about the price of the EV, which majority comments as being too high for a car in this segment. After the test drive, he said that almost nobody expected that the ride will be so calm and smooth. Reaction after are unexpectedly good diving experience, the drive is so quiet and relaxed, but on the other hand, you get as good or even better performances as the ICEV (in terms of acceleration, no gear shifting…). Even he was surprised that from all the week of test drives he could not remember even one person who didn't like the driving experience. The most doubts and questions relating to the battery life and if the capacity will stay good enough that they can sell the car after 10 years and that the car's range is still not sufficient for long drives when they go once or twice per year on vacation. He added: "When you think about all the equipment that EV have already as part of a standard package. There is no gear shifting so it works like automatic gear shift in ICEV which is an extra option and costs around 2000€. As a standard EV can preheat the cockpit which is again an extra option for standard ICEV with approximate 1000€ expanse. Headlight are in LED technology because they use less energy and are again 1000€ extra cost for an ICEV. After I explain these facts to the participants and they try out the car, they see that the price is not so unreasonable at all."

### 3.2.3 Test driving a battery electrical vehicle

During one other in-depth interview, we got our second chance to observe the advantages and disadvantages of EVs and get even deeper understanding by testing the electric car for one week. The test model we got was one of the most sold electric car models in Europe. For our further analysis, we did not focus on the technical characteristic of the car but more on practical factors for the EV user (driving experience, charging practice…). We decided not to plan any special trips with the car but to go through our ordinary week and see how EV will cope with it.

At the pick-up date, I got the car fully charged, showing us 167-kilometer range. I must say that the beginning was not so calm and smooth as it was mentioned by participants in the marketing event. The above average acceleration of the car and overall performance in combination with quietness resulted in exceeding the speed limit multiple times, without even being aware of. After the first excitement and trying out the vehicle capabilities, you get used to it and the ride becomes super calm and easy. On the first day of the test drive, the temperatures outside were around zero degrees, so during the ride, I increased the cockpit temperature which leads the car to go form ECO to NORMAL mode (The car has different modes. In every mode it has some predefined characteristics, for example in ECO mode, the car turns off air conditioning, lowers the cars performances and some other characteristics change, all in order to extend the car's range.). Changing of the mode dropped the range of the car for around 15 kilometers and the signals on the dashboard clearly pointed this out.

As I understand that AC is a big energy consumer, I anyway did not like that the range drop was so clearly pointed out, it felt like I was doing something wrong and further induced the filling that you are doing a compromise between your comfort and the range, which I think is a filling you should not get in a car for almost 40.000€. After the first three days the car was serving its job and as we did around 25 kilometers per day, I didn’t have to charge it jet. After the first three days the car was serving its job and as I did just 98 kilometers, it did not have to be charged yet. On the fourth day, I could try one more standard future which is the preheated cockpit. In that morning, the outside temperatures were below zero and I sat the heater to start working 10 minutes before I needed the car in the morning. This was great, coming out on a freezing morning and you don't have to remove the ice from the windows, but instead, you just sit in a warm car and drive away. The fourth day started with a 27.7 kilometers long ride from Ljubljana to Komenda where I had an activity in a municipality sports hall. The range was showing 38 kilometers which were enough to do the trip.

After driving for a couple of kilometers in the city, I came on the highway where my driving speed increase to 120 kilometers per hour. At this speed, the range started to drop faster than the driven kilometers were rising, which made me nervous, pressuring me to calculate if I will be able to reach the destination every minute of the ride. Furthermore, after visiting the sports hall I needed to reach my parent's house, 1.7 kilometers away, where I had a plan to charge the car. By lowering the speed to 100 km/h and setting the car in ECO mode, I managed to reach the destination with range for another 5.7 kilometers. Coming there I was surprised at the parking in front had a parking reserved for EV with a public charging station, where I parked and plugged in the car. I did not have to pay for the charging. Two hours later, when I came back, the car was partly filled and was enough for me to skip my parent's house and continue the drive to one store where I knew they have a charging station in front. This was convenient, as I didn't have to search for a parking spot, but I could park almost in front of the entrance and again plug-in the car free of charge.

After 20 min the drive continued towards my apartment block in Ljubljana, where I was challenged again. I had to return the car the next day but needed to charge it again. So, I had two options. First one was to find the nearest not occupied public station, walk home and after three hours, which is the maximum charging time for public stations, walk back to the car and re-park it at home. My second option was to suspend an extension cable down from my first-floor apartment and plug the car to charge. This was the point where I saw a big drawback of the EV, charging it if you leave in an apartment building with no option for charging.

All the above positive and negative experience with the EV are highly subjective so the aim of the test was not to make new conclusion based on it, but to provide us with more insights and dive deeper into the problem and potentials of the EV market.

## 3.3 Quantitative Research

### 3.3.1 Research Goals and Objectives

Based on the reviewed literature and observations from in-depth interviews it is expected that the GHG emission will be the most important factor for BEVs adoption. However, legislations will not have a direct effect on the final customers but on the OEMs and countries who will be trying to reach $CO_2$ targets in avoidance to pay penalties. The goal of this research is to discover the final customers buying decision factors, their driving pattern and understand their vision on the future of electric vehicle adoption.

### 3.3.2 Data analysis

As mentioned before we used convenient sample collecting method based on the snow-ball effect. We decided to collect data with this method because we determined that it will be the most efficient way to gather data from as many different European countries as possible. As our population are all the Europeans who are financially situated well enough to buy a new car in the next 12 years and have driver's license (or will get driver's license in the next 12 years) we have collected, with 212 responses, a small sample of the population which needs to be taken into account with certain degree of limitations. Additionally, even though we were trying to spread it around Europe as much as possible, our sample still includes 68 % of Slovenians, which accounts for less than 1 % of total European population.

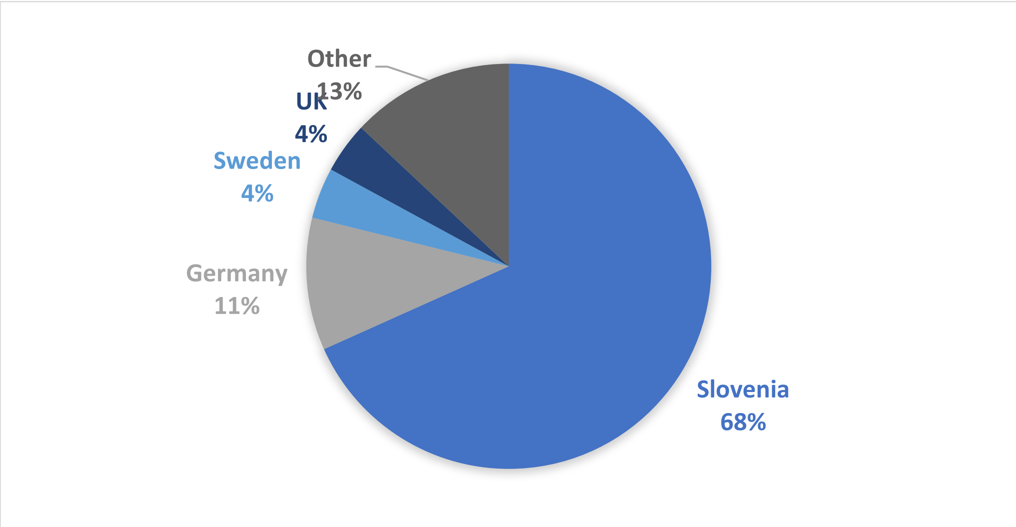
With the first question of the questioner we divided our sample into 4 groups: respondents who own electrical vehicle, respondents who don't own electrical vehicle, the ones who do not need or do not drive a car and respondents who have never heard about electrical vehicle. With the convenient sample collecting method we were able to gather 12 respondents who were owners of electrical car. To increase the number of respondents from this group we additionally used purposive sample collection method, meaning that we targeted just the population of BEV owners. We did this by signing up to around 15 different online forums, which are specializing in EVs and used them for publishing our survey. With this approach we collected 75 more answered surveys all from electrical car owners which increased our total respondents number to 287.

Before further analysis we cleaned our data from 13 respondents who were not from European country and were residents of: New Zealand, Japan, Brazil, USA and South Korea. Additionally, we got one respondent who have never heard of electrical vehicle, who we also excluded from the further analysis.

#### *3.3.2.1 Sample description*

After cleaning our gathered data, we got our total sample size of 273 respondents who are residents of 17 different European countries. The most represented is Slovenia with 68 % share of the sample, following by Germany with 11 %, UK and Sweden each with 10 respondents and approximately 4 % share. Austria, Belgium, Croatia, Czech Republic, France, Hungary, Lithuania, Luxembourg, Netherlands, Poland, Spain, Switzerland and Turkey were represented by less than 6 respondents per country, together accounting for 13 % of the total share (Figure 20).

*Figure 20: Distribution of the respondents based on their current country of residence (in %)*

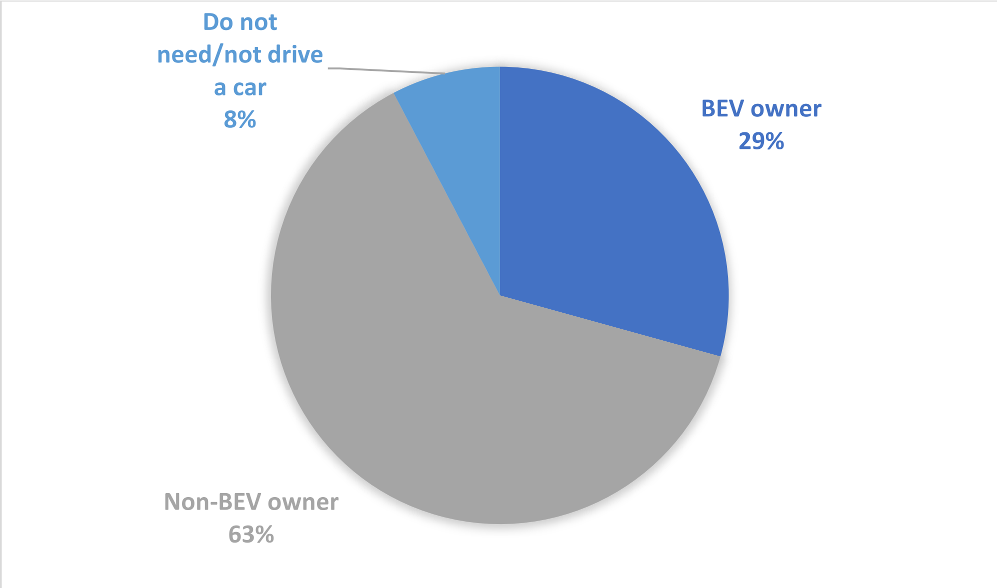



*Source: Own Source*

As described before, we structured the first question so to firstly divide surveyors into three different groups (firstly we divided them into four groups, but we did not include the respondent who have never heard of electrical vehicles). The biggest group, with 172 respondents (63 %), are the ones not owning electrical vehicle, the second group, with almost one third of the respondents, represent eighty battery electric vehicle owners (29%)

and with 8 % the smallest group are the ones who do not need or do not drive a car (Figure 21).

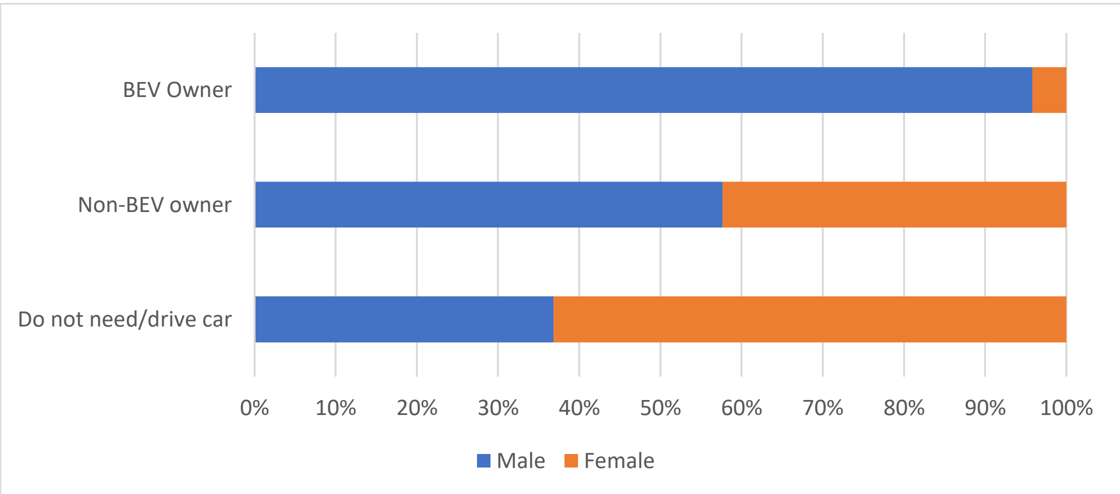
*Figure 21: Distribution of the respondents based on their car ownership type (in %)*




*Source: Own Source*

Two thirds of the sample are male respondents (67 %) and one third are females (33 %). If we look from the groups perspective, we see that man are highly represented in the BEV owners group (96 %), where we got just 3 female respondents. We think that this is partly because we were gathering them on the automotive forums which are in general overrepresented by the men. The group of non-BEV owners is spread fairly even between the genders, males represented by 58 % and females by 42 %. Don't need or don't drive a car group includes 63 % of females and 37 % of males, however there are just 21 respondents in this group so we need to take this into account (Figure 22)

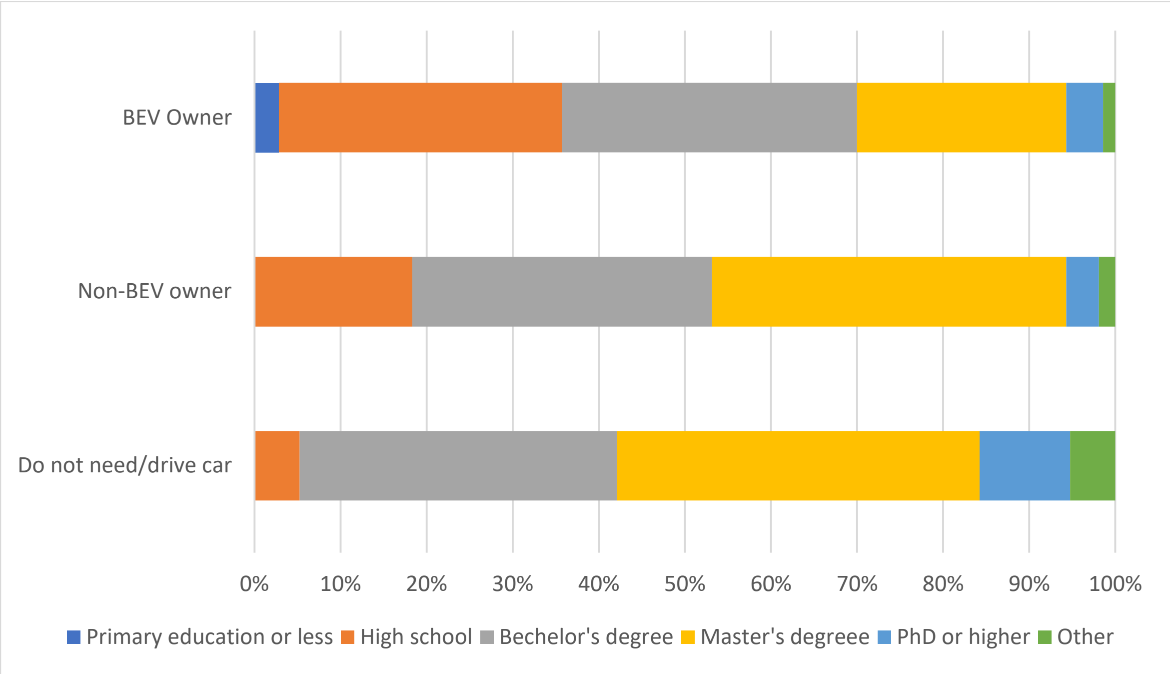
*Figure 22: Distribution of the respondents based on the gender and group (in %)*




*Source: Own Source*

Based on the education, 37 % of BEV owners have high school education or lower, which is the biggest percent compared to the other two groups, non-BEV owners with 18 % and non-drivers with just 5 % share. The share of people with bachelor's degree is quite similar for all the groups and presents around one third of the total share, BEV owners 34 %, non-BEV owners 32% and the one who do not drive a car 33 %. In addition, if we look at the ones who have master's degree or higher we see that BEV owners have 30 % of the share with this education, non-BEV owners 47 % and non-drivers 58 % (Figure 23). We see that the respondents who do not need or do not drive a car have the higher education and that BEV owners are represented by more than one third or the lower education which was a result that we did not expect. Based on the in-depth interviews and literature review the observation was that early adopters for electrical vehicles are higher educated.

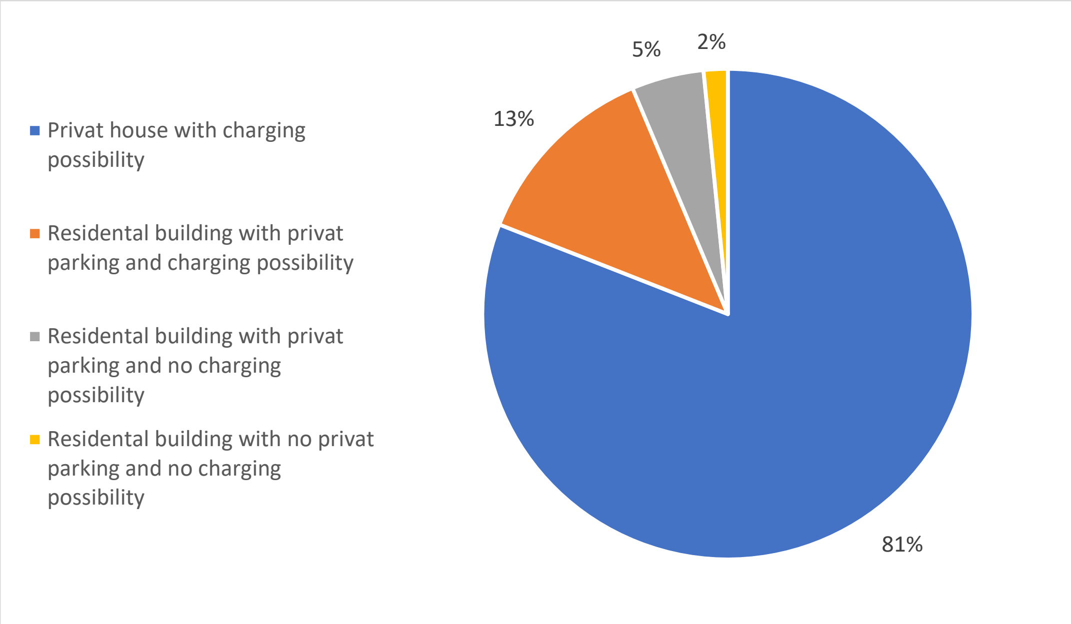
*Figure 23: Distribution of the respondents based on the  education and group (in %)*




*Source: Own Source*

We also analyzed the housing type of the sample. However, during the questioner preparation the housing type was observed only for BEV owners. We can see that with 81 % of them live in private houses with possibility of charging the car, 13 % live in residential building with private parking and charging possibility, 5 % of them live in residential building with their private parking but have no option for charging the car and just 1 respondent answered that he lives in residential building, with no private parking and no charging possibility at home (Figure 24). This result is confirming the observed ones from the in-depth interviews. The interviewee told us that majority of their clients live in private houses or have an underground garage with charging plug in their residential building.

*Figure 24: Distribution of the BEV owners based on the housing type (in %)*

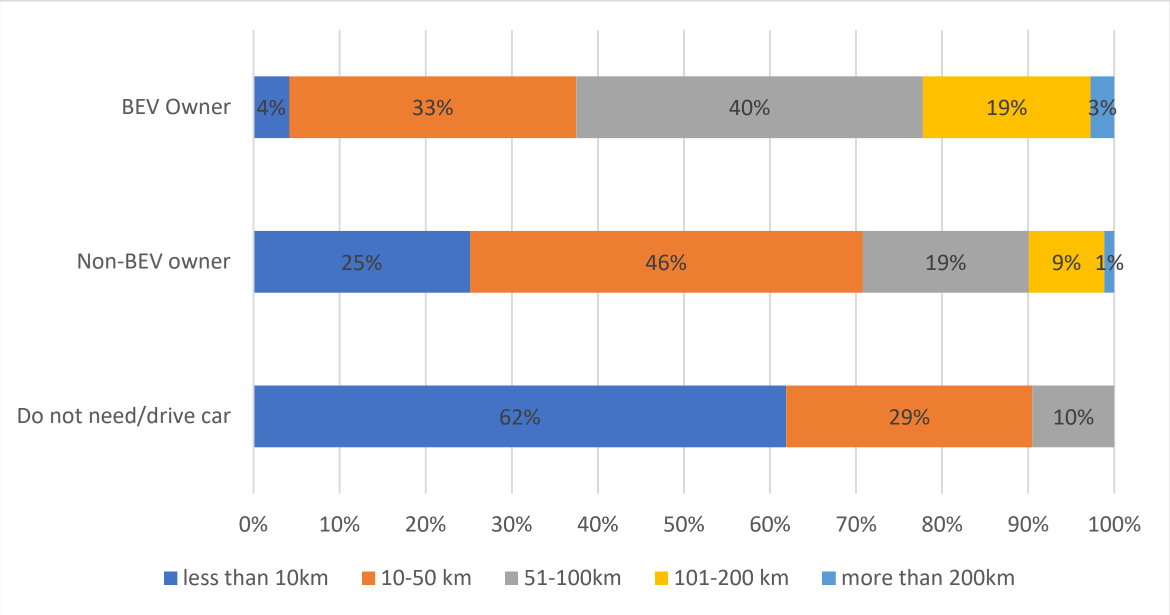



*Source: Own Source*

To understand respondents commuting pattern, we asked them “On average, how many kilometers do you drive (as a driver or a passenger) per day?”. The possible answers were: less than 10 km, between 10-50 km, between 51-100 km, between 101-200 km and more than 200 km.

As it can be seen from the Figure 25, the BEV owners have biggest share of respondents who do more than 100 kilometers per day (22 %) if we compare it to other two groups. Analyzing only BEV owners, the biggest share are the ones who do between 51 and 100 kilometers per day (40 %) and the rest of 37 % do less than 50 kilometers per day. Just 4 % of BEV owners drive less than 10 kilometers per day. This is the smallest percent of all groups, and it is more than six times smaller than in the non-BEV owners group. Together with the biggest share of non-BEV owners who do between 10-50 kilometers per day, they account for 71 % of their total share, which means that less than two thirds of them (29 %) do more than 50 kilometers per day. As expected, the respondents who do not need and do not drive car have the lowest daily driving distances. 62 % of them do less than 10 kilometers per day, 29 % do between 10 and 50 kilometers per day and just 10 % of them does on average 51 to 100 kilometers per day. None of our respondents from this group does more than 101 kilometers per day (Figure 25).

*Figure 25: Distribution of the respondents daily driving distances based on groups (in %)*

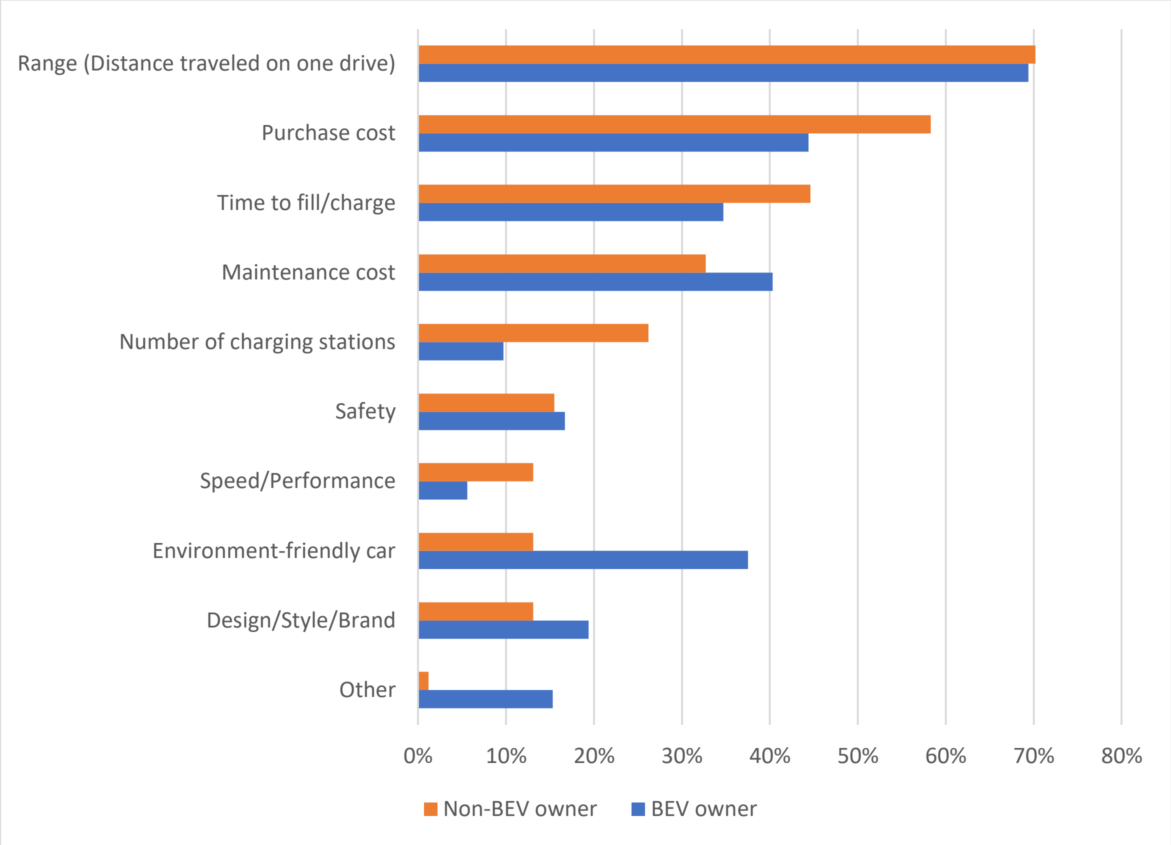



*Source: Own Source*

### *3.3.2.2 BEV buying decision factors*

Based on the literature review and our qualitative research, we determinate nine factors that affect potential BEV buyer decision: Design/Style/Brand, Environment-friendly car, Maintenance cost, Number of charging stations, Purchase cost, Safety, Speed/Performance and Time to fill/charge. To find out the most important factor we asked them to choose 3 most important factors for them (from here on we excluded the respondents who do not need or do not drive a car from the analysis). We found out that range is the most important factor for the non-BEV owners (70 %), following by Purchase cost (58 %), Charging time (45 %), Maintenance cost (33 %) and all the other factors are important for less than a third of the respondents in this group. With similar percentage (69 %), range was the second most important factor for BEV owners when they were buying the car; however, this was the only factor important for more than half of the respondents. The importance of the factors from second to fifth place is more evenly distributed compared to the non-BEV owners. They are referring to the same factors, however for BEV owner's maintenance cost is slightly more important than charging time. Furthermore, the main difference is in the importance of the environmental-friendly factor. For BEV owners it is on the fourth place, important for 38 % of the respondents, and for the second group it is sharing the seventh place together with speed/performance factor with only 13 % of the respondents (Figure 26).

*Figure 26: Distribution of the respondents most important factors when buying a car (in %)*

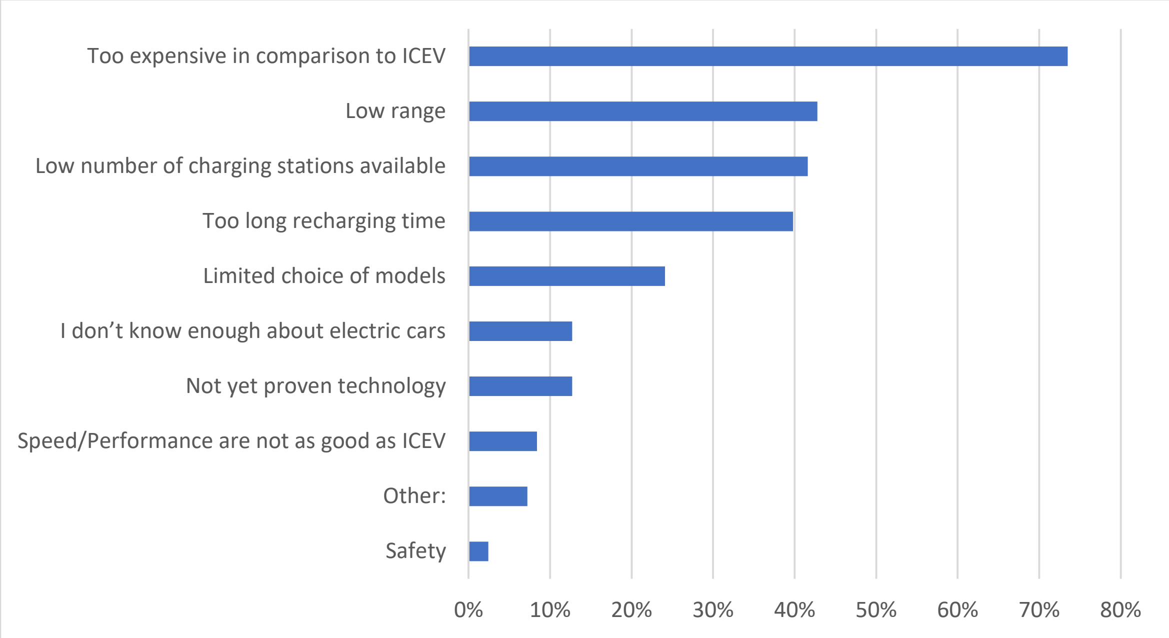



*Source: Own Source*

Furthermore, we analyzed which of these factor are seen as the main drawbacks that are stopping the respondents who do not own BEV from buying one. With the 74 % of the response rate, the price of BEV compared to ICEV is the main drawback. After the price the three drawbacks are low range (43 %), low number of charging stations (42 %) and long charging time (40 %). Limited choice of models is seen as a drawback for almost one quarter of the respondents (24%) and all the others were mentioned by less than 13% of the respondents (Figure 27).

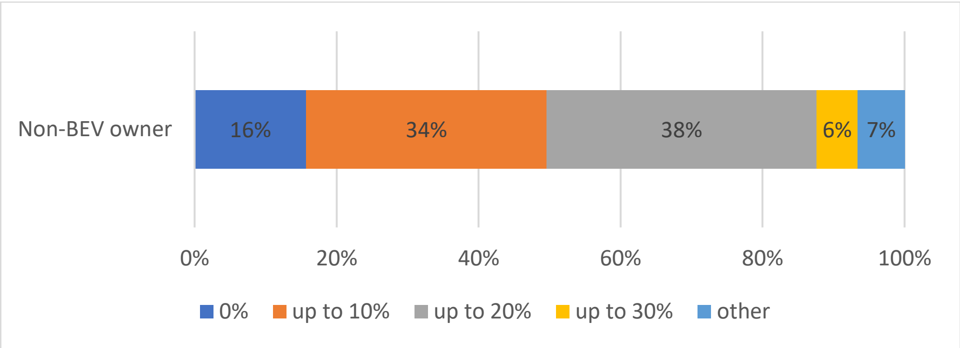
Even though the price is the main drawback, we found out that if choosing between BEV and ICEV with same style and performance, respondents are willing to pay more for BEV. Only 16 % of the respondents from the non-BEV owners group are not willing to pay more for BEV than ICEV, however 34 % would pay up to 10 % more, 38 % up to 20 % more and 6% up to 30% more as for the ICEV with the same characteristics (Figure 28).

*Figure 27: Distribution of the respondents based on the drawbacks which are stopping them from buying a BEV (in %)*




*Source: Own Source*

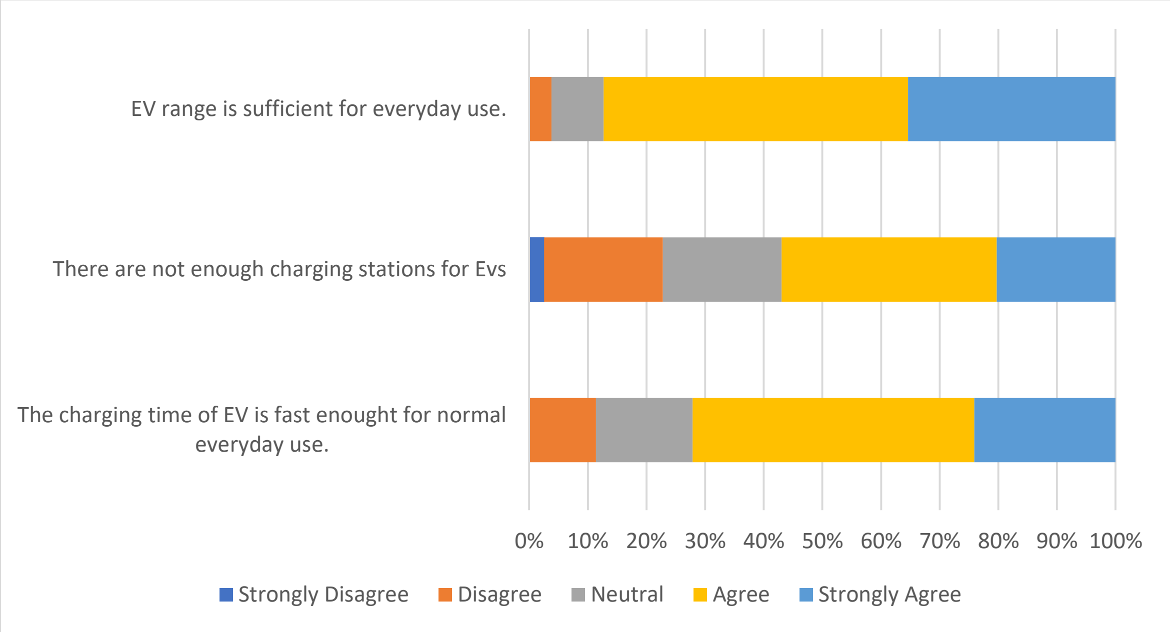
*Figure 28: Distribution of the respondents based on the drawbacks that are stopping them from buying a battery electric vehicle (in %)*




*Source: Own Source*

As mentioned before, important drawback beside the price are, low range, low number of charging stations and long charging time. We wanted to see what the current BEV owners think about the factors that are exposed as drawbacks from the non-BEV owners. Regarding the drawbacks, we prepared three statements, EV range is sufficient for everyday use, there are not enough charging stations for electrical vehicles and that the charging time of EV is fast enough for normal everyday use. The respondents could have answered with: 1-Strongly disagree, 2-Disagree, 3-Neutral, 4-Agree and 5-Strongly agree. The results are on the Figure 29.

*Figure 29: Distribution of the respondents based on the answer to three statements regarding BEVs (in %)*




*Source: Own Source*

From the Figure 29 and Table 13 we can see that BEV owners agree that range is sufficient for everyday use (μ range = 4.19 +/- 0.75). Regarding the statement that there are not enough of charging stations, their response is somewhere between neutral and agreeing (μ charging stations = 3.52 +/- 1.11) and they are also leaning towards agreeing on the statement that the charging speed for electrical vehicles is fast enough for normal everyday use (μ charging time = 3.85 +/- 0.92).

### *3.3.2.3 Hypothesis testing*

One of the main barrier for BEV adoption, mentioned in reviewed literature is low range (Egbue & Long, 2011; Hackbarth & Madlener 2016). We confirmed this also with our quantitative research, as more than 70% of our respondents replied that range is the most important factor for them when buying a car. Furthermore, there are no major improvements in the battery development foreseen for the next five years (Fisker Inc., 2017; Albano, 2017). On the other hand, based on our in-depth interviews, the experts told us, that it seems that their BEV clients drive on average longer distances per day than other drivers. If the observations from experts are true and BEV drivers do on average more kilometers then other divers, this indicates that range is more psychological problem for people than a technical problem of electrical car. Understanding this would mean, that BEV future adoption could grow faster by investing in people's awareness and their understanding, that the range of BEVs is already sufficient for their driving habits, resulting in faster BEV adoption. To analyze if driving distance is related to BEV ownership we developed a hypothesis:

**H1: Average daily driving distance and BEV ownership are independent variables**

For our hypothesis we will be analyzing only categorical variables, so we decided to do a Chi squared test. With this test we will determine the independence between our categories' variables, so: how the frequency of the BEV ownership differ across the average daily distance. First variable has two categories: 1-BEV owner and 2-Non-BEV owner. The second variable about the average daily driven kilometers include four different categories: 1- less than 10 km, 2-between 10 and 50 km, 3-between 51 and 100 km, 4-between 101 and 200 km and 5-more than 200 km.

*Table 13: Chi squared test result*

| | **Value** | **df** | **Asymp. Sig. (2-sided)** |
|---|---|---|---|
| Pearson Chi-Square | 27.973[a] | 4 | 0.000 |

a. 2 cells (20.0%) have expected count less than 5. The minimum expected count is 1.19.

For Chi test to be valid, not more than 20 % of all cells need to have expected count above five and at the same time all expected counts need to be above one. We can see from our result (Table 13), that we are just at this border but that the test is valid. 2 cells or in total 20 % of the cells have the count less than 5 and our minimum expected count is 1.19. This is because we had only 4 respondents in the category "more than 200 kilometers". The association between BEV ownership and average daily driven distance is $\chi 2(4) = 27.97$ with asymptotic significance p=0.000. This means, that the probability that our variables are independent is 0.000. With this strong significance we can reject our null hypothesis and conclude that BEV ownership is dependent on daily driving distance. Looking at the cross tabulation table 14, we see that for longer daily distances the BEW owners had higher count than expected, and Non-BEV owners had lower count than the expected one.

*Table 14: Cross tabulation between average daily driving distance and battery electric vehicle ownership type*

| | | **< 10km** | **10-50 km** | **51-100km** | **101-200 km** | **> 200km** |
|---|---|---|---|---|---|---|
| BEV owners | Count | 3.0 | 24.0 | 29.0 | 14.0 | 2.0 |
| | Expected Count | 13.6 | 30.2 | 18.4 | 8.6 | 1.2 |
| Non-BEV owners | Count | 43.0 | 78.0 | 33.0 | 15.0 | 2.0 |
| | Expected Count | 32.4 | 71.8 | 43.6 | 20.4 | 2.8 |

*Source: Own Source*

### 3.4 Discussion

In this part of our master's thesis, we will discuss our findings, which were identified by the appropriate analyses and described before. We focused our research on EV and EU market. Our assumption is that focusing on BEVs would bring additional interesting findings to the table once BEVs are more likely to undergo important changes and influence in the future.

Searching for advanced insights for our research questions:

- Which factors will most influence the future demand for battery electric vehicles?
- In what way will these factors influence the demand for battery electric vehicles?

Our research and studies implied some key findings that are worth highlighting. From our conducted in-depth interviews with experts from electric automotive industry, it came out clear their view that the automotive industry's most important factors and reasons to develop, promote and further sell BEVs in the present and in the upcoming years is to reach the $CO_2$ targets set for 2021 by the regulatory commissions in Europe. Diesel and petrol engine have faced continuous improvement during their century of existence, but it is agreed between the interviewees that they are slowly reaching their maximum efficiency, with no big leap of innovation being foresaw. With this in mind, the automobile industry's clear alternative is the advance to PHEVs and BEVs.

Our survey corroborated with the literature in a list of important components, for example, that the environmental view of EVs is not the most important factor for a higher adoption of alternative powered vehicles, once this factor took just the 7th place, being important for less than 15 % of respondents. The early adopters are shown to be environmentally engaged and already aware of the ecological benefits of EVs, so additional awareness campaigns focusing in this group would not bring additional value.

Another point were our surveys and interviews were aligned with the available literature was referring to the importance of the initial purchase price and the EV range. Based on the interviews, both points were listed as the most important ones from the buyer's perspective, but with divided opinions about which one was the most important of the two. Our surveys also shown a clear lead for these 2 factors, with "purchase cost" ranked as the first drawback for BEVs (74 %) followed by "low range" (43 %) and having "number of charging stations" (42 %) in third place.

Regarding the top 2 highlighted concerns, range is one of the main problems. Our findings via interview and survey revealed that people would consider buying BEVs if the range would be more than 400 – 500 km, based on the survey. Interestingly enough, the current BEV owners do on average more kilometers per day than other type of vehicle owners, but from these same BEV drivers, 92 % answered that BEV's range is sufficient for everyday use. It seems that the "range" problem is a perception from non-BEV users and could be that people will need to get used to it as it was the case for smart phones, where you get used to charge it almost every day and this could happen also to the BEVs perception. Another contribution to the mitigation of the range problem are the significant improvements that were made in BEV range. For example, Tesla Model S grew from 334 kilometers per charge in 2013 to 400 kilometers per charge in 2017. New releases from BEV automakers are also displaying range beyond 400 km in a full charge, case of the Nissan Leaf 2018 (Nissan Motor Co., n.d.).

As seen, initial purchase prices for BEVs are a drawback for drivers, but sufficiently intriguing is the fact that 30 % of our survey respondents would be willing to pay up to 20 % more for BEV than ICEV, 22 % would pay up to 10 % more for BEV than ICEV. As examined in chapter 2.7, total cost of ownership of BEVs will meet the total cost of ownership of ICEV already in 2018, and 2025 is foreseen as the tipping point between BEVs and ICEVs.

In our survey, 80 % of EV owners live in houses, so they see most of the problems for charging the BEV outside the cities, where the charging stations infrastructure could be a limitation. On the other hand, as the number of BEV currently makes a relatively small percentage of all the vehicles on the road, and they mainly have their own charging station at home, it looks like the charging infrastructure in cities is not seen as a current problem for ongoing users. Based on our EV test drive we realized that potentially big problem for people living in residential buildings is that they cannot simply implement a box charging station as people living in their own houses can. The survey also pointed out this issue with around 45 % of Europeans living in flats, which means that the infrastructure framework will present a big problem for adoption for people living in residential buildings (Eurostat, 2017).

In one of the in-depth interviews, the electric power expert explained, that currently underestimated great challenge in the future of BEV adoption will not be energy generation (there is enough energy being generated in EU even if 100 % of the cars are BEVs), but the problem in energy capacity power to distribute the energy to the large numbers of BEVs without an overcurrent problem in the city power network. In an electric power system, overcurrent or excess current is a situation where a larger than intended electric current exists through a system, leading to excessive generation of heat, and the risk of fire or damage to equipment.

Long charging time drawback is partly sorted by the fast charging systems, but this is more question of how fast the charging infrastructure will grow and not as much question of the battery technology. Focusing only on the above mentioned three points, it is obvious that the development of the battery (technology and pricewise) will play a big role in the future adoption of electric vehicles.

# CONCLUSION

The automobile industry is facing a turbulent environment of change, having each OEM striving to achieve and innovate as much as possible. EV technology is changing rapidly so both, customers and manufactures, have to adapt to it. EU offers an especially interesting scenario of a flourishing EV market, coming out of 2009's crisis with growing GDP economies, interested consumers and governmental support for more environmental friendly solutions for mobility.

All these aspects were considered as the purpose of this master’s thesis, being the primary motivation to achieve knowledge comprehension of EU’s EV market by the examination done in EV sales and analyzing the possible connections between present and future sales numbers of EVs. The determinant influence of legislative polices and end-user impressions, conveying a general investigate of the EU’s EV market, with the shown potential for further improvements and conceivable outcomes. The focal point of our consideration was (1) analyzing European current automotive industry; (2) challenges and opportunities for the EV industry inside EU and globally; (3) how EVs technology will affect EU’s EV market demand in the next decades; (4) analysis of available sources and literature; (5) end-user research conducted via questionnaire applying online survey, in-depth interviews with experts from electric automotive industry and EV test-drives. All done having in mind the research questions: which factors will have the biggest influence on the new BEVs buyers? And what kind of effect will these factors have on the BEVs future demand?

The results of the research indicate that experts from electric automotive industry consider the reach the $CO_2$ targets set for 2021 by the regulatory commissions in Europe the principal incentive to promote and further sell BEVs in Europe. Diesel and petrol engine have faced continues improvement during their century of existence, but it is agreed between the interviewed that they are slowly reaching their maximum efficiency, pointing out that PHEVs and BEVs are clear alternatives.

Our survey corroborated with the researched literature that the environmental view of EVs is not the most important factor for a higher adoption of alternative powered vehicles and that early adopters are shown to be environmental engaged and already aware of the ecological benefits of EVs. Referring to the importance of the initial purchase price and the EV range, both points are proven to be very important from the buyers perspective. Our surveys also shown that range is viewed as the first drawback for BEVs followed by purchase price and having charging time in third place.

Our finds via interview and survey revealed that people would consider buying BEVs if the range would be more than 400 - 500km, even though the current BEV believes that BEV's range is sufficient for everyday use. Our conclusion is that the “range anxiety” problem is a perception from non-BEV users and can be solved having people getting used to drive and charge BEVs. The upcoming releases from Tesla and Nissan with a range around 400 kilometers per charge are aligned with our findings.

Initial purchase prices for BEVs are still a drawback for drivers, but our survey showed that 30% of respondents would be willing to pay up to 20% more for BEV than ICEV, and with total cost of ownership for BEVs meeting the total cost of ownership of ICEV already in 2018, this drawback is also being mitigated.

EU charging infrastructure is still not ideal but for the moment, most of EV owners live in houses and can charge their BEVs during the night. Now BEVs counts for a small percentage of the vehicles but based on our EV test drive and our survey this infrastructure framework will present a big problem for BEV’s adoption for people living in residential buildings.

Initial high price, “range anxiety”, and lack of infrastructure are proven to be still the main obstacles for a large adoption of BEVs in Europe, but political support with upgrading and expanding the charging network, subsidies, better information dissemination and manufactures working to improve battery duration and charging speed are signs that the BEV adoption in Europe has everything to increase in the future.

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# APPENDIXES

## Appendix 1: Povzetek (Summary in Slovene language)

Gospodarska rast Evropske unije v povezavi z vladnimi subvencijami, padajočimi cenami baterij in ekonomijo obsega vodi Evropski avtomobilistični trg proti scenariju, kjer naj bi bili vsi novo prodani avtomobili električni. S projekcijo, da bi električna vozila dosegla 50 procenten delež prodaje v letu 2029, bi to predstavljalo 50 milijonov novo prodanih vozil (Yang, 2010). Doseganje višjega deleža električnih vozil so se Evropske države lotile na različne načine, z davčnimi olajšavami in finančno podporo proizvajalcev avtomobilov, podporo in investicijskim denarjem za razvoj novih tehnologij, izgradnjo potreben infrastrukture in dodatnim ugodnostim za lastnike električnih vozil (Ichinohe & Endo, 2006). Z omenjenimi spodbudami trg električnih vozil počasi raste, vendar so rezultati pod pričakovanji. Skeptiki pravijo, da Evropa še ni pripravljena na drastično povečanje trga električnih vozil, na drugi strani pa optimisti predvidevajo da bo Evropa en najpomembnejših trgov za električna vozila. Je pa Evropa kot celota še vedno zelo raznolika, južne države so očitno manj razvite od severnih in osrednje Evropskih držav. Prav tako pa so pomembne razlike med urbanimi mestnimi središči in podeželjem. Vse te razlike se bodo seveda prav tako odražale pri sprejemanju in rasti nove tehnologije kot so električna vozila.

Kupci imajo trenutno na voljo več različnih tipov električnih vozil. Proizvajalci avtomobilov jih trenutno ločijo v pet glavnih podkategorij: električna hibridna vozila, priključna hibridna vozila, električna vozila s podaljševalniki dosega, električna vozila na gorivne celice in popolnoma električna vozila. Električna hibridna vozila vsebujejo kombinacijo električnega pogona in klasičnega motorja na notranje izgorevanje, pri katerem se baterije za pogon polnijo preko bencinskega ali dizelskega motorja. Priključni hibridi delujejo na podobni način le da se njihove baterije polnijo preko zunanjega električnega vira. Električna vozila s podaljševalnikom dosega za svoj pogon uporabljajo samo električni motor, katerega baterije se polnijo preko zunanjega vira energije in dodatno še s pomočjo dizelskega generatorja, ki je nameščen v vozilu. Vozila na vodikove gorljive celice, so prav tako na nek način električna vozila oziroma lahko bi rekli, da so dejansko male električne elektrarne, saj iz vodikovih celic proizvajajo elektriko iz izpuhov pa izpuščajo le vodo. Zadnja kategorija pa so popolnoma električna vozila, ta za svoj pogon uporabljajo samo električni pogon, gnan z elektriko shranjeno v baterijah, ki se polnijo samo preko zunanjega vira elektrike. V najini magistrski nalogi se fokusirava na zadnjo kategorijo popolnoma električnih vozil.

Glavni namen najine magistrske naloge je pridobiti poglobljeno in celostno razumevanje Evropskega trga popolnoma električnih vozil, raziskovanje povezav sedanje prodaje z prihodnjo, tehnologij električnih vozil ter celosten pogled na možnosti in potencialen trg električnih vozil v Evropi. V ta namen sva analizirala trenutni avtomobilistični trg v Evropi, izzive in priložnosti električnih vozil v Evropi in po svetu in raziskala, kako bi lahko razvoj novih tehnologij električnih vozil vplival na povpraševanje v prihodnosti. Najini raziskovalni vprašanji sta: Kateri faktorji bodo v največji meri vplivali na rast tržnega deleža električnih vozil v Evropi? Na kakšen način bodo omenjeni faktorji vplivali na rast tržnega deleža električnih vozil v Evropi?

Z namenom dosega ciljev in namena najine magistrske naloge, sva najprej pregledala dosedanjo literaturo, opravila poglobljene intervjuje s strokovnjaki iz avtomobilske in elektro industrije, sama testirala električno vozilo in intervjuvala inštruktorja varne vožnje, ki je bil odgovoren za testne vožnje popolnoma električnih vozil na marketinškem dogodku organiziranem s strani svetovno znane avtomobilistične znamke. Na koncu pa sva opravila še kvalitativno raziskavo na podlagi odgovorov pridobljenih s pomočjo vprašalnika, ki je bil sestavljen na temelju prejšnjih ugotovitev. V zadnjem delu magistrske naloge so prestavljeni empirični rezultati analiziranega odziva na vprašalnik ter narejena diskusija empiričnih rezultatov v povezavi z ugotovitvami pridobljenimi iz literature in kvalitativnega dela analize.

Glede na najini ciljni vprašanji o tem kateri faktorji bodo v največji meri vplivali na rast tržnega deleža električnih vozil v Evropi in na kakšen način bodo omenjeni faktorji vplivali na to, sva ugotovila naslednje. Najpomembnejši faktor, ki vpliva na sam razvoj, promocijo in dejanski razlog za prodajo električnih vozil s strani avtomobilističnih znamk, je doseganje $CO_2$ ciljev, ki so zastavljeni za prihodnja leta. Proizvajalci avtomobilov so soglasni, da razvoj dizelskega in bencinskega motorja v smislu izkoristka in količine izpusta $CO_2$ plinov, dosegel svoj maksimum. Vsaka minimalna optimizacija zahteva vse večje finančne investicije in proizvajalci ne pričakujejo več drastičnih sprememb na tam področju. Kar pomeni, da so električna vozila ključna alternativa za avtomobilsko industrijo. Ekološki faktor električnih vozil glavni pomembne predvsem za proizvajalce vozil, ter da je bil to pomemben faktor prvih kupcev električnih vozil. Vendar so rezultati vprašalnika pokazali, da ekološki faktor ne bo več igral tako pomembne vloge pri potencialnih bodočih kupcih električnih vozil. Namreč ugotovila sva, da je ekološki faktor po pomembnosti pri nakupu vozila šele na sedmem mestu, pomembne za manj kot 15 procentov vprašancev.

Na podlagi ankete sva potrdila, ugotovitve pridobljene s poglobljenih intervjujev in obdelane literature in sicer, da bosta za rast deleža novih električnih vozil najbolj pomembna 2 faktorja in sicer nakupna cena avtomobila in doseg električnega vozila z enim polnjenjem. 74 procentov vprašancev namreč meni, da je električni avto predrag v primerjavi z vozilom z dizelskim oziroma bencinskim motorjem. Poleg tega sva ugotovila, da bi bilo 30 % vprašancev pripravljenih plačati do 20 % več za električni avtomobil kot za dizelskega oziroma bencinskega, dodatno pa še 22 % vprašancev, ki bi bili pripravljeni plačati do 10 % več. Glede na projekcije, se bodo zaradi vse nižjih cen baterij in ekonomije obsega cene električnih avtomobilov na raven dizelskih oziroma bencinskih že do leta 2025, kar bo predstavljalo pomembno točko v prodaji in rasti tržnega deleža električnih vozil.

Kot omenjeno bo doseg električnega avtomobila pomembno vplivali na rast tržnega deleža električnih vozil. 43 % vprašancev, ki še niso lastniki električnega vozila, namreč meni, da je trenutni doseg električnega vozila prekratek. Vendar sva na podlagi vprašalnika ugotovila, da trenutni lastniki električnih avtomobilov v povprečju prevozijo dnevno več kilometrov kot vprašanci, ki nimajo električnega avtomobila, poleg tega je 92 % lastnikov električnih vozil odgovorilo, da je doseg električnega vozila zadosten za normalno vsakdanjo uporabo. Ugotovitev je zanimiva predvsem zato, ker očitno problem dosega električnega avtomobila ni v dejanskem dosegu vendar v navadah ljudi, ki trenutno lahko v povprečju z enim polnjenjem bencinskega ali dizelskega avtomobila prevozijo več kot 800 kilometrov. Z ozaveščanjem ljudi o nihovem vzorcu vožnje in o razumevanju dnevnih potreb vozila in dejanskega dosega električnega avtomobila, bi se povpraševanje lahko hitreje povečalo. Kar pomeni, da ne bi bilo potrebno čakati predvidevanih 5-8 let, da bo razvoj novih baterij dosegel trenute zahteve kupcev.

**Appendix 2: EU institutions legislative documents**

- The Kyoto protocol to the United Nations framework convention on climate change (UNFCCC, 1998)
- Green paper. Towards a new culture for urban mobility; (COM, 2007)
- Communication COM(2007) 541 to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: towards Europe-wide safer, cleaner and efficient mobility: the first intelligent car report (COM, 2007)
- Treaty of Lisbon amending the treaty on European Union and the treaty establishing the European Community, signed at Lisbon, 13 December 2007 (The Official Journal of the European Union 2007, C306/1-271; 2007)
- Communication COM(2008) 433 final to the European Parliament and the Council: greening transport (COM, 2008)
- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009. On the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (The Official Journal of the European Union 2009)
- Communication COM(2009) 490 final to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: action plan on urban mobility (COM, 2009)
- Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009. On the promotion of clean and energy-efficient road transport vehicles (The Official Journal of the European Union, 2009)
- Regulation (EU) no. 443/2009 of the European Parliament and of the Council of 23 April 2009. Setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce $CO_2$ emissions from light-duty vehicles (The Official Journal of the European Union, 2009)
- Communication COM(2010) 186 final to the European Parliament, the Council, the European Economic and Social Committee: a European strategy on clean and energy efficient vehicles (COM, 2010)
- Communication COM(2010) 2020 final from the Commission: Europe 2020—a strategy for smart, sustainable and inclusive growth (COM, 2010)
- Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011. Setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce $CO_2$ emissions from light-duty vehicles (The Official Journal of the European Union, 2011)
- Communication COM(2011) 112 final to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: a roadmap for moving to a competitive low carbon economy in 2050 COM(2011)

- Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011. Setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce $CO_2$ emissions from light-duty vehicles (The Official Journal of the European Union 2011)
- Communication COM(2012) 582 final to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: a stronger European Industry for Growth and Economic Recovery (COM, 2012)
- Communication COM(2013) 17 final to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: clean power for transport: a European alternative fuels strategy (COM, 2012)

**Appendix 3: In-depth Interview**

**Interview with the Sales director for Slovenian region at one of the globally well-known automotive brand**

**What is your view of the current state of the battery electric car market?**

As you probably know we already have in our fleet couple of hybrid and also fully electrical car models. So, we are going with the trend and must follow it. I don't know if you heard about it, but London had already closed some parts of their center for petrol and diesel cars. Just electric cars are allowed to enter it. In Netherland they are doing even more, free parking's for electrical cars, possibility to use bus lanes in cites and I don't know what more... Furthermore, new $CO_2$ legislations are prepared for the coming years, local governments are also pushing the adoption with investing in infrastructure for charging systems, giving subsidies for buying a new electric car. So no matter what we think about this, we see that is getting more attention every year and this is why we as an important car brand need to be also a part of it.

**What are your current sales and what are you planning for the coming years?**

If we look at the year 2016 and 2017, we doubled our sales. However, I must say that we have really small percent of private buyers. We have now in our CRM (Customer Relationship Management) only four or five private clients. Mostly we sold cars to car sharing companies, then couple of others private companies and local municipality. This are the buyers at the moment.... but now is like this. President of Mercedes group once said, what I think is a great statement that he was sitting in their cafeteria, he was eating French fries and he had a bottle of ketchup next to it. And when he wanted to pure ketchup on the French fries it did not want to go out, so he was tapping on the bottle and then suddenly everything burst out and this is what will happen with electrical cars. Nothing, nothing, nothing and then boom. My philosophy with the electrical vehicles is, that manufacturers decided that they will sell electrical vehicles. They decided for this, because they see the potential and that there is no other way. Now before you can really start selling electrical car, this is not like printing a paper where you decide today what will be inside and tomorrow you print it, but you need to adopt the production plant, you need to gather enough raw materials for batteries, you need to order batteries, you need to decide if you will produce them on your own or you will buy them from somebody, have the contracts ready for how much will you order... All this in not really easy, but they decided that they will do this. So for our concern the forecasts are that we will have in 2020, our really first mid-sized battery electric vehicle, which will not be manufactured on the chase of our standard model. And the price should be below 30.000 euros. Till year 2025 the concern expects to launch around 30 new fully electric models. So a lot of thing will be happening on this field. So as I said, firstly the production will adopt, when you will have the production capacities, your price of the batter and price per unit will drop, so you can become competitive on the market. On the other hand, diesel and petrol car price, will because of the increasing costs that are invested in developing cleaner exhaust fumes, also rise. If you look at them, they have actually become a small chemical factory. It is expected, that just water and oxygen should come out from the exhaust pipe...*laughing.* So as forecast, the prices of diesel and petrol cars will start rising, prices of electrical cars will start falling and they we come to a similar level. And then it will be on you as a user to decide which one o buy.

**Based on this, do you think it can happen that more than 50% of new sold cars will be electric in 2025?**

No, no, this will not go so fast…*silence*

**What do you see as the main barriers for the electrical vehicle adoption, also from the perspective of your clients?**

As I told you, we had really few private clients till now and also because the market is so small, we are not investing in researches, what would clients like in this segment. But in general, there are three main problems, price, range and charging. About the price we already talk about, as I told you our new model in 2020 should be already below 30.000 euros. And also you need to understand, that if the price of the electric car would be lower now, our demand would be too high and we actually have the production capacities already full for this year. So the price needs to be set so high at the moment...*silence*

**...you mentioned also range?**

O, yes. I think the range is more a problem in people's heads. Our electrical car from this model year, can do already more than 200 kilometers on one charge, which I think is already sufficient for normal use. And the model forested for 2020 should have already around 400-kilometer range. Actually, from one of the statistical reports for Europe, I think something like 80 percent of Europeans do less than 100 kilometers per day, or something like that. I don't remember the exact numbers, but when you think about this, the problem is maybe just that we are to use of our cars, which we fill once per week or so. What we know from the sales of the petrol and diesel cars, people care about the price, so when the price of the electrical car will be even for just 10 euros lower compared to diesel or petrol car, people will adopt to the range limits and different charging style.

**So, you think that charging speed is not a problem?**

It is for sure one of the problems that potential buyers see, but when you think about how much time is car parked and how much time it is driven I think that charging speed is not a problem. People will just need to get used that every time they stop, they will need to plug-in the charger. Bigger problem than the speed will be charging infrastructure. So if you will actually have a change to plug it somewhere when you stop...*laughs*

But this is also the chicken and the egg problem. There is not enough charging stations, so people do not buy electrical cars and on the other hand because there is not enough electrical cars, there is no investment in charging stations. But I think this will grow slowly together. As I already said couple of times, I think for the customers to adopt electrical cars, the purchase price will need to go down. And at the point when people will determine, that it is for them economically better to buy EV and not diesel or petrol car, all the other factors like range and charging will be something that will just change in their routine. Because if we look from the other side, if EV would have range now 1000 kilometers and the price would be as high as it is, the sales would not go much up.

**Appendix 4: Questionnaire**

Thank you for agreeing to take part in this important survey evaluating European electric vehicles market. We are two students from the Faculty of Economics and we are gathering this data for our Master Thesis research. Today we will be gaining your thoughts and opinions in order to evaluate the electrical vehicle market in Europe. Be assured that all the individual answers you will provide will be kept confidential and will be only used for educational purposes.

Q1 - Read the statements below, choose the one that best describes your current position towards buying a fully electric vehicle (from now on acronym EV will be used for electric vehicle):

1 I already own a fully electric car
2 I am considering about buying fully electric car in next few years
3 I have thought about buying a fully electric car, but I haven't decided yet
4 I haven't thought about buying a fully electric car
5 I have never heard of electric car
6 I don't need/ I don't drive a car

IF (1) Q1 = [4]

Q2 - We understand that you have never thought about buying electrical vehicle (EV) but we would kindly ask you to state your opinion on the following questions.

IF (2) Q1 = [5]

Q3 - We understand that you have never heard about electrical vehicles (EVs) but we would kindly ask you to state your opinion on the following questions.

IF (3) Q1 = [6]

Q4 - We understand that you don't need or don't drive a car, but we would kindly ask you to state your opinion on the following questions.

IF (4) Q1 = [1] ( EV owner )

Q5 - Below are some statements people have made about EVs. For each statement, please indicate whether you personally agree or disagree with it.

| | **1 Strongly Disagree** | **2 Disagree** | **3 Neutral** | **4 Agree** | **5 Strongly Agree** |
|---|---|---|---|---|---|
| EVs have better performance (acceleration, speed...) than petrol/diesel: | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| EVs are environmentally friendlier than petrol/diesel vehicle: | | | | | |
| It is cheaper to charge an EV then the fuel cost for a petrol/diesel vehicle: | | | | | |
| EV cost about the same to buy as the petrol/diesel vehicle: | | | | | |
| EV range is sufficient for everyday use: | | | | | |
| There are not enough options and models of EVs to choose on the market: | | | | | |
| There is not enough charging stations for EVs: | | | | | |
| The charging time of EV is fast enough for normal everyday use.: | | | | | |

IF (4) Q1 = [1] ( EV_owner )

IF (5) Q5e = [1, 2]

Q6 - What would need to be the range (in kilometers) of an electric car on a fully charged battery for you to consider it sufficient for everyday use?

IF (4) Q1 = [1] ( EV_owner )

IF (6) Q5g = [4, 5]

Q7 - Where do you have the biggest problems to find charging stations for EV?

IF (4) Q1 = [1] ( EV_owner )

IF (7) Q5h = [1, 2]

Q8 - How fast (in hours or minutes) would the electric car need to fully charge for you to consider it sufficient for everyday use?

IF (4) Q1 = [1] ( EV_owner )

Q9_2 - Please share with us some additional advantages and disadvantages that you have experienced as an EV user:

Q9 - On average how many kilometers do you drive (as a driver or a passenger) per day?

1 Less than 10 kilometers
2 10 - 50 kilometers
3 51 -100 kilometers
4 101-200 kilometers
5 more than 200 kilometers

Q10 - From the list below, please choose 3 things that were, or would be, most important for you when buying an EV: (Choose 3 answers)

1 Range (Distance traveled on one charge)
2 Design/Style/Brand
3 Purchase cost
4 Maintenance cost
5 Speed/Performance
6 Safety
7 Time to fill/charge
8 Number of charging stations
9 Environment-friendly car
10 Other::
11 I don't know

IF (8) Q1 != [1]

Q11 - What are the drawbacks of an electrical car that are stopping you from buying one:

1 Too expensive in comparison to the petrol/diesel car
2 Too long recharging time
3 Limited choice of models
4 Low number of charging stations available
5 Low range
6 Speed/Performance are not as good as traditional petrol/diesel cars
7 Safety
8 Not yet proven technology
9 I don’t know enough about electric cars
10 Other:
11 I don’t think there are any drawbacks

Q12 - In what way is the safety of EV problematic in your opinion?

Q13 - How fast (in hours or minutes) would the electric car need to fully charge for you to consider buying one?

Q14 - What would need to be the range (in kilometers) of an electric car on a fully charged battery for you to consider buying one?

Q15 - What percent more would you be willing to pay for the new electric car with the same style and performance of a petrol/diesel car?

1 0%
2 Not more than 10%
3 Not more than 20%
4 Not more than 30%
5 Other:

Q16 - When do you think that more than 50% of all cars sold will be electric?

1 Before 2020
2 Before 2025
3 Before 2030
4 Before 2040
5 Never
6 I don't know
7 Other:

IF (17)Q1 = [1] ( EV owner )

Q17 - I live in:

1 Private House with possibility to charge EV at home
2 Residential building with my own parking and a possibility to charge EV at home
3 Residential building with my own parking with no possibility to charge EV at home
4 Other:

Q18 - Gender:

1 Male
2 Female

Q19 - Education:

1 Primary education or less
2 Secondary education or high school
3 Bachelor's degree

4 Master's degree
5 Doctorate or higher
6 Other:

Q20 - Current Country of Residence: