UNIVERSIDAD PONTIFICIA COMILLAS

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

OFFICIAL MASTER'S DEGREE IN THE ELECTRIC POWER INDUSTRY

Master's Thesis

MONITORING OF ELECTRIC MOBILITY IN SPAIN AND THE IMPACT OF TRANSITION POLICIES

Author: Diana López-Velarde Domínguez
Supervisor: Ainhoa Cabetas Azcoitia

Madrid, July 2019

Master's Thesis Presentation Authorization

THE STUDENT:

Diana López-Velarde Domínguez

....

THE SUPERVISOR

Ainhoa Cabetas Azcoitia

Signed: .... Date: 19/ 7/ 2019.

THE CO-SUPERVISOR

Signed: .... Date: ....../ ....../ ......

Authorization of the Master's Thesis Coordinator

Dr. Luis Olmos Camacho

Signed: .... Date: ....../ ....../ ......

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Summary

The transition to electric mobility is happening, there is no doubt about that. The European Union has established limits on the emissions of the road transportation sector, which all Member states should comply with. For now, the only way to comply with these limits is to introduce electric vehicles in the vehicle fleets.

For Spain, this transition supposes a very important challenge since it is the second major producer of vehicles in Europe, which mainly depends on the production of internal combustion vehicles for now. For this reason, the design and implementation of the right policies and support measures is essential for the benefits of this transition to overcome the negative impacts.

By comparing the policies implemented in Spain and in Norway, which is the country with the highest electric vehicle market share of new registrations, it can be observed that Norway's support measures are directed at decreasing the price of electric vehicles well below the price of gasoline or diesel cars. But these measures are extremely costly, and may not suppose the best option for Spain, which may have to include other options in its strategy.

Analyzing the influence of some socio-economic factors on the penetration of electric vehicles will help to focus on the most relevant ones like number of charging points per every 100km.

Since the Spanish automotive industry will have to change and adapt for this transition, it is very important to invest in R&D and in training the workforce in the production of electric vehicles which involves more and new technology than the production of internal combustion vehicles.

In the oil sector, important benefits are expected since Spain is one of the countries that imports more crude oil, and decreasing this dependency will save the state billions of euros and will increase its energy security.

The energy sector, should focus on reinforcing the distribution network and digitalizing it in order to allow smart charging which will help to optimize the use of existing generation and network infrastructure and will promote a greater integration of renewable energies and demand response services.

This study offers some recommendations for Spain to maximize the penetration of electric vehicles in the Spanish fleet in order to comply with the emission limits imposed by the European Union to fight against climate change, and to maximize the benefits and opportunities created with the transition to electric mobility while minimizing the negative impacts on the economy.

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I thank life for all the opportunities it has given me, and for the new ones to come.

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1. Introduction, objectives and methodology

1.1 Introduction and motivation

Climate change is a fact accepted by scientists all over the world, and everything indicates that the main reasons for it is the greenhouse gas emissions caused by us humans. From those emissions, almost 50% comes from energy supply and transport in the European context (Transport & Environment , 2018). These sectors are also the main responsible for atmospheric pollution due to the consumption of fossil fuels which causes important effects on the human health.

It is because of this, that new technologies are being developed constantly with the purpose of mitigating human environmental impacts while adapting without having to change our way of life completely. Some of these technologies are renewable energies, batteries, energy efficient buildings and electric vehicles.

All of these technologies started out being too expensive to have an important penetration in the market, but as years go by and technology keeps on evolving, these costs have reduced enormously. Between 2005 and 2015, the costs for onshore wind power have decreased 40% and for solar photovoltaic 80%, making them very competitive with other conventional technologies.

The same has happened with electric and hybrid vehicles, for which the most expensive part has always been the ion lithium battery. However, it has already decreased its cost from 890 €/kWh in 2008 to 239 €/kWh in 2015 (Arcos, Maza, & Núñez, 2018). Nowadays, electric vehicles continue to be more expensive than the internal combustion models with similar characteristics, and some people still refuse to make the change due to their still limited autonomy and lack of charging infrastructure in the cities.

Nevertheless, BloombergNEF predicts that by 2030 there will be 30 million electric vehicles in the global market, and if Europe wants to be prepared for this, the number of charging stations need to grow 20 times the current figure in the next years. In order to achieve this, it is clear that we need new policies, incentives, and support mechanisms in order to achieve an effective transition to the electric mobility, and to achieve the 2030 climate and energy targets to increase the use of renewable energies to a 32% share, to improve energy efficiency by 32.5%, and to reduce greenhouse gas emissions by 40% from 1990 levels (European Commission, 2018).

Being Spain the second major producer and the fifth biggest market of vehicles (European Climate Foundation, 2018) in Europe, its transition to electric mobility is very relevant and must be analyzed deeply in order to ensure a fair transition that creates new quality jobs and that guarantee environmental, social and economic sustainability.

This study aims to analyze, quantify and give recommendations for Spain to maximize the penetration of electric vehicles in their vehicle fleet in order to comply with the emission limits imposed by the EU to fight against climate change, and also to maximize the benefits and opportunities created with this transition while minimizing the negative impacts on the economy.

Defining the best policies and support measures that should be implemented is of utmost importance since they are the main tool that will make these maximizations possible and so this will also be a relevant part of the study.

1.2 Objectives

There are two main objectives which are then divided in secondary objectives:

- Analyze, quantify and give recommendations for maximizing the electric vehicles penetration in the Spanish vehicle fleet
    - Analyze and quantify the impact and effectiveness of mobility de-carbonization policies and incentives and determine the possible facilitators and barriers in order to continue supporting the electric mobility in the best way.
    - Analyze and quantify the socio-economic factors that influence electric vehicles penetration in some European countries in order to determine some measures that can be taken to increase electric vehicle penetration.
- Analyze, quantify and give recommendations in order for Spain to maximize the benefits and opportunities created with the transition to electric mobility while minimizing the negative impacts in the economy.
    - Understand the current automobile industry and analyze its competitiveness and impacts on the economy, society and environment.
    - Analyze and quantify the new opportunities and challenges created by the electric mobility transition.
    - Analyze and quantify the impact of electric mobility in the oil and energy sectors.

1.3 Methodology

This document, besides offering an extended picture of the electric mobility transition, will focus in four main aspects:

- Comparative analysis between the country with highest EV penetration and Spain in order to give recommendations and proposals.

- Analysis of the correlation between proposed socio-economic factors and electric vehicles penetration in the European countries with more EV penetration in order to identify the key variables responsible for the electric transition.
- Analysis of new opportunities and impacts of the electric mobility transition in the oil and energy sectors.
- Analysis of the main challenges for Spain regarding this transition, and recommendations to maximize the benefits and minimize the negative impacts.

The methodology to develop this study of the Master Thesis consists in the following:

First, a deep qualitative and quantitative research of the following issues is required:

- Vehicle park characterization in Spain
- Vehicles manufacturing, exports and imports, employment impact
- Impact of the automobile sector on the Spanish economy, health and environment.

After that, all the policies regarding climate change and electric mobility in Europe will be discussed, followed by the explanation of Spanish legislation regarding electric mobility and incentives programs.

Then, research about the ranking of countries regarding EV penetration and charging points installed among other important factors of electro mobility around the world will be explained. This has the purpose of deciding which is the country that has the highest development of electric mobility, which will be the one used for the next part which is the comparison with Spain. In that section, a comparative analysis about the policies and incentives of both countries will be developed and it will be analyzed to what extent Spain can implement or not some of the support methods for EVs and the reasons for it. It will also include a quantitative comparison between incentives aimed at purchase and ownership costs, and the impact of them.

The next section aims at proposing some socio-economic factors that might influence in the EV penetration in the European countries with highest EV market shares. To do this, a correlation analysis will be developed using the Data Analysis Excel Toolpak which will provide the correlation coefficients between the factors and electric vehicles penetration in order to obtain some conclusion about which are the most relevant factors and how to use this information in favor of the transition to electric mobility.

The third focus point includes analyzing the new opportunities that the transition to the electric mobility will bring including the creation of new employments, new technologies and the potential impacts in the oil and energy sectors like the reduction of oil imports and the increase of electricity consumption which will require new investment in national electricity generation, increasing the reliability of the electric Spanish system.

Finally, the possible barriers and main challenges of this transition to electric mobility will be discussed and some recommendations for the continuous creation of value will be proposed, and conclusions will be made.

2. Understanding of the Spanish automobile industry and analysis of competitiveness and impact

2.1 Spanish Vehicle Park

According to the Dirección General de Tráfico (DGT), which is the public department responsible for the Spanish road transport network, at the end of 2018 there were 33.729.982 vehicles in Spain (trucks, vans, buses, cars, motorcycles, industrial tractors and other vehicles) (DGT, 2018).

As it can be seen in *Table 1. Evolution of the Spanish Vehicle park per type of fue* and *Figure 1. Spanish vehicle park per type of fuel* elaborated with data from the DGT (DGT, 2018), most of the vehicle park has always been formed by gasoline and diesel vehicles, with a share of only 0,35% of the total park using alternative fuels in 2018.

Nevertheless, a significant increase of vehicles using alternative fuels can be seen from 2017 to 2018.

Year	Gasoline	Diesel	Other
2006	14,536,169.00	14,124,314.00	17,044.00
2007	14,614,733.00	15,283,326.00	15,539.00
2008	14,626,982.00	15,906,979.00	16,634.00
2009	14,261,822.00	16,155,934.00	25,373.00
2010	14,115,695.00	16,528,513.00	27,154.00
2011	14,018,320.00	16,806,305.00	28,888.00
2012	13,850,018.00	16,909,000.00	33,816.00
2013	13,510,906.00	16,959,627.00	38,456.00
2014	13,301,665.00	17,216,298.00	44,929.00
2015	13,377,184.00	17,541,220.00	44,769.00
2016	13,641,959.00	17,968,013.00	52,950.00
2017	14,030,385.00	18,367,474.00	71,433.00
2018	14,563,270.00	18,574,542.00	117,433.00

Table 1. Evolution of the Spanish Vehicle park per type of fuel. (DGT, 2018)

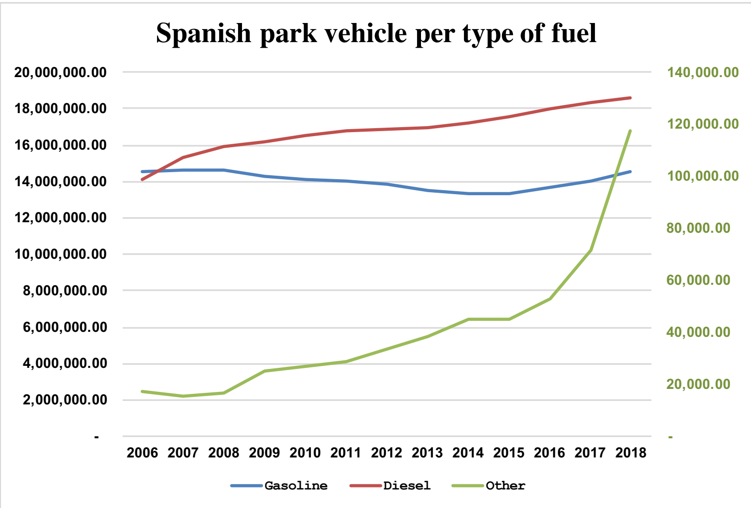

Figure 1. Spanish vehicle park per type of fuel[1] (Authors own elaboration, 2019)

[1] In Figure 1, the gasoline and diesel trend lines (blue and red) correspond to the scale on the left and the trend line of others (green) correspond to the scale in the right.

According to the Guide for Electric Mobility published by Red Eléctrica de España (REE), Instituto para la Diversificación y Ahorro de la Energía (IDEA) and Federación Española de Municipios y Provincias (FEMP) (REE, IDAE & FEMP, 2019), there were approximately more than 63.000 electric vehicles (EV) in Spain in 2018, from which only 28.000 are passenger cars (EAFO, 2019). This means that approximately 0.13% of all the passenger cars in Spain are electric.

Most of these vehicles circulate in the most populated regions: Madrid and Cataluña, which accounts for 21.672 (34%) and 16.708 (27%) electric vehicles respectively.

There are several types of electric vehicles: Battery Electric Vehicles (BEV), Plug-in Hybrid Electric Vehicles (PHEV) and Extended Range Electric Vehicles (EREV), all of which are powered totally or partially from electric energy coming from batteries that are charged in different ways. From these types of EVs, only BEVs and PHEVs are charged by plugging them into a suitable EV charger.

As we can see in *Figure 2. Evolution of EV and PHEV sales in Spain*, elaborated with data from Asociación Empresarial para el Desarrollo e Impulso del Vehículo Eléctrico (AEDIVE , 2019), the number of EV and PHEV sales has been increasing considerably in the last 3 years. In 2018 the EV market share of new passenger cars registered in Spain was almost 1%.

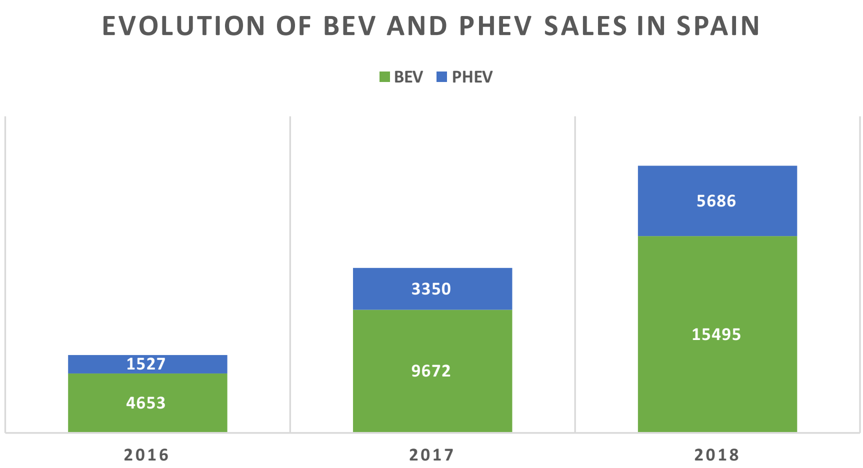

Figure 2. Evolution of EV and PHEV sales in Spain (Authors own elaboration, 2019)

Nevertheless, the Spanish circulating park is growing old. Regarding passenger cars, the average age is 12 years, and for industrial vehicles it rises to 14. This means that there are more than 7 million vehicles over 10 years old circulating on the Spanish roads and streets. According to Asociación Española de Fabricantes de Automóviles y Camiones (ANFAC), in the absence of active policies to renovate the park, there will be more than 4 million vehicles with an age greater than 20 years old circulating in Spain by the year

2026. The second-hand car market is also affected by the aging of the park, since 57% of the sales of second-hand cars correspond to cars more than 10 years old. This is a huge problem since 20% of the oldest cars correspond to 80% of the total pollution generated. (Albor, L., 2018)

2.2 Charging Infrastructure in Spain

Regarding public charging infrastructure, there are more than 5.000 public charging points in Spain, from which 600 offer charging above 22 kW and 200 are super-fast charging points (>150kW), which can charge 80% of a 40kWh battery in between 6 and 13 minutes (REE, IDAE & FEMP, 2019). With this new technology, the recharging time of an electric vehicle becomes very similar to the time it takes for a gasoline car to fill its tank.

Most of the charging points are located in urban areas, nevertheless the number of charging points in highways is increasing. Some of the main energy utilities of Spain including Iberdrola and Endesa, have very ambitious plans for the following 5 years, to install fast and ultrafast charging points in the main highways of the country at least every 100km. With these plans, driving around the main cities in an electric vehicle will not be a problem (Pareja, 2018).

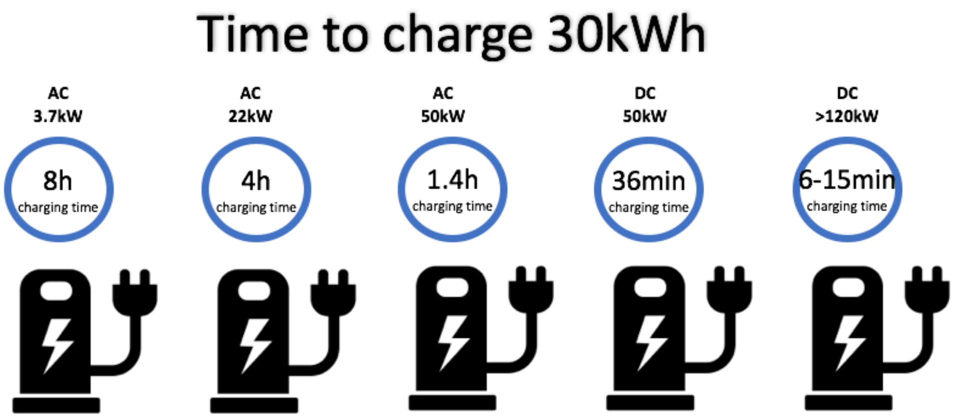

Figure 3. Charging time of 30kWh with different charging points. (Authors own elaboration, 2019)

2.3 Impacts of the automotive sector in the Spanish economy

Regarding the automobile industry, Spain is the 1st producer of commercial vehicles in Europe, 2nd producer of passenger cars also in Europe, and 8th vehicle producer in the world, making up for 3% of the global vehicle market. In 2017, 2.848.335 million units were produced, from which 2.243.220 (79%) were passenger cars and 605.115 (21%) were industrial vehicles. There are 17 Spanish factories, which manufacture 43 models, 20 of them exclusively worldwide, and generate, together with the automobile component industry, 300.000 direct jobs and two million indirect jobs. This represents 9% over the total labor force (ANFAC, 2019)

In 2017, 2.318.217 motor vehicles were exported, which represents 81% of the total production, and 14% over total Spanish exports. The motor vehicle imports represent 7% over the Spanish imports value (ANFAC, 2019).

The sector share of GDP is near 10% if we take into consideration all the other sectors related to the automotive industry like distribution, finance, insurance etc. which means this sector is making a key contribution to the country's GDP and employment. (ANFAC, 2019)

The transportation sector consumes 42% of the final energy in Spain. From this percentage, 80% corresponds to road transport that depends on oil derivatives by 95%.

2.4 Impacts of the automobile sector regarding health and air pollution

The transportation sector accounts for 26% of the total greenhouse gas emissions and from that number 93% corresponds to road transport (Aparicio, 2019). This is because nowadays most of the vehicles in the park are internal combustion vehicles, and they emit many substances, including nitrogen oxides (NO_x) and particulate matter (PM). According to the study titled "Fuelling Spain's Future" (European Climate Foundation, 2018), Spanish vehicle park emits about 115.000 tons of NO_x and 3.600 tons of PM annually. This is worrying since NO_x emissions cause diseases like asthma, bronchitis and pulmonary edema. Nitrogen monoxide (NO) causes pulmonary edema and harms the blood due to the formation of methemoglobin. On the other hand, nitrogen dioxide (NO_2), causes irritation on the mucus membranes, lungs and eyes, plus exacerbates respiratory diseases like asthma, bronchitis, and other allergies and irritations. In Spain, the number of premature deaths caused by NO_2 were estimated of 6.704 in 2014.

Regarding particulate matter (PM10, and PM2,5), it is estimated that they were responsible for at least 17.190 premature deaths in Spain. When inhaling this particulate matter, they produce diseases like asthma, strokes or other cardiopulmonary diseases, and may have carcinogenic consequences if there is a prolonged exposure to them.

Most pollution is mainly concentrated in the big cities like Madrid and Barcelona due to its large number of circulating cars. According to "Fuelling Spain´s Future" (European Climate Foundation, 2018), mortality by NO_x in Madrid accounts for 43.400, which represents almost 1,3% of the population and the sanitary costs caused by this is approximately 54.473.657 euros. In Barcelona PM represent the main problem due to its meteorology and geography. In this case, mortality accounts for 32.700 cases per year.

Another urban traffic pollutant is noise, which causes diseases like heart attacks and stress. There are more than 1.000 premature deaths caused by this in Spain. Electric motors are very quiet in low speed motion, which gives electric vehicles another advantage in cities.

Besides all these health issues, another huge problem is CO_2 emissions caused by the transport sector which is responsible for almost 30% of the EU´s total CO_2 emissions, of which 72% comes from road transportation. From that number, 60.7% of the CO_2 emissions account for passenger cars (European Parliament , 2019).

A right amount of carbon dioxide (CO_2) is an essential component in the Earth's atmosphere in order to keep it warm and assure animals and plants survival. CO_2 is a greenhouse gas that helps regulate the Earth's temperature by absorbing the sun's energy and by avoiding that it escapes outside the atmosphere. But a high volume of CO_2 can have serious consequences, leading to an increase in the Earth's temperature, which causes fires, melting ice caps, oceans levels rising, flooding and other natural disasters.

The largest sources of this greenhouse gas include fossil fuels such as gas, coal and oil which are mainly used in transportation, industry, construction and electricity generation, although these last one is decreasing with the renewable energies being included in the energy mix (see *Section 4.2.2 Energy sector* for more information).

3. Transformation of the automobile sector

3.1 Low-emissions mobility policies

One of the main actions taken worldwide in order to stop or at least reduce climate change was the Paris Agreement which was signed by 195 countries including Spain, with the purpose of establishing a global action plan to maintain the world's average temperature increase below 2°C above pre-industrial levels.

In order to achieve these goals, some specific plans are continuously being developed to reduce greenhouse gas emissions. One of the most active regions regarding this matter is the European Union, which sets targets that all Member States should accomplish by establishing national or local policies and incentives. The EU also invest in project that can help the Member States to achieve these targets.

One of the most important policies in the EU at the moment, is the 2020 climate & energy package, which sets a target to reduce by 20% the EU GHG emissions from 1990 levels, achieve a 20% share of renewables in the final energy consumption, and a 20% improvement in energy efficiency. For 2030, these targets increase to 40%, 275 and 27% respectively (European Comission, n.d.).

Since road transportation sector is responsible for more than a quarter of green-house gas emissions, the EU decided huge efforts should be centered on improving this issue.

One of the first action plans of the EU regarding this matter was the Clean Mobility Package (2017), which includes legislative and non-legislative proposals to boost the transition to zero and low emission vehicles.

One of the main things this Clean Mobility Package includes is the mandatory emission reduction targets for new passenger cars and light commercial vehicles (vans). It was established in 2019 and its objectives are that in 2020, the EU fleet-wide average emission target for 95% of new passenger cars will be 95 g CO_2/km, and then starting from 2021 this measure applies for 100% of new passenger cars. Then, for 2025 the average emissions will have to be 15% lower than in 2021, and for 2030 30% lower. The same applies to vans, but their starting point is 147 g CO_2/km. (European Commission , n.d.)

In order to comply with this, starting from 2021, the emission targets will be based on the new emissions test procedure, the World-wide Harmonized Light Vehicle Test Procedure (WLTP), which was already introduced on September 2017. This test procedure is expressed as percentage reductions compared to the average of the specific emission targets for 2021.

This mandatory emission reduction target of 95 g CO_2/km has still not entered into action, but vehicle manufacturers are already starting to take measures and to increase investment in developing new technology and renewing their products so they comply with these measures. If a manufacturer's fleet exceeds the average CO_2 emissions target in a given year, it will have to pay an excess emissions premium for each car registered. The sanction established by the European Commission is of 95 euros for each CO_2 gram exceeding the limit, multiplied by the number of vehicles sold that year. This means that unless manufacturers develop a plan to reduce emissions, which in many cases has been introducing zero or low emission vehicles into their products, they will face fines of thousands of million euros.

To help manufacturers achieve these goals, the EU offers incentives for eco-innovation in form of emission credits. Manufacturers are also encouraged to group together to share knowledge regarding new technologies or other information that can help them meet their emission target.

Another plan included in the Clean Mobility Package is the trans-European deployment of alternative fuels infrastructure, which aims to support investments in the transport network and in urban areas, so users can have available charging infrastructure that allows them to drive an alternative fuel vehicle around Europe (European Commision , 2017).This plan includes a fund of up to €800 million, available for grants and loans under the Connecting Europe Facility, which is an EU funding instrument that supports the development of trans-European networks of energy, digital services and transport (European Commission , 2019).

However, the results of all the effort and investment previously mentioned would be reduced without standardization and interoperability of charging infrastructure. In the absence of proper legislation about technical aspects of charging infrastructure, many different plugs were designed around the world, and depending on the brand and model of the vehicle, users could end up with a different type of plug. In the following *Table 2. AC and DC charging connectors ,* developed with information from the study "Charging infrastructure for electric road vehicles" (Ecofys, 2018) all the type of plugs are shown:

AC Charging Connectors				
Type	Type 1 (Yazaki)	Type 2 (Mennekes)	Type 3 (EV Plug Alliance)	Tesla (USA)
Geographic Distribution	North America and Japan	Europe and China	Italy and France	Tesla vehicles in North America
Automakers	USA and Japanese automakers	Mandatory for EU sales	Not produced anymore	Tesla
DC Charging Connectors				
Type	Type 4 (CHAdeMO)	CCS COMBO1 (North America)	CCS COMBO2 (Europe)	Supercharger
Geographic Distribution	Japan and Europe (until 2019)	North America	Europe	North America and Europe
Automakers	Nissan, Mitsubishi, Kia, Citroën, Peugeot	BMW, Daimler, Ford, Fiat, Chrysler, General Motors, Honda, Hyundai, Volkswagen		Tesla vehicles

Table 2. AC and DC charging connectors (Authors own elaboration, 2019)

All these different types of plugs made it difficult for users to charge their vehicle in public charging points. That is why on 2014 the European Commission introduced the norm EN 62196, in which the charging connector Type 2 (Mennekes) was chosen as the European standard AC connector and CCS Combo2 for DC. This last one is used for fast and ultra-fast charging points. Nevertheless, there are still many charging points that use Type 3 or Type 4 that were built before 2014 (Ecofys, 2018).

Since Tesla has recently become one of the automakers with more sales in Europe thanks to Tesla Model 3, and up until recently their cars could only be charged in Tesla charging points which resulted in an inconvenient for their users, they decided to change their strategy and include a CCS Combo2 charging port in Model 3. In addition, they also developed an adapter for their other vehicles so they can charge in a CCS Combo2 charging point (García, 2019).

In order to assure interoperability, charging stations should also offer a friendly payment system which can be used by anyone without barriers like a contract with the operator of the charging point, or without the need to use multiple mobile apps or access cards. So far there is not a concrete legislation that guarantees payment interoperability and this will have to evolve at the same pace as technology because eventually all charging infrastructure will have to be digitally connected in order to achieve this goal.

Other plans of the Clean Mobility Package include the development of bus connections over long distances as a way of offering alternative options to the use of private cars, and incentive public procurement as a way to stimulate demand for new low or zero emission transportation.

3.2 Low-emissions mobility policies and incentive programs in Spain

In this section, some of the most relevant policies and incentive programs supporting electro mobility in Spain will be evaluated.

One of the first steps for the efficient deployment of charging infrastructure in Spain was the modification of the Horizontal Property Law 19/2009, which eliminated the need for the rest of the neighbors to vote when a single user needed to install a charging point in a shared parking place. Currently, the only requirement is for the user to communicate to the community (BOE, 2009).

In 2011, the Royal Decree 647/2011 defined for the first time the activity of the system's load managers. It stated that this activity consists in the realization of energy charging services for electric vehicles and specified the rights and obligations of the load managers. It also regulated the procedure and the necessary requirements for exercising this activity, while taking into account that this new load manager is a consumer and a supplier at the same time, thus resembling a retailer (BOE, 2011).

Nevertheless, later on 2018 the Ministry of Energy Transition eliminated this figure of system's load manager in the Royal Decree-Law 15/2018 on "Urgent measures for the energy transition and the protection of consumers" (BOE , 2018). This is because this figure was becoming a barrier for electro mobility for being very rigid and demanding. Any provider of charging services had to become a system's load manager, and the process of becoming one was very tedious. By eliminating this figure, the charging service could be carried out by any merchant company without the requirement that its corporate purpose be to sell or buy energy. Consequently, the charging activity became more accessible and encouraged the deployment of charging points in shopping centers, parking lots, hotels and other public establishments. Likewise, the administrative process was updated and streamlined, to start the charging activity by electronic means and for the entire Spanish territory.

This Royal Decree-Law, also stated that the main objective of the charging services is to deliver energy either free of charge or charged, and that any consumer has the right to exercise this service as long as they comply with certain requirements that include the registration of the charging facilities in each region. The charging service for one or many locations can be exercised directly or through a third party through interoperability agreements.

A very important step was the approval of the Royal Decree 216/2014, which establishes the methodology for calculating the regulated electricity tariff PVPC, which stands for Precio Voluntario para el Pequeño Consumidor (BOE, 2014). This regulated tariff for consumers with contracted power under 10kW that are connected to the low voltage grid, offers 3 types of rates which each consumer can choose according to their preferences and consumption habits:

- Toll 2.0 A: General or Default rate with no time discrimination (one period)
- Toll 2.0 DHA: tariff with time discrimination (two periods)
- Toll 2.0 DHS: tariff with time discrimination (two periods including a super valley rate for charging electric vehicles).

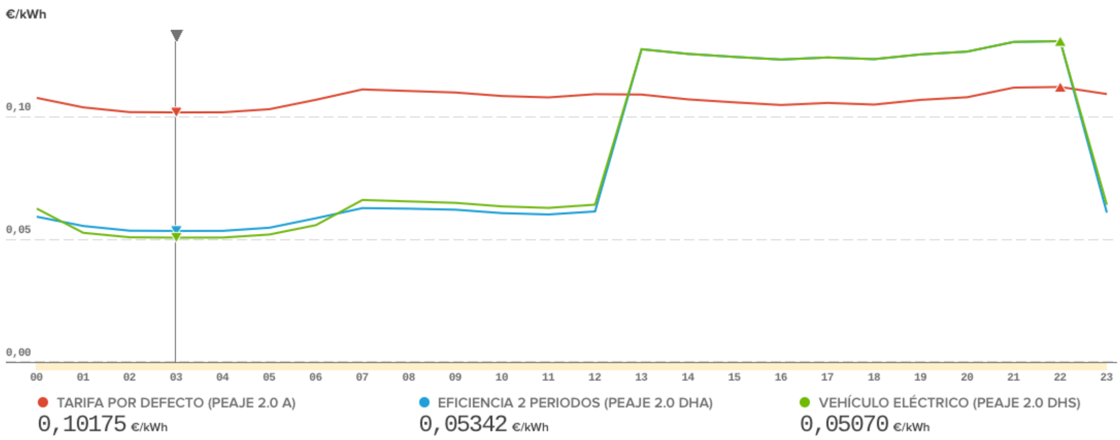

Figure 4. PVPC hourly prices (REE, 2019)

The Toll 2.0 DHS aimed to incentivize charging the electric vehicle at night (1am-7am) when the electricity has its lowest price and the cost of each km driven becomes 10 times cheaper than the cost when using gasoline or diesel. This also aims to accommodate the increase of demand caused by electric vehicle in a time lapse that affects the least the electricity system.

This type of tariff is also available in the liberalized market since most of the biggest energy utilities in the country are offering a special tariff for electric vehicles too.

Continuing with the legislation, the Royal Decree 1053/2014 (BOE, 2014), established that all parking of new apartment buildings and buildings already built that will have a significant reform, need to design a pre-installation that allows referrals for future charging point in spaces for electric vehicle in case users decide to install one.

It also stablishes that new public or private parking of private fleets, malls, businesses etc. should guarantee a minimum of one charging station for every 40 parking lots.

Besides these policies, there are others implemented differently in each Spanish region. One policy that was implemented in Madrid and Barcelona regulates the entrance to the city centers depending on the label of each vehicle. These labels are assigned depending on the level of pollution each vehicle emits. The four categories are the following (DGT, 2016)

- Label Cero: for motorcycles, passenger cars, vans and merchandise vehicles that are registered in the Vehicle Registry of the DGT as electric battery vehicles (BEV), extended range electric vehicle (REEV), and plug-in hybrid electric vehicles (PHEV) with a minimum autonomy of 40 km or fuel cell vehicles.
- Label ECO: same vehicles mentioned before that are either PHEV with an autonomy of less than 40 k, or that are non-plug-in hybrid vehicles (HEV), or vehicles powered by natural gas (LNG or CNG) or liquefied petroleum (LPG).
- Label C: For gasoline vehicles registered as of January 2006 and on and for diesel vehicles registered as of 2014.
- Label B: For gasoline vehicles registered from the year 2000 and on, and for diesel vehicles registered as of 2006.

Some autonomous communities like Madrid and Barcelona only allow those vehicles with labels ECO and Cero to enter their city centers.

According to the environmental organization "Ecologistas en Acción", thanks to this measure established in Madrid by the name Madrid Central, May 2019 had an historic reduction in the nitrogen dioxide (NO_2) levels in the center and north of the city as it is shown in *Figure 5. Evolution of NO2 levels registered in Madrid.*, developed with information from an article by Europa Press (Rubio, 2019). This proves the effectiveness of these measures.

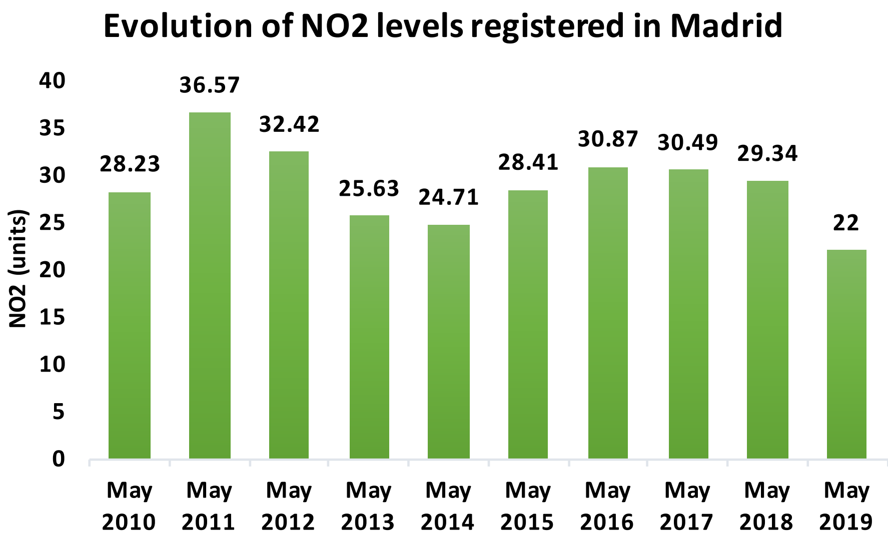

Figure 5. Evolution of NO_2 levels registered in Madrid. (Authors own elaboration, 2019)

Nevertheless, starting from the 1 July of the present year Madrid Central will be eliminated due to a change in the government with different priorities.

The implementation of all these policies have helped to reduce some of the barriers for electro-mobility and to offer some clarity regarding the changes that the transition will create.

But even if these policies support electric vehicles in some ways, in order to have a real impact, people need to start acquiring electric vehicles. But this may suppose a barrier if the technology is still not competitive in the market due to its expensive cost. For this reason and in order to help electric vehicles to become competitive in the market, incentives are needed. These incentives are a type of market-pull policies, which main objective is to create a market for the technology that needs the support.

Spain has offered several national incentive programs starting with MOVALT Plan in 2017 which had a budget of 20 million euros to apply for the aid of purchasing alternative energy vehicles. Then in 2018 the MOVALT Plan for Charging infrastructure, granted another 20 million euros for the financing of direct acquisition or renting of charging points (OVEMS, 2019).

After this program, later that year came the VEA Plan, which granted 50 million euros for the aid for the purchase of electric vehicles and 16,6 million euros for the installation of charging infrastructure. Besides these national programs, many autonomous communities established their own incentives.

The current incentive program, which was approved by the Council of Ministers on the 8th of March 2019, with the Royal Decree 132/2019, is the Efficient Sustainable Mobility Incentives Program (MOVES), which is endowed with 45 million euros and aims at encouraging the purchase of alternative vehicle, the installation of charging infrastructures for electric vehicle, the development of incentives to implement lending system for electric bicycles and the implementation of measures included in Transportation Plans to work centers (IDAE, 2019).

In addition to this program, a line of 15 million euros will be set up to support singular sustainable mobility projects that work on World Heritage cities, municipalities with a high pollution index or located on islands, or innovation projects on electro-mobility.

Finally, the Integrated National Plan of Energy and Climate 2021-2030 (PNIEC) was approved by the Council of Ministers at the beginning of 2019, and it includes that the penetration of renewables in the mobility sector will reach 22% in 2030 through the incorporation of 5 million EVs that will represent 16% of the expected mobile fleet in that year. The objective is to ensure a zero-emission mobile fleet by 2050 (Ministerio para la Transición Ecológica, 2019).

It also suggests that the municipalities with more than 50.000 inhabitants should introduce in urban planning restrictive measures for non-ecological vehicles. Regarding public charging stations, the intention is to install charging points with power >=22 kW in the gas stations that sell more liters of fuel.

Based on this commitment, an Integral Support Plan for the Automotive Sector 2019-2020 has been established, with 562 million euros to promote actions that lead to the achievement of these goals.

3.3 Electric Mobility from a global perspective

In order to assess the performance of Spain regarding electro-mobility and to define the next necessary steps to achieve the desired goals, it is important to first analyze the global situation.

Increasing penetration of electric vehicles in the market is happening all over the world. As seen in *Figure 6. Global passenger EV sales by region.,* obtained from the Electric Vehicles Outlook 2019 (BloombergNEF, 2019), in 2018 the top 3 regions with highest EV sales were China, Europe and United States.

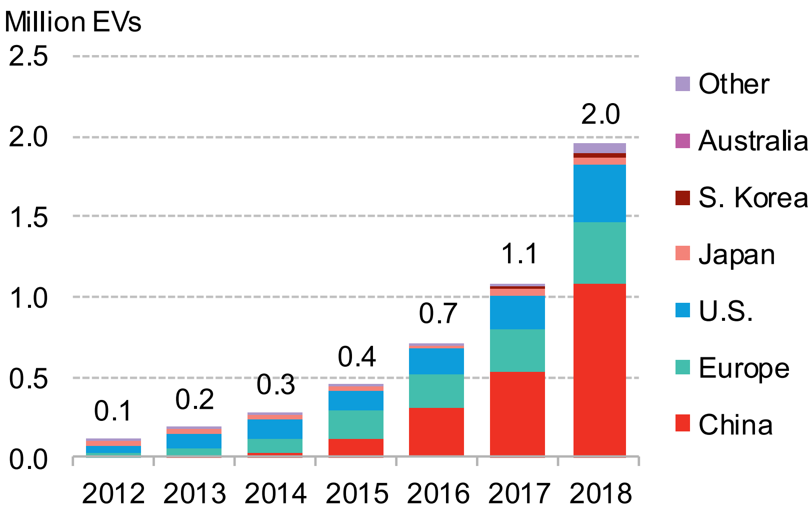

Figure 6. Global passenger EV sales by region. (BloombergNEF, 2019)

The forecast is that this tendency will continue for the next 20 years, as seen in *Figure 7. Annual passenger EV sales by region*.

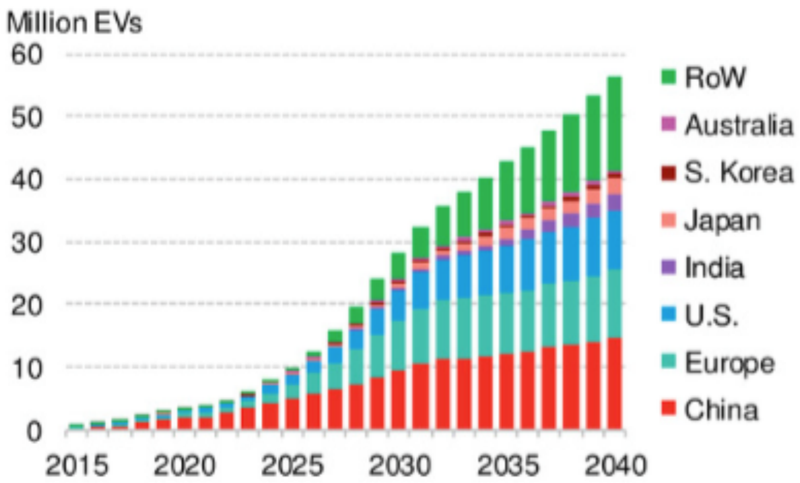

Figure 7. Annual passenger EV sales by region. (BloombergNEF, 2019)

Nevertheless, Norway keeps having the worlds' first place by far regarding highest share of plug-in EVs (EV+PHEV) in new passenger car sales in 2018, followed by Iceland and Sweden.

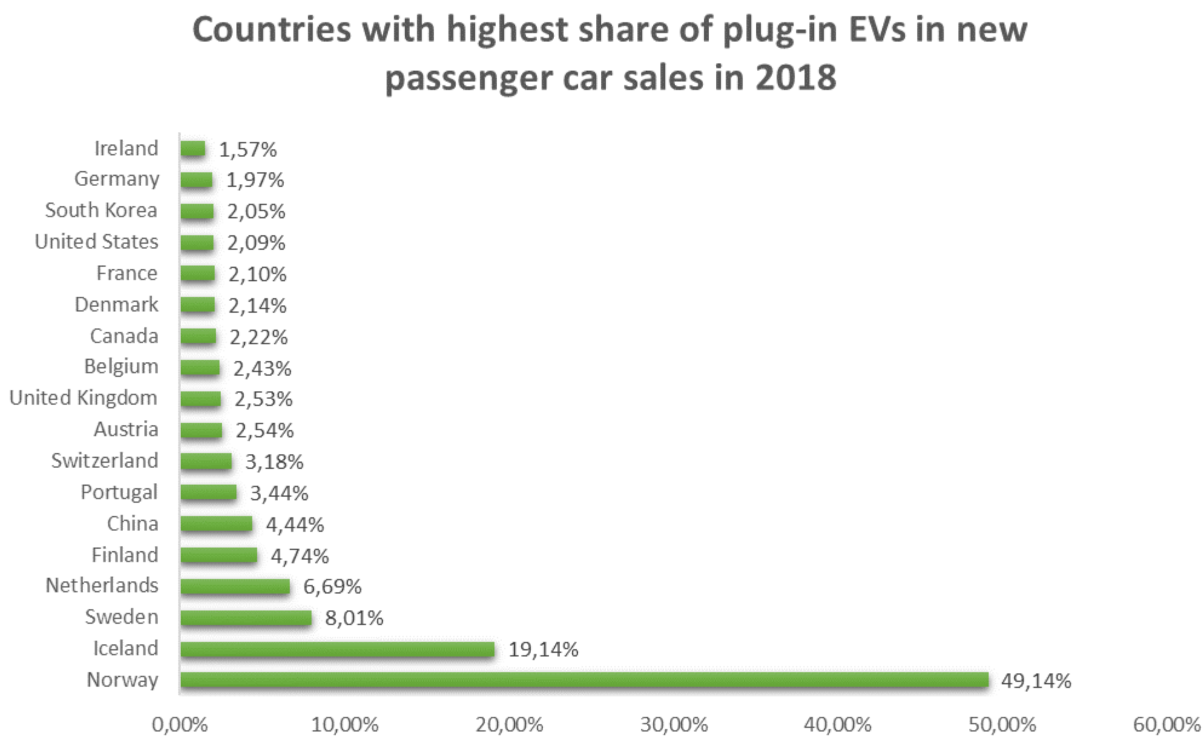

Figure 8. Countries with highest share of plug –in EVs in new passenger car sales in 2018. (Authors own elaboration, 2019)

Comparing Spanish share of sales of EVs (less than 1% of the share in new passenger car sales) with the other countries seen in the previous *Figure 8. Countries with highest share of plug –in EVs in new passenger car sales in 2018.*, developed with information from the World Economic Forum (Fleming, 2019), it can be seen that it is still very far behind the situation of other countries in the European Union.

Regarding the deployment of charging infrastructure, the Netherlands is the country with more charging points. Spain is positioned not so badly regarding this matter and in 2018 it was the 7th country in Europe with more charging points.

Besides, some private companies are carrying out plans to enrich the public charging infrastructure in the coming years. Iberdrola and Endesa, which are two of the biggest energy suppliers in Spain, have within their plans to contribute to increase the public and private charging infrastructure by more 125.000 in 2023, which is 25 times the current number of charging points (Pareja, 2018).

But even though the number of charging points continues to grow each year, Spain is also significantly behind other European countries.

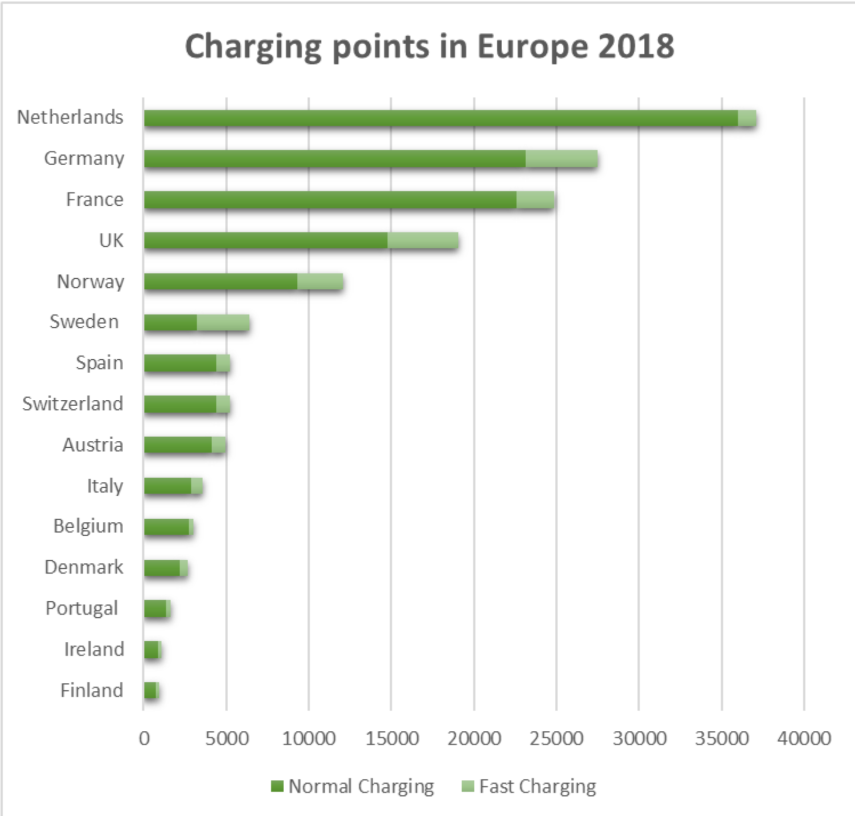

Figure 9. European countries with more charging points. (Authors own elaboration, 2019)

In order to analyze the reasons why Spain is behind other European countries in the development of EV sales and the deployment of a public charging infrastructure, it is necessary to study the different characteristics of these countries and analyze the measures taken by them.

According to data published by The European Automobile Manufacturers' Association, there is a correlation between the GDP per capita of the EU member states and the sales of electrically chargeable vehicles (EV and PHEV = ECVs) (ACEA, 2019). This data shows that the European countries with less than 1% of ECVs market share, have a GDP per capita bellow €29,000. This is the case of countries like Greece, Italy, Lithuania and Spain among other countries.

On the other hand, countries with a ECVs market share above 3,5%, have a GDP above €42,000 like Norway, Sweden and the Netherlands.

The economic performance of a country clearly impacts the penetration of EV and even though we cannot expect the same results of every country, at least the EU Member States should take this fact into account in order to comply with all of the policies regarding climate change, energy and transportation, explained in more detail in *chapter 3.1 Low-emissions mobility policies*, that binds them to take certain actions.

This shows a great need for the governments to implement more incentive programs in order to make low and zero emission transportation affordable in every country.

3.4 Quantitative analysis and evaluation of polices and incentive programs

In this section, an evaluation of the efficiency and impact of policies and incentive programs will be developed. In order to do this, the first step is to compare the incentive programs of the country with higher EV penetration and quantify its impact regarding the penetration of EVs in their market share.

As it was mentioned in section *3.3 Electric Mobility from a global perspective,* Norway is leading the share in the EV market penetration, and this is due to the implementation of policies and incentives enacted by their government and sustained for over almost 30 years.

These incentives also aim to achieve Norway's Climate strategy to reduce by 50% the emissions from transport by 2030 (Innovation Norway , n.d.). This strategy sets the following specific goals regarding land and marine transportation:

- All new vehicles including passenger cars, light vans and city buses have to be zero-emissions after 2025.
- New heavy vans, 50% of new trucks and 75% of new long-distance buses need to be zero emissions by 2030.
- Almost all of the good distribution in urban centers has to be emissions free by 2030.
- New speed boats and ferries should be low or zero emission or run on biofuels
- Major ports should have shore side charging points available for ships by 2025.
- 40% of local shipping ships should be low or zero emission or run on biofuels by 2030.

In order to accomplish these goals, the government implemented technology policies, which aim to make certain technology competitive in the market. These policies are usually implemented with rebates on the purchase and tax-related subsidies, which are exactly some of the main incentives the Norwegian government implemented with the purpose of reducing the price of the EVs, so they become a better and cheaper alternative than ICE vehicles. This goes in accordance with the results from the yearly survey conducted by the Norwegian EV Association in 2017, which shows that the main reason why people choose EVs is to save money (Lorentzen, Haugneland, Bu, & Hauge, 2017).

The following *Table 3. Norwegian EV Incentives.* ,shows the incentives introduced by the Norwegian EV association throughout the years:

Year	Norwegian EV Incentive	Functioning
1990	No purchase/import taxes	This tax can reach €10.000 or more dependending on the car model. The calculation of this tax depends on mass, engine power and CO2 and Nox emissions. BEV are exempted and PHEV has a discount of 26% on the tax.
1996	Low annual road tax	BEV pay €52 instead of the normal €367.
1999	Introduction of special registration plates	License plates with prefix EL or EK. Implemented to make administration of incentives easier, like allowing access to bus lanes .
1999-2017	Reduction on municipal parking	At the beginning it was free, but with the increasing number of EV, in **2018** only a maximum reduction of 50% was agreed. This incentive can save drivers up to hundreds of euros per year.
2000-2018	Reduced company car tax	Initially there was a 50% reduction but in **2018** it was reduced to 40% on the company car tax for BEVs
2001	Exemption from 25% VAT on purchase	BEVs are exempted from paying 25% of the value added tax on the purchase or leasing rate.
2005	Access to bus lanes	BEV have access to bus lanes. In **2016** this changed and now there is only access as long as there is more than one passenger in the car during rush hours.
2009	Reduction on toll road and for ferries	BEVs were exempted from road and ferried tolls that can amount to several thousand euros a year on certain roads, but since **2019** there is only a reduction of 50% for roads and 50% for ferries since **2018**.
2015	Exemption from 25% VAT on leasing	Implemented in line with the VAT tax exemption at purchase.

Table 3. Norwegian EV Incentives. (Authors own elaboration, 2019)

Besides these incentives, in 2018 fiscal compensation for the scrapping of fossil vans when converting to a zero-emission van was also established, and from 2019 holders of driver license class B are allowed to drive electric vans class C1 up to 2450 kg.

These current incentives for zero emission cars will be in place until the end of 2021 except for the VAT exemption which was approved until the end of 2020. After 2021, these incentives will be revised and adjusted accordingly to the development of the market.

According to the same survey developed by the Norwegian EV Association mentioned before (Lorentzen, Haugneland, Bu, & Hauge, 2017), the most relevant EV incentives are the ones that address the purchase price of the vehicles. On the first place is the exemption from 25% of the VAT, followed by the exemption from road toll, no purchase taxes and the others.

Norway has also supported the development of charging infrastructure. Their first support scheme was implemented in 2009-2010, and it consisted in funding 100% of the installation cost for 1800 Schuko charging points, which are the conventional household socket. The total support was of 5.162.500€ (Lorentzen, Haugneland, Bu, & Hauge, 2017).

Nevertheless, the Schuko outlets have proven that they are not the best option for long term EV charging due to their high maintenance cost and very long times to charge an EV battery, and so most of these outlets are now out of service. It is important to take into account that these points were implemented before international standards were adopted.

After this, from 2010 to 2014, the government started to implement support schemes for fast charging stations, with a budget of 5.162.500€ aimed for the installation of charging points, but not for the operating costs. An issue that arose in that moment was that there was no national payment system for the charging service, and so each charging operators was responsible of implementing the payment system they considered best.

In 2015, Enova, which is a state enterprise responsible for promotion of environmentally friendly production and consumption of energy, implemented a support scheme with the purpose of covering the main roads in Norway (approximately 7500 km) with fast charging stations every 50km. All stations were equipped with at least two standard fast chargers (CCS and CHAdeMO) and two 22 kW Type 2 charging points.

These were some of the main relevant actions implemented by Norway in order to boost the transition to electric mobility.

In order to compare Norway's situation with the Spanish one, the incentives and fiscal benefits established in Spain to promote electric mobility and to comply with all the EU and Spanish policies and goals mentioned before regarding emissions are detailed in the following table:

Spanish EV Incentive	Functioning
No registration tax	The registration tax is calculated according to the CO2 emissions of the vehicle. Below 120gr/km cars do not pay. The tax is usually between 1.000€ or 2.000€.
Reduction on the tax on mechanical traction vehicles	Municipalities can apply bonuses of up to 75% of the tax depending on the fuel used, the characteristics of the engine and its environmental impact. BEVs, PHEVs and NG cars apply. This tax is usually between 20€ and 200€ per year depending on the vehicle.
Free Parking for CERO and reduction for ECO	In some of the big cities, vehicles with label CERO, have free parking without a time restriction. Vehicles with label ECO have a discount of 50% of the cost, which can usually amount between 100€ and 200€ per year.
Reduction on the Personal Income Tax (IRPF)	The acquisition of cars by companies for the transfer, for private or mixed use, to their employees implies the imputation of a remuneration in kind in the income tax of said employees. BEVs, PHEVs and EREVs get a 30% discount on this tax.
Access to restricted city centers	Big cities in Spain have restricted the access to the city centers so that only vehicles with ECO and CERO label can enter.
MOVES Plan	Spain offers between 1.300€ and 5.500€ as support when buying a BEV or PHEV passenger car with a price below 40.000€. For vans the aid can amount to up to 15.000€

Table 4. Spanish EV Incentives. (Authors own elaboration, 2019)

Comparing the Spanish and Norwegian incentives, we can see that the Norwegian incentives are more substantial, especially at the moment of purchasing the vehicle. In the following tables and graphs we can see the difference of costs of the purchase of an EV, in this case the Volkswagen Golf and Volkswagen e-Golf (Volkswagen España, 2019), in both Norway and Spain:

	Norway	
	Volkswagen Golf	Volkswagen e-Golf
Import price	24.814 €	34,646.000 €
CO2 tax	4.348 €	-
NOx tax	206 €	-
Weight tax	1.715 €	-
Scrapping fee	249 €	249 €
25% VAT	8.663 €	
Total retail cost	**39.995 €**	**33.286 €**

Table 5. Purchase Price of a VW Golf and e-Golf in Norway (Authors own elaboration, 2019)

	Spain	
	Volkswagen Golf	Volkswagen e-Golf
Purchase price	20.307,3 €	39.460 €
Registration tax	1.012,7 €	-
MOVES Plan	-	5.500 €
Total retail cost	**21.320 €**	**33.960 €**

Table 6. Purchase Price of a VW Golf and e-Golf in Spain (Authors own elaboration, 2019)

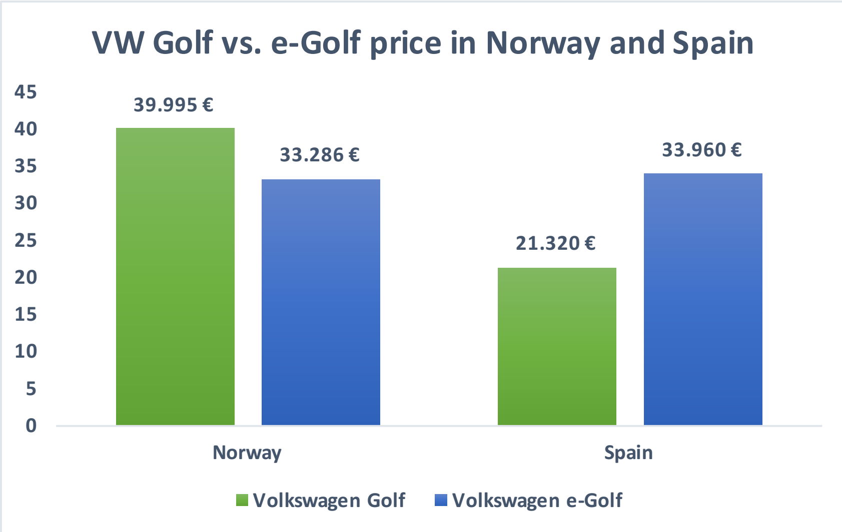

Figure 10. VW Golf vs e-Golf Price in Norway and Spain (Authors own elaboration, 2019)

As we can see in *Figure 10. VW Golf vs e-Golf Price in Norway and Spain,* while the incentives in Norway manage to reduce the purchase price of the EV until it is cheaper than the ICE, in Spain the purchase price of the EV is still more expensive than the ICE alternative.

Part of the success of the penetration of EVs in Norway lies in the decrease of the VAT and the purchase taxes which amount to a very significant amount of money. That is why these are some of the most relevant incentives.

ANFAC and some automobile manufacturing companies insist on this issue, asking for a reduction in the VAT as a way to encourage the purchase of EVs in Spain. So far, only the Canary Islands parliament has decided to eliminate the Canarian Indirect General Tax (IGIC in Spanish) in the purchase of electric, hybrids and gas vehicles. In all other communities in Spain, EVs pay the same VAT rate as ICE models.

The registration or purchase tax exemption in Norway is also very relevant since it can amount to approximately 10.000€. In Spain, even though it is not a negligible amount (between 1000€ and 2000€), the effect of its exemption will certainly not be the same as in Norway.

The life time cost of an EV vs Gasoline and Diesel alternatives is also a fact to take into account: while in Norway owning an EVs is cheaper since the moment it is bought, in Spain it takes many years of useful life for EVs to show a lower life time cost than ICE vehicles, even if incentives directed to the use of the EVs are included,

For these calculations, the Volkswagen Golf was also used in its three fueling options mentioned before. The following *Table 7. Costs of owning an electric, gasoline or diesel VW Golf.,* shows all the concepts taken into account:

Electric Car: Volkswagen e-Golf	
Price (€)	39,460.00
Consumption (kWh/100km)	15.80
Charging point and installation	1,400.00
Electricity price (€/kWh)	0.08
Gasoline Car: Volkswagen Golf 1.0 TSI	
Price (€)	21,320.00
Consumption (L/100km)	5.70
Gasoline price (€/L)	1.44
Diesel Car: Volkswagen Golf 1.6 TDI	
Price (€)	24,410.00
Consumption (L/100km)	4.90
Diesel price (€/L)	1.28
Other data	
Useful life of the car (years)	10.00
Anual expenditure in ORA or similar	200.00
Anual kilometers predicted	20,000.00
Annual circulation tax for gasoline	20.00
Annual circulation tax for diesel	59.00
MOVES Plan (€)	5,500.00

Table 7. Costs of owning an electric, gasoline or diesel VW Golf. (Authors own elaboration, 2019)

For the electricity price an average price of the PVPC tariff for electric vehicles was used and for gasoline and diesel prices also an average was used. For the parking expenses an average of 4 hours per week was assumed.

The results are the following:

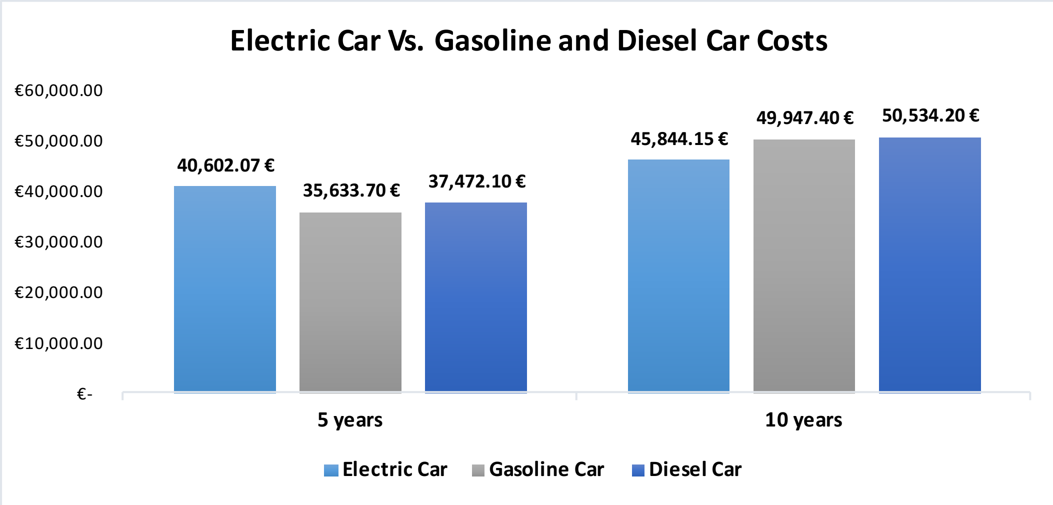

Figure 11. Electric Vs. Gasoline and Diesel Car Costs analysis in Spain. (Authors own elaboration, 2019)

As we can see in *Figure 11. Electric Vs. Gasoline and Diesel Car Costs analysis in Spain.* it takes approximately 10 years for an EV to become cheaper than an ICE vehicle in Spain. It is important to note that without the help of the MOVES Plan, the EV would not even become cheaper after 10 years.

Defining if a policy is effective, requires more than only quantitative information, but for the sake of this study the impact of these policies will be measured with the percentage of market share new registrations in both countries, as shown in *Figure 12. Norway: EVs Market Share New Registrations*, and *Figure 13. Spain: EVs Market Share New Registrations* , with information from the European Alternative Fuels Observatory (EAFO, 2019).

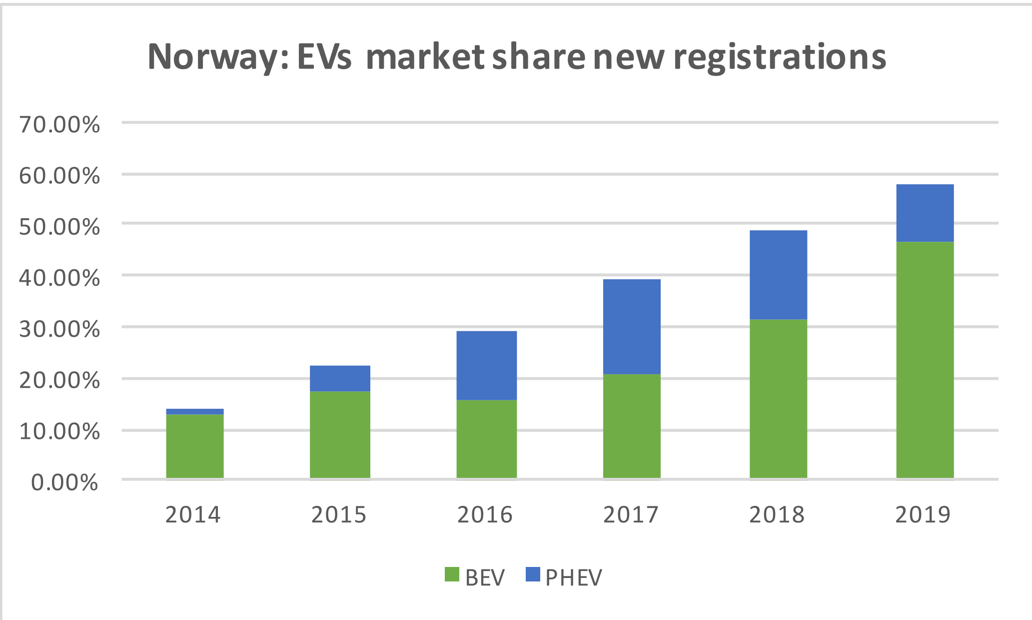

Figure 12. Norway: EVs Market Share New Registrations (Authors own elaboration, 2019)

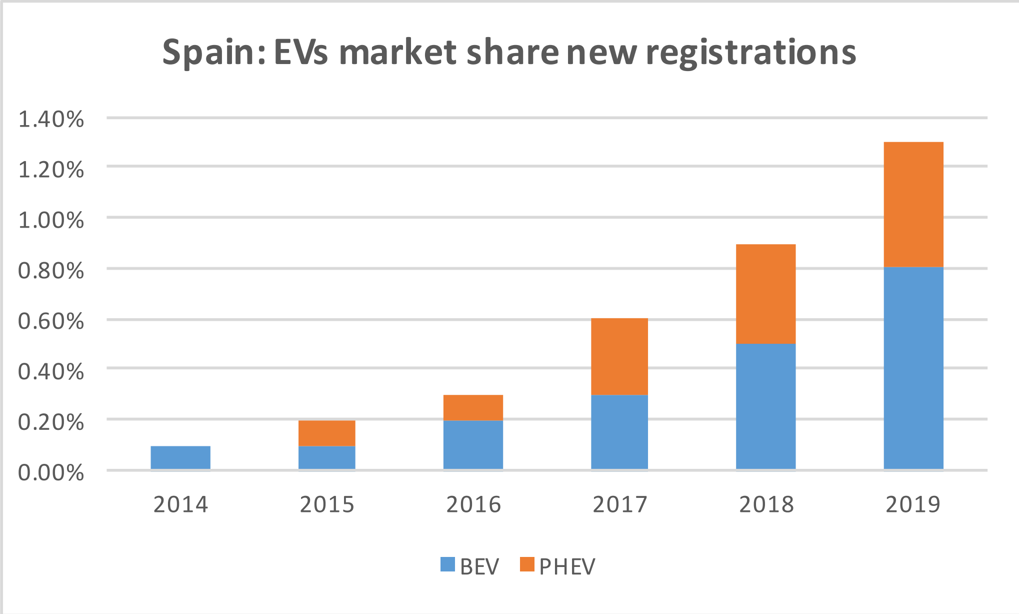

Figure 13. Spain: EVs Market Share New Registrations (Authors own elaboration, 2019)

As we can see in the previous figures, the difference between market share of new registration is remarkable.

Even though it is clear that Norwegian support measures to make EVs competitive in the market were effective, they are not the most efficient either. One of the reasons is that these measures are extremely costly and so they might not be a viable option for most countries. To give a quick perspective, Norway's GDP per capita is 69,73% higher than the one in Germany and 168% higher than Spain's (The World Bank, 2019)

Another reason is they have also created a side effect which is that they are motivating high-income families to buy a second car, and this highlights the issue that usually appear with subsidies, which is free riding.

Subsidies are sometimes being used by high income people that can afford buying any type of car, EV or ICE, but they still use the subsidy and so they now have money to buy a second car. This means that the government is giving a substantial amount of money to people that does not need it. On the other hand, other people may not still afford these vehicles even if they use the subsidy that is offered.

That is why it is very important to analyze the signals that policies are sending in order to design the most efficient policy scheme.

It is also important to remark that technology policies should have an expiration date, as is the case with Norwegian incentives. The reason is that, in case they were effectively implemented, after a few years, the technology should not need the support any more. If the technology needs the support for a very long or undefined time, then maybe this technology should have never been supported since there is no point in creating a market for something that will never be cost competitive.

The good news is that this does not seem to be the case of electric vehicles since their cost has actually been decreasing with time. According to BloombergNEF's EV Outlook 2019 (BloombergNEF, 2019) from 2022 EVs will become cheaper than ICE vehicles in the EU thanks to the decreasing price of batteries, which is the most expensive part of the EVs and for a long time amounted for more than half of the cost of the car. However, in 2022 it will be reduced to 25% of the total cost of the EV. This is a signal that these technology policies should be facing their last years.

Some key point to take into account regarding the success of Norway that suppose an important difference regarding Spain:

- Norway's wealth: Norway is an oil-rich country, in which oil represents 43% of its total exports and 21% of the country's revenues. Oil is also the largest contributors (17%) to its GDP (Steinbacher, Goes, & & Jörling, 2018). This gives Norway a surplus in their budget that can be used for incentives, which in the case of Norway are very substantial. Also, Norway's per capita income is almost 3 times higher than the Spanish one, thus it is probably easier for Norwegians to make bigger investments in more eco-friendly technology.
- Very high taxation of vehicles: taxes related to owning a vehicle in Norway are very high compared to Spain. In Norway, the purchase tax can add up to almost a third part of the price of a new ICE vehicle.
- National Automotive Industry: In Spain, the automotive industry is of mayor importance. Being the second major producer in Europe, it creates 9% of employments over the total labor force and contributes with almost 10% of the GDP in the country. For this reason, Spain has been moving more carefully and slowly towards the transition, and also because there is still a lot of opposition due to the fear of how this will damage the industry and employment. In the case of Norway this is not an issue since this country is not a big producer of vehicles.
- Anticipation and experience: it is very difficult to compete with Norway's anticipated vision of the transition to electric mobility. As mentioned before, Norway started with its first incentives for electric mobility in 1990, which is almost 20 years before Spain implemented its first actions to promote electric mobility. This means 20 extra years of experience and planning.

3.5 Influencing factors on the penetration of EV in Europe

This section aims to analyze the correlation between various socio-economic factors from different European countries and EV penetration. The eleven countries chosen for this study were some with the highest EV market shares: Norway, Netherlands, United Kingdom, France, Germany, Italy, Sweden, Finland, Denmark, Portugal, and Spain.

The proposed factors (variables) chosen for this study are the following:

- BEV Market share new registrations (EAFO, 2019)
- % of BEVs passenger cars over the total passenger cars fleet (EAFO, 2019)
- Public charging point >=22kW per 100km of highway (EAFO, 2019)
- Country's GDP (The World Bank, 2019)
- Electricity price (Eurostat , 2019)
- Average gasoline price (Bloomberg, 2019)
- Environmental Performance Index (EPI, 2018)
- % of total crude oil imports (World's Top Exports , 2019)
- Motor Vehicle production in EU (ACEA , 2018)
- Support for BEV purchasing

2018 figures were taken to analyze the correlation between these variable and the EV penetration. The reason for introducing this last variable was because as the Norwegian EV Association survey mentioned in section 3.4, the most relevant EV incentives are the ones addressing the purchase price of the vehicles, and so it is relevant to analyze if there is a positive correlation between these incentives and BEV penetration.

Since the amount of subsidies are different depending on the type of EV, all the figures used for this calculation were taken to be related to BEV only and not to PHEV in order to avoid obtaining confusing and unprecise correlations. For this study, the Volkswagen e-Golf was used as base.

The following *Table 8. Support Measures for BEVs purchasing* shows the values calculated with information from the ACEA Tax Guide 2019 (ACEA, 2019), which explains all the taxes and support measures related to purchasing and owning a vehicle and how to calculate them.

Support Measure for BEV purchasing			
Country	Purchase Subsidies	Registration Tax Saving	VAT Savings
Norway	-	€ 10,000.00	€ 8,663.80
Netherlands	-	€ 131.00	-
United Kingdom	€ 3,895.57	€ 189.00	-
France	€ 6,000.00	€ 264.00	-
Germany	€ 4,000.00	-	-
Spain	€ 5,500.00	€ 1,012.70	-
Italy	€ 6,000.00	-	-
Sweden	€ 5,712.00	-	-
Portugal	€ 2,250.00	€ 3,229.88	€ 5,946.88
Finland	€ 2,000.00	€ 3,030.73	-
Denmark	€ 5,359.20	€ 17,970.00	-

Table 8. Support Measures for BEVs purchasing. (Authors own elaboration, 2019)

Purchase subsidies refer to direct granting of money for the purchase of a BEV. The registration tax savings and the VAT savings were calculated based on the savings of these taxes corresponding to the gasoline Volkswagen Golf. This is to demonstrate the relative amount "saved" in taxes for having bought the BEV model instead of the gasoline one.

In order to compare the implication of each government in the EV transition (through incentive policies), a new variable which considers the different incentives is calculated following this formula:

$$\frac{Purchase\ susidies\ (€) + Registration\ Tax\ Savings\ (€) + VAT\ savings}{Purchase\ price\ of\ the\ VW\ e - Golf}$$

The final table, which shows the different variable taken into account for the correlation analysis, was separated in *Table 9. Indicators part 1* and *Table 10. Indicators part 2* for the convenience of the reader:

Country	BEV Market share new registratios 2018 (%) Passenger Cars	% of BEVs passenger cars over the total pasenger cars fleet	Public Charging Point >=22kW per 100km highway	GDP per capita 2018 (EUR)	Electricity prices (EUR/kWh) 2018
Norway	31.20	6.50	553.00	71990.34	0.19
Netherlands	5.40	0.54	35.00	46620.99	0.17
United Kingdom	0.70	0.22	122.00	37392.43	0.20
France	1.40	0.38	20.00	36487.97	0.18
Germany	1.00	0.23	34.00	42412.13	0.30
Spain	0.50	0.07	5.00	26861.03	0.25
Italy	0.30	0.03	11.00	30200.19	0.22
Sweden	2.00	0.43	183.00	47618.56	0.20
Portugal	2.00	0.19	10.00	20368.22	0.23
Finland	0.60	0.07	33.00	43964.98	0.17
Denmark	0.70	0.37	41.00	53324.13	0.31

Table 9. Indicators part 1. (Authors own elaboration, 2019)

Average Gasoline price (2018) (EUR/L)	Environmental Performance Index 2018	% of total crude oil imports	Motor Vehicle production in the EU	Support for BEV purchasing
1.59	77.49	0.10	0	0.43
1.49	75.46	4.10	302996	0.00
1.34	79.89	2.20	1597850	0.10
1.40	83.95	2.40	2337910	0.14
1.37	78.37	3.80	5642732	0.11
1.18	78.39	2.90	2928955	0.17
1.52	76.96	2.80	1028316	0.15
1.41	80.51	0.90	329158	0.14
1.41	71.91	0.60	306697	0.27
1.42	78.64	0.60	112252	0.12
1.49	81.60	0.20	0	0.54

Table 10. Indicators part 2. (Authors own elaboration, 2019)

In order to analyze the correlation between BEV penetration and all these indicators, the Data Analysis Toolpak from Excel was used. With it, the correlation coefficients (*R*) between the indicators were obtained and they are shown in the following *Table 11. Correlation Coefficients:*

	BEV Market share new registratios 2018 (%) Passenger Cars	***% of BEVs passenger cars over the total pasenger cars fleet***
Public Charging Point >=22kW per 100km highway	0.933	0.949
GDP per capita 2018 (EUR)	0.734	0.752
Electricity prices (EUR/kWh) 2018	-0.256	-0.206
Average Gasoline price (2018) (EUR/L)	0.559	0.547
Environmental Performance Index 2018	-0.157	-0.081
% of total crude oil imports	-0.349	-0.396
Motor Vehicle production in the EU	-0.290	-0.268
Support for BEV purchasing	0.432	0.489

Table 11. Correlation Coefficients. (Authors own elaboration, 2019)

When the coefficient (*R*) is close to 1 it means there is a strong correlation between the variables, when it is close to zero it means there is almost no correlation and when the coefficient is close to -1 it means there is a strong negative correlation.

With these values, the following conclusions can be obtained:

- Positive and high correlation between Public Charging points with a charging power greater than 22kW, and BEVs market share (*R=0,93; 0,94)*: This factor shows the strongest correlation with EV penetration of the study. It explains that more public charging points reinforces the confidence of potential EV buyers in their decision to purchase one. Also, charging points with higher power can charge faster and this is also something EV buyers take into account in order to consider EV as an alternative for a car they can use for travelling.

- Higher GDP, more BEVs (*R=0,73; 0,75)*: this proves what was mentioned before about the data published by ACEA (ACEA, 2019), about countries with higher GDP having a higher EV market share.
- Higher gasoline prices, more BEVs (*R=0,55; 0,54)*: this follows the same logic as the previous point about electricity. Users in countries with higher gasoline prices might find more attractive the idea to buy and electric car than those living in countries with low gasoline prices. Some Governments have tried to solve this issue by increasing taxes on fuels in order to make ICE vehicles less attractive for purchase.
- More relative support for BEV purchasing, more BEVs (*R=0,43; 0,48)*: this result indicates that support measures addressing the purchase price of electric vehicles, does have positive correlation with BEVs penetration. This is because it is usually the EV purchasing cost that people find harder to face. But the price of EV will continue to decrease as the price of batteries decreases too.
- More crude oil imports, less BEVs (*R=-0,34; -0,39)*: more crude oil imports means that the country's economy is significantly based on oil for transportation, heat, electricity or other uses. The amount of imported oil might decrease as soon as BEV market share starts to rise. It is also important to remark that countries will less oil imports have a higher GDP, and a higher GDP might help countries to boost electric mobility with more subsidies if their budget allows them.
- Higher vehicle production, less BEVs (*R=-0,29; -0,26)*: even though this shows a weak negative correlation, it might be relevant for this study since it is the case of Spain being the second major automobile producer in Europe. These results suggest that countries which produce a higher volume of motor vehicles, present a lower BEV market share, and it makes sense since any changes related to the automobile industry can highly affect their economy. Hence, these countries tend to be more cautious with the measures to promote electric mobility in order not to damage the industry and all its value chain.
- Weak negative correlation between higher electricity prices and BEVs market share (*R=-0,25; -0,2)*: for countries with very high electricity prices it might not be so attractive to buy an electric vehicle. If these countries want to increase EV penetration in their fleet, they will have to take some measures to show an economic advantage of charging a car with electricity over gasoline or diesel.

Nevertheless, this is a weak correlation which will require further analysis in order to draw more exhaustive conclusions.

- Almost no correlation between the Environmental Performance Index (EPI) and BEV penetration (*R=-0,15; -0,081)*: this is interesting since the hypothesis was that countries with better EPI performance would show higher BEV penetration levels. Nevertheless, there seems to be almost no correlation and with a negative sign, which might not be conclusive. The EPI takes into account 24 performance indicators across 10 issue categories that cover ecosystem vitality and environmental health, which are shown in *Figure 14. EPI Framework Indicators* (EPI, 2018). Almost all of the countries selected for this study are at the top of the EPI list with the best results, but the comparison between their indexes and their EV market share showed a negative correlation. One reason which could explain this result is that it will take more years for the impacts of electric vehicles with the environment and ecosystems to truly reflect themselves in a more evident way. After all, the share of EV out of the total vehicle fleet of these countries is still very small compared to the share of ICE vehicles. In fact, there is very little difference between the value of this index across different European countries which were analyzed although the EV share varies greatly among them.

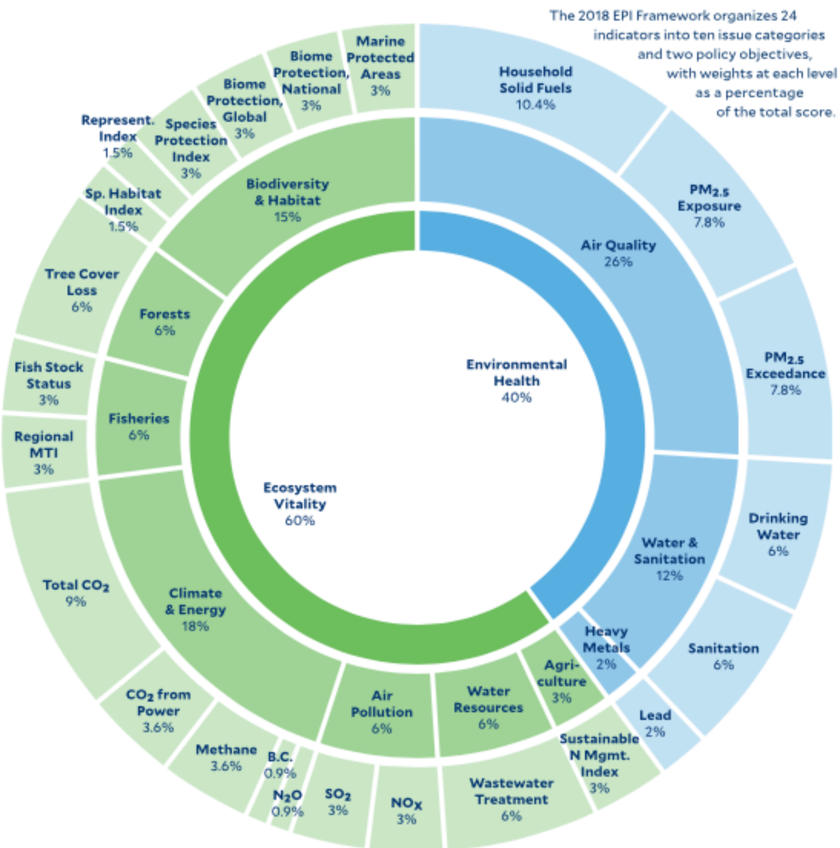

Figure 14. EPI Framework Indicators (EPI, 2018)

4. Analysis of new opportunities for the electric mobility transition

4.1 Employment and new businesses

The transition to the electric mobility is a very complex transformation of the actual industry and society. There is much concern about this change, about how it will impact employment, how this might affect the economy, how fast we need to adapt, etc. The truth is that any transformation will have benefits and challenges.

This chapter will focus on the impact that this transformation will have on employment and the new businesses that it will create.

The massive production of electric vehicles has brought concern to many people working in the automobile sector. This is because the production of an EV requires almost a third less components than ICE and their assembly is considerably simpler and automatable.

For this reason, the entire value chain of the current vehicles factories will change, requiring a new design and substantial investments. It will also decrease the needed workforce and new professional profiles will be required. This supposes a great challenge for Spain since 22% of the companies that make up the Spanish component industry produce elements related to ICE vehicles (Aparicio, 2019).

Nevertheless, according to "Fuelling Spain´s Future" (European Climate Foundation, 2018), the transition from a mobility mostly based in oil to a mobility based in electricity will allow the creation of 23.185 additional jobs in Spain for the year 2030 and also an increase in the GDP of 2.696 million euros.

It is expected that in the short and medium term employment will slightly increase due to the production of new models of electric and hybrid vehicles, but in the long term (2050) it is foreseen that employment directly related with production of cars will decrease due to the less needed workforce. But this will probably be compensated with the creation of employment in other sectors related to electricity and services which are very intense in terms of needed workforce.

Litte by little Spanish factories are starting to produce electric and hybrid models. The French group PSA that integrates Peugeout, Citroën, DS, Opel and Vauxhall has the objective to have an electric version of each of their vehicle models by 2025. In order to achieve that goal they are investing in their 3 factories in Spain which are Vigo, Madrid and Zaragoza, so they can manufacture vehicles that are 100% electric by 2020.

The following *Table 12. Currently and future EVs manufactured in Spain.* , shows all the EVs currently or soon to be manufactured in Spain:

Year	Model	Factory
Currently	Citroën Berlingo Electric BEV	Vigo
Currently	Peugeot Partner Electric BEV	Vigo
Currently	Nissan e-NV200 BEV	Barcelona
2019	Mercedez Benz e-Vito BEV	Vitoria
2019	Seat León PHEV	Matorell Barcelona
2020	Renault Megane PHEV	Palencia
2020	Peugeot 2008 BEV	Vigo
2020	Opel eCorsa BEV	Figueruelas
2021	Opel Combo Electric BEV	Vigo
2021	Citroën C4 Electric BEV	Madrid

Table 12. Currently and future EVs manufactured in Spain. (Authors own elaboration, 2019)

The transition to electric mobility, will eventually merge the automobile and the technological sector, and according to the study "Transición hacia una movilidad sostenible" (Aparicio, 2019), the technology market is 8 times bigger than the automation market. This means that the value of the opportunities that will be created is very significant.

The automobile sector is one of the most relevant drivers of knowledge and innovation, which according to ACEA (ACEA, 2019), represent Europe's largest private contributor to R&D, with an annual investment of €54 billions.

This can be explained by taking into account all the businesses directly or indirectly related to the automotive industry and now more than ever with all the new businesses that are being developed due to the changing transportation sector that has to comply with all the climate change policies.

Figure 15. Businesses and Direct and Indirect Sources of Employment in the Automotive Sector. (Authors own elaboration, 2019)

Some of the most promising new businesses are the following:

- Batteries research and development: Currently, this is one of the main topics of interest in the EU. This is due to the fact that there is a continuous increase in the electric vehicles market share, and most if not all the batteries in those EVs are developed and manufactured in Asia. This puts Europe in a position of dependence and disadvantage, which has never been the case since Europe has always been known as a region where the automotive industry has always been strong. So, in order to solve this issue, the EU has created The European Battery Alliance (EBA) with the main objective to "create a competitive manufacturing value chain in Europe with sustainable battery cells at its core", which has an estimated annual market value of €250 billion from 2025 onwards (European Commission, 2019). This alliance includes more than 120 industrial and innovation actors from several of the Member States. The Spanish Minister of Industry, Commerce and Tourism has already confirmed the participation of six Spanish companies in the alliance.

- Charging technology: Besides developing technology to charge EV batteries faster, investments have been made to develop wireless or inductive charging points. According to a study developed by Allied Market Research (AMR) (Ministerio para la Transición Ecológica, 2019), the market of wireless charging for electric vehicles is growing and will probably reach a value of €1.264 millions.

- E-Sharing: Access restrictions and all the different standards that limit the level of emissions in cities have created what is now called e-sharing. This new business consists on the short-term rental of low or zero emission vehicles including cars, motorcycles and scooters mainly. The most outstanding characteristic of this new concept is that it generates a clean alternative for the urban transport. Currently there are more than 40 e-sharing companies present in Spain.

- IoT /Apps: this segment has become essential for a business to succeed. EV users need apps to map all the available charging points available, to manage their charging point at home or at work and eventually to manage vehicle to grid charging.

- Artificial Intelligence/Autonomous driving: most of the main vehicle companies already have agreements with technology companies to develop autonomous vehicles.

4.2 Potential economic impact in the oil and energy sectors

4.2.1 Oil sector

The transportation sector consumes 42% of the final energy in Spain. From this percentage, 80% corresponds to road transport that depends on oil derivatives by 95% (IDAE, 2019).

Because Spain lacks domestic petroleum resources, it imports all of the oil needed to meet its demand. In 2018 Spain imported a value of 29 billion euros of oil, which represents 2.9% of the total crude oil imports. This sets Spain as the 8th country that imports more oil in the world (World's Top Exports , 2019).

This means that Spain could save a very significant amount of money by reducing its oil consumption, and use it to invest in the development of charging infrastructure, improvement of the distribution network and to keep on incentivizing the use of electric vehicles.

Also, reducing oil dependency is one of the main goals that the whole European Union has been trying to achieve with this transition to electric mobility. The reason for this is that according to the EU (European Commission, n.d.), 54% of Europe's energy needs are imported, and from that amount petroleum products including crude oil, account for 67% followed by gas with 24% and solid fuels with 9%. Most of the crude oil imported comes from Russia (32%) and since sometime the relationship between EU and Russia can be very fragile at times, independence in terms of crude oil from this country is of most importance.

The PNIEC published its predictions of the evolution of the final energy consumption in the transport sector and also on the primary energy sources and imports and exports, in order to achieve the objectives of the plan. These predictions are shown in the following table made with data from the PNIEC (Ministerio para la Transición Ecológica, 2019):

Final energy consumption in the transport sector (excluding non-energy uses) for the Objective Scenario of the PNIEC (ktoe)				
Year	**2015**	**2020**	**2025**	**2030**
Petroleum Products	27.979	32.369	29.030	23.362
Natural Gas	328	508	720	684
Electricity	480	423	953	1.776
Renewable Energies	756	2.283	2.006	1.568
Total	**29.542**	**35.583**	**32.702**	**27.390**

Table 13. Final energy consumption in the transport sector. (Ministerio para la Transición Ecológica, 2019)

As it is shown in the previous *Table 13. Final energy consumption in the transport sector.* , petroleum products used for the transportation sector will decrease 9007 ktoe from 2020 to 2030 that are equivalent to 64,34 million barrels of oil equivalent (mboe). According to some predictions of future crude oil prices offered by EIA's Annual Energy Outlook (EIA, 2019), by 2020 the average price of a barrel of Brent crude oil will be 66.78€/b, then in 2025 it will be 72.77€/b and in 2030 it will be 82.78€/b. Taking these figures into account, an estimation of more than 4.8 billion euros in savings were calculated.

4.2.2 Energy sector

As it is shown in *Table 13. Final energy consumption in the transport sector.* , the transition to electric mobility will increase the electricity demand by more than four time the current values. Spain needs to get prepared for this increase by investing in new national electricity generation to avoid increasing the electricity imports that in 2018 were equivalent to 4.3% of the demand (REE, 2018).

Balance of international physical electrical energy exchanges (GWh)

	France	Portugal	Andorra	Morocco	Total
2014	3,567	-903	-235	-5,836	-3,406
2015	7,324	-2,266	-264	-4,927	-133
2016	7,802	5,086	-278	-4,951	7,658
2017	12,465	2,685	-233	-5,748	9,169
2018	**12,047**	**2,655**	**-210**	**-3,389**	**11,102**

Positive value: importer balance; Negative value: exporter balance

Table 14. Balance of international physical electrical energy exchanges. (REE, 2018)

However, in order for electric mobility to really provide all of its potential environmental benefits, the increase of electricity generation should come from renewable energies. In 2018, more than 40% of the generation was renewable, but this number is expected to keep increasing. If the objectives of the PNIEC (Ministerio para la Transición Ecológica, 2019) are achieved, they predict that by the year 2030, 74% of the electricity generated will be renewable and that number will reach 100% in 2050.

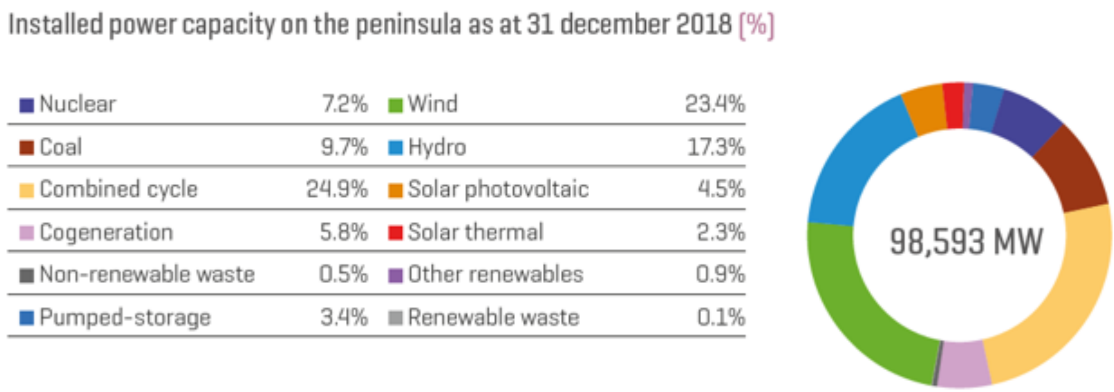

Figure 16. Installed power on the Spanish peninsula 2018. (REE, 2018)

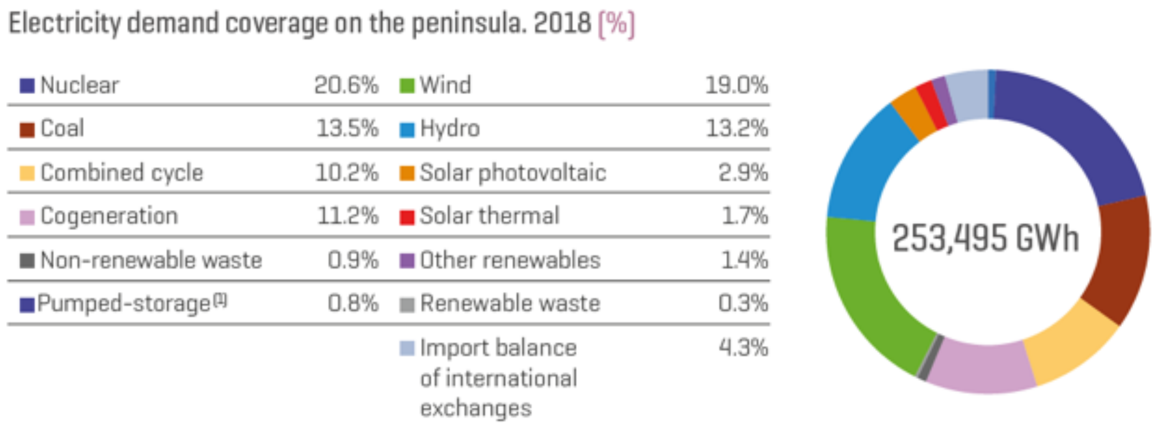

Figure 17. Electricity demand coverage on the Spanish peninsula 2018 (REE, 2018)

Figure 16. Installed power on the Spanish peninsula 2018. , shows how the Spanish installed power is provided by different technologies, though this situation will soon change significantly since there is already a plan to close the nuclear plants in Spain by chronological order in the period between 2025 and 2030. Nevertheless, the PNIEC predicts there will still be approximately 3 GW of nuclear in 2030.

Besides nuclear generation, some coal generation plants are also facing the last years of its lifespan after the EU established stricter pollutants (NO_x, SO_x and PM) limits from large combustion plants, and if those limits are trespassed, those plats will have to shut down before June 2020. This affects 50% of the coal plants in Spain that will have to be replaced by renewables and natural gas combined cycle plants, which are more efficient and have less CO_2 emissions per kWh (Aparicio, 2019).

With these changes to the electricity mix, charging an electric vehicle will be less polluting. Currently, charging an EV at night in the super valley hours equals to 13gr of CO_2/km, but as penetration of low or zero emission generation technologies increase, this number will improve.

If a million ICE vehicles were substituted by EVs, CO_2 emissions could be reduced by 6,4% and the energy consumption would only increase by 1,1% which is acceptable for the network (Aparicio, 2019).

Moreover, a study conducted by VUB University in Brussels about the lifecycle emissions of vehicles, found that even in countries with the most carbon intensive electricity mix, EVs emit less greenhouse gases than an ICE vehicles as it is shown in *Figure 18. Electric vehicles' climate impact in different energy mixes.* (Transport & Environment , 2017).

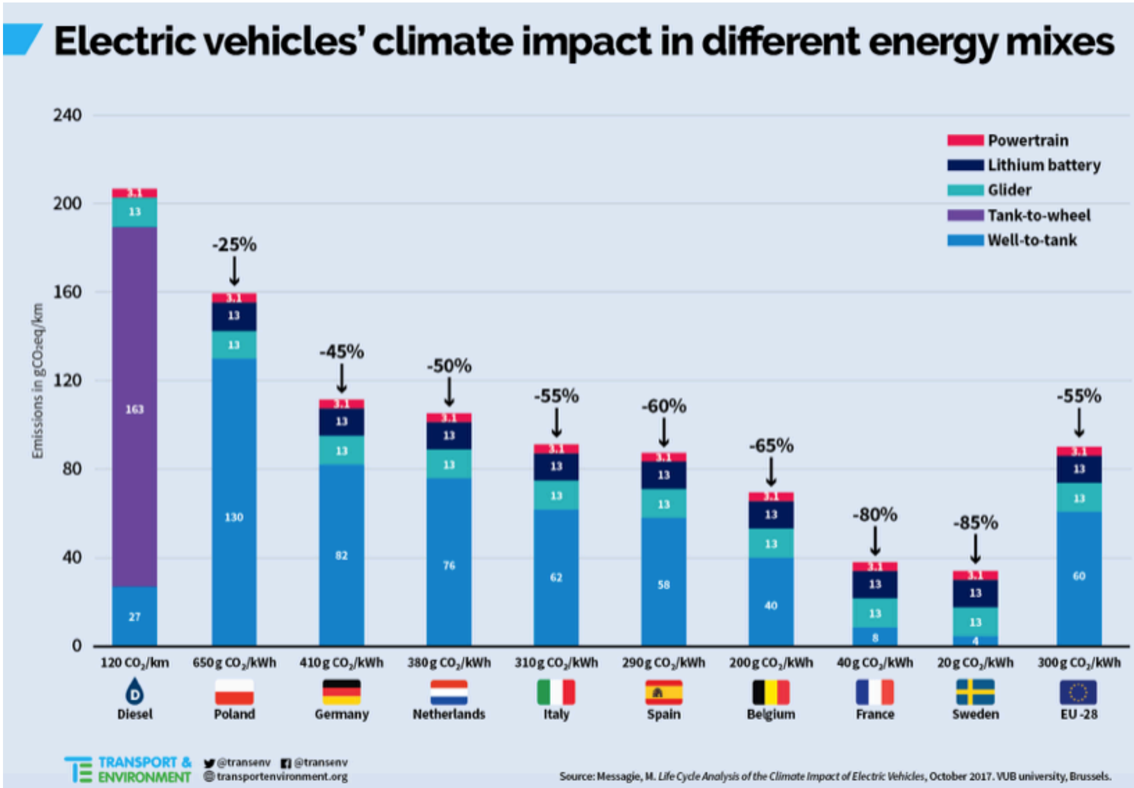

Figure 18. Electric vehicles' climate impact in different energy mixes. (Transport & Environment , 2017)

Focusing on Spain, in 2017 an EV emitted 60% less CO_2 over its lifetime than a diesel vehicle.

Another important impact of electric mobility has to do with the electricity transmission and distribution network. The ability of the current electricity network to endure the increase of demand caused by electric mobility will depend on the type of charging that is used, and above all, the time of day when the charging is done.

According to the study "Transición hacia una movilidad sostenible" (Aparicio, 2019), if the charging of EVs is done at night in when the electricity network is less saturated, the current network conditions might be enough to withstand the complete electrification of the Spanish vehicle fleet. Nevertheless, if charge of short duration and high power are made in flat or peak periods, not only the local stability of the network will be put at risk, but the current capacity may not be sufficient to withstand high levels of electrification of road transport.

Since it is almost impossible to coordinate thousands and eventually millions of EV users to charge at the times where there is less impact, the electricity network should prepare itself to withstand EV charging at any time. This means there are some significant investments that need to be done.

The medium voltage distribution networks that will connect big public electric stations, will be the focus point since they will require important reinforcements to withstand high intensities and avoid energy quality issues (Aparicio, 2019) . It is also important to take into account that most of the use of public charging points is not done at valley hours, and so the impact on the network is higher.

In order to integrate the EV to the entire electrical system, it will be necessary to develop an intelligent recharge management system. This will require the development of meters and charging devices that allow vehicle-network communication (smart grids) with the system operator. In addition, efficient price signals should be introduced, promoting energy offers with hourly discrimination rates that encourages users to charge their EV in off-peak hours (REE, n.d.).

Smart charging strategies will help to decrease charging simultaneity, flattening the demand curve thanks to the charge in off-peak hours, optimize the use of existing generation and network infrastructure and will promote a greater integration of renewable energies.

The increasing penetration of EV will be beneficial for the Spanish electrical system, in the sense that charging activities will increase the income via access tariffs and by providing demand response services.

Regarding this last point about demand response with EV, a very interesting technology that is already in the market is called “Vehicle to Grid” or V2G. It consists in using the battery of the EV as a storage unit that can be managed to consume energy in periods when the network is unconstrained and the prices of electricity are low, store it and then inject it back again into the network when the electricity prices are high and the network is constrained. These services should be operated by aggregators depending on the geographical location where the injection is needed, and the participation in local electricity markets should be managed and led by the different electricity distribution companies. These services should also be economically compensated for serving the electricity network.

In terms of battery wear, if the charge and discharge is made within a range of 30% to 70% of its capacity and maintaining a low power, the battery will not age prematurely due to this additional use (Aparicio, 2019).

5. Challenges, recommendations and conclusions

5.1 Challenges and recommendations

In the past sections, the opportunities and benefits of electric mobility have been discussed, but there are still some barriers and challenges that need to be addressed in order to enjoy all the benefits and value creation of the transition to electric mobility.

The first challenge is the huge difference between the purchase price of EVs and ICE vehicles that was already discussed in section *3.4 Quantitative analysis and evaluation of polices and incentive programs*. As it was mentioned before, the purchase price of EVs will soon decrease as the cost batteries decreases too, until it equals the price of an ICE vehicle or becomes even cheaper.

However, before that happens and until then, technology policies are needed in order to make this technology competitive and to create a market for it. These support measures should be carefully designed in order to avoid negative side effects like it is happening in Norway with high-income families buying a second EV and free riding. A recommendation to solve this problem is to apply the measures that were taken in California, where the eligibility and the amount of the subsidy for a household is decided depending on three factors: income of the household, location and the possession of a qualifying trade-in vehicle (Muehlegger, 2018).

Also, for other countries not as wealthy as Norway, the recommendation would be to establish support measure that are not very costly for the State, and some of them might be implemented as standards in the form of restrictions. An example of this is the suggestion in the PNIEC that municipalities with more than 50.000 inhabitants should introduce urban planning restrictive measures for non-ecological vehicles. A date for the start of this restrictions should be established in the medium term, so people have enough time to choose on their own if they want to make the change to an electric vehicle or face the consequences.

These types of measures do not draw results as fast as Norwegian subsidies, but they are cheaper for the country. A faster result would require reducing the price of electric vehicles till they become cheaper to buy than ICE vehicles, but this will suppose giving up a very significant part of the taxes collected, which might not be an option for Spain at the moment.

The second challenge is the still insufficient charging infrastructure in the country. According to Red Eléctrica de España (REE, 2018), by 2025 there should be 90.000 charging points, 100.000 in 2030 and then 120.000 in 2035, in order to achieve the expected deployment of EV. At the moment, with only a little more than 5.000 public charging point, these objectives seem a little bit too optimistic, but if private companies like Iberdrola and Endesa truly achieve their plans to install together more than 125.000 charging point in the country by 2023, then this would mean the objectives of REE would be achieved 15 years in advance.

Nevertheless, comparing the forecast of 5.000.000 EVs in Spain by 2030 made in the PNIEC, with the objectives of REE for the same year mentioned above, that would mean 50 EV for every charging point. This number would suppose big difficulties for EV users and could generate rejection and distrust towards the acquisition of EVs.

On the other hand, for the third mobility package the European Commission published that in order to achieve the objectives of CO_2 reduction for passenger cars and light commercial vehicles, in 2025 Europe should have 2 million charging points from which 300.000 would correspond to Spain (Aparicio, 2019). This figure seems more reasonable taking into account 5 million VE in 2030 since there would be almost 17 EVs per charging point. It also means that the actual number of charging point needs to be multiplied by 60 in 6 years.

Another barrier, is that currently the high cost of the charging stations, especially fast and ultra-fast ones, and the little or null current profitability of the investments is delaying the deployment. For this reason, as it is stipulated in the Directive 2019/944 (Parlamento Europeo , 2019), in case that the private initiative has not been able to provide charging services for EVs at a reasonable cost and at the needed time, the distribution network operators may own, develop, manage and operate charging points.

Also, a solution to the lack of private parking space has to be addressed since there are 15 million vehicles in Spain that do not have a private parking lot and they cannot install a private charging point to use at night with the super valley tariffs. Unless the planning of charging infrastructure deployment takes this issue into account and finds a solution, these 15 million vehicles might never become electric.

Additionally, there is huge need to facilitate the payment system and make it interoperable so that users can charge their EV regardless of the region or the country they are driving to, without the need of numerous mobile application in their smartphones. To achieve this, alliances must be formed between companies from different countries that dedicate themselves to offering these charging services.

As it has been discussed in section *4.1 Employment and new businesses,* the transition to electric mobility will create new sources of employment, while some of the actual jobs will disappear. So, the third challenge is to make sure that the new jobs created are higher in number than the jobs that disappear, and that everyone that lost their job find an equivalent one in terms of remuneration and quality.

In order to achieve this, Spain needs to maintain its position as one of the main vehicle producers worldwide even after the transition. Important investments regarding training of the workforce in technologic areas is needed as well as in research and development of batteries, charging infrastructure and information technologies.

As it is mentioned in the study “Transición hacia una movilidad sostenible” (Aparicio, 2019), it is essential and urgent to design and implement a specific industrial policy for the Spanish automotive sector, managed by the Spanish Administration but involving the competent bodies of the European Union, to support their adaptation and recreate a competitive environment in a world of electric-mobility in which Spain may risks a large part of its economic future.

The fourth challenge is to develop a robust electricity system in term of generation and network that withstands the impact of an increasing EV penetration. To achieve this, it is necessary to invest in facilities and infrastructure of clean energy generation and in the distribution network. Regarding this last one, the investment should be more directed to reinforcements other than expansion, and mostly in monitoring and intelligent management in order to integrate new bidirectional energy flows created by services provided by EVs to the network like V2G.

Investing and developing a smart grid, will make this transition easier and faster, since it is not possible to electrify transportation without digitalizing the electricity network

The good thing is that Spain is already one step ahead of this in the sense that thanks to the current regulations (RD 1110/2007, Order ITC 3860/2007 and IET 290/2012), electricity distribution companies had to substitute before the end of 2018 all the analog meters whose contracted power is less than 15 kW, for new smart meters that allow time discrimination and that have capacity for telemanagement (Pérez, n.d.). This is good for EV users that have their own charging point at home, because they can choose an electricity tariff for electric vehicle which allows them to charge their EV at a very low price in the off-peak period. Nevertheless, further monitoring in the distribution network will be required.

Finally, it is of utmost importance to establish incentives to renovate the older vehicles in the Spanish park which are the most polluting.

5.3 Conclusions

Penetration of EV in the vehicle fleets is increasing all over the world in an attempt to fight against climate change. In Europe, the EU has already stablished limits of emission coming from road transportation and all Member states should comply with them. The transition to electric mobility is happening and is inevitable. The question is not whether there is going to be transition anymore, it is how it is going to be managed and what will be the impact.

This suppose a special challenge for Spain, since the automotive industry is of utmost importance in the country with a 10% contribution to the GDP and 9% of the labor force, mostly dedicated to the production of ICE vehicle models for now.

This study has documented these main challenges faced by Spain with the transition to electric mobility, but has also given some recommendations that attempt to maximize the penetration of EVs in the Spanish vehicle fleet while minimizing the negative impacts in the economy and maximizing the benefits and opportunities created with the transition.

The tool that will make this transition take place under these conditions is the implementation of adequate policies and support measures that adapt to the economic and industrial situation each country.

Expertise from other countries that are leading the path of this transition can help to choose the right policies or to learn from their mistakes by analyzing their strategy. In this case, Norway which is the country with higher EV market share in new registration, was able to provide some intel about the key to their success and the costs of it.

Also, it is important to analyze which socio-economic factors influence the most in the penetration of EV in a country in order to focus the efforts on the most relevant ones like number of charging points per every 100km.

Spain requires a specific industrial policy for its automotive sector to support their adaptation and recreate a competitive environment in this new world of electric-mobility in which Spain risks a large part of its economic future.

Besides this, it is very important to invest in R&D and in training the workforce in the production of electric vehicles which involves more and new technology than the production of ICE vehicles.

Important benefits in the oil sector are expected since Spain in one of the countries that import more crude oil, and decreasing this dependency will save the state billions of euros and will increase its energy security.

Regarding the energy sector, the focus should be on reinforcing the distribution network and digitalizing it in order to allow smart charging which will help to optimize the use of existing generation and network infrastructure and will promote a greater integration of renewable energies and demand response services among other benefits.

Also, as generation with renewable energies increases year by year and will attempt to reach 100% by 2050, charging an EV will become cleaner, contributing with the fight against climate change.

In conclusion, the transition to electric mobility is not something to be afraid of. It will bring challenges as any other transition, but if it is managed intelligently, the benefits will be greater than the negative impacts.

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