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MASTER'S DEGREE IN PUBLIC POLICIES, STRATEGIES AND DEVELOPMENT

ANALYSIS OF CURRENT PUBLIC POLICIES FOR ELECTRIC VEHICLES PROMOTION IN EUROPE

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FOREWORD

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SUMMARY

The road transport sector is responsible for external effects, like air pollution, greenhouse gas emissions, noise, accidents, traffic congestion and demands the construction, maintenance, and managing of transport infrastructure. Currently, Electric Vehicles (EVs) promotion is seen as an opportunity to address some of these challenges, since EVs are an important mechanism for decarbonization of road transport and a crucial step towards the transition to a clean energy system. Nevertheless, EVs have to compete with conventional internal combustion engine vehicle (ICEV), which already achieved a high level of technological advancement and social acceptance.

Government support is still a key factor since EVs are residual in passenger car stock and market share in Europe. This EV transition is affected by several policies at the same time and by the need to combine different policy instruments. This reflects the notion of multi-level, multi-actor, and multi-governance since governments operate on various scales of jurisdiction and in different areas.

With this in mind, we analyze the European policy instruments implemented by the different vertical governance levels: international, supranational, national and local, while we are taking into account their different policy objectives, in a dialogue with Policy Mix concept through a qualitative approach - literature review. After that, our study focus on the future impact of car tax benefits given currently to EVs on national and local government revenue with a quantitative approach - simulation modeling of annual Spanish car taxation from 2018 to 2050.

We discover that each vertical governance level has its role in promoting electric mobility in Europe, despite the conflicts and coordination issues in their policy objectives, which can be exponentiated by the existence of an automobile industry relevant to the country's GDP. In fact, it is at the national and local level, where most of the action takes place since the supranational authority provides the main guidelines that must be transposed by each European country to national legislation, pressured by the international level. In addition, the current low EV taxation will lead to great national and local government revenue losses in the future, due to the emphasis of car taxation regime on the asset and not on driving distance.

In this way, the breakdown of taxation in our simulation model is concentrated on the use of the vehicle, since government revenue in Spain is centered on fuel taxes and EVs eliminate most of this source of income. Thus, we suggest changing the electricity tax rate, which has not yet been adapted for electric mobility, to try to keep taxation stable over time, but this change eliminates one of the main BEV advantages - which is its low operating costs. Therefore, it is necessary to rethink the current car taxation regime with the increased penetration of electric mobility in the passenger car fleet.

KEYWORDS: Electric vehicles; Public Policy; Europe; Policy mix; Norway; Portugal; Spain

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RESUMO

O setor de transporte rodoviário é responsável por efeitos externos, como poluição do ar, emissões de gases de efeito estufa, ruído, acidentes, congestionamento e exige a construção, manutenção e gestão da infraestrutura de transporte. Atualmente, a promoção de veículos elétricos (EVs) é vista como uma oportunidade para enfrentar alguns destes desafios, uma vez que os EVs são um mecanismo importante para descarbonização do transporte rodoviário e um passo crucial para a transição para um sistema de energia limpa. No entanto, os veículos elétricos precisam de competir com o veículo convencional de motor de combustão interna (ICEV), que já alcançou um alto nível de avanço tecnológico e aceitação social.

O suporte governamental ainda é um fator-chave, pois os EVs são residuais no stock *de carros de passageiros e na quota de mercado na Europa. Esta transição é afetada por várias políticas ao mesmo tempo e pela necessidade de combinar diferentes instrumentos de política. Isso reflete a noção de multi-nível, multi-ator e multi-governança, uma vez que os governos operam em várias escalas de jurisdição e em diferentes áreas.*

Portanto, analisamos os instrumentos de política implementados pelos diferentes níveis de governança vertical: internacional, supranacional, nacional e local na Europa, enquanto consideramos os seus diferentes objetivos de política, em diálogo com o conceito do Policy Mix, por meio de uma abordagem qualitativa - revisão da literatura. Posteriormente, o nosso estudo concentra-se no impacto futuro dos benefícios tributários correntes dados aos EVs nas receitas do governo nacional e local, com recurso a uma abordagem quantitativa – modelo de simulação da tributação anual dos carros de passageiros em Espanha de 2018 a 2050.

Descobrimos que cada nível de governança vertical tem o seu papel na promoção da mobilidade elétrica na Europa, apesar dos conflitos e questões de coordenação, no que toca aos objetivos de política, que podem ser exponenciados pela existência de uma indústria automobilística relevante para o PIB do país. De facto, é no nível nacional e local, onde a maioria da ação ocorre, uma vez que a autoridade supranacional fornece as principais diretrizes que devem ser transpostas por cada país europeu para a legislação nacional, pressionadas pelo nível internacional.

A reduzida tributação atual dos EVs levará a grandes perdas de receita do governo nacional e local no futuro, devido à ênfase do regime de tributação de automóveis no ativo e não na distância percorrida (km). Desta forma, a divisão da tributação no nosso modelo de simulação concentra-se no uso do veículo, uma vez que a receita do governo em Espanha é centrada nos impostos sobre combustíveis e os EVs eliminam a maior parte dessa fonte de receita. Assim, sugerimos uma alteração na taxa do imposto de eletricidade, para tentar manter a tributação estável ao longo do tempo. Porém, essa alteração elimina uma das principais vantagens do BEV - que são o seu baixo custo operacional. Portanto, é necessário repensar o atual regime de tributação dos carros de passageiros com o aumento da penetração da mobilidade elétrica na frota de automóveis de passageiros.

PALAVRAS-CHAVE: Veículos elétricos; Políticas públicas; Europa; Policy Mix; Noruega; Portugal; Espanha

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LIST OF ABBREVIATIONS AND ACRONYMS

BEV	Battery electric vehicles
CO_2	Carbon Dioxide
EC	European Commission
EEA	European Economic Area
EP	European Parliament
EU	European Union
EV	Electric vehicles
FCEV	Fuel-cell electric vehicles
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
ICE	Internal combustion engine
ICEV	Internal combustion engine vehicle
IDAE	Instituto para la Diversificación y Ahorro de la Energía
ISV	Imposto sobre veículos
IUC	Imposto Único de Circulação
IVTM	Impuesto sobre Vehículos de Tracción Mecánica
Km	Kilometers
Mobi.E. program	Program for Electric mobility
Mov. Avg	Moving Average
NDCs	Nationally Determined Contributions
NEDC	New European Driving Cycle
NEEAP	National Energy Efficiency Action Plan
NO_X	Nitrogen Oxides
OEM	Original Equipment Manufacturers
PA	Paris Agreement
PAMEAP	Programa de Apoio à Mobilidade Elétrica na Administração Pública
PHEV	Plug-in hybrid electric vehicles
PLDV	Passenger light-duty vehicles
$PM_{2.5}$	Fine Particulate Matter
R&D	Research and Development
RES	Renewable Energy Sources
SDGs	Sustainable Development Goals
SDS	Sustainable Development Scenario
SO_2	Sulphur Dioxide
SuM4all	Sustainable Mobility for All
UN	United Nations
UNFCC	United Nations Framework Convention on Climate Change
VAT	Value-Added Tax
WLTP	Worldwide Harmonized Light Vehicle Test Procedure
ZEV	Zero-Emission Vehicle

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CHAPTER 1 - INTRODUCTION

On the horizon of 2050, the transport sector appears to be one of the main drivers of increased energy demand. SUM4ALL (2020) predicts that the demand for transport will increase strongly in the next years. By 2050, road transport may have a passenger car fleet of 1.2 billion and an annual passenger traffic increase of 50%.

Most contemporary means of transport are based on fossil fuels and are a source of air pollution and environmentally harmful emissions. In 2017, road transport accounted for 44% of global oil consumption (OECD/IEA, 2018b).

Consequently, the road transport sector has received increasing attention concerning the dynamic study of sustainability transition. The turn of the century is marked by an energy policy effort to achieve energy security, reduce external energy dependency and Carbon Dioxide (CO_2) emissions, along with an attempt to mitigate urban mobility problems (air and noise pollution and traffic congestion), announcing an energy and transport technological transition that can be long.

With this in mind, the shift to less-polluting energy sources has gained prominence recently. Several possible solutions can be identified, ranging from hydrogen economy, flex motors, hybrid vehicles (especially with plug-in technology), and Electric Vehicles (EVs), along with the role of biofuels (ethanol and biodiesel), synthetic fuels, and fuel cells. Taking this into account, road transport faces an unprecedented degree of uncertainty, both in energy policy trade-offs and the variety of technological options that designed them (Pinto Jr et al., 2016).

Currently, the promotion of the electric vehicle is seen as an opportunity, since EVs are a good example of an important mechanism for decarbonization of road transport, as they offer several benefits: 1) reduce local air and noise pollution; 2) diminish oil dependency, especially if the electricity consumed is generated from nuclear or renewable resources; and 3) promote the industrial development (van der Kam et al., 2018, Langbroek et al., 2016, Kester et al., 2018).

It should be noted that EVs can be a crucial step towards the transition to a clean energy system, as road transport electrification is a key pillar for reducing car battery unit costs and hence promoting energy storage at low costs (OECD/IEA, 2019a).

The spillovers of the electric passenger cars (passenger light-duty vehicles - PLDVs) rapid development, drove the penetration of electric two-wheelers and buses. Therefore, there are emerging opportunities for the electrification of the other means of road transport other than PLDVs. However, for the purpose of this work, when referring to electric vehicles, we are considering electric cars in road transport, which include only PLDVs. Thus, we will focus exclusively on electric passenger cars and not in the electromobility phenome as a whole.

Additionally, the EVs denomination includes a variety of vehicle different technologies, namely powertrain system, the main ones are battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel-cell electric vehicles (FCEVs). Nevertheless, for the purpose of this study, we are not considering the FCEVs technology for its residual character.

EVs need to compete with conventional internal combustion engine vehicle (ICEV), which already achieved a high level of technological advancement and social acceptance. So to overcome this competitive disadvantage, innovations and sustainable technologies need to be accepted and promoted by key market players. Kieckhäfer et al. (2017) refer that acceptance by consumers, policymakers, and car manufacturers is required for EV dissemination.

Regarding car manufactures, the automotive sector was characterized by dynamic stability, achieved through economies of scale, sunk costs, and social learning, where car manufactures avoided radical innovations, like electric cars, as were seen as too risky and expensive. It is an industry that has changed little in the space of a century, since it is a sector that has a higher inclination towards reproduction and reorganization, than towards radical changes (Dijk et al., 2016, Seba, 2014). This stabilization can also be explained by the car manufacturers and oil companies' power among the large international cooperatives, which consolidated their influence with the growth in demand for light vehicles and oil products throughout the 20th century (Pinto Jr et al., 2016). Thus, the automotive sector exerts a lot of international and national pressure that can challenge the electric car penetration, since it represents 7% of the European Union (EU)'s total Gross Domestic Product (GDP) (ACEA, 2020b).

Apart from that, the future lies in the offer of more efficient vehicles that are resistant to environmental, energy safety, cost, and performance tests. So, it is implicit the need for major technological advances and large investments that will be shaped in part by government preferences (Pinto Jr et al., 2016).

Electric vehicles have a growing maturity, but government support is still a key factor (OECD/IEA, 2019a). Recently, government support for electromobility has grown strongly, but the penetration of electric vehicles is still low in most countries of the world (less than 1% of the registered passenger cars fleet) (Rietmann and Lieven, 2019b).

Over the last twenty years, Europe has benefited from policies that were associated with tax incentives and emissions-level requirements that could be met by ICE incremental innovations (Wilson and Tyfield, 2018). Consequently, these initiatives had not been enough to boost electric mobility in Europe.

Given current advances in technical performance and cost reductions for EVs, literature has shifted from focusing solely on the technological and economic dimension and has begun to explore the role of public policy, policy mechanisms, and policy mix (Kester et al., 2018). As mentioned before, sustainability transitions (as the electric car transition) are influenced by public policies and the strategies of the actors involved (Lindberg et al., 2018). In fact, transitions are affected by several policies at the same time and by the need to combine different policy instruments.

To capture the variety and potential interactions between different policies, as well as their ongoing changes, Rogge and Reichardt (2016) and Flanagan et al. (2011) suggest the study of the policy mix.

Policy Mix has been studied in various scientific fields, but especially in the environment, economics, innovations studies, and policy analysis. It is widely used in the climate and energy field in an attempt to the transition of a decarbonized energy system. This concept was commonly defined as a combination of numerous policy instruments. However, Rogge and Reichardt (2016) and Flanagan et al. (2011) defend that policy mixes are more than just a combination of policy instruments since this concept also includes the processes of creation and interaction of such instruments. Consequently, in our study, when we are referring to the policy mix, we are using Rogge and Reichardt (2016) and Flanagan et al. (2011) definition.

Note that the Policy Mix concept is compatible with the definition of the modern state, where there is a dispersion of power, both upwards and downwards, from the national level to supranational and local level. Until then, the idea of the State was associated with traditional neoclassical economic theories of welfare and the unitary policy maker (Flanagan et al., 2011). Policy Mix represents the replacement of traditional state-centric models of government by the notion of multi-level, multi-actor, and governance.

Therefore, governments operate on various scales of jurisdiction and in different areas. Consequently, to present the different solutions found by policymakers in promoting electric cars promotion in Europe, we will take into account the governance levels of the Policy Mix concept, which divides public policies into four levels of vertical governance: i) international (United Nations (UN), Paris Agreement (PA), SuM4all); supranational (European Union (EU) – state-members or European Economic Area (EEA)- for non-state members); national (country); and lastly, local policies (city or region).

Given this context, this master's thesis will attempt to answer the question: **How do the different vertical governance levels (international, supranational, national, and local) of European policy mixes influence the policy objectives and policy instruments adopted to promote electric car mobility in Europe?**

To answer this main research question, two methodological approaches were used throughout our work. Thus, in the first part – Chapter 2, 3, 4 - to analyze the different policy objectives and policy instruments implemented by each vertical governance level, we used a qualitative approach of literature review and document analysis. In the last chapter – Chapter 5 - to understand the future impact of EV market penetration on the government revenue, related with the car taxation from 2018 to 2050, we opted for a quantitative approach using a simulation modeling of the evolution of the Spanish passenger car fleet created by Casado (2020) and developed our own model with regard to car taxes associated with passenger cars, using the Excel main tools.

As we have seen, the study was divided into four major chapters. Firstly, in Chapter 2, the role of public policy to encourage electric mobility in Europe is discussed in an attempt to dialogue with the policy mix literature, focusing on the vertical governance level dimension (international, supranational, national and local) and recognizing the role of horizontal level (different departments and ministries). In addition, a small analysis of the use of this concept by the transport sector is made, as well as a characterization of the papers that analyze the importance of public policies in the EV market promotion.

Secondly, in Chapter 3, the pressure and the diverse policy objectives of the vertical governance levels - International and Supranational - are analyzed, in addition to the main European initiatives created for the promotion of electric mobility by vehicle, charging infrastructure, and energy. Then, it is carried out an analysis of the European panorama of the adoption of the electric cars and to associate it with its level of pollution, traffic congestion, energy dependency, the share of renewables, centralization or decentralization government level, and charging infrastructure. This study allows the selection of three representing countries of each cluster of countries: Norway, Portugal, and Spain.

Subsequently, in Chapter 4, a brief systematization of the economic and non-economic incentives adopted at the national and local levels by Norway, Portugal, and Spain for the promotion of electric cars and their impact on the car tax collection is carried out. Additionally, a comparison between the different national incentives adopted by these three countries is made at the end of this chapter.

Finally, in Chapter 5, we intend to understand the possible impact of the current economic incentives given to electric cars in the car tax collection level in Spain, more simply, in national and local government revenue. For this, we used a simulation modeling of three possible BEV market penetration scenarios for one country – Spain. The ideal would have been to carry out this analysis for the three representative countries, but for reasons of time and data limitation, we concentrate only on Spain, the analyzed country with the least penetration of BEVs.

1.1. OBJECTIVES

1.1.1. Main objective

Review and comparison of public policies for EV promotion in Europe at different vertical governance levels and quantitative analysis of economic incentives impact on the car taxation on national and local government revenue.

1.1.2. Specific objectives

i. Recognize the multi-level governance (especially vertical) influence in public policies of EV promotion in Europe, based on Policy Mix – **Chapter 2**;

ii. Identify the impact of international and supranational vertical level in the promotion of electric vehicles in Europe with an overview of the current situation. Then, categorize the European countries in three different clusters and choose three representative countries of each cluster, based on % Auto Industry in GDP; EV share and EV market share - **Chapter 3**;

iii. Identify the main economic and non-economic incentives used on EV boost for each representative country and compare the different policy instruments implemented in these three countries – **Chapter 4**;

iv. Quantify the impact of different BEV penetration levels (three possible scenarios) on government revenue in Spain, maintaining the current taxation regime in a 2050 simulation modeling and change the electricity tax rate in order to compensate government revenue loss in the future – **Chapter 5**.

1.2.METHODOLOGY

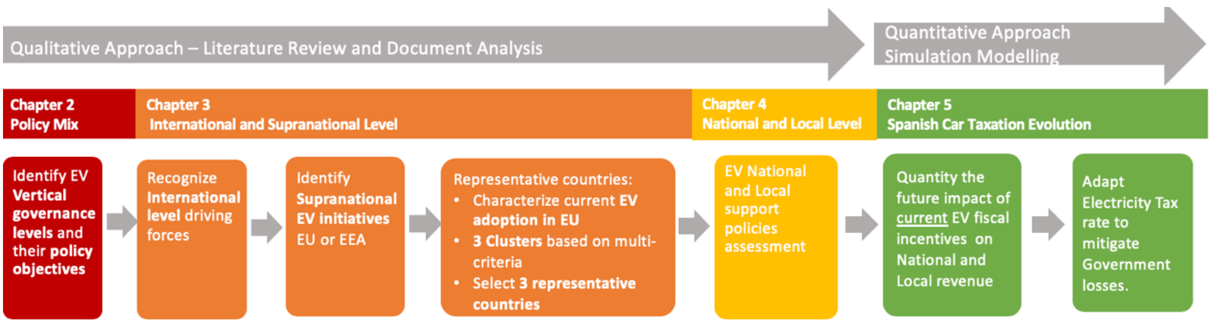
As previously emphasized, in the first part of the study, we opted for a research method with a qualitative approach - Chapters 2, 3, and 4 -, through a literature review and analysis of Policy Mix concept adapted for the electric car promotion in Europe. In the second part - Chapter 5 - we use a quantitative approach to understand the future impact of EV diffusion on government revenue, maintaining car taxation as we know it today.

Our research method is in line with Rogge and Reichardt (2016) statement that Policy mix concepts are defined and analyzed mostly in a qualitative approach, however, these insights should be taken into account in quantitative analysis with, for instance, a simulation modeling of policy instruments.

Since the Policy mix concept is more than the identification of the deal combination of policy instruments, Flanagan et al. (2011) recommend a qualitative analytical approach that recognizes the multi-actor and multilevel governance of the concept. This is aligned with our study, since we are proposing to study the public policies used in Europe in the promotion of electric cars, but taking into account the impact of the different international, supranational, national and local jurisdictions.

In other words, we will use the policy mix analytical approach focusing in the governance level dimension and their effect in elements - the policy objectives and policy instruments (instruments mix), since the policy mix difficulty results from more coordination and governance issues than from specific technical issues (Magro and Wilson, 2019). As a result, we will try to understand the influence of the international and supranational governance level in the national and local policy adopted in a selected number of representative countries, illustrated in **Figure 1-1**.

Figure 1-1 - Flowchart of Study Methodology



Source: Own elaboration

In order to be able to do what we proposed earlier, we had to carry out a literature review in Chapter 2. Thus, it was necessary to collect papers from: i) Policy Mix concept; ii) Governance Level and iii) Public policies to promote EV penetration.

Therefore, the main references selected for the definition of our theoretical approach - Policy Mix - are: (Flanagan et al., 2011); (Howlett and Rayner, 2007); (Howlett and Rayner, 2013); (Kivimaa and Virkamäki, 2014); (Kivimaa and Kern, 2016); (Rogge and Reichardt, 2016); (Kern et al., 2017).

In addition to the conventional references associated with the Policy Mix, it was necessary to focus on the impact of the governance level in the literature, with the main contributions found in two articles: (Magro and Wilson (2019); (Veeneman and Mulley, 2018).

Finally, we had to analyze the literature associated with public policies for the penetration of EVs, these being the main references: (Kempton et al., 2014); (Lieven, 2015); (Langbroek et al., 2016); (Contestabile et al., 2017); (Figenbaum, 2017); (Egnér and Trosvik, 2018); (Jang et al., 2018); (Kester et al., 2018); (Liu and Xiao, 2018); (Magueta et al., 2018); (Rietmann and Lieven, 2019b).

In Chapter 3, to recognize policy objectives of the international and supranational levels, we categorize the United Nations Sustainable Development, SuM4all (especially green mobility), Paris Agreement policy objectives to identify main targets and pressure performed at Supranational and National Level. Later, at Supranational Level (European Union for state-members and Economic European Area for non-state members), we systematize main EU initiatives - regulations, targets, and industrial policies - in a table, affecting diverse areas: vehicle, charging infrastructure, and energy.

In this chapter last section, for the selection of the countries to be studied in Chapter 4, we do an analysis of the European panorama of the adoption of electric cars based on the following categories:

- **Share of automobile Industry in the GDP** (high/medium/low);
- **Registered EVs share in the total stock of registered passenger cars** (high/medium/low);
- **EVs market share** (high/medium/low);
- **Pollution and traffic congestion levels** – associated with urban population share, main means of transportation; commute average distance and time;
- **Energy dependency and renewables share**;

- **Centralization or decentralization** – through taxes collection share by national, regional and local level;
- **Charging Infrastructure** – number of fast and normal chargers available per electric car

Next, we found that countries, where the automobile industry is relevant to national GDP (more than 10%), are the ones lagging behind in EV adoption and countries without the automobile industry are the leaders in electric mobility promotion. Therefore, based on the first three categories shown in **Table 1-1**, we are able to identify three different clusters of European countries and chose one representative country for each cluster identified: Norway, Portugal, and Spain. It should be noted that these representative countries were selected based on data availability.

Table 1-1 - Variables chose for each cluster of countries

Auto Industry share in GDP	EVs share/total cars	EVs market share	Country chosen
Low	High	High	Norway
Medium	Low	High	Portugal
High	Low	Low	Spain

Source: Own elaboration

For these representing countries, in Chapter 4, we identify policy objectives and relate their impact in economic and non-economic policy instruments adopted at the national and local levels. Here, the study identifies the main economic and non-incentive policy instruments adopted for each representing country in the promotion of electric cars, highlighting the car taxes during the car acquisition, ownership, use, and scrappage **(Table 1-2)**.

Table 1-2 - Economic policy instruments - car tax incentives

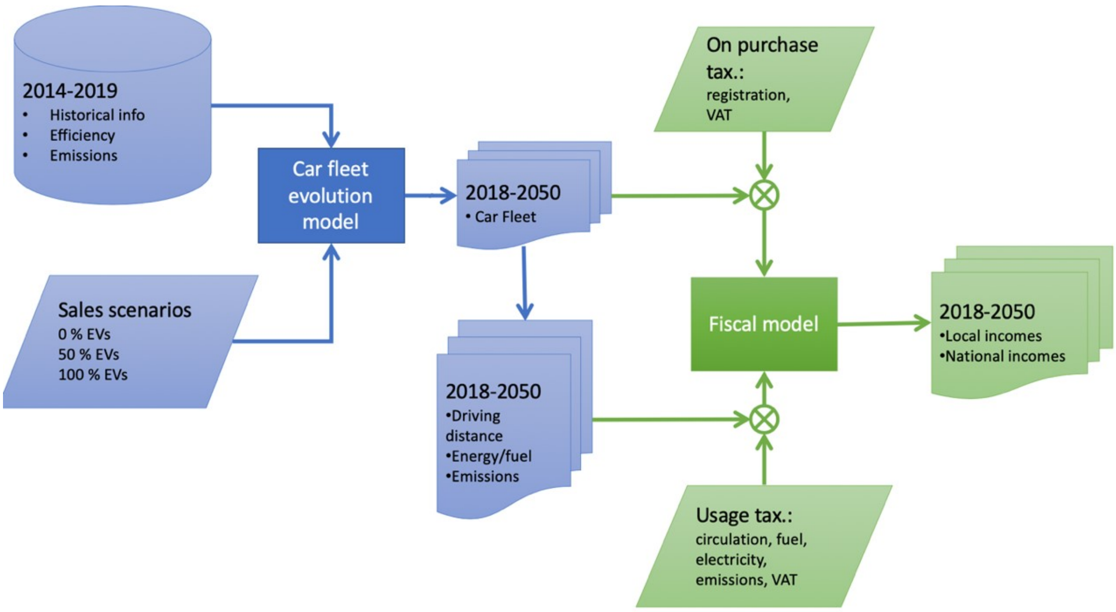
	Vehicle Acquisition					Use of Vehicle and circulation									
					VAT on taxes / charges				Fuel Excise duty and Electricity tax				Tolls and vignettes		
	Vehicle Purchase Tax	Registration Tax	Scrapping Tax	Subsidiy	Value-Added Tax (VAT)	Value-Added Tax (VAT)	Vehicle ownership	Vehicle circulation Tax	Petrol Fuel Tax - ICE Vehicles	Diesel Fuel Tax - ICE Vehicles	EU Emission Trading Schemes (ETS)	Electricity Tax - non-business use - BEVS + PHEVs	Distance-based road charges (tolls)	Distance-based road charges (vignettes)	Urban road pricing schemes
Description	One-off Tax on purchase tax of a new vehicle	One-off Tax on registration of a new vehicle	Scrap na old contaminating vehicle in exchange for getting a discount when purchasing a new one		Indirect Tax	Indirect Tax	Periodic tax on the ownership	Periodic tax on the ownership	Comsumption tax on transport fuel	Comsumption tax on transport fuel	CO2 emissions of electricity production	Comsumption tax on electricity charged for vehicles	Charge for the passage along the road network	Charge for access to road network for a specific period	Charge for using urban roads

Source: Own elaboration based on (ACEA, 2019, IRENA, 2019, EC, 2019e)

Afterward, in Chapter 5, we combine the results obtained previously with a quantitative approach, done by a 2030/2050 simulation modeling with three possible BEV market scenarios. Thus, we try to understand the future possible impact of the economic policy instruments (car tax incentives) given by the national and local governance level on government revenue, through a Spanish passenger car fleet simulation modeling provided by Casado (2020) maintaining the current car taxation **(Figure 1-2)**. Due to time restraints, we were required to choose only one of the three representative countries for this analysis – Spain - since is at the beginning of EV penetration.

In this chapter, we use the simulation model of the evolution of the Spanish Passenger car fleet of Casado (2020) for the three EV scenarios - 100%, 50%, and 0% sales BEV in 2040 - and combine them with the current fiscal model. Note that these scenarios were selected because Spain in 2019, considered that in 2040, should have 100% of their car sales with zero emissions (Spain; 2019), and since we are studying electric mobility, we focus on the effects of the market penetration of BEVs. This fiscal model was created by us and is developed in chapter 5.2. Therefore, we maintain 2019/2020 taxation fixed during our time horizon.

Figure 1-2 – Spanish Car Taxation Simulation Modeling Flowchart



Source: Own elaboration

It should be noted that we divided tax collection into two moments: on vehicle purchase and vehicle usage **(Table 1-3)**. The main variables selected in Casado (2020) simulation modelings were the annual new car registrations and car stock per powertrain system, in order to multiply them by the respective taxes. We assumed that the Spanish passenger car fleet is only composed of Volkswagen Golf Models – Petrol and Diesel ICEVs, BEVs, and PHEVS.

Table 1-3 - Different Car Taxation purchase and on its use

Vehicle Purchase	Vehicle Usage (per year)
Registration Tax	Circulation Tax
Value-Added Tax (VAT) (21%)	Fuel Tax + VAT on fuel
Individual Purchase Subsidy	Electricity Tax + VAT on Electricity

Source: Own elaboration

Regarding Car Taxation, registration and circulation tax are dependent on CO_2 emissions. On the other hand, the Fuel and Electricity Tax are based on average annual driving distance and fuel and energy consumption. It is valuable to note that annual driving distance is obtained by INE (2008) and is fixed and equal to all powertrains technologies. Even though, fuel and energy consumption is calculated based on the car manufacture website – Volkswagen.

Most importantly, we use Excel as our main tool to perform the calculations, to build the tables with regard to total car taxes, and finally to put the information in graphs to be able to present our main findings.

In this way, we will then begin our analysis in Chapter 2 by reviewing the Policy Mix literature, the importance of multi-level governance, and finally the adaptation of this theory for the electric mobility context.

CHAPTER 2 - EV PROMOTION THROUGH PUBLIC POLICIES WITH THE VISION OF POLICY MIX CONCEPT

Given current advances in technical performance and cost reductions for EVs, literature has shifted from focusing solely on the technological and economic dimension and has begun to explore the role of public policy and policy mechanisms (Kester et al., 2018). Nowadays, there are a wide variety of policies in place to contribute to EV market penetration in Europe, especially in the light-duty vehicle sector.

As mentioned before, sustainability transitions (as the electric car transition) are influenced by public policies and strategies of the actors involved (Lindberg et al., 2018). Transitions are affected by several policies at the same time and by the need to combine different policy instruments. Policies are coming in complex packages and comprehending the nature of their design is increasingly important, creating multi-policy, multi-objective and multi-instrument mixes (Howlett and del Rio, 2015, Ajanovic, 2014).

In contrast, Policy Mix concept has benefited from little attention by the transportation literature (Bhardwaj et al., 2020). Nevertheless, Policy mix literature seems pertinent to address this multi-governance level challenge in public policies in the promotion of electric cars in Europe, since the majority of transport studies are focused only on one policy instrument type and in one country.

Consequently, in this second chapter, the role of public policy to encourage electric mobility in Europe is discussed in an attempt to dialogue with the policy mix literature, focusing on the vertical governance level dimension (international, supranational, national, and local) and recognizing the role of horizontal level (different departments and ministries). Please note that policy mix concept review is made, mostly by non-transport literature through policy studies, environment, energy, economic, and innovations studies.

With this in mind, this chapter is divided into two sections. The first section is associated with the definition of the Policy Mix concept still under construction, the importance of multilevel governance, that is often overlooked in the literature, and the focus on the vertical level, that is, the influence of International and Supranational level at the national and local level. Finally, in the second section, the combination of this theory with the promotion of electromobility in Europe is carried out. In summary, the view of the policy mix concept will guide our research in the next chapters, regarding public policies adopted in Europe in the promotion of electric cars.

2.1. INTRODUCTION TO POLICY MIX CONCEPT

To capture the variety and potential interactions between different policies, as well as their ongoing changes, Rogge and Reichardt (2016) and Flanagan et al. (2011) suggest the study of the policy mix.

In the past, public policy literature was focused in the analysis of individual instruments, then become fixated on comparative studies of instrument selection and later emphasized the choice of policy instruments and its complex decision-making and implementation background.

Policy Mix has been studied in various scientific fields, but especially in the environment and energy (Kern and Howlett, 2009, Kern et al., 2017, Rogge et al., 2017, Lindberg et al., 2018), economic, innovations studies (Rogge and Reichardt, 2016, Flanagan et al., 2011, Kivimaa and Kern, 2016, Rogge and Schleich, 2018) and in policy analysis (Howlett and Rayner, 2007, Howlett and Rayner, 2013, Howlett et al., 2017, Howlett and del Rio, 2015). Unquestionably, it is widely used in the climate and energy field in an attempt to the transition of a decarbonized energy system.

It is important to highlight that Policy Mix was a concept imported from economic policy debates and appeared in the economic policy literature in the 1960s. (Flanagan et al., 2011). This concept was commonly defined as a combination of numerous policy instruments (Howlett and Rayner, 2007). Besides, Howlett and Rayner (2013) stress that policy design is the way in which policy instruments are combined in an attempt to obtain policy objectives. Thus, the definitions of policy instruments and policy objectives are highlighted in **Table 2-1**.

In this case, public policies are treated as a toolbox from where the best tools are or should be chosen (Flanagan et al., 2011). However, policy instruments can have different meanings over time, place, and actors in terms of rationales, goals, or means. Instruments are not neutral and they have a different history, social and technical values. Thus, policy instruments are flexible and evolve.

Table 2-1 – Policy Instruments and Policy objectives definition

Policy Instruments	**Policy objectives**
Are tools or techniques of governance to achieve main policy objectives. These instruments are adopted by a governing body and can be called as measures, programs, or policies in the studies. Each instrument is associated with a specific goal. These goals are the desired effect of the instruments to accomplish the main policy objectives.	Long-term environmental, social, and economic targets with ambitions levels based on visions of the future.
Howlett and Rayner (2007) and Rogge and Reichardt (2016).	Rogge and Reichardt (2016)

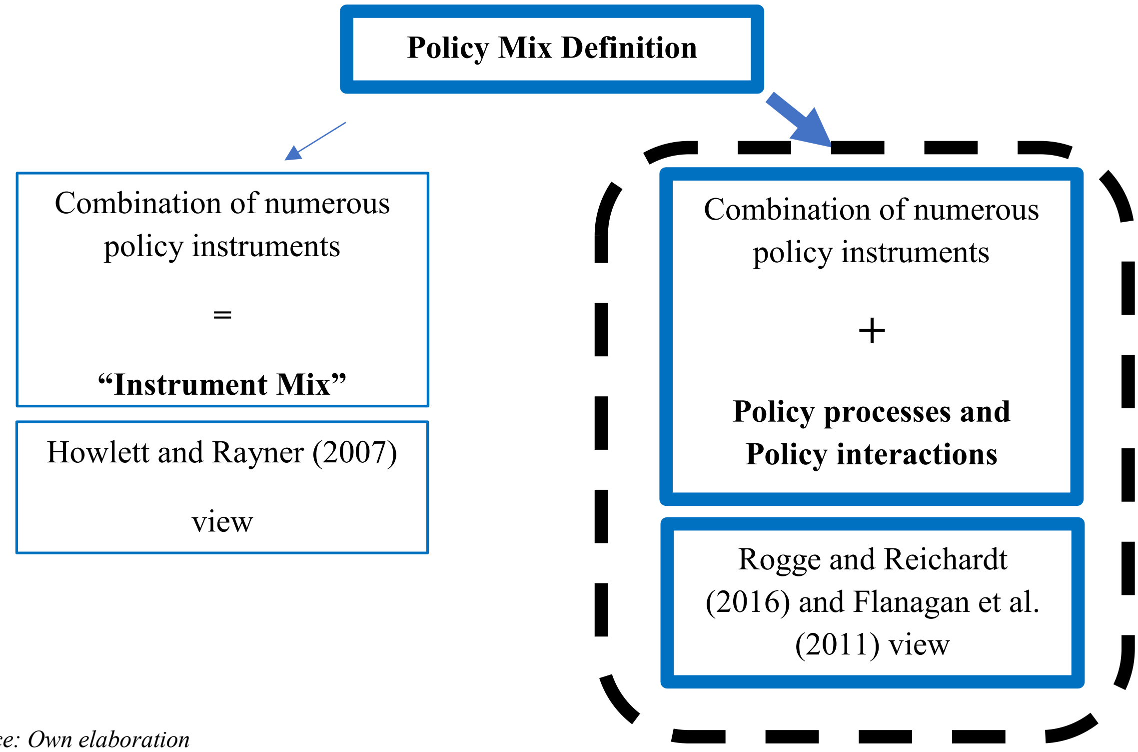
Source: Own elaboration based on Howlett and Rayner (2007) and Rogge and Reichardt (2016).

On the other hand, Rogge and Reichardt (2016) and Flanagan et al. (2011) defend that policy mixes are more than just a combination of policy instruments since this concept also includes the dynamic processes of creation and interaction of such instruments. Flanagan et al. (2011) state that this concept is an opportunity to consider some hidden assumptions to deal with a disordered, complex, multi-level, and multi-actor public policy experience since interactions and interdependencies between policies affect how the policy objectives are understood.

Consequently, as emphasized before for studies focused only on the policy instruments interaction, we use the term “instrument mix” and not policy mix, as shown in **Figure 2-1**.

Indeed, studies in the past were concerned about the identification of the ideal combination of instruments. However, taking into account the latest body of research, the Policy Mix concept should reflect the complexity of real-world policy, going beyond interaction and combination of policy instruments and consider the long-term horizon (Rogge and Reichardt, 2016). Consequently, in our study, when we are referring to the policy mix, we are using Flanagan et al. (2011) and Rogge and Reichardt (2016)’s definition.

Figure 2-1 - Different Policy Mix Definitions



Source: Own elaboration

As mentioned by Bhardwaj et al. (2020), the Policy Mix concept is currently under construction and used by several areas of study, therefore its terminology is still ambiguous. In brief, Policy Mixes do not employ consistent terminology (Howlett and del Rio, 2015).

To comprehend the Policy Mix concept, Rogge and Reichardt (2016) suggest the division in three "building blocks": a) elements; b) policy processes; c) characteristics, which can be specified with the different dimensions.

In this way, we will use the division of the concept of Policy Mix of these authors in blocks to facilitate the exposition of the understanding of this theory. First, we will address the block of elements, then the policy process, and finally the characteristics. Finally, a definition of the dimension is carried out to understand that public policies are also influenced by the space where they are implemented.

Therefore, the first "building block" - elements - is composed of Policy Strategy and Instrument Mix, as illustrated in **Table 2-2**.

Table 2-2 - Components of the first "building block" – Elements

a) Elements	
Policy Strategy	**Instrument Mix**
Offers direction to actions and decisions with policy objectives and principal plans (framework conventions, guidelines, strategic action plans, and roadmaps).	Is the combination of policy instruments. Instruments are multiple, so we can classify them according to: - type (economic instruments; non-economic instruments; and regulation); - purpose (technology push or demand-pull); - importance (core and complementary).

Source: Own elaboration based on Rogge and Reichardt (2016)

As we have seen, instruments do not come isolated from each other and they are combined to fit into a mix (Howlett and del Rio, 2015). Policy instrument interactions represent a key component of the policy mix concept since policy instruments are influenced by the co-existence of the previous ones (Kern and Howlett, 2009).

Indeed, instruments are combined in a complex way and their interaction may lead to potential conflicts or synergies (Río, 2009, Howlett and del Rio, 2015). Valuable to note that coordination between policy instruments and objectives varies. Thus, interactions and trade-offs of these tools are fundamental and emerged previously from the macroeconomic policy debates (Flanagan et al., 2011).

Policy instruments interdependencies depend on the instrument mix and policy objectives combination effect, as well as the path previously followed. Policy instruments combination is normally found in attempts to address multiple policy objectives (Howlett and del Rio, 2015).

Therefore, policy instruments are an intervention at a certain moment, but sometimes their output is seen much later. Thus, Flanagan et al. (2011) defend that is unrealistic to expect an identification of "good" mixes since policy objectives are often in conflict or tension and the challenges arise when the instruments belong to different territorial governance levels (Howlett and del Rio, 2015).

The second "building block" - Policy Process – is formed by Policy Making and Policy Implementation **(Table 2-3)**, which is particularly pertinent to instrument mix, because the complexity and insufficiency of the implementation can result in political resistance at other vertical and horizontal governance levels, jeopardizing its complete potential.

Table 2-3 - Components of second "building block" – Policy Process

b) Policy Process	
Policy making	**Policy implementation**
It includes all stages of the policy cycle: identification of the problem; agenda-setting; policy formulation, legitimization, and adoption; implementation; evaluation; policy adaptation, succession, and termination.	is the measures adopted by authorities and actors to put the policy instruments in action.

Source: Own elaboration based on Rogge and Reichardt (2016)

Policy processes are a result of socio-economic, cultural, infrastructure, and institutional conditions, as well as result in policy learning. It should be noted that policy processes sometimes take a long time to play out. Therefore, policy processes are different across space, time, and highly resistant to change, particularly from actors with assigned interests. This can explain why new supporting instruments are added to the existent regime, instead of replacing it. This creates incoherent policy objectives and uncoordinated instruments (Howlett and Rayner, 2007).

As we have seen, public policies are an output of policy instruments accumulated over time, adding complexity and cost to implementation, as well as a counter-productive (no coherent and consistent) and path-dependent instrument mixes. Without a doubt, previous policy choices can constrain the deployment of a new policy, since the old ones are institutionalized, creating a sub-optimal policy mixes or a failed restructuring, resulting in modest outcomes.

Indeed, policy mixes have been implemented incrementally over the years and can emerge typically through four processes identified by Kern and Howlett (2009) and exemplified in **Table 2-4**.

Table 2-4 - Four processes of policy mixes implementation

LAYERING	**DRIFT**	**CONVERSION**	**REPLACEMENT**
New goals and policy instruments were added to the previous ones, creating incoherence between goals, and inconsistency among instruments.	New goals replace the previous ones, but the policy instruments are the same, generating new goals inconsistent instruments and probably infective outputs.	Adjusting new policy instruments with previous goals, this should create problems between means and ends of the policy.	Policies re-creation and restructuration, through new goals and new policy instruments, accompanied by replacement of the old ones, trying to achieve consistency, coherence, and congruence.

Source: Own elaboration based on Kern and Howlett (2009)

According to Kern and Howlett (2009), the appearance of potentially incoherent, inconsistent, or incongruent policy mixes is more likely to create contradictory effects and surprising outcomes. However, their results seem to indicate that even “poor” policy mixes not lead to so poorer outcomes, so are emerging opportunities for handling sustainability transitions without the replacement of existing policy regimes.

For this reason, Rogge and Reichardt (2016) created the third “building block” - characteristics –to demonstrate that elements and policy processes or even the policy mix itself can be consistent, coherent, credible, and comprehensive **(Table 2-5)**. However, these characteristics do not take into account the congruence highlight by Howlett and Rayner (2013), which is the capability of policy goals and policy instruments to work together in a unidirectional or reciprocally supportive way.

Table 2-5 - Components of the third "building block" – Characteristics

c) **Characteristics**			
Elements Consistency	**Processes Coherence**	**Policy mix Credibility**	**Policy mix Comprehensiveness**
Understand if elements are aligned with each other to meet policy objectives. In other words, is the capacity of elements to reinforce in each other in the chase of their policy objectives. The consistency can be evaluated in terms of policy dimensions: - policy strategy, - consistency of instrument mix; - consistency of the instrument mix with the policy strategy;	The ability of various policy goals to co-exist with each other, across different policy fields and governance levels. Policy goals should be logically related to overall policy objectives and without noteworthy trade-offs (Kern and Howlett, 2009). This requires advanced organizational capacities, challenged by multiple actors that can be addressed through policy integration and coordination.	The Policy mix is believable and reliable across elements and processes.	Extension and exhaustion of the elements and processes.

Source: Own elaboration based on Rogge and Reichardt (2016) and Howlett and Rayner (2013)

That is why Howlett and Rayner (2013) and Kern et al. (2017) built two different concepts: policy patching and policy packaging, defining two different methods for reaching the same policy objective **(Table 2-6)**.

As we have seen, the second method seems to be a more realistic way of policy design, since the result of policy mixes are an outcome of diverse policies, which change over time with the sum or subtraction of different elements. In sum, policy objectives are not static, coherent, or hierarchical, since they change over time and sometimes are in conflict (Kern et al., 2017). Thus, as previously emphasized by Flanagan et al. (2011), there are no unambiguously “good” mixes.

Table 2-6 -Policy patching and policy packaging definition

Policy packaging	Policy patching
Idealized approach to reach an optimal combination of policies across different policy domains. Policy Mixes are built from “scratch”, I mean, previous policies are discarded. Most of the time, cannot be seen as a realistic option in real-world policy making.	Recognizes real-world policy making reality and accepts a reasonable or suitable policy mix, namely a sufficient complementary and coherent mix. It is more adaptative to current circumstances and less ideologically-rigid.
Allows only the replacement process.	Compatible with layering, drift, and conversion processes, resulting in inconsistent and incoherent policy mixes.

Source: Own elaboration based on Howlett and Rayner (2013), Kern et al. (2017) and Bhardwaj et al. (2020)

However, as argued by Bhardwaj et al. (2020), policy patching process allows policy interaction and collectively they can achieve the overall policy objectives. What happens, in reality, is the amendment of existing policies by adding new instruments instead of creating a new policy mix.

Therefore, the policy implementation can be influenced by the policies previously adopted and by political acceptability of diverse policies through interest groups (for example key stakeholders) and society. It is important to highlight that political acceptability can offer a rationale for policy mixes when the ideal policy is not politically acceptable. Thus, this concept is compatible with the policy patching process (Bhardwaj et al., 2020).

On the other hand, policymakers are not completely free in their decisions and sometimes policy mixes are path-dependent (Kern et al., 2017). After all, the policy mix implementation results frequently in imperfect outcomes from a complex system with multiple actors and governance levels.

In addition, from the standpoint of processes coherence between different policy fields and governance levels, these two complete characteristics might be unmanageable together, since systems are complex and deal with path-dependence, lock-in, the resistance of regime actors, conflicting interests and tension and fragmentation of policy making. Thus, the intention is to maximize the coherence within the instruments available, representing a mean and not a goal of the policy mix performance (Rogge and Reichardt, 2016).

Lastly, the policy mix can be delineated by several dimensions **(Table 2-7)** which show the space where the interactions can happen, pointing the origin of the policy mix components.

Table 2-7 - Dimensions where the policy mix components interactions may occur.

Dimensions			
Policy field	**Governance level**	**Geography**	**Time**
Emphasizes policy domain: energy, environmental, climate, innovation, technology, science, industrial and transition policy.	Vertical (international, supranational, national and local) and Horizontal jurisdictions (different departments and ministries).	is the abstract space of governance level.	Should capture policy mix dynamic nature and how it develops over time.

Source: Own elaboration based on Rogge and Reichardt (2016)

As we have seen in the Governance level dimension in **Table 2-7**, the Policy Mix concept is compatible with the definition of the modern state, where there is a dispersion of power, both upwards and downwards, from the national level to the supranational and local level. Until then, the idea of the State was associated with traditional neoclassical economic theories of welfare and the unitary policy maker (Flanagan et al., 2011).

Therefore, governments operate on various scales of jurisdiction and in different areas. This division is conceptualized as multi-level governance since it was created to support the comprehension of supranational (EU) and federal (the United States - US) governments challenges. Thus, Policy Mix represents the replacement of traditional state-centric models of government by the notion of multi-level, multi-actor, and governance.

After analyzing the three “building blocks” – Policy Process, Elements and Characteristics - and dimensions – Policy Field, Governance Level, Geography and Time - that made up the

Policy Mix, the **Figure 2-2** allows systematization of this complex concept and understand the various forces that are influencing the implementation of public policies in packages.

In our study, we will use only the “building block” – Elements - namely policy strategy and instrument mix; and the governance level dimension (vertical), highlighted by a red line in **Figure 2-2**.

These Policy Mix components were chosen to the understand impact of different policy instruments implemented by each vertical governance level, since the different scales have diverse perspectives and policy objectives, resulting in conflicts and coordination problems.

In the next section, the multi-governance coordination issue will be explored in much great detail, focusing on the vertical dimension and combined it with the EV diffusion problematic.

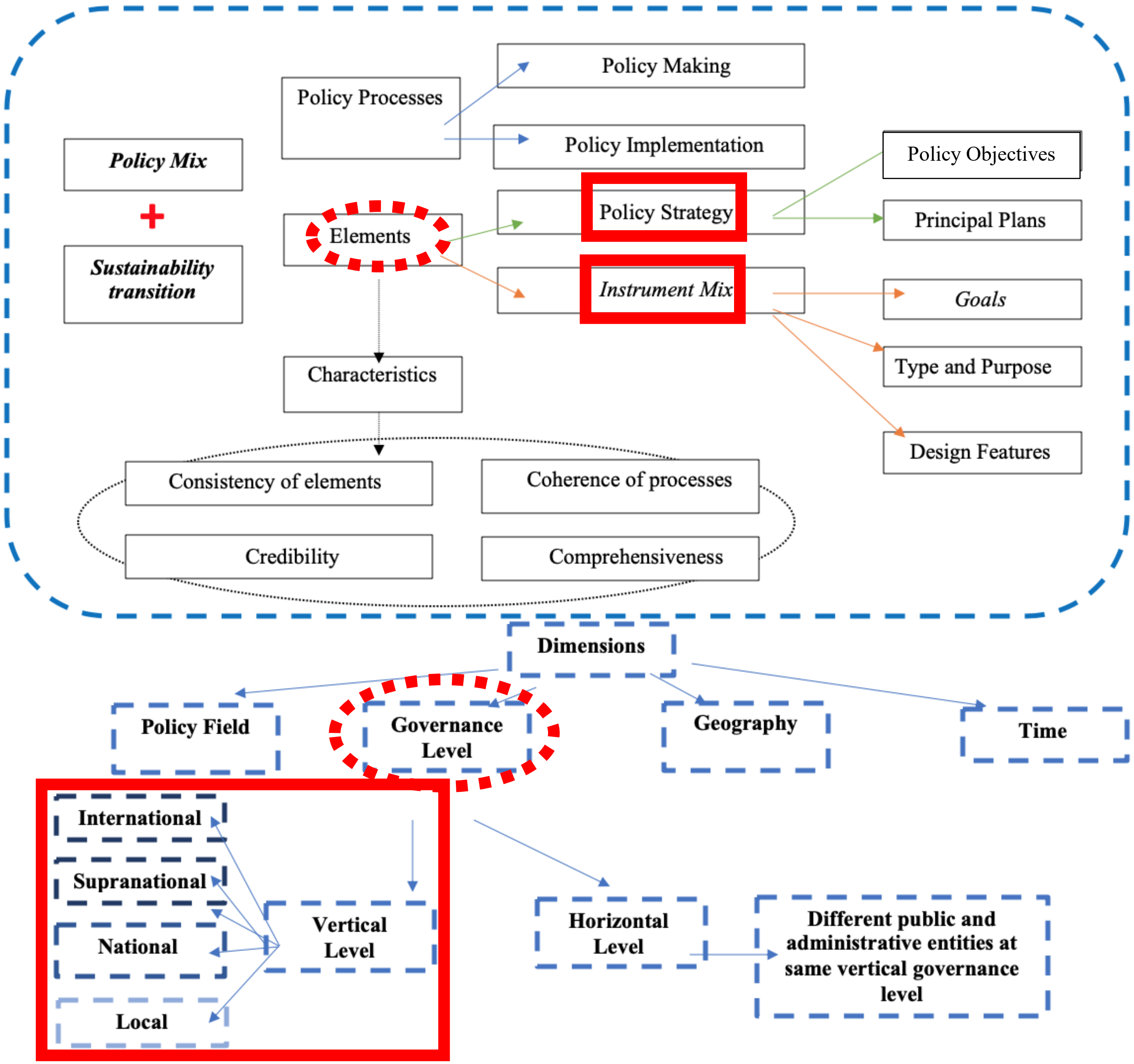


Figure 2-2 - Different Policy Mix components

Source: adapted from Rogge and Reichardt (2016)

2.1.1. Multi-level governance challenges

2.1.1.1. Dimension: Vertical and Horizontal Governance Level

As we have seen previously, it is important to comprehend why the results of the electric mobility can diverge so significantly between jurisdictions, since difficulties arise more from the coordination and governance issues than from specific technical issues (Magro and Wilson, 2019).

Veeneman and Mulley (2018) emphasize the importance of multi-level governance in the transport field, since the means of transport can have different values on different scales and be valued contrarily by governments of different governance jurisdictions.

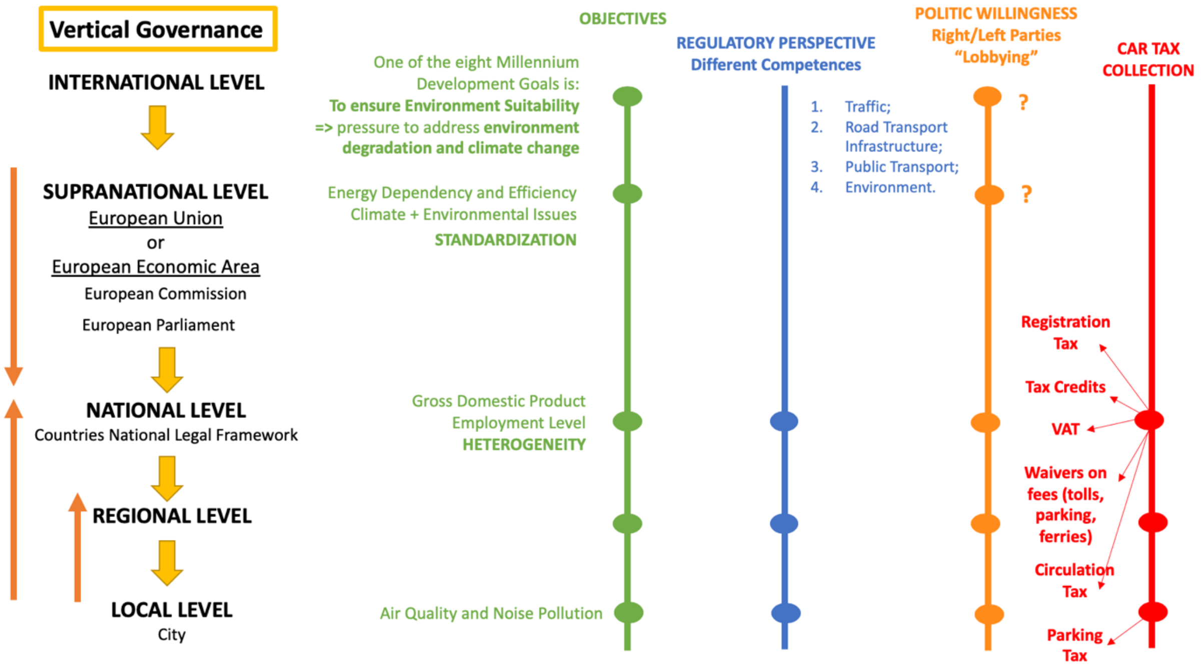
The Policy Mix concept is commonly treated as uncomplicated and problems arise when studies consider only a single level of governance and their coordination is seemed as unproblematic, since policy complexity is increasing. Indeed, studies tend to focus on a single unitary state actor or a limited set of actors, while they are operating at multilevel of governance and omit how instruments are selected and implemented (Flanagan et al., 2011).

However, Veeneman and Mulley (2018) highlight the coordination is impossible, regarding the multi-level, multi-actor and dispersed context mentioned above. So, coordination can mean a mutual adjustment between actors and systems. As far as we know, governance level problem is systemically depreciated in literature.

Indeed, policy coordination failure can justify the existence of policy mixes through the lack of multilevel coordination across systemic levels (Rogge and Reichardt, 2016). Howlett et al. (2017) state that to obtain better policy integration, policy makers should adopt policy instruments capable of overcoming or avoiding conflicts and contradiction in a policy mix.

Consequently, in order to present the different solutions found by policy makers in promoting electric cars promotion in Europe, we will take into account the governance levels of Policy Mix concept, which divides public policies into four levels of vertical governance: i) international (United Nations, Paris Agreement, SuM4all); supranational (European Union – state-members or European Economic Area - for non-state members); national (country); and lastly, local policies (city or region) **(Figure 2-3).**

Figure 2-3 - Vertical Governance Level



Source: Own elaboration

The vertical governance dimension has a multilevel government and governance contexts. As can be seen in **Figure 2-3**, the different vertical governance levels have multiple policy objectives, which can have something in common, as well as different policy objectives and preferences (Howlett and del Rio, 2015). For example, the international level is concerned with the environment degradation and climate change and has tried to promote sustainable mobility. In turn, the European Union's supranational level is under pressure from the international level, but it is also concerned with EU's external dependency on imported fossil fuels and efficiency, as well as providing secure and affordable energy to consumers (Río, 2009). In this way, the EU creates standard initiatives for Member States to comply with, which sometimes also include the European Economic Area members.

Then, the national level tries to transpose European measures into its national legislation. However, the answers are varied according to their culture, political ideology, industry and other factors. In fact, this level is more concerned with GDP and the level of employment. Thus, a great disparity in national public policies is created and, therefore, different levels of EV market penetration. Though, there are also countries that are pressing the European Union to take action. Take the case of Norway that intends to have Zero-emissions Vehicle (ZEV) sales in 2025, while the EU intends to be carbon neutral only in 2050. It is also at this level that there is a majority of car tax collection, at least for centralized government countries, that are the majority in Europe, as we will see later.

Finally, the local and regional level are mainly concerned with the air quality and noise level, land use, road safety and traffic congestion in the major urban areas, or more simply increase urban livability. This level may reinforce the national policy, or perhaps even contradict it. This level can adopt measures that increase the value of using EVs, accelerating their market promotion, without major consequences for their government revenue level. However, the same does not apply to the national level.

In sum, the existence of international, supranational, national and local policies may lead to conflicts, which can jeopardize the objectives of each vertical governance level. In addition, the efforts of coordination to moderate these conflicts is particularly challenging and may have limited effectiveness, since the instruments are implemented in different territorial scopes and have multiple objectives (Río, 2009). Indeed, reconciling the different policy objectives of each vertical level imply intra or intergovernmental barging and decision making (Howlett and del Rio, 2015).

This analysis of the vertical governance dimension in EV market penetration also creates a question: What is the most important level of vertical governance for the promotion of electric mobility? As can be seen below, the literature provides different answers and approaches to this question.

Accordingly to Lindberg et al. (2018), potential impact of public policies in the European Union and the European Economic Area is strongly dependent on how supranational legislation is converted to domestic legislation.

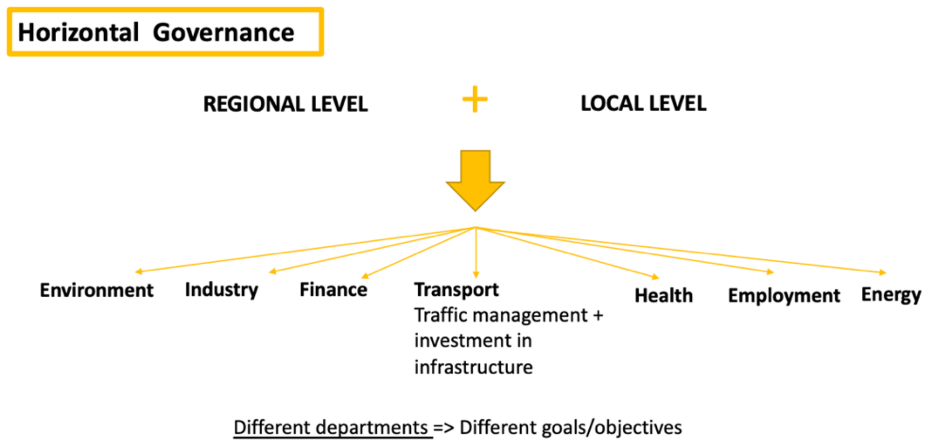
Regarding public policy action at the national level, these are validated technical standards that define the efficient level of public investment, charging infrastructure and direct and indirect actions to promote electric vehicles demand. Indeed, national policies appear to be a key level of intervention in promoting electric mobility and these can be reinforced by local policies at regional or city level with mostly non-economic incentives (Lepoutre et al., 2019).

On the other hand, Veeneman and Mulley (2018) and Magro and Wilson (2019) disagree, they argued that national level of government is not necessarily the central policy making unit, since National and Supranational government levels have a more macro vision of the world than the local authority. In addition, these authors also demonstrate that policy formulation and implementation is more like a continuous negotiation system among different vertical governance levels.

Then, throughout our study, we will realize the role of each of these international, supranational, national and local levels. However, we do not develop the local level in great detail, we only refer it in some situations.

Despite these complex vertical governance levels, the electric mobility is also influenced by horizontal governance levels, that is the interaction between diverse policy instruments and objectives, policies implemented by each Ministries of Environment, Industry, Finance, Transport, Health, Energy and Employment, *etc* – at National level – or departments – at local level – within the same vertical governance level **(Figure 2-4)**. Horizontal governance level has also potential to add more dissimilar interests among the same vertical governance level. However, this approach will not be developed in our study.

Figure 2-4 - Horizontal Governance Level



Source: Own elaboration

On the other hand, Howlett et al. (2017) defend that policy mixes with complex policy making have more risk of failure when horizontal and vertical dimensions are not integrated. That is because certain actors may promote some actions without taking into account their impact on other elements of a policy mix. This is particularly relevant for vertical governance, since integration is even more complex.

Additionally, conflict concerning policy objectives and instruments are probable more common when multiple jurisdictions are involved. For instance, in promoting electric mobility, the local level may take some measures that are counterproductive when are seen by national measures.

In addition, Howlett et al. (2017) argue the importance of resistance to change, that is, when previous policies and programs have benefited a particular sector can be very costly to shift to other arrangements. This is also the case for electric mobility, since the auto industry has always been encouraged by policy instruments and now sees itself forced to switch to an electric powertrain over which they do not technically dominate, losing many of its Research and Development (R&D) done so far and their economies of scale associated with the ICEV.

Given this context, Policy mix literature seems pertinent to address this multi-governance levels challenge in public policies in promotion of electric cars in Europe. Indeed, various governance levels take part of the policy mix concept, since they refer to the dimension where the interactions can occur.

However, the dimension of governance level in policy mix literature is often neglected, but when the governance level dimension appears is more like a distinction made, normally, in studies on policy coherence and consistency (Magro and Wilson, 2019). However, as stated by Flanagan et al. (2011), each governance level can have different actors with different roles at different times and it can create new actors - organizations or networks.

2.2. POLICY MIX AND EV MARKET PENETRATION PROMOTION

Transportation research has not actively used this concept, quite the opposite, it has almost ignored it except Givoni et al. (2013), Kivimaa and Virkamäki (2014), Veeneman and Mulley (2018) and recently Bhardwaj et al. (2020). In addition, only Bhardwaj et al. (2020) were concentrated solely on electric passenger car fleet and policy mix concept. The other ones applied the Policy mix concept to public transport or transport in general.

To understand how the EV promotion literature addresses public support policies, we created **Table 2-8**. This table highlights in the first category of analysis how many countries are analyzed in the study - one, two, three or more countries. The second category of analysis emphasizes whether the countries analyzed are located in Europe and refer to the influence of the guidelines defined by this level of governance. In the third category, the number of policy instruments analyzed is underlined. Finally, the last category of analysis refers to the type of policy instruments analyzed, that is, whether they are related to the moment of purchase, the use of the vehicle or the development of the charging infrastructure.

As we can see in **Table 2-8**, public policies in order to promote more sustainable mobility were analyzed with a policy instrument type in isolation (Holtsmark and Skonhoft, 2014, Sánchez-Braza et al., 2014, Hardman et al., 2017, Harrison and Thiel, 2017a, Harrison and Thiel, 2017b, Martínez-Lao et al., 2017) or just for one country (Brand et al., 2013, Holtsmark and Skonhoft, 2014, Sánchez-Braza et al., 2014, Bjerkan et al., 2016, Figenbaum, 2017, Haugneland et al., 2017, Martínez-Lao et al., 2017, Cansino and Yñiguez, 2018, Magueta et al., 2018).

It is noteworthy that many of these articles are concentrated in Norway, as it is identified as a successful country in EV market penetration. In addition, most studies look at multiple policy instruments, but without much detail. These studies do a comparative analysis between different countries, usually more than four countries (Ajanovic, 2014, Sierzchula et al., 2014, Lieven, 2015, Lévay et al., 2017, Kester et al., 2018, Münzel et al., 2019, Rietmann and Lieven, 2019b, Santos and Davies, 2019, Wang et al., 2019). However, some studies compare two countries (Contestabile et al., 2017, Deuten et al., 2020) and here, the detail of the analysis is higher.

Table 2-8 - EV support policies literature analysis

Papers	Authors' Name	Brand et al. (2013)	Holtsmark and Skonhoft (2014)	Kempton et al. (2014)	Ajanovic (2014)	Sánchez-Braza et al. (2014)	Sierzchula et al. (2014)	Lieven (2015)	Bjerkan et al. (2016)	Coffman et al. (2016)	Contestabile et al. (2017)	Figenbaum (2017)	Hardman et al. (2017)	Harrison and Thiel (2017a)	Harrison and Thiel (2017b)	Haugneland et al. (2017)	Lévay et al. (2017)	Martínez-Lao et al. (2017)	Cansino and Yñiguez (2018)	Kester et al. (2018)	Magueta et al. (2018)	Münzel et al. (2019)	Rietmann and Lieven (2019)	Santos and Davies (2019)	Wang et al. (2019)	Deuten et al. (2020)
National Governance Level	One Country	✓	✓	No		✓			✓	No		✓	No			✓		✓	✓		✓					
	Two countries										✓				✓											✓
	Three Countries																									
	> more than four countries				✓		✓	✓						✓			✓			✓		✓	✓	✓	✓	
Supranational Level	Europe	✓	✓		✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Recognizes EU pressure				✓						✓			✓	✓			✓	✓	✓	✓		✓			✓
Quantity of Policy Instruments analyzed	One single policy instrument		✓			✓								✓												
	Two policy instruments																									
	Multiple Policy Instruments	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Policy Instruments Types	Policy Instruments used on EV support purchase (registration tax, purchase subsidy, scrappage schemes)	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
	Policy Instruments used on EV use (fuel tax, electricity tax, circulation tax)	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓				✓	✓	✓	✓	✓	✓
	Policy Instruments used to support EV charging infrastructure deployment			✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Source: Own elaboration

On the other hand, there are studies that although they are concentrated in several countries, they carry out a more detailed analysis. For example, Kester et al. (2018) analysis EV incentives comparing several policy instruments for the Nordic region.

Rietmann and Lieven (2019b) made the same kind of study, but for Norway, the Netherlands, Germany and Brazil. Additionally, Santos and Davies (2019) created a paper investigating the role of EV incentives in five European countries: Germany, Austria, Spain and United Kingdom.

Some other articles analyze the existing policy instruments for promoting electric mobility, without focusing on any particular country (Kempton et al., 2014, Coffman et al., 2016, Hardman et al., 2017). They are more theoretical papers that further develop the complexity of each policy instrument without a specific country example or case study.

Many of these studies do not pay particular attention to the role of international pressure or the European Union itself, although some of them mention at least the influence of the Supranational authority. With some exceptions, as Harrison and Thiel (2017b) focused on an analysis successful EV policies implemented by EU countries, referring the influence of EU directives in the national frameworks. Although most articles are concentrated in at least some countries in Europe.

The analysis of public policies to support EV market penetration is concentrated at the national level, although there are also studies focused on the local level. However, the international and supranational level have the least studies.

Although it is rare, some articles only focus on one single policy instrument (Holtsmark and Skonhoft, 2014, Sánchez-Braza et al., 2014). Most studies try to mention the incentives when purchasing the vehicle, throughout its use and also in the development of the charging infrastructure. However, most papers focus on the initial incentives associated with the vehicle purchase.

In brief, as we have highlighted in Table 2-8, the EV support policy literature has largely concentrated on the analysis of multiple policy instruments in pairwise instruments combination with short-term time horizon and with one or more than four countries.

Therefore, we defend as Kern et al. (2017), a further complementary analysis to capture the complexity in real world policy mixes is needed. While singe type instruments studies are valuable, their combination allows the comprehension of the wider context, as well as the way the policies are designed and implemented.

Even though, one of the gaps in the literature associated with promoting the penetration of EVs is not mentioning the rationales and motivations for the policy design (Bhardwaj et al., 2020). That is, most studies do not previously identify the purpose of the policy instruments adopted, namely policy objectives.

Additionally, as emphasized by Howlett and del Rio (2015) and Howlett et al. (2017), most studies are focused on single governance levels, more simply, they are concentrated on relation existing between policy instruments, objectives and policies within a single governance level and sector. As mentioned above, most studies are concentrated at the national level and sometimes at local level.

It is value to note that vertical dimension is often ignored in most of policy instruments choice and policy design literature and the same is happening in EV support policies research, since there are not many studies that recognize the influence of the international and supranational level, although they often refer to the role of the local level.

We try to fill this gap in our study, since the vertical dimension is related not only by the number of policy instruments, objectives and policies in a mix, but also the number of policy sectors involved and different jurisdictions active in policy formulation. Consequently, we aim to analysis policies to promote EV market penetration in Europe, based on this perspective. That is, we take into account in our study the different levels of vertical governance - international, supranational, national and local - their different policy objectives and then their instruments implemented for each level of vertical governance.

Although there is a greater emphasis on the automobile sector in our research, we also refer to the importance of synergies with the power sector, since the transition to the low carbon economy can only be achieved with the combination of disruptive changes in both sectors. However, we cannot perform the most detailed analysis for both sectors.

This vertical governance dimension requires efforts to reach administrative coordination and policy integration compatible with context, which a horizontal dimension analysis does not (Howlett and del Rio, 2015). Without a doubt, the vertical governance dimension have to take into account the preferences for different policy instruments, which favored some particularly sectors and governments.

This is also the case for electric mobility, since the automobile industry has always been encouraged by policy instruments and now sees itself forced to switch to an electric powertrain over which they do not technically dominate, losing many of its R&D done so far and their economies of scale associated with the ICEV.

Please note that literature is also focused on equity and distributive impacts of transport policies, since equity can challenge the policies addressed to vehicle ownership, transport accessibility and proximity to transport infrastructure. We will not discuss this in detail in our study.

To conclude, our analysis takes a boarder view, since we consider policy objectives and their policy instruments for each vertical governance level and not only the common national level, the existence of coordination and pressure between these “layers”. In brief, this study aims to contribute to the literature on policy mix in the transport sector and the importance multilevel governance on EV market promotion in Europe.

2.3. CHAPTER CONCLUSIONS

Transport policies are coming in complex packages and comprehending the nature of their design is increasingly important, creating multi-policy, multi-objective and multi-instrument mixes. Thus, Policy mix literature seems pertinent to address this great challenge.

The Policy mix is a concept under-conceptualized and with inconsistent terminology since its analysis has been made through studies from different scientific fields such as policy studies, environment, energy, economic, and innovation. While traditionally Policy mix is defined as a combination of numerous policy instruments, in our study we adopted the concept of Flanagan et al. (2011) and Rogge and Reichardt (2016), which defend that policy mixes are more than just a combination of policy instruments, since this concept also includes the dynamic processes of creation and interaction of such instruments.

Although the policy mix concept has multiple components, we will focus on the elements - policy strategy and instrument mix - and vertical governance dimension. First, Policy strategy is the direction given to actions and decisions by policy objectives and plans. Please note that policy objectives consist of long-term environmental, social, and economic targets.

Then, the instrument mix is the combination of policy instruments, which are tools or techniques of governance adopted by a governing body and can be called measures, programs, or policies in the studies.

Finally, the vertical governance dimension is compatible with the definition of the modern state, where there is a dispersion of power, both upwards and downwards, since governments operate on various scales of jurisdiction and in different areas. Therefore, vertical governance level is the existence of international, supranational, national, and local levels in public policies, which are able to create more conflicts between policy instruments and objectives. This happens because certain vertical governments may promote some actions without taking into account their impact on other elements of a policy mix.

Consequently, each vertical governance has its own policy objectives, which can have something in common with the other jurisdictions, as well as different policy objectives and preferences. For example, the international level is concerned with the environmental degradation and climate change and has been trying to promote sustainable mobility, while the supranational level is also worried about the previous policy objectives, as well as EU's external dependency on imported fossil fuels, efficiency and secure and affordable energy to consumers.

The national level tries to transpose European measures into its national legislation but is more apprehensive with GDP and the level of employment. Lastly, the local level is focused on increase urban livability.

Nevertheless, Policy Mix has benefited from little attention by the transportation literature with exception of Givoni et al. (2013), Kivimaa and Virkamäki (2014), Veeneman and Mulley (2018), and recently Bhardwaj et al. (2020) and even more regarding the vertical governance level problem that is systemically depreciated in Policy Mix literature.

As a matter of fact, the majority of studies are focused on the national level, ignoring the international level and if are located in the European Union, the Supranational level pressure. In addition, most studies are concentrated on the incentives associated with the vehicle purchase, but also refer to the instruments associated with the use of the vehicle and development of the charging infrastructure.

To conclude, our study will use the Policy Mix concept to analyze the actions taken by each level of vertical governance in the electric cars market promotion in Europe.

CHAPTER 3 - EV PROMOTION REVIEW IN EUROPE – INTERNATIONAL AND SUPRANATIONAL PRESSURE

In this chapter, we focus on the international and supranational vertical governance levels, their influence on electric mobility, and on the message that these levels are transmitting to the national level. For this, we identify the pressure and diverse policy objectives of the vertical governance levels – International (in subchapter 3.1.) and Supranational (in subchapter 3.2) and we end it with a systematic analysis of the electric passenger car adoption in Europe (subchapter 3.3).

First, in subchapter 3.1., we identify the importance of the transport sector, its environmental and social impact on the population's daily life, and show the transition or transformation that this sector is going through in order to achieve its decarbonization. However, the transport system decarbonization needs to be accompanied by a decarbonization of the power sector to achieve exponential impacts. Therefore, in this sub-chapter, we address the role of the Paris Agreement (3.1.1.) and the United Nations (3.1.2.), through the SuM4all organization in promoting sustainable and green mobility.

Then, in subchapter 3.2, we recognize the role of the European Union in electric mobility and highlight the main European regulations, directives, industrial policies, targets, and incentives created for its promotion mainly by vehicle, charging infrastructure, and energy.

Finally, in subchapter 3.3., we do an analysis of European panorama of the electric passenger cars adoption and associate it with its stock share, market share, government level of centralization or decentralization, energy dependency, share of renewables, charging infrastructure, level of pollution and traffic congestion. At the end of this chapter, the analysis carried out allows the selection of three representing countries of each cluster of European countries.

3.1. INTERNATIONAL LEVEL

The transport sector will face an uncertain pathway in the future, but it is already dealing with rapid change (SuM4all, 2017). Unquestionably, the way people and goods travel within and across the world is shifting quickly and digital technology use can change the vehicle ownership paradigm through vehicle sharing, ride-hailing, and carpooling. As has been emphasized by SuM4ALL, transport shapes markets simplify trade, links, and connect local communities to the world.

Transportation has the potential to improve lives and livelihoods, as a result of the impact of mobility has in people's life. The transport sector affects health, environment, and quality of life and can be meet with special attention on climate change (SuM4all, 2017). This sector has the power of shaping the physical world where people live in since mobility is linked to land use and spatial configurations of cities, regions and countries (SuM4all, 2019b).

This main transformation is particularly problematic, concerning that the transport sector has a significant contribution to national GDP, employment, and national and local revenues.

As already stated, this sector needs to overcome a major transformation, including improving massively of efficiency and move from oil to electricity and other low-carbon fuels, since this sector represents the largest or the second-largest energy-consuming sector.

This is happening since road transport creates numerous of negative externalities. At the global level, greenhouse gas emissions (GHG) result in climate change and at the same time, air pollutant emissions have consequences for human health (Deuten et al., 2020).

Please note that carbon dioxide (CO_2) is the main responsible for GHG emissions. CO_2 emissions are directly linked to fuel consumption. In other words, the amount of CO_2 emitted by a car is related to the amount of fuel consumed (WLTP, 2020).

Indubitably, climate change creates major threats to infrastructure investments and services through triggering longer-terms changes, such as average temperature growth, sea-level rise, shifting precipitation patterns, permafrost melting, or desertification. But the key point here is the gravity and frequency of disaster risks, like flooding, storms, and heatwaves (SuM4all, 2019b).

Please note that air pollution is relevant since it has major consequences on health, globally: Nine-out-ten people breathe polluted air every day, triggering more than 5 million premature deaths each year. Three main air pollutants are Sulphur dioxide (SO_2) – related to non-desulfurized fuels; along with nitrogen oxides (NO_2) and fine particulate matter ($PM_{2.5}$) - linked to diesel engines (OECD/IEA, 2019b). Most larger cities are dealing with substantial or severe air pollution, while the transport sector is the largest contributing sector to $PM_{2.5}$. Therefore, some of these emissions not only affect global warming and climate change, but they are also responsible for acid rain, which affects air quality in local areas (Lamjon, 2012).

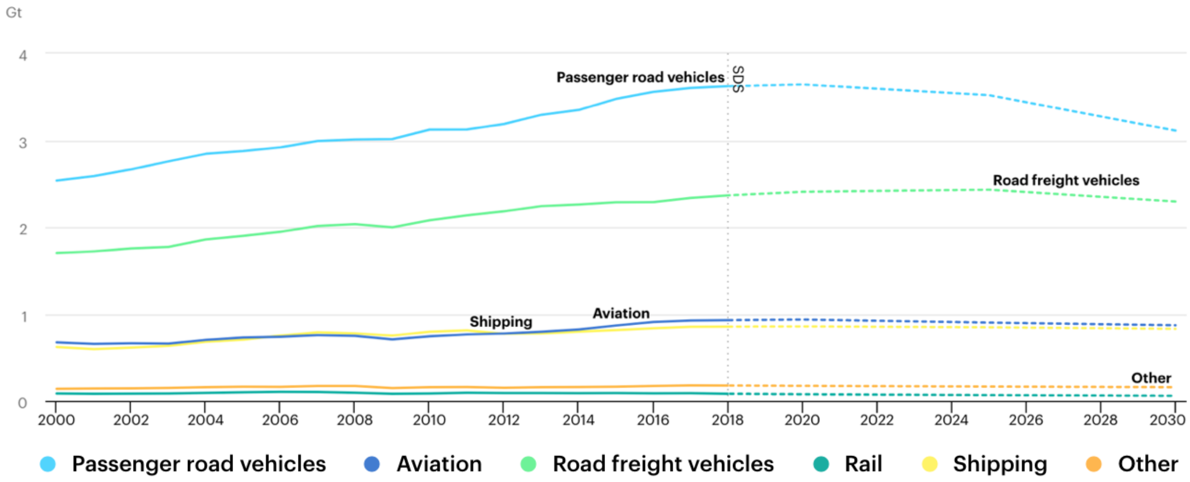
Petrol and diesel cars cause both GHG and the other air pollutant emissions, but diesel cars have higher air pollutant emissions such as NO_2, despite their lower GHG emissions (Deuten et al., 2020).

Besides GHG emissions, noise, and local air pollution, road transport is also responsible actually for dependence on foreign energy sources, compromising energy security (Lévay et al., 2017).

At the same time, noise pollution is also connected, since has been related to serious health risks, linked to a deteriorated quality of life from increased stress levels, sleep disturbances, and interferences with cognitive development and performance, causing hypertension and heart diseases (SuM4all, 2019b). In fact, road traffic (and also honking) is a major source of the noise.

The shift is so imperative for this sector since it is responsible for 24% of direct CO_2 emissions from fuel combustion, regarding that oil is the main source of CO_2 emissions in the transport sector (OECD/IEA, 2019b). Particularly, the road transport sector – cars, trucks, buses, two- and three-wheelers – represents approximately three-quarters of transport CO_2 emissions **(Figure 3-1)**. In accordance with SuM4all (2019b), road transport environment and health impacts are absolutely the greatest within the current transport sector. Therefore, it requires particular attention in our study.

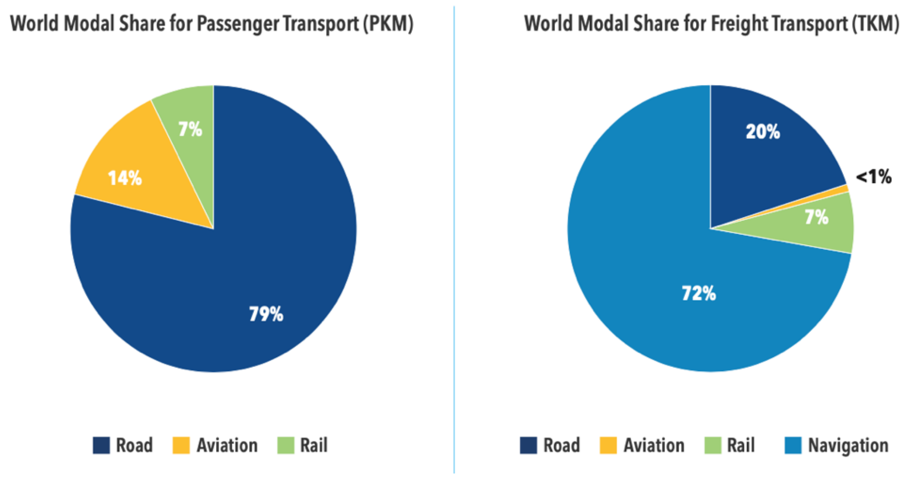
Figure 3-1 - Transport Sector CO_2 emissions by Mode of Transport in SDS scenario 2000-2030



Source: (IEA, 2019a)

At the same time, private car transport accounts for three-quarters of all passenger mobility, representing the largest modal share of the world's passenger transport, while road transport is the second transport modal share for freight **(Figure 3-2)** (SuM4all, 2017, SuM4all, 2019b).

Figure 3-2 - World Transport Modal Share for Passengers and Freight (2015)

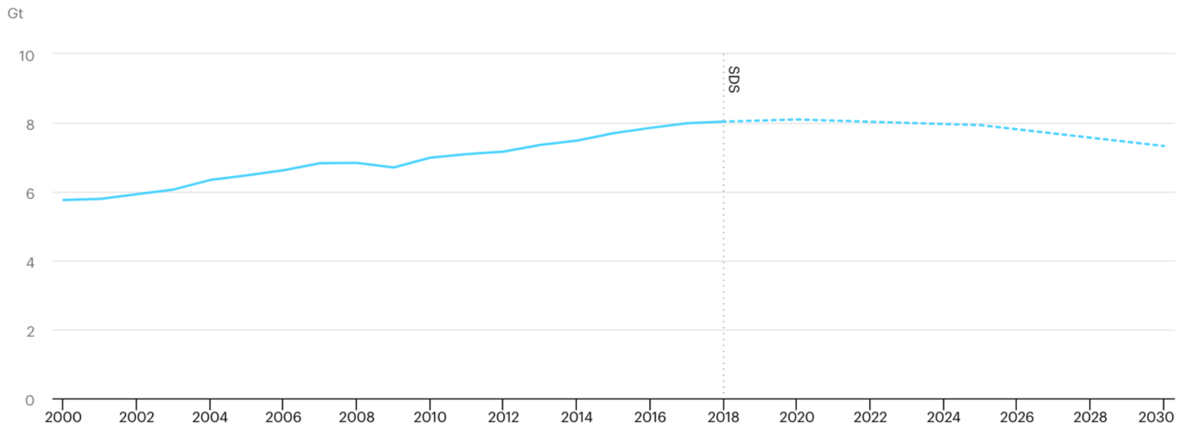


Source: SuM4all (2019b), page 10

In fact, the majority of daily urban trips are made by private motorized modes in the cities of developed countries. Consequently, car traffic has increased strongly, while cycling and public transport have faced timid growth. Then, the most challenges faced in developed countries are related to time spent in traffic, integrating the schedules of public transport services to compete with private modes, and prioritization of non-motorized transport. On the other hand, in developing countries, the problems are related to physical and financial barriers to access.

When we are analyzing global transport emissions, the tendency is to slow down its growth rate from 1.6% annually to 0.6% in 2018 **(Figure 3-3)** (IEA, 2019a).

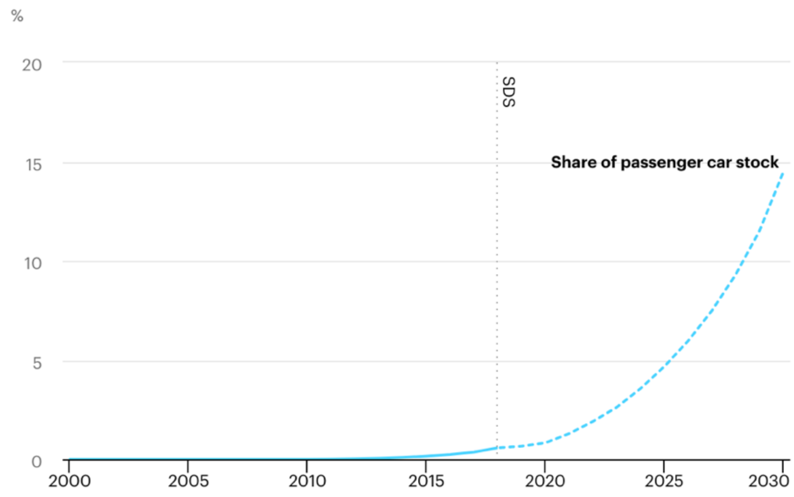
Figure 3-3 - Transport sector CO_2 emissions in SDS scenario, 2000-2030



Source: (IEA, 2019a)

Alternatively, road transport emissions have amplified despite the progress made with electrification. In 2018, the global share of electric car sales increased by more than 2,5% **(Figure 3-4)**. This is happening because car buyers are continuing to buy larger and heavier vehicles and more efficient diesel cars, camouflaging the effect of EV penetration (IEA, 2019b). Road transport emissions reduction will only be possible with the incentive of use of public transport, enhancing the efficiency of ICEV and electrification growth.

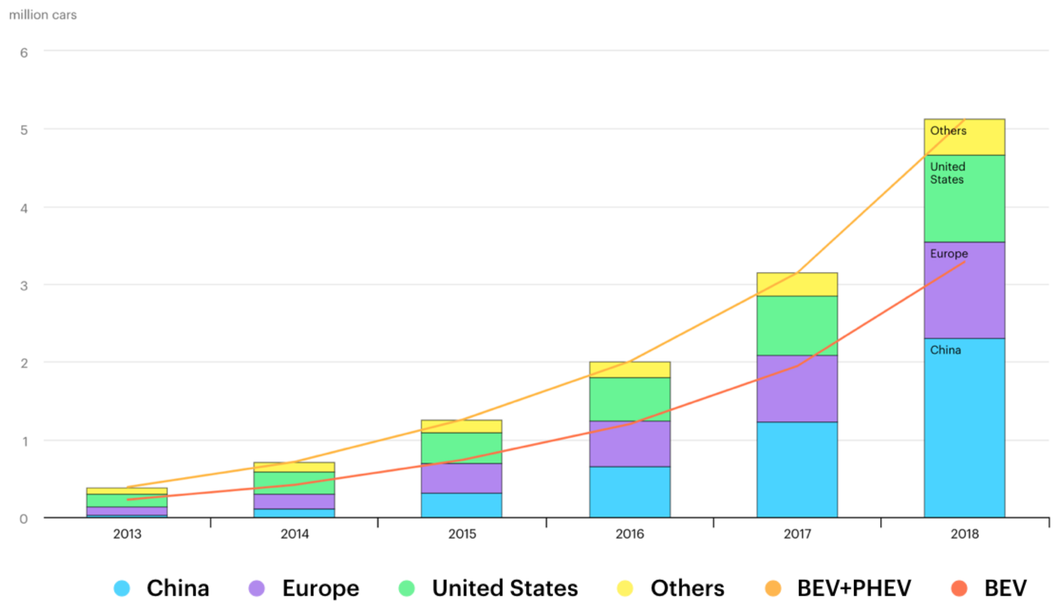
Figure 3-4 - Electric Passenger car stock in the SDS, 2000-2030



Source:(IEA, 2019b)

EVs are perceived as best suited to reduce emissions from light-duty vehicles (Hannula and Reiner, 2019). Although the global share of electric mobility is still residual (5.12 million in 2018 – less than 1% of global car fleet), their fleet is growing quickly (sales increased 68% in 2018). China continues to be the world's largest market, followed by Europe and the United States. Particularly, Norway has the highest market share for sales **(Figure 3-5)** (IEA, 2019b).

Figure 3-5 - Electric car stock by region and technology, 2013 -2018



Source:(IEA, 2019b)

IEA (2019b) highlights that acceleration of CO_2 emissions reduction will only be conceivable with progress in the decarbonization of the power sector combination. In fact, electric mobility can have an important role in increasing the flexibility of power systems, promoting the integration of intermittent renewable energy resources into the generation mix (OECD/IEA, 2019a).

With regard to CO_2 emissions reduction, EVs reduce local air pollution from circulation, but when we are taking into account the overall EV CO_2 footprint, it can exceed ICEV actual emissions without a combination of decarbonization of the energy system, which requires a change in the way electric energy is produced and consumed. More simply, CO_2 and GHG emissions related to EVs over its life cycle are associated with his average carbon intensity of electricity generation (OECD/IEA, 2019a). Naturally, if the power generation mix is still dominated by coal, hybrid vehicles have lower CO_2 emissions than BEVs (OECD/IEA, 2019a).

For this reason, the deployment of renewables is a key option, since the cost of solar photovoltaic and wind have fallen expressively recently and are expected to decline much more further in the future.

Despite road transport emission evolution and global economic growth, improvements in efficiency, electrification, and fuel switching are putting energy demand stable, even with the electrification of mobility and heating (OECD/IEA, 2019b). In fact, efficiency has also a key role to play, since is a mutual denominator across transport and energy and also for their cost-effectiveness characteristic. In 2050, a conventional car sold will consume less than 50% of the fuel required by the average car sold nowadays.

As we have seen, the transport sector is within the critical transition and needs to be accompanied by power sector decarbonization. In fact, EVs are an essential step for the transition to a cleaner energy system and to facilitate the availability of energy storage (OECD/IEA, 2019a). This transition should be aligned with the Paris Agreement on Climate Change and Sustainable Development Scenario, meaning increase efficiency and reduce energy demand transversely by all transport modes (IEA, 2019b).

3.1.1. Paris Agreement

The greatest advancement during the COP21 Paris Climate Conference in December 2015 was the acceptance of a collaborative initiative, called the Paris Declaration on Electromobility and Climate and the Call to Action (Lévay et al., 2017). Indeed, it represents the first international climate agreement which defines mitigation obligations to all countries, including the developed and developing countries (Magueta et al., 2018).

Paris Agreement (PA) on Climate Change has an objective of holding the increase in the global temperature to well below 2°c above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °c above pre-industrial levels (OECD/IEA, 2019b). Consequently, electromobility promotion should be achieved to a more sustainable transport sector pathway, since the energy and transport sector are responsible for about two-thirds of the global GHG emissions (Lévay et al., 2017).

It has been ratified in 2016 and the key elements for action include mechanisms for developing countries and Nationally Determined Contributions (NDCs) (SuM4all, 2017). NDCs are the climate action plans of each Party of the United Nations Framework Convention on Climate Change (UNFCC), taking into account not only mitigation but also adaptation.

Please note that would be necessary to achieve carbon neutrality in the second half of this century that each NDCs should submit their country's long-term development strategies with low GHG emissions by 2020 (RNC2050, 2019).

However, most of the NDCs made so far, with a 5 years' time horizon updated, are concentrated on the role of passenger transport and urban mobility. Naturally, NDCs need to be more determined in order to meet the PA objective, and to do so, freight transport and adaption should be emphasized (SuM4all, 2019b).

Consequently, the Paris Agreement embodies the world's commitment to move towards a low-carbon economy, making pressure for countries to implement policies that simplify the transition to cleaner economies (EC, 2017c). These targets suggest a global obligation for all economic sectors, although the transport sector is one of the main emitters. In conformity to SuM4all (2019b), the peak of CO_2 emissions should happen by the mid-2020s or latest by 2030, taking into account PA objectives. As referred to Hannula and Reiner (2019), in order to accomplish these CO_2 emissions reductions required by Paris Agreement, the transport sector can opt for decarbonizing fuels or vehicle technologies, or the combination of these two.

In sum, the Paris Agreement is a global game-changer, although is determined by national efforts that vary greatly (EC, 2017b). Finally, another global instrument is the United Nations (UN) 2030 Agenda for Sustainable Development, which implies ambitious Sustainable Development Goals and attempts to meet the Paris Agreement Climate change targets.

3.1.2. United Nations and Sustainable Mobility for All

Sustainable transport and mobility are essential to meet the UN 2030 Agenda for Sustainable Development and also to achieve 17 Sustainable Development Goals (SDGs). In fact, sustainable mobility is essential to meet 6 of the 17 Sustainable Goals (SuM4all, 2019b). Although there is no Sustainable Development Goal solely dedicated to transporting, there are two SDGs targets transport-related (SuM4all, 2017):

- Offer access to safe, affordable, accessible and sustainable transport for all – women, children, persons with disabilities and elderly people (SDG 11.2);
- Achieve half the number of global deaths and injuries related by road traffic accidents SDG 3.6);

For this reason, OECD/IEA (2019b) created a Sustainable Development Scenario (SDS) that shows a pathway to reach the United Nations Sustainable Development Goals (SDGs), mostly related to transport and energy (SDG 7).

As a matter of fact, reduction of GHG emissions (SGS 13) has to be recognized together with decisive action on energy (SDG 7) and sustainable transport, since countries cannot provide food security (SDG 2) and healthcare (SDG 3) without a transport system and an infrastructure to support economic growth and human well-being, which is reliable, sustainable and resilient (SDG 9.1.). Indeed, road safety in cities needs to improve, expanding public transport (SDG 11.2) (SuM4all, 2017).

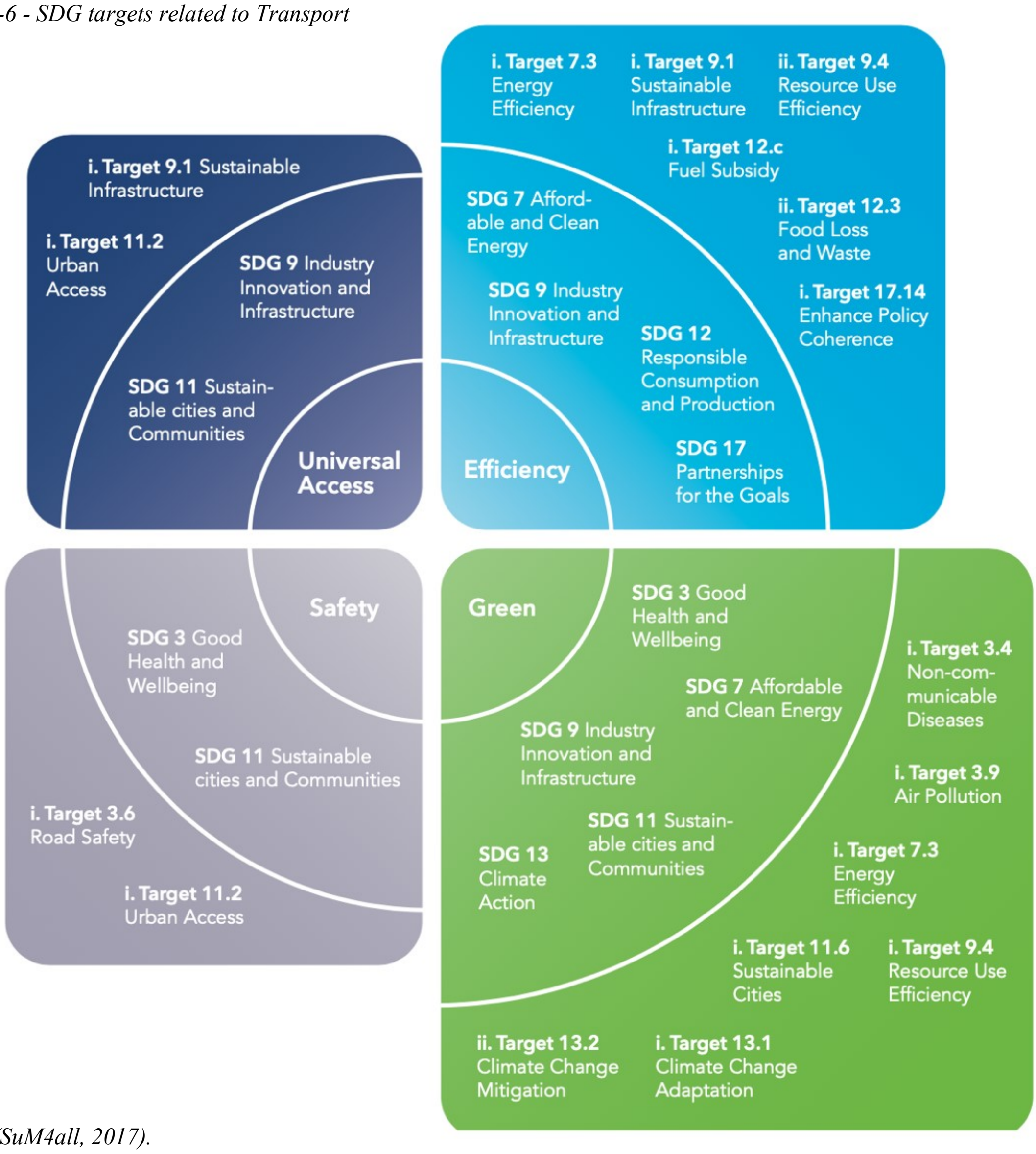
More importantly, children cannot attend classes (SDG 4), women cannot have employment and empowerment opportunities (SDG 5), persons with disabilities and older persons cannot have their independence and dignity without a transport that is accessible to everyone (SDG 9 and 11).

As stated before, this SDGs will only be accomplished with the progress made on energy: reducing the impact of air pollution on illnesses or deaths (SDG 3.9 or 11.6); tracking climate change and include them into national policies, objectives, and planning (SDG 13); achieving universal energy access (SDG 7) with doubling the global rate of improvement in energy (SDG 7.3); rationalization of inefficient fossil-fuel subsidies (SDG 12.c); and increase adoption of clean and environmentally technologies and industrial processes, like renewables (SDG 9.4) **(Figure 3-6).**

Thus, policies promoting these SDS are complementary but sometimes can have some trade-offs (OECD/IEA, 2019b). As a consequence, these SDGs objectives have complex trade-offs, as well as synergies, which make decision-making challenging. With this in mind, policy coherence should be fostered by a strengthening country-level policy instruments. In sum, SDGs do not offer a defined trajectory for transport and mobility but offer the conditions under a sustainable pathway (SuM4all, 2017).

Sustainable Mobility for All (SuM4all) is a platform for international cooperation on transport and mobility issues, formed by a global coalition of public organizations and private companies. SuM4all is focused on the future of mobility, which needs to be aligned with the Sustainable Development Goals and the Paris Agreement (SuM4all, 2017).

Figure 3-6 - SDG targets related to Transport



Source: (SuM4all, 2017).

As a matter of fact, market forces do not distribute equitably transport infrastructure and its services, do not provide an efficient transport system (traffic congestion is an example), but creates market failures in road safety and climate change, generating a local air and noise pollution. That is why this organization believes in an accessible, efficient, safe and green mobility, which are their objectives **(Table 3-1)** (SuM4all, 2019a).

First of all, universal access objective intends that everyone has access to the transport required, in order to take advantage of economic and social opportunities, especially in rural areas, where most poor people live. For this reason, equity and inclusivity are the main concerns of this global objective.

Secondly, system efficiency has the goal of providing transport at the least possible cost, given a set of available resources. This global objective is related to productive efficiency and allocative efficiency.

Third, safety is the global objective concentrated on avoiding fatalities, injuries, and crashes which have resulted from transport. However, this objective is challenging, since measuring safety has been proving to be difficult and it is focused on roads because the number of deaths and serious injuries from road crashes is the highest, regarding all other modes of transport.

Finally, Green Mobility aims to deal with climate change by mitigation and adaptation, in order to reduce air and noise pollution. This is the global objective more related to the Paris Agreement under UNFCC and NDCs. Those Green Targets are set at the national level, but they need to be consistent with international agreements when they exist. In this case, for climate change, SuM4all adopts Paris Agreement, but for air quality, there is no internationally agreed quantitative target.

Table 3-1 - SuM4all Four Global objectives

EQUITY	**EFFICIENCY**	**SAFETY**	**GREEN MOBILITY**
• Promote access across: gender, age, disability status, and geographical location; • Expand access to jobs and careers opportunities; • Encourage access to markets and basic services - health and education;	• Superior and quick access to world markets, in order to improve global trade; • Regional integration; • Efficient-use of resources – energy, technology, space, institutions, and regulations; • Smooth border crossing;	• Decrease of fatality, injury, and crash rates across all modes of transport; • Improve security for pedestrians, bicyclists, and children; • Reduction of transport social costs in health and forgone productivity.	• Improve air quality and lower noise pollution; • Preserve ecosystems and deal with climate disasters; • Reduce health costs related to air and noise pollution.

Source: adapted from SuM4all (2017)

3.2. SUPRANATIONAL LEVEL (EUROPEAN UNION)

As we have seen, the European Union (EU) chases sustainable development and was the driving force behind the Paris Agreement on climate action and the Sustainable Development Agenda for 2030. The EU is at the forefront of the global transition towards a low-carbon and circular economy (EC, 2017b).

Indeed, 2030 Climate and Energy legislative framework represents an EU-level policy NDC under the Paris Agreement, which define the targets and objectives for the period of 2021-2030, embracing a reduction of at least 40% of GHG emissions (compared to 1990 levels), 32% of the energy generated from renewable sources and an energy-efficient improvement of 32,5%. This was presented in the European Commission Communication of 2018, called: “Clean Planet for All”, offering an EU basis long-term development strategy to be submitted by each European country by 2020 (RNC2050, 2019).

Nowadays, mobility represents the largest economic sector in the world. In the EU, the transportation and storage sector account for more than 11 million people, represent more than 5 percent of total employment, 20 percent EU exports to the EU’s main trade partners, and approximately 5 per cent of EU GDP (EC, 2017a).

To deal with transport challenges, the EU created a Roadmap called EU White Paper on Transport in 2011, representing an important initiative to create a competitive transport system, increasing mobility and deal with fuel growth and employment, as well as reduction of energy dependency of Europe and cut CO_2 emissions (EC, 2011).

Additionally, transport activity in Europe is expected to remain growing. EC (2017a) supposes a growth of 42 percent of passenger transport and a growth of 60 percent of freight transport from 2010 to 2050. Particularly, road transport is the main transport used in the EU, domain citizens personal transportation, and half of the total freight transport activity.

Though, it should be clear that EU citizens spend an average of almost 10 hours commuting per week, traveling an average of 34.7 km (kilometers) per day, and expend 13 percent of their total consumption on transport-related items (EC, 2017a). After all, EU citizens face a daily experience of traffic jams in the major urban areas. Consequently, the European Commission made communication in 2013 to point the need for urban sustainable mobility reinforcement in the main capitals, indicating a direction and targets (EC, 2013b).

At the same time, road transport is also the main contributor to air pollution, which means a severe threat to public health (EC, 2017a). The transport sector remains the largest contributor to NOx emissions. Following what has been happening in the world, in 2016, road transport was the main GHG emitter in the EU. Despite the EU has been facing GHG emission reduction, this reduction was not significant in comparison to 1990 levels. In fact, GHG emissions were 25% higher in 2016 than 1990 levels (ERBACH, 2019).

Similarly, road transport was accountable for 78% of EU oil consumption in 2015. Again, the energy consumption was 23% higher than in 1990 (ERBACH, 2019). Passengers cars and vans, called commonly by light commercial vehicles, were responsible for around 12% and 2.5% respectively of total EU CO_2 emissions (EC, 2019b). In 2015, cars and vans accounted for 73% of road transport GHG emissions (EC, 2017d).

With these main problems, the EU built-in 2016 a European Strategy for low-emission mobility, acknowledging the importance to design an improved and efficient transport-system through digital technologies, smart road charging and multimodality, low-emission energy powertrains (EC, 2016).

One year later, European Commission launched the Clean Mobility Package with the purpose to drive innovation, improve competitiveness, reduce CO_2 emissions, improve air quality and public health and increase the safety of transport, putting Europe on the Move in a socially fair transition towards clean, competitive and connected mobility for all (EC, 2017c(EC, 2018, EC, 2017a).

Thus, EVs are seen as an opportunity and are aligned with the main targets defined by the EU, since they are air pollutant emission-free transport, essential to meet the EU's energy and climate objectives for 2030 and 2050 (EC, 2017d).

Therefore, decarbonization, the use of low-emission technologies, like electric powertrains for vehicles, and expansion of cooperative, connected, and automated mobility are seen at the same time as chances and main challenges.

Electric mobility is growing at a rapid pace. In 2018, the global electric car stock reached 5.1 million, representing a growth of 2 million cars in only one year. Not to mention, the evolution of new electric car sales, which almost double its absolute value in solely one year (OECD/IEA, 2019a).

In 2018, Europe had 24% (1.2 million) of the global stock of electric cars, representing the second-largest electric car market. By far, Norway was the global leader, regarding stock share[1] and market share[2] and Europe hosts the other countries with the largest penetration of electric car sales (Iceland and Sweden). In terms of volume sales, Norway was followed by Germany, the United Kingdom, and France (OECD/IEA, 2019a). In addition, Europe remained a strong market for PHEV sales, dominated by Finland, Sweden, and the United Kingdom.

Please note that the European Union's relative success in promoting EVs is also associated with the definition of regulations, directives, targets, and industrial policies that should be transposed into national legislation within defined deadlines.

Normally, the EU directives process creation happen as follow (ERBACH, 2019):

i) European Commission proposes a new or a revised Directive;
ii) The proposal needs to be referred to the European Parliament’s Committee in charge of a report format.
iii) The Committee adopts the report;
iv) The report should be voted by the European Parliament in a plenary session;
v) A trialogue agreement has to be reached and should be approved in plenary.

This is the case of the following directives and regulations for low-emission vehicles promotion: Availability of consumer information on fuel economy and CO_2 emissions in respect of the marketing of new passenger cars Directive (Directive 1999/94/EC); Emissions performance standards for new passengers cars (Regulation (EC) 2009/443); and Clean Vehicle Directive (Directive 2009/33/EC).

Meanwhile, national policies continue to have a key role. In fact, the leading countries, such as China and Norway, implement a variety of policy instruments to help to bridge the cost gap between electric, and conventional vehicles and promote the evolution of charging infrastructure (OECD/IEA, 2019a).

Currently, the economic incentives are accompanied by other policy instruments that intensify the value proposition of EVs (access to bus lanes, lower tolls and parking fees)

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[1] We adopted OECD/IEA 2019a. Global EV Outlook 2019 - Scaling-up the transition to electric mobility. Paris, France. definition: Share of electric car stock as a percentage of total passenger light-duty car stock.

[2] We adopted OECD/IEA 2019a. definition: Share of new electric car registrations as a percentage of new passenger light-duty car registrations.

(OECD/IEA, 2019a). The EU has been trying to follow the Paris Agreement, as the world has committed to moving towards a low-carbon economy, while the automotive industry is undergoing profound transformation (EC, 2017d). The EU was taking unprecedented action in order to become a global leader in the run for clean vehicles (EC, 2017c).

Recently, policy support at the supranational level has been focused in address the strategic importance of the battery technology value chain and it is waste management and environment requirements (OECD/IEA, 2019a). In an effort to better deal with scarce resources (EC, 2017a). After all, battery end-of-life management is crucial to reduce the dependency of critical raw materials and to constraint risks of shortages (OECD/IEA, 2019a).

To illustrate the importance of EU industrial policy and the urgency for updating it, the European Commission held a communication called Renewed EU Industrial Policy Strategy in 2017 to reinforce the main direction and to make European industry stronger and more competitive (EC, 2017b).

At the same time, vehicle manufactures are announcing ambitious intentions to electrify the car market, which implies a new and bigger demand for new materials in the automotive sector, announcing challenges in the traceability and transparency of the raw material supply chain and on second-life applications of automotive batteries. It seems like original equipment manufacturers (OEMs) are responding proactively to policy signs and technology improvements (OECD/IEA, 2019a). This represents a trend in the leading countries in electric mobility, which have a large automotive industry, are stimulating EV innovation and battery research and development (R&D), through strong industrial policies. This explained why the European Battery Alliance was created in 2017, in order to establish a complete value-chain for battery development and manufacturing in the EU.

Please note that the automotive sector has particular importance in the EU, creating jobs for more than 12 million people in manufacturing, sales, maintenance, and transport. As already stated, this sector is facing a fundamental transition globally, related to digitalization and automation, as well as electrified powertrains and connected vehicles. However, the EU car market share has declined in the last decade from around a third to 20%, reveling extra industrial importance to reach other markets with an advancement (EC, 2017d).

The automobile industry is among the world's biggest producers of motor vehicles and is the largest private investor in R&D, representing its global technological leadership.

As we have seen, electric mobility represents an opportunity to ensure that the EU automotive industry maintains its technological leadership, competitiveness and stimulate employment since EU industry has been able to reverse the deterioration in the EU industry export market shares and in the shares of the industry of total value added (EC, 2017b). Therefore, the EU needs to unceasingly adapt and innovate by facilizing investment in the new technologies and embracing changes brought on by digitalization, the transition to low-carbon, and more circular economy.

However, this structural change can also be disruptive, which may mean a redesign of its value chain, investment priorities, and technological choices with consequences for its global competitive position. In other words, this transformation can create new jobs, but can also do others obsolete. It needs new skills, good working conditions, investment, and more important - adaptation (EC, 2017a).

In accordance with EC (2017b), Europe's car industry must react to this challenge, get ready and hurry the transition to electric cars and other low emission technologies. If Europe grabs this opportunity, this will create sustainable jobs and better livelihoods for its regions and communities. Although would need different actors in the value chain, from raw materials providers, suppliers and vehicle manufacture, to dealers and aftermarket.

On the other hand, charging infrastructure has been developed by key power sector market players, such as utilities, major energy companies traditionally focused on oil, charging point operators, and charging hardware manufactures (OECD/IEA, 2019a). As a matter of fact, charging infrastructure includes charging at home, at work, publicly accessible chargers and fast chargers concentrated on highways.

For this reason, the EU launched the Alternative Fuels Infrastructure Directive (Directive 2014/94/EU) setting deployment targets for publicly accessible chargers in 2020, 2025, and 2030, and to create requirements for appropriate minimum infrastructure on the compatibility of fuels and vehicles (EP, 2014). Additionally, the European Energy Performance of Building Directive (Directive2012/31/EU) was also implemented, in order to establish minimum requirements in new or refurbished buildings and parking lots, incentivizing the installation of charging points.

However, the global number of publicly accessible chargers per electric car has diminished from 0.14 in 2017 to 0,11 at end of 2018, the ratio is still superior than 1 charger per 10 electric cars, which is recommended by the Alternative Fuels Infrastructure Directive. On the contrary, Norway has a ratio of 1 charger per 20 electric cars, indicating that EV roll-out is not automatic and varies on country geography, population density, access to workplace charging infrastructure, commute distance per workday, and vehicle range.

Regarding the power sector, in 2019, the Clean Energy for all Europeans Package represented an EU update of the energy policy framework, which ease the transition away from fossil fuels towards cleaner energy and to achieve the Paris Agreement for reducing GHG emissions (EC, 2019a). Indeed, this is aligned with the EU aim to be climate-neutral by 2050 with an economy with net-zero greenhouse gas emissions, called European Green Deal.

In Europe, incentives supporting EV penetration and deployment of charging infrastructure are usual. As a consequence, many European countries have regulatory policy instruments active, while in some advanced markets, like Norway, are starting phasing out phase of their EV support policies (OECD/IEA, 2019a).

Alternatively, some European frontrunners countries in electric mobility are facing a transition on policy approaches, switching from a purchase incentive paradigm to zero-emission vehicle mandates and/or regulatory requirements associated with fuel economy and pollutant and GHG emissions (OECD/IEA, 2019a).

An overview of the main EU policies to support EV penetration is presented in **Table 3-2.** and **Table 3-3** in greater detail.

As seen in **Table 3-2** and **3-3**, the European Union and European Economic Area have several initiatives, regarding the promotion of electric vehicles, the development of charging infrastructure, and energy.

These regulations, targets, industrial policies, and incentives provide general guidelines that put pressure on countries at the national level, as some of these measures must be transposed into national legislation in a given deadline.

Therefore, this vertical governance level is essential to create a European pathway in promoting EVs. In the next section, we will do an EV adoption overview in Europe.

Table 3-2 - Overview of EV support policies in the European Union

MAIN EUROPEAN EV POLICIES		**EUROPEAN UNION**
Vehicles	**Regulation**	▪ Availability of consumer information on fuel economy and CO_2 emissions in respect of the marketing of new passenger cars **(Directive 1999/94/EC)** ▪ Emissions performance standards for new passenger cars **(Regulation 2009/443/EC)** ▪ Clean Vehicle Directive **(Directive 2009/33/EC)**
	Incentives	Economic incentives schemes for zero and low-emission for PLDVs at the national level in 26 EU Member States
	Targets	▪ EU White Paper on Transport (2011) ▪ Urban Mobility Package (2013) ▪ European Strategy for low-emission mobility (2016) ▪ Clean Mobility Package (2017) ▪ Europe on the Move (2017)
Charging Infrastructure	**Regulation**	Energy Performance Buildings Directive **(Directive 2012/31/EU)**
	Industrial Policy	▪ Renewed EU Industrial Policy Strategy (2017) ▪ Battery Initiative Alliance (2017)
	Incentives	Economic incentives schemes for supporting the charging infrastructure deployment (nationally)
	Targets	Alternative Fuels Infrastructure Directive (**Directive 2014/94/EU)**
Energy	**Regulation**	▪ Regulation on the Governance of the Energy Union and Climate Action **(2018/1999/EU)** ▪ Renewable Energy Directive **(Directive 2018/2001/EU)** ▪ Energy Efficient Directive **(Directive 2018/844/EU)** ▪ Electricity Market Design: new electricity directive **(2019/944/EU)** and regulation **(2019/943/EU)**
	Targets	▪ Clean Power for Transport: a European Alternative Fuels strategy (2013) ▪ Clean Energy for all Europeans Package (2019)

Source: adapted of (OECD/IEA, 2019a)

Table 3-3 - EV support policies in the European Union with greater detail.

NAME	YEAR /LAW	OBJECTIVES	MEASURES	REFERENCES
VEHICLES				
Regulation				
Availability of consumer information on fuel economy and CO_2 emissions in respect of the marketing of new passenger cars	**Directive 1999/94/EC,** Amend by 2003/73/EC,	**Support an informed choice when an EU consumer is buying or leasing a new passenger car, based on fuel economy and CO_2 emissions**	Obligates Member States to provide information related on fuel-efficiency of new passenger car, associated with fuel consumption and CO_2 emissions	(Magueta et al., 2018); (EP, 2008, EC, 2013c);
Emissions performance standards for new passengers cars	**Regulation (EC) 2009/443 (cars)** Replaced by 2019/631	**Mandatory CO_2 emissions targets for new cars (2009), applying from 2025 to 2030. => Benefits: 23% reduction of GHG emissions from road transport in 2030 (compared to 2005).** It has a mechanism to promote zero and low-emission vehicles (ZLEV – CO_2 emissions between 0-50g/km) in a technology-neutral way.	**SUPPLY-SIDE MEASURE** **15% reduction of GHG emissions from 2025 on and 37.5% reduction from 2030 onwards.** It takes into account the full life-cycle CO_2 emissions of cars.	(EC, 2019b, EP, 2019, EC, 2017d)
Clean Vehicle Directive	**Directive 2009/33/EC,** Amend by 2019/1161	**Public procurement instrument to promote clean and energy-efficient road transport vehicles, ensuring a steady demand.** It applies to vehicles purchased by contracting authorities/entities and public transport operators. Ensures a steady market demand. Differs from light-duty vehicles (CO_2 and air-pollutant emissions) from heavy-duty vehicles (alternative fuels).	**DEMAND-SIDE MEASURE** **Stimulation of clean, energy-efficient vehicles market and reduction of CO_2 emissions**	(ERBACH, 2019, EC, 2009, EC, 2019c)

Targets				
EU White Paper on Transport	**Roadmap** 2011	Adopted by EC with 40 concrete initiatives for the next decade to create a competitive transport system, increasing mobility and deal with fuel growth and employment, as well as reduction of energy dependency of Europe and cut CO_2 emissions.	**European Strategy:** Roadmap to a Single European Transport Area – Towards a competitive and resource-efficient transport system	(EC, 2011)
Urban Mobility Package	**Communication** 2013	Reinforce urban sustainable mobility in the major EU cities.	Support local authorities in the economic, environmental, and social challenges with urban mobility patterns on relevant issues, such as: i) Urban logistics; ii) Urban Access regulations; iii) Road safety.	(EC, 2013b)
European Strategy for low-emission mobility	**Communication** 2016	Improve transport-system efficiency by digital technologies, smart road charging and multimodality, low-emission energy (electricity and advanced biofuels) for transport. Allows Europe to respond to the increasing mobility of people and goods.	GHG emissions by 2050 from transport will be at least 60% lower than in 1990.	(EC, 2016)
Clean Mobility Package	Proposals 2017	Drive innovation; improve competitiveness, reduce CO_2 emissions, improve air quality and public health, and increase road safety.	Includes: i. **Emissions performance standards for new passengers cars Regulation;** ii. **Clean Vehicle Directive;** iii. **Alternative Fuels Infrastructure Directive;** iv. **Combined Transport Directive;** v. **Regulation on Passenger Coach Services;** vi. **Battery Initiative**	(EC, 2017c)

Europe on the Move **An Agenda for socially fair transition towards clean, competitive and connected mobility for all**	**Communication** 2017	Wide-range set of initiatives to make traffic safer, promote smart road charging; reduce CO_2 emissions, air pollution, and congestion; cut red-tape for businesses, combat illicit employment and ensure proper conditions and rest times for workers.	A smooth transition towards a mobility system that is safe, clean, connected and automated.	(EC, 2018, EC, 2017a)
Public-Private Partnership				
European Green Cars Initiative (EGVI)	**Public-Private Partnership** 2013	Deliver green vehicles and mobility system solutions through promotion and facilitation of pre-competitive research on road transport vehicles within the European Research Area.	Contractual Public-Private Partnership.	(EGVI, 2020)
CHARGING INFRASTRUCTURE				
Regulation				
European Energy Performance of Building Directive	**Directive 2012/31/EU** Amend by 2018/844/EU	Minimum requirements for EVs in new or refurbished buildings and parking lots.	For new or renovated non-residential buildings: - Mandates at least one-fifth of parking space to be equipped with conduits, allowing the installation of chargers. - if the parking space has more than 10 parking places, it needs a charging point available. For new or renovated residential buildings: - if the parking space have more than 10 parking places, all the parking places should be prepared with conduits for future chargers.	(EC, 2019d, EP, 2010, EP, 2018, OECD/IEA, 2019a)

Industrial Policy				
Renewed EU Industrial Policy Strategy	**Communication** 2017	Make the European industry stronger and more competitive to stay or become the world leader in innovation, digitalization, and decarbonization.	Reinforce the main direction and priorities of a comprehensive and holistic strategy for industrial policy strategy competitiveness, which includes EU policies, regulation, and financial programs.	(EC, 2017b)
European Battery Alliance	**Industrial Policy** 2017	Strategic EU's integrated industrial policy to ensure that mobility solutions for tomorrow and their components will be invented and produced in the EU. Establish a complete value-chain for battery development and manufacturing in the EU.	A platform for gathering countries, stakeholders, banks to work together to create a battery ecosystem in UE. Create a battery industry in Europe, since it represents one of the nine strategic value chains for the competitiveness of EU industry and to achieve decarbonization target.	(OECD/IEA, 2019a)
Targets				
Alternative Fuels Infrastructure Directive	**Directive 2014/94/EU**	Trans-European Deployment of alternative fuels infrastructure. Provision of common standards on the internal market. Creation of requirements for appropriate minimum infrastructure on the compatibility of fuels and vehicles.	Set deployment targets for publicly accessible chargers in 2020, 2025 and 2030, as their national policy framework	(EP, 2014)

ENERGY				
Targets				
Clean Power for Transport: a European Alternative Fuels strategy	**Communication** 2013	Broadest possible use of alternative fuels for transport and to promote sustainable electric mobility.	Transformation of Europe energy supply for transport, based on alternative fuels to break the dependence from oil and improve security, as well as strengthen the competitiveness of the industry and reduce GHG emissions.	(EC, 2013a)
Clean Energy for all Europeans Package	**Proposals** 2019	Agreement on this new energy rulebook. It is a key step towards the implementation of the Energy Union Strategy (2015). Brings benefits from a consumer, environment, and economic perspective.	i. Energy Performance in Buildings (EU 2018/884, emending 2010/31/EU – are the single largest energy consumer in the EU); ii. Renewable Energy Directive (2018/2001/EU) – the target of 32% for RES in the EU's energy mix by 2030 iii. Energy efficient Directive (2018/844/EU) – the target of 32.5% by 2030, compared to business as usual scenario iv. Regulation on the Governance of the Energy Union and Climate Action (2018/1999/EU) – each Member State have to establish an integrated 10-year national energy and climate plan (longer-term view -2050). v. Electricity Market Design: new electricity directive (2019/944/EU) and regulation (2019/943/EU), risk preparedness regulation (2019/941/EU) and regulation promoting a stronger role for the Agency for the Cooperation of Energy Regulators (ACER) (2019/942/EU).	(EC, 2019a)

FREIGHT TRANSPORT AND PUBLIC TRANSPORT				
Combined Transport Directive	**Directive 92/106/EEC** Amend by 2006/103/EC 2013/22/EU	Promotion of a combination of different modes of freight transport for the transport of goods: trucks or trains, barges or ships.	Aims to increase the combined transport competitiveness (defined as intermodal transport with a strictly limited road leg). Offers financial support to multimodal/intermodal transport.	(EC, 2020)
Regulation on the rights of passengers in bus and coach transport	**Regulation (EU) nº 2006/2004** Amend by Regulation (EU) nº 181/2011	Stimulation of creation of bus connection over long distances In Europe and offer alternative options to the use of private cars.	Sets a series of minimum rights for passengers who travel by bus and coach in the European Union: i. Non-discriminatory transport conditions. ii. Access to transport for disabled persons and persons with reduced mobility, iii. Minimum Rules on information to all passengers before and during their travel, as well as general information about their rights. iv. Obligation to set a mechanism for handling claims available to all passengers.	(EP, 2011)

Source: adapted from (OECD/IEA, 2019a)

3.3. CURRENT SITUATION OF EV PROMOTION IN EUROPE

To understand the adoption of electric cars in Europe, it was decided to carry out a panoramic analysis of the different European countries.

With this in mind, in the first part we relate the data of each European country, regarding their electric registered car stock (i), electric vehicle market share (ii), the importance of the automobile industry in GDP (iii), centralization government level (iv), Power sector (v), charging infrastructure (vi), urban population and commute per workday (vii), as well as Population, Pollution and traffic congestion (viii). In **Table 3-4**, we do a summarization of the EV adoption panorama in Europe, based on multi-criteria referred previously and developed in greater detail in **Appendix A**.

As you can see, the stock of electric cars is residual in Europe, representing in the majority less than 0.75% of the fleet. However, when observing EVs share in the new car registrations, we realize that there is a short-term trend to promote electric mobility with some countries having a percentage between 2-9%.

There appears to be a correlation between countries with a large presence of the auto industry in GDP and those that are lagging behind in EV penetration. However, some of these countries have a medium market share. On the other hand, the countries where the auto industry is residual in GDP are those with the highest EV shares. Note that this analysis is limited by the lack of data and the source of the data obtained in this variable.

In addition, most European country governments are centralized at the national level, giving little power at the local level.

Concerning energy dependence and the penetration of Renewable Energy Sources (RES), we realize that most European countries have a dependence greater than 25% and less than 20% of RES in the electricity mix. However, countries that are ahead in electric mobility have levels below 25% and 30% respectively.

It is also worth noting that the countries with the most electric cars are those with a higher ratio than that stipulated by the EU of 1 charging point for every 10 electric cars.

Additionally, most countries are dependent on private modes of transport for their daily commute, making the most populous countries the ones with the highest levels of GHG emissions.

Table 3-4 - Overview of EV adoption in Europe

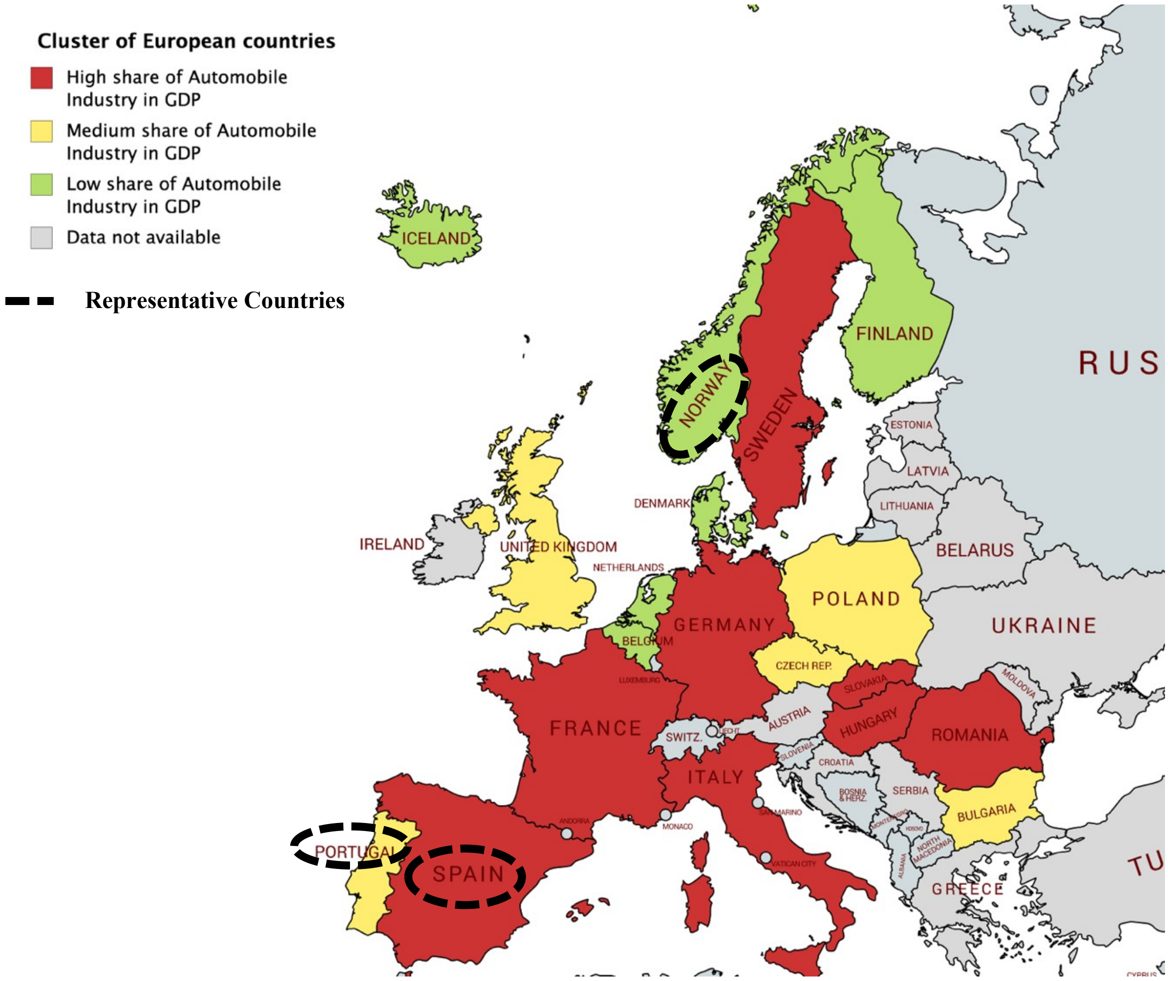
		2019/2017	2019	2018	2017	2017	2018	2019	2020	2017
		STOCK - PASSENGERS	MARKET SHARE - PASSENGERS	AUTOMOBILE INDUSTRY	TAX REVENUES	POWER SECTOR		CHARGING INFRASTRUTURE	MODES OF TRANSPORT USE ON COMMUTE	GHG EMISSIONS
#	Countries	Total EVs % of registered passenger cars	EVs % Market share	% Automobile Industry in GDP	Decentralized governance	Energy Dependecy Rate (%) - 2017	% RES in gross final energy consumption	> 10 EVs per Charging point	Main mode of tranposrt	Greenhouse gas emissions by country (in thousand tonnes)
1	Austria	Low	Medium	N/A	-	Medium	High	-	Public	Medium
2	Belgium	High	Medium	Low	-	High	Low	-	Private	Medium
3	Bulgaria	Low	Low	Medium	-	Medium	Medium	-	Private	Medium
4	Croatia	Low	Low	N/A	-	Medium	Medium	-	Private	Low
5	Cyprus	Low	Low	N/A	-	High	Low	Yes	Private	Low
6	Czech Republic	Low	Low	Medium	-	Medium	Low	-	Public	Medium
7	Denmark	Medium	Medium	Low	Yes	Low	High	-	Non-Motorized	Medium
8	Estonia	Low	Low	N/A	-	Low	High	-	Public	Low
9	Finland	Low	Medium	N/A	Yes	Medium	High	Yes	Public	Medium
10	France	Low	Medium	N/A	-	Medium	Low	-	Public	High
11	Germany	Low	Medium	High	Yes	Medium	Low	-	Non-Motorized	High
12	Greece	Low	Low	N/A	-	High	Low	Yes	Private	Medium
13	Hungary	Low	Low	High	-	Medium	Low	-	Public	Medium
14	Iceland	High	High	N/A	Yes	Low	High	Yes	Private	Low
15	Ireland	Low	Medium	N/A	-	High	Low	-	Private	Medium
16	Italy	Low	Low	High	-	High	Low	-	Private	High
17	Latvia	Low	Low	N/A	-	Medium	High	-	Private	Low
18	Lithuania	Low	Low	N/A	-	High	Medium	-	Private	Low
19	Luxembourg	High	Medium	N/A	-	High	Low	-	Private	Low
20	Malta	Low	N/A	N/A	-	High	Low	-	Non-Motorized	Low
21	Netherlands	High	High	Low	-	Medium	Low	-	Non-Motorized	High
22	Norway	High	High	N/A	-	Low	High	Yes	Private	Medium
23	Poland	Low	Low	Medium	-	Medium	Low	-	Public	High
24	Portugal	Low	Medium	Medium	-	High	High	-	Private	Medium
25	Romania	Low	Low	High	-	Low	Medium	-	Private	Medium
26	Slovakia	Low	Low	High	-	Medium	Low	-	Public	Low
27	Slovenia	Low	Low	N/A	-	Medium	Medium	-	Private	Low
28	Spain	Low	Low	High	Yes	High	Low	-	Private	High
29	Sweden	High	High	N/A	Yes	Medium	High	Yes	Public	Medium
30	Switzerland	Medium	N/A	N/A	Yes	N/A	N/A	-	Public	Medium
31	Turkey	Low	N/A	N/A	-	High	Low	-	Private	High
31	United Kingdom	Medium	N/A	Medium	-	Medium	Low	-	Private	High
32	Liechtenstein	Low	N/A	N/A	-	N/A	N/A	N/A	Private	Low
		High > 1%	High > 9%	High > 9%		Low < 25%	High > 30%			Low < 50 000
		Medium 0,75%-1%	Medium 2%-9%	Medium 4%-9%		Medium 25% - 65%	Medium 20%-30%			Medium 50 000 - 200 000
		Low < 0,75%	Low < 2%	Low < 4%		High > 65%	Low < 20%			High > 200 000
	Data Source				OECD (2017)	Eurostat (2017)	Eurostat (2018)	EAFO (2019)	Numbeo (2018)	OECD (2017)

Source: Own elaboration

As we cannot carry out a detailed analysis of electromobility in Europe to all European countries, we decided to divide the countries into three clusters of European countries, as evidenced previously.

In **Appendix B**, systematization of the European scenario is carried out in the adoption of EVs, taking into account the importance of the automobile industry in GDP (high, medium, and low share). There also appears to correlate with EV share and market penetration and the importance of the auto industry in national GDP. Subsequently, a map of Europe **(Figure 3-7)** shows the division of countries into three different clusters, based on the findings of Appendix B. The color red is used for countries with a high share of Automobile Industry in GDP, color yellow for medium share, color green for low share and color grey for the countries where we did not find data.

Figure 3-7 - Three different European countries clusters.



Source: Own elaboration

As we have seen on the map, the European countries with a high share of the Automobile Industry in GDP are Germany, Romania, Slovakia, Italy, Spain, and Hungary. France and Sweden were included in this cluster, despite the lack of data.

These countries are characterized by a strong traditional automobile industry and are those that are still lagging behind in electric mobility in EV share and most cases, also in EV market share. They are mostly countries with low penetration of renewable sources and with high energy dependence. All of these countries comply with the European Alternative Fuels Infrastructure Directive of 10 electric vehicles per charge point. This cluster has populous countries and their population is concentrated in urban areas, using mainly private transport for their daily commuting. In addition, they are more polluted and more traffic congested.

Secondly, the European countries with a medium share of the Automobile Industry in GDP are the Czech Republic, Bulgaria, Poland, the United Kingdom, and Portugal. These countries are characterized by an average automotive industry with an EV share of less than 1%, but with a market share of more than 2% in some countries. In addition, they are countries that also comply with the European Alternative Fuels Infrastructure Directive and some of them use private transportation for the daily commute, having an intermediate level of pollution.

Finally, the European countries with a low share of the Automobile Industry in GDP are Norway, Iceland, Denmark, Finland, Netherlands, and Belgium. This cluster is illustrated by countries with no tradition in the auto industry, which consequently are also the leaders in electric mobility in Europe (EV share and market share). It consists of the Nordic countries and the Netherlands. These are the countries with the lowest energy dependence and the highest penetration of renewable sources. However, they do not yet have a charging infrastructure deployment so far.

Please note that we did not find data for Ireland, Switzerland, Austria, Liechtenstein, Slovenia, Croatia, Estonia, Lithuanian, and Latvia.

From this division into three clusters with similar characteristics, we had to choose a representative country for each cluster (highlighted by a black dotted circle in the map in **Figure 3-7**). Each representative country will allow an analysis of the economic and non-economic incentives given at national and local levels on Acquisition, Use of the Vehicle, Company ownership, and infrastructure categories and their impacts in the EVs diffusion results in the next chapter.

The selection was made adopting as main criterium the different shares of the Automobile Industry in GDP:

i. Spain – for the high share of Automobile Industry in GDP;
ii. Portugal - for the medium share of Automobile Industry in GDP;
iii. Norway - for the low share of Automobile Industry in GDP.

As previously emphasized in the Methodology section, the selection of representative countries was based on data availability.

Consequently, Spain is characterized by a high conventional automotive industry and by a high intensity of mobility (in relation to GDP), even higher than Germany, France, the United Kingdom, and Italy (Gago, 2017). On top of that, the car manufactures have their decision-making headquarters outside Spain, helping a possible EV boost in this country compared to other European car producers, such Germany, France and Italy (Cansino and Yñiguez, 2018).

On the other hand, Portugal has been referred to as a country that has invested in electric mobility recently and has an EV market share above 5 percent. In addition, it had a certain dependency on the Volkswagen Autoeuropa factory, with this industry representing 4% of GDP. Besides, Portugal was at the top of the raking for the lowest CO_2 emissions, regarding the other European Member States (Magueta et al., 2018).

Finally, Norway was is the global forerunner in electric mobility, the EV growth has been formidable in last years and does not have a traditional automotive industry installed. The apparent success of its policy support in increasing the EV sales does Norway an interesting case to learn from, especially for countries that aim to move into the same pathway. Additionally, the incentive variety used in Norway allows the discernment of the strategies which are more likely to be successful in the EV boost (Bjerkan et al., 2016).

Indeed, the Norwegian EV policy was successful in reducing the overall GHG emissions, however, this cannot easily be convertible to other countries, since electricity in Norway is generated mostly from renewable energy especially in form of hydropower, and is one of the cheapest in Europe (Deuten et al., 2020).

3.4. CHAPTER CONCLUSIONS

The transport sector affects health, environment, and quality of life and it can be meet with special attention on climate change, improving massively the efficiency and move from oil to electricity and other low-carbon fuels, since this sector represent the largest or the second-largest energy-consuming sector.

Consequently, its transformation is particularly problematic, concerning that the transport sector has a significant contribution to national GDP, employment, national and local revenues. Besides GHG emissions, noise, and local air pollution, road transport is also responsible actually for dependence on foreign energy sources, compromising energy security.

Currently, private car transport accounts for three-quarters of all passenger mobility, representing the largest modal share of the world's passenger transport. Therefore, car traffic has increased strongly, while cycling and public transport have faced timid growth.

EVs are perceived as best suited to reduce emissions from light-duty vehicles. Although the acceleration of CO_2 emissions reduction will only be possible with the progress made in the decarbonization of the power sector. For this reason, EVs are fundamental for the transition to a cleaner energy system and to facilitate the availability of energy storage.

In brief, Paris Agreement on Climate Change and Sustainable Development Goals are the main forces behind the international level, pressuring the Supranational (European Union for the Member States and European Economic Area for non-Member States) and national governance levels to act, fostering the electric mobility.

Nowadays, the European Union is at the forefront of the global transition towards a low-carbon. In 2018, Europe represented the second-largest electric car market, although most countries have a percentage of stock of electric vehicles in their total passenger light-duty car less than one percent.

This leadership may be explained by the definition of regulations, directives, targets, and industrial policies that should be transposed into national legislation within defined deadlines by the European Union and some of them by the European Economic Area. The main areas of intervention to boost electromobility are the vehicles, the charging infrastructure, and energy.

Please note that the automotive sector has particular importance in the EU. Indeed, this sector is one of the most powerful forces in Europe and this can be seen by the weight that this industry has in the GDP, the gross added value, and the share of total employment. Therefore, EV penetration embodies a large challenge to this conventional sector, requiring a redesign of its value chain, investment priorities, and technological choices. In fact, it seems that the countries with a strong automobile sector tradition are not the leaders in electric mobility Apart from that, it appears that where the automobile industry is not relevant, the EVs share and EV market share are higher.

Consequently, European countries were divided into three different clusters according to the importance of the automobile industry in GDP (high, medium, low) and three representative countries from each cluster were selected in order to carry out an analysis in the next chapter of the initiatives carried out at national and local governance levels. The selected countries were Spain, Portugal, and Norway.

In conclusion, this chapter demonstrates the pressure exerted at the international level at the supranational level and the main initiatives adopted in the European Union that should be transposed to the national legislature in a given deadline. We also demonstrate the dispersion of EVs adoption in Europe.

CHAPTER 4 - NATIONAL LEVEL – NORWAY, PORTUGAL, AND SPAIN CASES

There are deep changes underway in road transport and in mobility, more than what has changed in the last century. The next decade may be marked by the shift to electromobility and possibly combined with a reduction in car ownership, an increase of vehicle sharing, and the introduction of autonomous cars (Transport&Environment, 2019).

As we have seen in Chapter 3, public policies are still relevant in the electric mobility boost, considering that EV penetration is residual across most European countries and has a range of barriers associated with their actual cost, technological conservatism, unproven technological performance, unfamiliarity, and lack of knowledge (Bjerkan et al., 2016, Elbil, 2020, UVE, 2020b).

Indeed, the international governance level is putting strong pressure on the European Union to adopt measures to promote sustainable mobility. In turn, the supranational and international levels are forcing the national and consequently local level to adopt EV support policies.

Unquestionably, national and local public policies help to reduce the cost gap between electric and conventional vehicles and support the deployment of charging infrastructure. Historically, the economic incentives – namely financial and fiscal incentives related to government revenue and taxes - have been fundamental for the introduction of alternative fuel vehicles (Bjerkan et al., 2016, IRENA, 2019). Nowadays, the key challenge is with the definition of the battery technology value chain (OECD/IEA, 2019a, UVE, 2020a).

In conformity to OECD/IEA (2019a), the implementation of public policies at national and local level start with the definition of the main objectives and with the initial step of procurement programs adoption. This will allow the creation of steady demand and encourages the traditional car manufacturer to increase the availability of EV on the market, providing a stimulus for a kick-start of publicly accessible charging infrastructure.

Yet, at the same time, some countries have taken a further step and announced bans on the sales of ICE cars or sales objectives for 100% zero-emissions vehicle (ZEV) to achieve a zero-emission car fleet.

As previously accentuated in the Methodology section – subchapter 1.2 – this research is focused on three countries: Norway, Portugal, and Spain. Again, Norway is the country more target ambitious, aiming to have only ZEV sales in the light-duty vehicles and public bus segments by 2025. On the other hand, Portugal and Spain are planning to have 100% ZEV sales target by 2040 **(Table 4-1)** (OECD/IEA (2019a).

It should be highlighted that these national initiatives are combined with a local governance level encouragement since several municipal administrations have already restricted and/or prohibited access to certain areas for ICE vehicles, allowed free or discount parking for EVs and access to bus lanes.

Table 4-1– Key policy objectives of Norway, Portugal, and Spain

Country	Key policy objectives	Year
Norway	100% EV sales in PLDVs by 2025	2016
Portugal	100 % ZEV sales in PLDVs by 2040	2019
Spain	100 % ZEV sales in PLDVs by 2040	2019

Source: elaboration based on (OECD/IEA, 2019a)

Please note that these Norwegian, Portuguese, and Spanish key policy objectives are planned to be achieved by the implementation of the polluter-pays principle and not via command-and-control regulation, like sales ban for traditional vehicles (Deuten et al., 2020). Thus, EV penetration will be accomplished with a strengthened green tax system (Elbil, 2020).

As already stated, the EV penetration in Europe requires strong political efforts at different vertical governance levels. For instance, at the Supranational level, the bet is made by the emissions penalties for car manufactures, for information on the GHG emission of each vehicle at the time of purchase, and the reinforcement of the ZEV purchase by the State and its strengthened at the national level by economic and non-economic incentives for consumers (Deuten et al., 2020). Please note that other non-economic policy instruments are used to increase the value proposition of EVs, regarding local air and noise pollution benefits of these vehicles, mostly by local governance level.

This chapter begins with a brief conceptualization of the EV support policies adopted at the national and local level and a description of the main economic and non-economic policy instruments, in subchapter 4.1.

Afterward, a brief systematization of the economic and non-economic incentives adopted at the national and local levels by Norway in subchapter 4.1.1., Portugal in subchapter 4.1.2. and Spain in subchapter 4.1.3 for the promotion of electric passenger cars is carried out.

At last, in subchapter 4.2., this chapter ends with a comparative analysis of the policy instruments implemented at the national level between the three different representative European countries to promote electric mobility.

4.1. NATIONAL EV SUPPORT INCENTIVES

The current framework of vehicle and fuel taxation is not prepared for the individual road transport revolution, since are driving to an unsustainable transport system characterized by personally owned cars powered by engines with high negative externalities on society. Thus, a vehicle tax reform should be implemented at the national level in order to achieve the climate objectives defined on the Paris Agreement (Transport&Environment, 2019).

It is important to highlight that environmental and energy security issues mentioned previously have guided national governments to introduce these EV support policies, stimulated by long-term international and supranational objectives for climate change mitigation and energy dependence (Wang et al., 2019).

Even so, most of the European countries are already making progress from their initial phases of EV support policy efforts, which includes, for example: the standards definition; public procurement; charging infrastructure requirements; and economic incentives.

In 2018, 33 European countries (26 within the EU) had a national EV incentive policy for passenger cars (OECD/IEA, 2019a). However, the rhythm increased considerably, between 2010 and 2016, regarding the number of countries offering incentives for electric vehicles (EEA, 2018). Thus, most countries offer policy instruments manly at the national level and these incentives should not be treated as fixed, since governments modify them over time.

Nevertheless, in the majority of these European countries, EV sales remain insignificant, significantly below 2% (Magueta et al., 2018, Rietmann and Lieven, 2019a).

Indeed, the disparities appear in the form and in incentives implemented at the national government level and in EV market shares. Therefore, a cross-national perspective to compare this diversity on policy instruments adopted is valuable to understand their efficacy (Rietmann and Lieven, 2019a).

In agreement with Rietmann and Lieven (2019a), we tried to include the greatest forms of economic and non-economic policy instruments used on EVs diffusion, such as purchase subsidies, tax benefits, import-duty exemptions, tax deductions, free use of fast bus lanes, free parking, access to vehicle restricted areas, exemption or reduction of toll roads and ferries fees.

Nevertheless, we focused more deeply on fiscal measures, their complexity, and significant differences between countries and local governance levels within Europe.

According to EEA (2018), the main incentives and taxes supporting EV penetration can be divided into four different categories: i) acquisition/purchase; ii) company-owned; iii) infrastructure; and iv) recurring (use of the vehicle). Please, find the main car taxes and incentives in **Table 4-2** and **Table 4-3**.

While Rietmann and Lieven (2019a) made their analysis based on consumer perspective, we tried to consider the company's incentives, since they are significant for the European passenger car fleet.

According to IRENA (2019), the financial and fiscal monetary incentives aim to support the EV purchase with a one-time subsidy or with other initiatives to reduce the ownership costs. However, some economic incentives (like income tax credit) differ in the way money is received, since the credit is returned to the EV consumer at the time of the annual tax declaration.

These financial and fiscal incentives are important to address the vehicle purchase decision of individuals or companies and can be the total or partial tax exemption or direct subsidies (Lévay et al., 2017). In 2016, most European Countries employed these fiscal incentives based on emissions to drive the acquisition of low-emission cars.

Therefore, taking into account the initial registration or purchase taxes, there is the tendency to phase out some EV purchase incentives, especially in the frontrunners countries to zero-emissions vehicles mandates and/or regulatory requirements related to fuel economy, and pollutant and greenhouse gas emissions (OECD/IEA, 2019a).

Nonetheless, the initial registration or purchase taxes are still fundamental, while the purchase price of an EV is higher than an ICE vehicle, helping the early deployment of charging infrastructure and ensure a smooth integration of EV charging demands into power systems (OECD/IEA, 2019a). Although in some countries, the purchase incentives have been adjusted from an equity point of view, limiting their application to vehicles.

Table 4-2 - EV incentives - Acquisition, Company, and Infrastructure

	Vehicle Acquisition						Company	Infrastructure
	Vehicle Purchase Tax	**Registration Tax**	**Scrapping Schemes**	**Bonus/Malus Schemes**	**Subsidy**	**Value-Added Tax (VAT)**	**Car taxes**	**Development of Charging facilities**
Description	One-off Tax on purchase tax of a new vehicle	One-off Tax on registration of a new vehicle	Scrap an old contaminating vehicle in exchange for getting a discount when purchasing a new one	Low emitting cars receive a tax cut (bonus) Polluting cars above a certain threshold are heavily taxed (malus)	Subsidy given on purchase	Indirect Tax	Car taxes related to company acquisition and ownership	Government funds for installation of charging facilities for low emissions vehicles
Vehicle/ Energy/ Infrastructure	Vehicle	Vehicle	Vehicle	Vehicle	Vehicle	Vehicle	Vehicle	Infrastructure

Source: Own elaboration based on (ACEA, 2019, IRENA, 2019, EC, 2019e)

Table 4-3 - EV incentives on Recurring (use of vehicle)

	Use of Vehicle and circulation											
				Fuel Excise duty and Electricity tax				Tolls and vignettes				
	Value-Added Tax (VAT)	**Vehicle ownership**	**Vehicle circulation Tax**	**Petrol Fuel Tax - ICE Vehicles**	**Diesel Fuel Tax - ICE Vehicles**	**EU Emission Trading Schemes (ETS)**	**Electricity Tax - non-business use - BEVS + PHEVs**	**Distance-based road charges (tolls)**	**Distance-based road charges (vignettes)**	**Urban road pricing schemes**	**Parking**	**Preferential lane use**
Description	Indirect Tax	Periodic tax on the ownership	Periodic tax on the ownership	Consumption tax on transport fuel	Consumption tax on transport fuel	CO_2 emissions of electricity production	Consumption tax on electricity charged for vehicles	Charge for the passage along the road network	Exemption/Charge for access to road network for a specific period	Charge for using urban roads - congestion and low emission zone	Reduced or Free Parking	Access to BUS lanes
Vehicle/ Energy/ Infrastructure	Energy	Vehicle	Vehicle	Energy	Energy	Energy	Energy	Infrastructure	Infrastructure	Infrastructure	Infrastructure	Infrastructure

Source: Own elaboration based on (ACEA, 2019, IRENA, 2019, EC, 2019e)

In fact, EV high purchase price is seen as the main barrier when buying a new electric car. According to OECD/IEA (2019a), purchasing a standard medium size EV is around 40% more expensive than a traditional ICE vehicle of similar size. Even so, the purchase price does not show the total cost of ownership (TCO), since do not consider the operational costs, making the up-front costs more deeply emphasized (Brand et al., 2013). Normally, consumers do not have enough information, regarding potential fuel, maintenance, and cost savings.

Without a doubt, consumers are not entirely economically rational in their decision behavior and the ones associated with the automotive sector are not an exemption. Or rather, purchase incentives are not successful because of the calculated financial savings, since consumers are unable to do this kind of forecasts, but instead are a consequence of imperfect and biased decisions (Hardman et al., 2017). Consequently, social norms and range anxiety[3] can be an important non-fiscal barrier to EV market penetration (Lévay et al., 2017).

The registration taxes are effective in the EV boost, forcing the European countries to establish their taxes according to CO_2 emissions. This allows the reduced or exempted registration taxes of the ZEV vehicles to be financed by the more polluting ICEV models or through the bonus-malus approach (Transport&Environment, 2019).

Indeed, the zero-emission vehicles should be exempted from registration tax and PHEVs should benefit from a reduction and its value must be between BEVs and ICEVs. It is worth to mention that PHEVs are often driven on their ICE and are hardly charged. On the other hand, penalizing higher emitting cars with really high registration taxes may be unlikely to have a significant environmental benefit, as the sales are really low.

Many European countries have or have had direct subsidies for the EVs acquisition. Normally, when this incentive is given, the strength of EV price competitiveness is weaker, since the vehicle taxation scheme is not so high (Bjerkan et al., 2016). In addition, these purchase subsidies are typically part of government budget to promote sustainable mobility and have a short-term application, since are renewed and revised each year (IRENA, 2019). These purchase subsidies have boosted sales in some European countries (Transport&Environment, 2019).

[3] The fear that a BEV has insufficient range to reach the final destination. Definition of AUTOVISTAGROUP. 2019. *Range anxiety: still a concern or a distant memory?* [Online]. Autovista group: we value the future of mobility. Available: https://autovistagroup.com/news-and-insights/range-anxiety-still-concern-or-distant-memory [Accessed 11.05 2020]..

Nevertheless, as highlighted by Wang et al. (2019), some countries which are offering purchase subsidies are the ones with large automotive makers and local manufacturing plants.

Additionally, countries are using the direct purchase subsidies jointly with the scrapping schemes, which are implemented diversely in the world, but the general idea is to scrap an old contaminating vehicle in exchange of getting a discount or access to a direct subsidy, when purchasing a low emission vehicle (IRENA, 2019).

This policy instrument has consequences since it does not represent a sustainable approach to grow the electric passenger car fleet, leading to its withdrawal and causing the market to stall. In an equity point of view, it is dubious if the governments should be using taxes collected to help citizens to buy any vehicle. In addition, it does the automobile industry dependent on subsidies and its costs and profits might be inflated (Transport&Environment, 2019).

In sum, the fiscal incentives allow consumers to make a vehicle acquisition, based on the improved perceived value of EVs through these policy instruments. Thus, Hardman et al. (2017) believe that consumers are more likely to buy an EV if purchase incentives are available.

Regarding company cars and their incentives, in the Transport&Environment (2019) view, the use of a company car for private purposes can be seen as a tax break for the employee and an indirect subsidy for car manufactures.

At the same time, the company car market is noteworthy in shaping the passenger car market in Europe, since influences the second-hand market and has a long-term effect on the passenger car fleet. Consequently, their taxes are fundamental for shaping the passenger car fleet and should be linked to CO_2 emissions, similarly with registration and circulation taxes. Thus, this category of incentives represents an opportunity for the acceleration of the EV penetration into the mainstream and second-hand markets. Indeed, these company car incentives are not as explored in the literature, as the previous one.

As referred to vehicle recurring incentives, circulation tax is linked to the engine power, cylinder capacity, or fuel consumption. This tax is not so influential in the electric car price, because their payment is on a monthly or annual basis (Magueta et al., 2018), but it represents an opportunity to increase the attractiveness of low CO_2 emissions second-hand vehicles. Nevertheless, the circulation taxes should include an air quality component, concerning air pollution in major cities. As we have seen, the best practices applied to registration taxes also affect circulation taxes (Transport&Environment, 2019).

Regarding fuel taxes, they are able to limit energy consumption in road transport, promote the acquisition of vehicles more energy-efficient, and change drive patterns. This tax is essential for energy security, because of volatility in fuel prices and geopolitical instability in the main oil-producing areas (Magueta et al., 2018). In most countries, diesel is still taxed at lower rates, compared with petrol, although is more energy and carbon-intense (Transport&Environment, 2019).

The electricity taxation has not been adapted so far for transportation and the national rates vary even more than transport fuels. Some utilities are offering different electricity rates for commercial or private customers for charging their EVs, lowering the total cost (IRENA, 2019).

Consequently, some governments are using policy instruments, like fiscal purchase incentives to promote the purchase EV over ICE vehicles. According to Hardman et al. (2017), sales tax exemptions, VAT exemptions and purchase subsidies are the most effective in promoting EVs sales and this effect is superior when the sales tax and VAT are higher for ICE vehicles, which is the case of Norway. So, high revenues from ICE taxation can finance EVs incentive schemes and this type of scenario can last far longer.

Additionally, the incentives should differ between the BEVs and PHEVs. And not only between the high- and low-end BEVs, since the incentives were found to be more imperative at low-end BEVs, but also high- and low electric range PHEVs, which should beneficiated proportionally higher incentives (Deuten et al., 2020).

Presently, in conformity with Magueta et al. (2018), the main fiscal policy instruments used to encourage consumers adopting innovative technologies with decreasing environmental consequences are:

i) Initial registration or purchase taxes;
ii) Circulation or motor taxes;
iii) Fuel taxes.

Accordingly to Sierzchula et al. (2014), economic policy instruments and charging infrastructure has a positive correlation with EV market share. Most of EV consumers find these economic incentives helpful, but consider relevant a sufficient charging infrastructure implemented on highways (Lieven, 2015).

Various national governments provide incentives for charging infrastructure deployment and they originate a variety of policy instruments at the local level within the same country. Most European countries implemented tax deductions, subsidies for private installations, public funding, or even free use of charging infrastructure (Rietmann and Lieven, 2019a). Indeed, charging infrastructure is important for an increasing consumer EV acceptance (Wang et al., 2019)

On the other hand, the non-monetary incentives which are complementary, are able to increase the value proposition of electric vehicles with regulatory measure and to achieve better environmental performance associated with local air and noise pollution. It does the EVs more convenient and cost-efficient and has normally implemented at the local level.

Examples of these policy instruments are: driving permission in restricted areas (like city centers), road toll exemptions or reductions; circulation in reserved lanes for public transport (IRENA, 2019).

Concerning the air and noise pollution and congestion caused by an increase in-car use and sales, a local effort to restrict access in city center or taxes associated to the age of the vehicle is an excellent way of managing traffic and influence the choice of vehicle (Magueta et al., 2018).

Furthermore, parking permission and free charging can help road and congestion charging, since the solution to the urban mobility and planning is to limit available parking spaces in the city centers, increasing the price of parking. The parking fee can be based on the emissions of the vehicle (Transport&Environment, 2019).

As referred to EEA (2018), when the National and Local governments put in place the appropriate incentives, their citizens buy vehicles with lower CO_2 emissions. However, this context can be influenced by other factors, such as the availability of new technologies and economic conditions. Without a doubt, public policies associated with EVs should be carefully designed, avoiding rebound effects and opposing impacts, like increased emissions of other pollutants.

Therefore, as we have seen, taxation and incentives programs differ across several aspects and their effectiveness in reducing CO_2 emissions is related with the number and monetary value of incentive on offer, their position in the vehicle life cycle (acquisition incentives or use of vehicle incentives), type of owner targeted (private individuals or companies) and the type of vehicle chosen to incentivize (efficient conventional engine, hybrid, electric vehicles) (EEA, 2018).

All things considered, purchase incentives should be used until the market penetration is not reached, then should be reduced, taking into account the EV market maturity. In sum, fiscal incentives are able to offer strong incentives to renewal rapidly the car fleet and influence consumer's behavior transition to more fuel-efficient passenger cars (Magueta et al., 2018).

4.1.1. Norway

As demonstrated in chapter 3, Norway has become a global forerunner in electric mobility and is leading the way for a transition to zero-emission in transport (Elbil, 2020). One possible reason for this leadership in the world can be the robust economic and non-economic incentives for promoting the purchase and ownership of BEVs (Bjerkan et al., 2016). Thus, is important to analyze how policy instruments adopted can contribute to the successful adoption of EVs in Norway (Rietmann and Lieven, 2019a). After all, the speed of the low carbon transition is closely connected to policy instruments and a wide range of incentives.

As previously emphasized, Norway has no automobile industry in the country and their fuel price are among the highest in Europe, as opposed to the low-priced electricity with 96% generated from hydroelectric power plants (Figenbaum, 2017). In fact, electricity prices in Norway are between the cheapest in Europe (Wangsness et al., 2020).

Equally important, Norwegian EV incentives exist since the mid-90s and are focused particularly on BEVs. The incentives have started with an exemption on import tax and registration tax for BEVs in 1990, pressed by some enthusiasts who imported the first BEV, through the justification of testing EVs (Deuten et al., 2020). In 1996, this exemption became permanent.

After that, the initial effort has developed under the Oslo municipal, electric utilities fleet, and NGOs efforts in order to test the technology, without any support or criticism from the traditional automotive industry. This pressure made by non-government organizations, namely lobbying, has fundamental to the introduction of incentives (Figenbaum, 2017).

Consequently, lobbying for incentives was well received by politicians, since ICE regime was weak in Norway and the government does not have to reflect on the impact of electric cars on the competitiveness of national car manufactures and employment level lost with this clean transition.

According to Figenbaum (2017), the Norwegian actors were influenced by the 1990 California ZEV mandate, which established an obligation of selling 2% of BEV from 1998, 5% in 2001, and 10% in 2003, to achieve the reduction of local pollutant target and the introduction of decarbonized electricity into the car transportation system, although at the beginning (back to 1990) they were focused in the creation of a Norwegian EV industry and commerce network. Nowadays, the targets changed and they move towards climate policy objectives (Lévay et al., 2017).

The Norwegian road transport sector is profoundly taxed, range from taxes on new vehicles, annual taxes, fuel taxes, and abundant toll roads (Figenbaum, 2017). From the start, the majority of political parties believe that it should always be economically beneficial to choose zero and low emissions cars over high emission cars and this is being achieved through the polluter-pays principle in the car tax system.

In other words, high taxes should be applied for high emission cars and lower taxes for low and zero-emission cars. In this case, taxes on polluting cars can finance incentives for more low carbon vehicles without any loss in government revenues (Elbil, 2020).

This country has also the highest purchase/import taxes on new cars in the world. This can explain why exemptions from purchase tax (1990) and VAT (2001) (currently is at 25%) seem to be critical, revealing that up-front price reduction is the most powerful incentive supporting the EV penetration in Norway. In fact, these incentives allow BEV purchase price to be more or less identical to the price of a traditional ICE vehicle (Bjerkan et al., 2016).

In Norway, the purchase tax for all new cars is obtained based on a combination of weight, CO_2 , and NOx emissions. In recent years, the emphasis is on emission and not on weight. Please note, this tax is progressive, as a result: big cars with high emissions are very costly (Elbil, 2020).

This car tax system makes most BEVs models cheaper to buy compared to similar petrol models, even when the import price for EVs is much higher. That is why, for Elbil (2020), the Norwegian EV market is so successful compared to any other country. Indeed, incentives reducing the purchase price have been the most effective in boosting the diffusion of EVs, compiling with the idea that European markets with substantial incentives are the ones with larger market shares comparing with those with less or no incentives (Figenbaum, 2017).

On top of that, since 1990 BEVs are exempted from vehicle registration tax, adding more significant savings. However, with regard to EVs as a whole, PHEVs are not considered in this taxation scheme, but its total tax value is relatively low, in agreement with their CO_2 and NOx emissions (Bjerkan et al., 2016).

In addition, BEVs have the lowest rate of the vehicle license fee. This exemption does not give so much savings, but are cyclic (Bjerkan et al., 2016). From 1996 until 2016, BEVs benefited from a reduction in circulation tax. To illustrate, in 2016, BEVs paid 50€ on fees, instead of 350-410€ paid by traditional cars.

In sum, these various fiscal incentives made EVs cost competitive in comparison to ICE vehicles, having a great impact on EV sales (Lévay et al., 2017). Interestingly, the very first BEV imported to Norway in 1990 benefited from import and registration tax exemptions through imposition. Twenty-six years later, the ICE high tax combined with EVs exemption became a prerequisite for BEV market expansion. Additionally, the VAT exemption was introduced to reduce BEV's price disadvantage, led in 2013 to a price advantaged. Indeed, tax reductions have gradually evened out the price difference between the two powertrains, creating a cost advantage since 2013 (Figenbaum, 2017).

Since 1997, there are government incentives for the deployment of home and public charging infrastructure (Deuten et al., 2020). Regarding the charging habits in Norway, the EV owners normally charge at home and they do not rely on fast charging daily, but EV consumers believe to be essential having the option of fast charging when required. Consequently, a well-organized charging network has to be done for long-distance trips in Norway, even with a three times more expensive charge (Elbil, 2020).

This can be explained, since the majority of Norwegians (around 73%) live in row houses, family homes, detached and semi-detached houses, allowing in-house charging change. With this in mind, seems that normal recharging infrastructure was not critical for the purchasing of a EV so far, although a fast one might be more relevant (Bjerkan et al., 2016). Additionally, the majority of households have a sufficient power capacity to charge EVs, as a result of their heating features (74% are electric) (Figenbaum, 2017).

Trying to accomplish that, the Norwegian Government launched in 2017, a program to finance the creation of at least two multi-standard fast charging each 50 km on all principal roads in Norway. In addition, in 2016, Norway implemented a Regulation with the requirements for charging infrastructure in new buildings and parking lots and for parking lots and areas a minimum amount of 6% to EVs (EAFO, 2020). However, until now, EVs are used as a second family car, due to range limitations and charging infrastructure low deployment.

Finally, since 1997, exists other financial exemptions linked with road tolling, ticket fees on ferries, and free parking on municipal public parking established initially by national law (Bjerkan et al., 2016). Meanwhile, in 2017, the local governments started deciding the incentives, regarding access to bus lanes and free municipal parking. In fact, the Norwegian Parliament implemented the 50% rule, making the municipalities do not charge more than 50% of the price for fossil fuel cars on ferries, public parking, and state ferries. However, a 50% rule on toll roads was just applied in 2019, and taking into account the parking fee, this will be implemented from 2019 onwards (Elbil, 2020).

To summarize, Norway has a long-term policy of relevant tax exemption, including vehicle acquisition, ownership, reduced toll, ferry and parking fees, and charging infrastructure. For this reason, in 2016, Norway had the lowest average CO_2 emissions from new cars in Europe, approximately 93 g CO_2 /km (EEA, 2018).

With regard to the replicability of the successful Norwegian case to other European countries, some measures can be adopted but must be adjusted to their circumstances. The power of the economic incentives is due to the high level of vehicle taxation. Thus, in the case of lower vehicle taxation regimes, the results would not be the same (Bjerkan et al., 2016).

Please note that Norwegians do not benefit from a direct cash acquisition subsidy, as it has been paid in other European countries. Consequently, these subsidies open the door for business opportunities. Indeed, the majority of second-hand vehicles bought between 2017 and 2018 in Norway were imported from countries where buyers received substantially cash subsidies: Germany, USA, Sweden, South Korea, France, Belgium, Italy, United Kingdom, Spain, and Romania (Elbil, 2019).

At the same time, one factor that seemed fundamental to EV diffusion was the fair board support across the Norwegian political parties. Although, they were criticized since EV incentives can be seen as an incentive for the wealthiest in society. This happened because of the EV owner profile: higher educated and higher income, compared to the general population and ICE owners (Bjerkan et al., 2016).

Currently, these zero-emission car incentives will be applied until the end of 2021. After that, the incentives will be revised and adjusted based on market maturity (Elbil, 2020). However, in 2017, BEVs incentives have been downsized gradually, trying to avoid any setback. These laws and regulations without end dates made at the national and sometimes at the local level permitted the creation of a long-term stable framework supporting electric mobility (Figenbaum, 2017).

In sum, various aspects influenced the successful diffusion of EVs in Norway and especially significant economic and non-economic incentives offered at national and local government, summarized in **Appendix C**, **Table C-1**. Nevertheless, one important factor for this leadership was the collaboration between diverse actors, as national and local governments, companies, and organizations.

4.1.2. Portugal

The transport sector is characterized by the highest energy intensity and the largest indirect contribution to primary energy imports and energy dependence-related. In 2016, Portugal had the lowest average CO_2 emissions (105 g/km) in the European Union, plus Norway, Iceland, and Switzerland EEA (2018). Although air pollution emissions were reduced, due to the introduction of catalytic converters and cleaner fuels. Additionally, vehicle taxes are intensely discriminated according to CO_2 emissions, few passenger cars are bought new and are smaller than the EU average (Magueta et al., 2018). Therefore, unlike Norway (10,5 years), the average age of the passenger car fleet in Portugal is higher (12,9 years in 2018) (Autoalan, 2020).

The automotive industry in Portugal constitutes an important pillar of the Portuguese economy, contributing strongly to national GDP. Additionally, automobile component manufacturing is the most representative sector in this industry, continuing to generate jobs and exporting 84 percent of its production (AICEP, 2016).

Consequently, Portugal believes that road transport will face a revolution within the next years, with the use of low-emission solutions for urban areas and proactive use of public transport systems, stimulating the expansion of networks and multimodal integration (RNC2050, 2019).

In this context, mobility electrification based on renewable energy will soon face a rapid transition from conventional ICEV to EVs. According to RNC2050 (2019), hybrid vehicles can play an important role in the decarbonization of individual transport in a transitional phase, but electricity will be responsible for 30% of light passenger transport mobility demand in 2030, with a potential to reach 100% by 2050 and stimulated by share and/or autonomous mobility forms

Portugal has introduced green taxes to support the introduction of low-emission vehicles, relatively early, in 2007. However, the Law no 22-A/2007, June 29th allowed EVs to benefited from an exemption of the environment component of Registration Tax (Imposto sobre veículos – ISV) and the exemption from the annual road tax (Imposto Único de Circulação – IUC) (Magueta et al., 2018).

Later, in 2009, Ministries Council Resolution nº 20/2009 and Ministries Council Resolution nº 81/2009 created the Mobi.E. program (Program for Electric mobility), in order to introduce and support the EV penetration in Portugal by the deployment of an innovative system which included electric grid supervision (Magueta et al., 2018) (Table).

Consequently, in 2013, Ministries Council Resolution nº 20/2013 initiated several energy efficiency measures, which symbolized an update of the National Energy Efficiency Action Plan (NEEAP 2013-2016) and where the transport sector was included: with the promotion of the acquisition of EVs (Magueta et al., 2018, IEA, 2016).

Shortly, in 2014, the "Green Taxation" legislation (Law no 82-D/2014, December 31st) has been implemented, called the Eco-car program (IEA, 2016). This legislation allows the establishment of new incentives for BEVs and PHEVs, including car tax reductions and even purchase incentives.

Here, BEVs are exempted from Registration Tax, as well as Circulation Tax. Please note, that only PHEV have to pay 25% of the registration tax and pay the annual road tax like any other car, there is no reduction, discount, or tax benefit (Magueta et al., 2018, impostosobreveiculos.info, 2020, UVE, 2020c).

The Eco-car program includes also a component centered in the construction and upgrading of the existing charging infrastructure for EVs, including the Mobi.E program (Magueta et al., 2018). Please note that the Mobi.E pilot charging network was free, until 2020. However, there are still free charging stations, often located in commercial spaces, parking lots, restaurants, where the owners offer the charging to their customers (UVE, 2020b).

Exclusively for companies, BEVs are exempted from Autonomous Taxation[4] (Tributação Autónoma) under IRC[5] and VAT (Imposto sobre o valor acrescentado – IVA) - Value Added Tax (VAT) is deductible (with a maximum total car sale price of €62 500) (UVE, 2020c, impostosobreveiculos.info, 2020). On the other hand, PHEVs benefit from an Autonomous Taxation reduction, up to € 25,000 pay 5% instead of 10%, between € 25,000 and € 35,000 pay 10% instead of 27.5% and over € 35,000 pay 17.5% and VAT is also deductible, but with a lower total car sale price maximum of €50 000 (impostosobreveiculos.info, 2020).

In the past, from 2000 to 2010, Portugal had an initiative aiming the increase of vehicle replacement through new acquisitions. In 2014, this program was replaced by the incentive of the end-of-life vehicle slaughter program (Incentivo ao Abate de Veículos em fim de vida), which add a new requirement for a new car, demanding low-emission vehicle. The main idea was to remove vehicles with more than 10 years and replace them with less polluting cars (Magueta et al., 2018).

In 2016, Portugal created an incentive for the acquisition of low-emission vehicles without the necessity to deliver an old vehicle (Incentive for the Introduction of Low Emission Vehicle Consumption - Incentivo pela Introdução no Consumo de Veículos de Baixas Emissões – Decree-Law no 42- A/2016) – especially implemented to BEVs and includes light-duty vehicles, heavy-duty vehicles, mopeds, motorcycles and bicycles- financed by Environment Fund (Fundo Ambiental), which is the successor of Portuguese Carbon Fund. The amount changes every year, as well as their requirements. For 2020, Dispatch nº 3169/2020, the value of the incentive for individuals is € 3 000 (for a maximum of 1 passenger car unit) and for companies, it is € 2 000 (for a maximum of 4 passenger car units). This subsidy is limited to 700 units for private owners and 300 units for companies. The selection process is associated with the time of application. In addition, the maximum total cost of the BEV must be up to € 62 500 (UVE, 2020a).

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[4] In addition to the general IRC, autonomous taxation is applied to certain expenses of Portuguese Corporate Income Tax taxpayers. Please note that expenses with passenger vehicles with the acquisition cost between €25 000 – €35 000 have to pay an extra tax of 10%-35%. AICEP. 2020. *Invest in Portugal: Fiscal System* [Online]. AICEP Portugal Global: República Portuguesa. [Accessed 22.04 2020].

[5] Imposto sobre o Rendimento das Pessoas Coletivas (IRC) – Portuguese Corporate Income Tax - is a tax levied on profits derived by both resident and non-resident entities.

With regard to the fleet of State passengers cars (Public Administration), Portugal has the Electric Mobility Support Program in Public Administration (Programa de Apoio à Mobilidade Elétrica na Administração Pública - PAMEAP) which aims to promote decarbonization and improve the environmental performance of the State Vehicle Park, in line within the Program for Sustainable Mobility in Public Administration 2015-2020 - ECO.mob (FundoAmbiental, 2019).

This program includes the financing of electric vehicle acquisition and support for the acquisition of charging points and the respective georeferencing and monitoring systems. Please note that these entities have to possess a light vehicle with more than 10 years old to slaughter for each electric vehicle applied and the limit is two vehicles per Municipality (FundoAmbiental, 2019).

PAMEAP finances 50% of the expenditure (including VAT) with the rents of the purchased EVs, under an operating and financial lease regime over a period of 48 months and 50% of the acquisition and installation of charging stations, up to a maximum number of chargers equal to the number of vehicles assigned to each entity and up to a limit of € 2,000 per station, in the case of conventional chargers, or € 4,000 per charger, in case of semi-fast charging point (FundoAmbiental, 2019).

Regarding parking, at local level, there are several Portuguese municipalities which have implemented benefits for electric vehicles, including discounts (Beja, Funchal, Guimarães, Lisboa, Loures, Mirandela, Oeiras, Oliveira de Azeméis, Póvoa do Varzim, Ribeira Brava, Setúbal and Vila Real) or exemptions (Funchal for PHEVs and Porto) from parking on public roads (UVE, 2018, UVE, 2020c).

Taking into account the traffic restrictions access, some Portuguese cities have traffic restrictions in order to reduce air and noise pollution. However, 100% electric vehicles are often allowed, since are an exception of restrictions. Particularly, in Lisbon, from August 2020 onwards, traffic restriction rules will be applied in the Baixa-Chiado and Avenida da Liberdade (called ZER - Reduced Emissions Zone), 100% electric vehicles are the exception and their circulation is allowed (UVE, 2020c, UVE, 2020b).

Consequently, Magueta et al. (2018) highlight the main policy instruments in place in Portugal, which are affecting mostly the price of the new passenger cars:

- Registration tax;
- Circulation Tax;
- Fuel Taxes;
- Subsides in the acquisition of EVs.

In sum, Portuguese green taxes have a positive impact on EVs car sales, especially BEVs which benefited more from purchase and ownership incentives compared to PHEVs, resulting in an exponential increase, since 2010. As we have seen, these tax incentives can explain the short-term trend of growth in EV market penetration.

In accordance with we have been saying, Portugal has relatively high purchase taxes (>30%), which include CO_2 emission component, when comparing to other EU member states. This represents one possible explanation for the relative success of 2014 car tax reform, since lower car taxes and higher monetary benefits associated with the EVs acquisition, result in income savings. Additionally, as referred by Magueta et al. (2018), increased availability of EV car models may also explain the behavioral change and sales growth, combined with where the citizens live, since they prefer to buy an EV for the daily moves in the major cities. The main economic and non-economic incentives offered by Portugal are summarized in **Appendix C,** in **Table C-2.**

4.1.3. Spain

The situation in Spain is completely different from Norway and Portugal since the automotive industry is really important in this country. This sector has a considerable contribution to the Spanish GDP, since the country is the second-largest manufacturer of automobiles in Europe, exporting 89% of the vehicles manufactured.

Therefore, the dominance of this sector and their lobbying groups may difficult and slow down the EV adoption process, since the stakeholders and the political and economic challenges add obstacles and complicate the collaboration between various interest groups involved in EV promotion.

Nevertheless, the transport sector in Spain remains the main contributor to energy consumption, as we have seen in Norway and Portugal, representing 39% of total national consumption. It is worth mentioning that, the passenger cars alone represent approximately 15% of the total final energy consumed in Spain (IDAE, 2020). In addition, Spain, like Portugal, has an aged passenger car fleet with an average of 12,4 years. Thus, Spanish incentives associated with the demand for electric passenger cars could send a clear message to car manufacturers to do not fall behind.

In 2010, the Spanish Government created the action plan: *Estrategia integral para el impulso del vehículo eléctrico en España* 2010-2014 - Comprehensive strategy to promote electric vehicles in Spain -, in order to reach the planned targets of 250 000 EVs (BEVs and PHEVs) in 2014, accomplishing only 2 835 passengers cars at the end of 2014 (Sanz, 2016). The promotion and development of the electric car was part of the Sustainable Economy Strategy adopted by the Spanish Government.

This Plan was proposed to act along with four main areas: i) the promotion of demand, ii) industrialization programs to promote the development and industrialization of electric vehicles in Spain, iii) promotion of charging infrastructure and demand management and iv) cross-cutting programs (actions communication and marketing, regulatory aspects, professional training, etc.) (Energiaysociedad, 2010).

In this way, the Spanish government created diverse state plans for the purchase of electric vehicles from 2010-2019: i) MOVELE 2014; ii) MOVELE 2015; iii) MOVEA Plan 2016; iv) MOVEA Plan 2017, v) MOVALT Plan 2017, and vi) MOVES Plan 2019. However, until 2019, all of these national plans had a very limited budget, quickly exhausting incentives to purchase for the most varied EVs (motorbikes, buses, and trucks).

All these plans are part of the scope of the EU Directive 2014/94/EU of the European Parliament and the Council of Europe of October 22, 2014, which establishes that member states must develop a specific National Action Framework to implement alternative energy in transport and its related infrastructure, within the European agenda for a cleaner, safer and more connected mobility and its Clean Mobility Package (IDAE, 2019).

These were coordinated by the Institute for the Diversification and Saving of Energy - Instituto para la Diversificación y Ahorro de la Energía – IDAE -and are managed by the autonomous communities and cities, which must make calls in their respective territories for the distribution of the amounts that have been assigned to them and distribute the aid between the final beneficiaries.

The latest Spanish incentive plan for electrical penetration - MOVES Plan 2019 - stood out with a higher budget, reaching 45 million euros. After one year with no state plan related to EVs, MOVES Program 2019 appeared with a different configuration and a higher maximum purchase price before taxes (€40 000 or 45,000 euros if the buyer is a person with a disability or a large family) (ElMotor, 2019).

Indeed, on purchase of any electric vehicle, the public subsidy must be added with the discount that the car manufacturer is obligated to do and, in addition, other State aid that covers part of the installation of the recharging point (in the previous plan the dealer had to provide it), so the sum may be the highest awarded so far, depending on the type of vehicle chosen.

To apply for current aid, EV buyers must request it before buying the vehicle or installing the charging infrastructure (ElMotor, 2019). BEVs, PHEVs, and FCEVs are subsidized up to €5 500 euros, depending on autonomy (350 km).

Regarding the aid for the installation of charging points is 30% for private companies and 40% for individuals, communities of owners, and public entities without commercial or mercantile activity.

While previous calls for aid for sustainable mobility ran out in a few hours, this new plan has not been exhausted, since the vehicle consumers must scrap a vehicle that is more than 10 years old, which has owned for at least one year (Autopista, 2020).

In fact, this obligation complicated the adhesion to the MOVES Plan 2019, because are the companies and public organizations that purchase the majority of electric cars on a rental basis and cannot cancel any car in return (Autopista, 2020).

In sum, these plans were unambitious and not structural like in other European countries, where aid is fixed and does not depend on stationary plans. Indeed, the lack of continuity of funds produces a strong seasonality in the acquisition of electric vehicles.

On the other hand, *Plan Programa de Incentivos al Vehículo Eficiente* 2016 (PIVE-8) had a budget of € 225 million, in order to encourage the sale of more efficient vehicles, as BEVs, PHEVs, and also diesel and petrol cars and whose theoretical purpose is also to reduce emissions from the most polluting vintage cars. Please note that this action plan had eight last versions (Movele, 2020).

With regard to purchase taxes, the registration tax - Impuesto de Matriculación - is exempted, due to the way this tax is calculated based on CO_2 emissions. Thus, BEVs and PHEVs are completely exempted (Nissan, 2020b). Alternatively, BEVs are not exempted from circulation tax or annual road tax - Impuesto sobre Vehículos de Tracción Mecánica (IVTM) -

, but can benefit from a reduction up to a maximum of 75% on the fuel that consumes the vehicle and it is designed at the local level, so it depends on the Autonomous Community (Nissan, 2020b).

Concerning the VAT, there is no benefit for EVs, so they are taxed at the standard rate of 21% (Nissan, 2020b).

As a referend to parking, in many Spanish cities, electric cars can park for free and without a time limit, as is the case in Madrid and Barcelona among others. The power over parking in regulated areas is at the local level (Nissan, 2020b). At the same time, in Madrid, BEVs will have a preference in the use of reserved loading and unloading places (Nissan, 2020a).

Regarding access to areas with traffic restrictions, defined at local level, BEVs are exempt from the restriction of access to the Central Area in Madrid (Nissan, 2020a).

Additionally, Madrid Plan A will allow the use of BUS-VAO[6]-ECO lanes by BEVs and PHEVs (Nissan, 2020a, autofacil, 2019).

Concerning the tolls exemption or reduction, defined at local levels, BEVs and PHEVs were fully exempted until 2019 in Catalonia. However, in 2020, BEVs and PHEVs benefited from toll reduction up to 75% and 30% respectively (Movilidadeléctrica, 2020).

All things considered, Spain has more or less the same economic and non-economic incentives, but of the three representative countries, it is the one that has the most favored PHEV - hybrid technology. **Appendix C** provides an overview of the policy instruments adopted in Spain to promote the dissemination of EVs, in **Table C-3**.

[6] The BUS-VAO lanes are sections of track reserved for buses and vehicles that transit with two or more people inside. Cars with a zero environmental mark can circulate with a single occupant. They are 100% electric and plug-in hybrids with a range of electric range greater than 40 kilometers. The autonomous authorities are responsible for regulating their traffic.
AUTOFACIL. 2019. *¿Qué vehículos pueden circular por el carril bus-VAO?* [Online]. Available: https://www.autofacil.es/movilidad/restricciones-de-trafico/2019/04/05/vehiculos-circular-carril-bus-vao/49560.html [Accessed 12.05 2020].

4.2. DIFFERENCES BETWEEN NORWAY, PORTUGAL, AND SPAIN IN THEIR EV SUPPORT POLICY

Table 4-4 – Overview of EV support policies in Norway, Portuga,l and Spain

EV SUPPORT POLICIES	Norway	Portugal	Spain
Vehicle Acquisition			
Exemption or reduction on **import taxes**	✓		
Exemption or Reduction from **registration costs**	✓	✓	✓
Purchase Subsidy		✓	
Purchase Subsidy combined with a **Scrapping Scheme**			✓
Exemption or reduction from **VAT**	✓		
Recurring or Use of Vehicle			
Exemption or reduction on **circulation taxes/annual road tax**	✓	✓	✓
None or reduced **charges on toll roads**	✓		✓
None or reduced **charges on ferries**	✓		
None or reduced **charges on municipal parking**	✓	✓	✓
Access to bus lanes	✓		✓
Access to restricted traffic zones		✓	✓
Driver license class B allows to drive electric vans class C1 up to 4250 kg	✓		
Company incentives			
EV purchase incentives for companies	✓	✓	
State passenger car fleet incentives			
EV purchase incentives for public administration fleet		✓	
Charging Infrastructure			
Subsidies	✓	✓	✓
Programs	✓	✓	

Source: Own elaboration

Nowadays, the EV market penetration is dependent on government support in the EV acquisition, ownership, and in the availability of charging infrastructure. As we have seen before, economic and non-economic incentives have helped the EV sale boost in some European countries (especially at the Nordic region) and have been implemented at different vertical governance levels: international, supranational, national, and local (regions and cities). After all, the evolution of policy incentives differs according to local conditions.

It should be noted that Norway has a passenger car fleet with a lower average age (about 10.5 years in 2018), while Portugal (12.9 years) and Spain (12.4) have an older car fleet that implies greater fuel consumption and therefore, higher CO_2 emissions (Autoalan, 2020). Additionally, electricity price in each country is also a determining factor, as Norway has one of the lowest prices in Europe and is produced mostly from renewable sources - hydroelectric. The same is not true in Portugal and Spain, which have one of the major tariffs **(see Figure 5-23 in the next chapter).**

As shown in **Table 4-4**, the financial and fiscal incentives implemented in Norway offer tax benefits or reductions/exemptions to EVs, while are increasing tax costs associated with ICE vehicles. It is important to note that the success of the electric vehicle incentive policy in Norway is partly due to the high level of taxation associated with the vehicle purchase, that is: import and registration tax. Thus, its registration tax exemption makes BEVs more attractive, compared to PHEVs, which only receive a reduction. These acquisition taxes are particularly high when compared to Portugal and Spain, making these incentives in Norway more effective.

In Portugal, BEVs are also exempt from registration tax, and PHEVs benefit from a 75% reduction. In Spain, BEVs and PHEVs are both exempt from registration tax, since the criteria are related to emissions up to 120 g/km of CO_2. As you can see, in the registration tax, Spain is the country with the highest level of incentive, since offers the exemption both to BEVs and PHEVs, unlike Portugal and Norway, which only provide an exemption for BEVs.

Though, in some countries like Portugal and Spain, they have introduced one-time subsidies for EV purchases. However, the implementation schemes differ, as in Spain, in the last incentive plan - MOVES Plan 2019 - for electric mobility, it was necessary to scrap a vehicle over 10 years old that has been in the owner´s property for at least 12 months. In Portugal, there was this requirement for the allocation of the incentive, but it has already been withdrawn. On contrary to previous plans, this aid has not been exhausted in some Spanish autonomous communities, since many agents who bought these vehicles before were on leasing modality and therefore did not have any vehicles to give in exchange.

It is important to highlight that the subsidy amount given in Spain is much higher (up to € 5 500 for BEVs) and also includes PHEVs (€ 2 600). In Portugal, it is only for BEVs and the value differs if it is for a company (€ 2 000) or a private individual (€ 3 000). It should be noted that the maximum purchase price for these vehicles can also benefit from this subsidy, it differs between Portugal (BEVs – € 62 500 after taxes) and Spain (BEVs € 42 800[7] after taxes – the Canary Islands, Ceuta and Melilla and € 48 400 for other autonomous communities). As you can see Portugal allows a higher price for electric cars to benefit from the subsidy.

As previously mentioned, this leads to free-rider behavior in countries that do not offer this incentive in the second-hand market, as is the case in Norway. Please take into consideration that Norway does not have this kind of economic policy instrument.

In addition, Norway also offers a VAT exemption (25%) for new and second-hand vehicles, which currently allows BEVs to be competitive against ICE petrol and diesel vehicles. In 2015, extended this exemption also to BEVs under leasing. In the case of Portugal, there is no exemption from VAT. However, in the case of companies, these are exempt from autonomous taxation in the case of BEVs, while PHEVs are liable to pay autonomous taxation, but in a reduced amount - up to € 25 000 pay 5% instead of 10%, between € 25 000 and € 35 000 pay 10% instead of 27.5% and over € 35 000 pay 17.5%. VAT is deductible if the vehicle price value after taxes is up to € 62 500 for BEVs and € 50 000 for PHEVs. Alternatively, in Spain, there is no VAT reduction or exemption for individuals or companies.

The VAT is particularly relevant, as it represents 25% of the sale price in Norway, 23% in Portugal, and 21%, and 7% (because of IGIC for the Canary Islands, Ceuta, and

[7] This is because these regions are subject to a 7% tax rate - *Impuesto General Indirecto Canario* (IGIC) - Canarian Indirect General Tax - for being on the islands, while the rest of the territory is subject to VAT - 21% .

Melilla) in Spain. Again, the incentives given in this category are higher in Norway, followed by Portugal and finally Spain without any assistance.

In addition, as can be seen in table 4-9, Portugal and Norway have incentives for the EV fleet of companies that is particularly important in Europe. In the case of Norway, they offer a tax reduction of 40% on the company use tax and VAT exemption in the leasing regime, which is particularly relevant for companies. Portugal also offers special conditions for VAT on companies. Spain only differs its incentives for companies in the case of incentives given for the charging infrastructure deployment (aid of 30% for private companies and 40% for individuals, communities of owners, and public entities without commercial or mercantile activity).

In brief, these economic incentives associated with the acquisition of the vehicle will be less important, as soon as EVs become cost-competitive with an ICE vehicle. However, as mentioned in the literature, these incentives have been considered the most impactful in EV promoting in this EV penetration initial phase, since most consumers do not take operational and maintenance costs into account in their purchase decision. It is vital to emphasize that in some countries, there is already a reduction in these purchase/acquisition incentives, according to the maturity of their EV stock in the passenger car fleet and of the EV technology experience.

Regarding the use of the vehicle, that is recurring charges, for the annual circulation tax is given a reduction or exemption for both Norway, Portugal, and Spain. In the case of Norway, this tax is based on the type of fuel and both BEVs and PHEVs benefit from a reduction and pay a minimum amount around € 50, instead of € 350-410. In Portugal, BEVs are fully exempt and PHEVs have to pay the equivalent of an ICEV. In Spain, the amount depends on the autonomous community in which the car is registered. In the case of the Madrid community, BEVs benefit from a reduction of up to 75%, while PHEVS have to pay the same as ICEVs. In this circulation tax, it seems that Portugal and Spain are benefiting BEVs more, insofar as Norway gives an equal incentive to BEVs and PHEVs, contrary to Spain and Portugal.

Therefore, it should be noted that while this circulation tax is levied at the national level, such as Norway and Portugal, this tax is levied at the local level, by Autonomous communities in Spain, making its level of taxation may vary within its territory.

Furthermore, non-fiscal or non-economic incentives have been used as a way to improve the EV value temporally, providing the access to bus lanes allowing EV consumers to avoid traffic jams, pay fewer toll roads and ferries, or giving access to restrict areas, like the city's centers. These incentives are implemented at the local level but are sometimes regulated at the national level.

In Norway, the national government created a special E-Number plate for EVs that gives local authorities the option to select the local incentives such as free parking, using bus lanes. Consequently, since 2016, Norwegian local authorities determine fees and exemption categories, producing different local regulatory frameworks.

In the case of the reduction or exemption of toll roads, Norway and Spain (only in the autonomous community of Catalonia) offer these incentives and Portugal does not. However, in the case of Norway, the incentives are higher, as it embraces urban and highway tolls roads exemption. Though, since 2019, BEVs have to pay toll fees, but a low one. In Spain, only in Catalonia Autonomous Community, BEVs benefit from a discount up to 75% and PHEVs up to 30%.

Regarding the exemption on ferries, Norway offers free access on most ferries that are connected to the national road network. Although on local road networks, local governments decide the ferries fee value. Unlike Norway, Portugal, and Spain do not have such incentives.

Considering the parking fee, PHEVs and BEVs benefit from exemption or reduction of the parking fee in Norway, Portugal and Spain, despite they differ strongly by the municipality (local level).

As referred to access to bus lanes, Norway allows free access, but several bus corridors are experiencing regular congestion during rush hour. In this manner, Oslo municipality granted access to the bus lane on two specific corridors during rush hours only to electric cars with two or more persons on board. In Spain, particularly in the Madrid Autonomous community, PHEVs and BEVs can circulate with a single occupant on BUS-VAO lanes. By contrast, Portugal has no such incentive.

Additionally, regarding access to restricted areas implemented at the local level, Spain and recently Portugal, have this type of incentive. However, in Norway, to our knowledge, there is no such incentive.

Last year, Norway started allowing Driver license class B to drive electric vans class C1 up to 4250 kg. This measure has not yet been adopted by Portugal and Spain so far.

With regard to the passenger car fleet owned by Public Administration, Portugal has created a program that assists the acquisition of BEVs and the installation of charging points. This program is particularly interesting because it only allows financing for vehicle purchases with the scrap of a vehicle over 10 years old. It is about revoking the fleet, but with a cleaner vehicles clause. To our knowledge, Norway and Spain do not have specific programs for the state fleet.

Finally, in reference to charging infrastructure, Norway has public funding to install fast-charging point every 50 km on main roads and regulations associated with new buildings and its parking lots and areas. In the case of Portugal, it also has incentive programs for the charging infrastructure, named Mobi.E Program. In the case of Spain, there does not seem to be an exclusive program for the charging infrastructure, but the annual programs finance a considerable percentage of the installation of the fast and slow charging points.

In conclusion, incentives associated with electric mobility vary greatly between the three representative countries. As can be seen, Norway has the greatest incentives associated with the vehicle purchase but with tax benefits and not direct subsidies, since it allows VAT exemption and ICEV vehicles are much more taxed in this country. In addition, Norway uses several non-economic incentives implemented at the local level that increase the advantages of this type of vehicle. It is also the country that has the most benefits of this type compared to the rest.

Portugal and Spain have more or less the same type of economic and non-economic incentives. Although, Portugal benefits companies more by allowing exemption from autonomous taxation and VAT deduction, unlike Spain which does not have any VAT measure. In addition, Portugal it has no benefit with regard to tolls in Spain it has only in the autonomous region of Catalonia.

As opposed to Norway, Portugal and Spain have a measure that Norway does not adopt, relating to a direct purchase subsidy implemented annually. It should be noted that Spain offers a much higher subsidy, also including PHEVs. Portugal offers a timid subsidy just for BEVs. This seems to be in keeping with the authors Wang et al. (2019), who claim that the countries that have a large preponderance of the automobile industry use strongly this kind of policy industry, also benefiting PHEVs, which are a hybrid technology with a conventional part vehicle part – ICE. Consequently, Portugal and Norway distinguish more the acquisition incentives for BEVs, compared to PHEVs paralleled to Spain.

4.3. CHAPTER CONCLUSIONS

As we have seen with the comparison and analysis of policy instruments implemented on EV promotion, between Norway, Portugal, and Spain, noteworthy differences occur in terms of kind, variety, and availability of economic and non-economic incentives adopted at the national and local levels. Please note that all these European countries benefited from an international and supranational level pressure that helps EV promotion, even when the countries are not the UE Member States but part of the European Economic Area, as Norway.

Indeed, in order to accomplish a more widespread EV adoption is important to implement combined policy support with a mix of policy instruments. These policy instruments have an impact on EV market shares and consequently on EV share in the total passenger car fleet.

In fact, economic incentives as purchase subsidies and tax benefits may offer an initial stimulus to purchase an EV instead of ICEV. In this manner, Norway has great incentives for the acquisition of BEVs such as exemption from import, registration, and VAT and tax benefits for PHEVs. Portugal is in an intermediate situation with exemption from registration tax and benefits associated with VAT for companies and Public Administration for BEVs. Once again, BEVs are much more benefited in these countries, compared to PHEVs, which gained only reductions on acquisition taxes. In this case, Spain also provides an exemption from registration tax, however it is subject to both BEVs and PHEVs.

In addition, Portugal and Spain offer direct purchase subsidies annually for the acquisition of BEVs, but in the case of Spain at a much higher value and also including PHEVs, but with a lower selling price. This seems to indicate that the countries where the automotive industry is more relevant, purchase subsidies exist, and are superior, still benefiting hybrid technologies – PHEVs - that partially include ICE engines.

Furthermore, Norway and Portugal, as opposed to Spain, have more measures associated exclusively with the promotion of the electric fleet in companies, since they represent a significant part of the total vehicle fleet. Particularly, the last Spanish annual incentive program - Moves Plan 2019 - required the scrapping of a vehicle over 10 years old in the owner's property for at least 12 months to receive the purchase subsidy, which made it difficult for companies that have their fleet mostly in the leasing regime.

As regards the recurring economic incentives associated with vehicle use, such as the annual circulation/road tax, Norway offers an equal minimum payment for BEVS and PHEVs and in the case of Spain and Portugal, PHEVs pay the same as an ICE vehicle, while BEVs are exempt in Portugal and pay a residual value in Spain. It should be noted that this tax in Spain is defined at the local level and therefore varies drastically at the national level, as we took the autonomous community of Madrid as an example.

Finally, when considering the non-economic incentives that are associated with the use of vehicles and that increase the EV proposition over time, they are usually defined at the local level. These are complementary to tax benefits implemented at the national level, reinforcing national EV support policies. Again, Norway has a wider range of local incentives, such as discounts or exemptions for toll roads, ferries, municipal parking, access to bus lanes, and even the fact that a driver license class B allows driving electric vans class C1 up to 4250 kg. Portugal and Spain have far fewer initiatives of this type, but allow EVs to access areas with restricted traffic in their capitals.

Regarding charging infrastructure, the national governance level should support a sufficient deployment of the network. Norway and Portugal have specific programs for the charging network, while Spain benefits from annual programs to encourage electric mobility. Nevertheless, national governments should emphasize a long-term perspective as Norway and not focus on short-term instruments such as annual programs implemented each year by Portugal and Spain.

One other important factor in EV penetration is the automotive industry dominance or not, illustrated here by Spain and Norway's case, because their lobbying groups can complicate the EV promotion and jeopardize the collaboration between actors. Consequently, some national measures can be contra-productive, since are supporting these industry interests.

In summary, the collaboration between national and local agents, car manufactures, importers, electricity producers, grid operators are fundamental, as have been happening in Norway on EV promotion.

CHAPTER 5 - IMPACTS ON GOVERNMENT REVENUE WITH INCREASED EV PENETRATION IN THE PASSENGER CAR FLEET IN SPAIN

As we have seen in Chapter 4, transport taxes differ across means of transportation, commercial or personal use of vehicle, energy efficiency, and other environment performances and represent a significant part of government revenue (OECD/IEA, 2019a).

Habitually, governments collect revenue from three tax bases: road use, vehicle, and energy use. First, road use is associated with highway tolls, congestion chargers[8] and cordon prices[9]. Secondly, the vehicle is related to registration and/or annual circulation taxes.

Finally, the energy use is linked to fuel taxes. Normally, these taxes are calculated by the application of taxes added to the petrol or diesel price. Alternatively, other countries subsidize oil-based fuels. Regarding the EVs, the majority of countries tax electricity use, instead of subsidizing it (OECD/IEA, 2019a).

Although the consequences of the EV transition have already been explored in several areas, such as environmental, technological, economic or employment, the fiscal dimension has been the least developed so far, while fuel, registration, and circulation taxes are crucial to the Spanish Car Taxation Structure (Sanz and Ventosa, 2019).

The actual vehicle taxation system is concentrated on the asset (car) and not in its use (km), resulting in the encouragement of personal ownership and the selection of vehicle models based on extreme uses. Consequently, people are buying much larger and higher emitting vehicles than they need for their daily trips (Transport&Environment, 2019).

As stated in OECD/IEA (2019a), when EV and charging infrastructure maturity grows, public policies should be adjusted, especially fuel and vehicle taxes, and their contribution to government revenue. If not done so, government revenue may be at risk. These revenues are important to guarantee the availability of funding for the development and maintenance of transport infrastructure. As previously seen in Chapter 4, this challenge can already be noticed in Norway. Therefore, in subchapter 5.1., we will briefly address the reason why passenger cars are taxed and where revenues are directed.

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[8] Vary across geographical area and time of day.
[9] For example: regulation of access to urban centers with the application of fees.

In other words, if we maintain a "business-as-usual" car tax scenario, a higher zero and low-emission vehicles market penetration in the total fleet of passenger cars would result in a net decline taxes collected. Thus, the main objective of this chapter is to quantify the impact of different levels of EV market penetration on car tax collection in Spain, maintaining the current taxation.

The ideal would have been to carry out this analysis for the three representative countries, but for reasons of time and data limitation, we concentrate only on Spain, the analyzed country with the least penetration of BEVs.

Consequently, section 5.2. starts with a section dedicated to current taxation schemes (2019/2020) – our fiscal model - associated with road transport in Spain. In this section, an attempt is made to understand the total taxes collected over the useful life of a car by a powertrain system, divided into two moments: at the time of purchase and when using the vehicle. It should be noted that we only performed the analysis for petrol and diesel ICEVs, PHEVs, and BEVs. The main objective of this subchapter is to understand the different levels of tax collection throughout the different powertrains.

Afterward, in section 5.3., we try to understand the possible tax collection loss associated with different BEV market penetrations over time, namely in the 2050-time horizon. For this, we use a simulation model of the evolution of the Spanish car fleet between 2018 and 2050 built by Casado (2020) with three possible penetration scenarios: 100% BEV sales in 2040, 50% BEV sales in 2040, and 0% BEV sales.

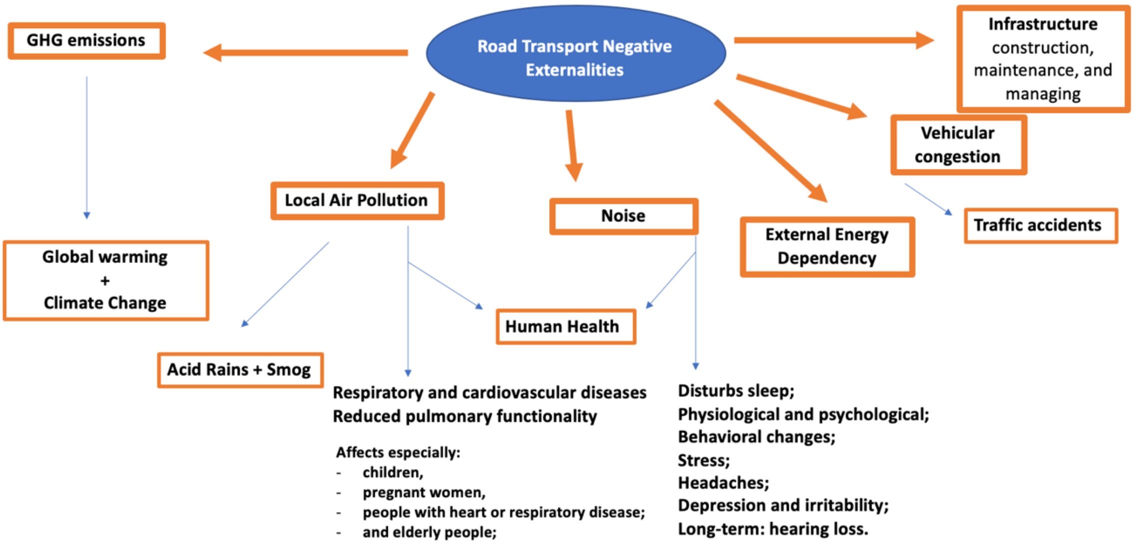
To be more specific, a simulation analysis of government revenues on passenger car fleet by powertrain in Spain on a yearly basis until 2050 is done. In each of the penetration scenarios, we maintain the current car tax regime and try to understand when the BEV penetration will create challenges in terms of total taxes collected. Lastly, we compared the values obtained from the tax collection for our basis year – 2018 - with the actual values provided by ACEA (2020a), to understand the limitations of our data.

Finally, in section 5.4., for the scenarios that admit BEV market penetration, a change in the electricity tax rate – based on electricity consumed - is made to see if the losses of the Government revenue can be mitigated with an increase of this tax rate. It should be noted that this tax in Spain is currently between 5%, while the fuel tax is around 35% for petrol and 30% for diesel (Autobild.es, 2020).

5.1. CAR TAXATION ROLE

As we have seen in Chapter 3, mobility is fundamental for our society, people's well-being, and economy. Nevertheless, transport is also responsible for some external effects, namely negative externalities[10], illustrated in **Figure 5-1**, as GHG emissions, local air pollution, noise, human health, external energy dependency; vehicular congestion (time delay and extra fuel consumption), and traffic congestion. Additionally, this sector demands the construction, maintenance, and managing of transport infrastructure, which is extremely costly.

Figure 5-1 - Road Transport Negative Externalities



Source: Own elaboration based on Lamjon (2012).

At the same time, these negative externalities and infrastructure costs are not paid by transport users, since they do not take into account these costs in their economic decisions. Therefore, as emphasized by EC (2019e), policy intervention is required in order to internalize the negative externalities and infrastructure costs, increasing the transport system efficiency.

Recently, governments are facing another challenge, regarding the implementation of "polluter-pays" and "user-pays" principles defended by Supranational vertical jurisdiction – European Union, pressure by International vertical level – United Nations. In contrast, there is a tendency of heterogeneity in national car fiscal measures in Europe, since road vehicle taxation is a responsibility of each EU Member State.

[10] Costs to society not reflected in the prices that people pay.

In an effort to achieve harmonization, the EU created some guidelines, as well as best practices for passenger car taxation (EC, 2012). Car taxes are all the taxes associated with ownership and vehicle usage, as well as infrastructure use, and were estimated to represent 3.5% of global GDP (OECD/IEA, 2019a).

On the other hand, car taxes are compulsory and unrequited payments collected by the national and local governments. As defend by EC (2019e), taxes are unrequited payments, since the benefits offered by governments are not perceived in the same proportion to taxpayers.

Indeed, the tax revenues typically go to a general budget or more simply are targeted for specific purposes. Consequently, car taxation allows the funding of infrastructure deployment and maintenance and non-auto related projects (ACEA, 2020c).

Additionally, car taxation influences citizens' decisions about vehicle acquisition and usage and can discourage the behavior that gives rise to negative externalities, as previously referred (Adam and Stroud, 2019).

Nonetheless, car taxation is a significant revenue source for the European Member States (EC, 2012), especially the fuel taxes, which are also subject to VAT. For this reason, increasing ICEV fuel efficiency and EV market penetration is challenging the current taxation model, because BEVs are two-to-five-times more efficient[11] than ICEV and are zero tailpipe emissions of local pollutants.

This is particularly relevant since the current road transport taxation is focused on the registration phase and recurring annual fees related to vehicle usage and if we maintain car taxation static, this will result in net car taxes decline, as EVs are subject to lower charges per Km compared with ICEVs.

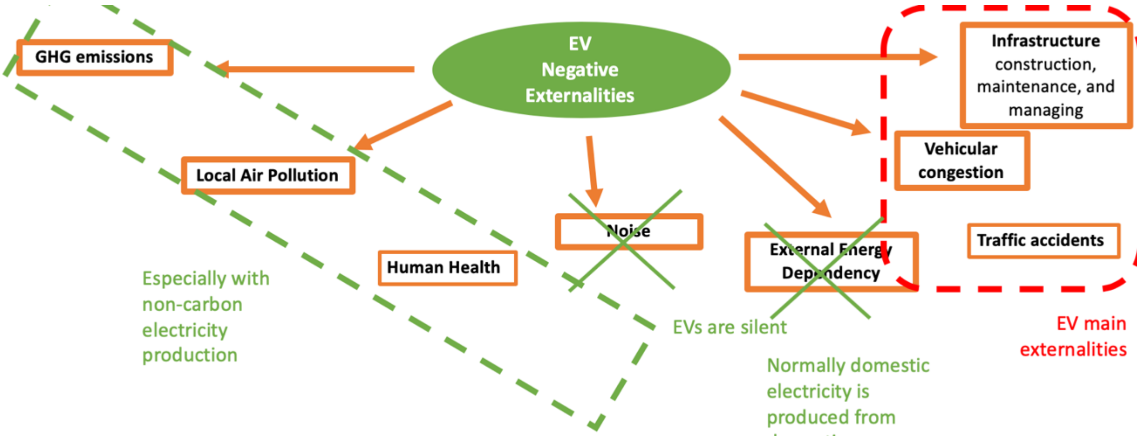
The current EV low taxation is particularly problematic, since EVs are also responsible for negative externalities, as shown in **Figure 5-2**. Nevertheless, it is unquestionable that electromobility may alleviate some of these negative effects

[11] A car will be more efficient - the less energy it consumes to carry out the same work, in this case, travel a distance of 100 km. To compare with ICEV must be expressed in the same energy units, in joule (J), or megajoule (MJ). It is important to note that, unlike the internal combustion engine, the electric vehicle is less efficient on highways. MOTORPASION. 2012. *Hablemos de eficiencia: coche de combustión vs coche eléctrico* [Online]. Available: https://www.motorpasion.com/coches-hibridos-alternativos/hablemos-de-eficiencia-coche-de-combustion-vs-coche-electrico [Accessed 14.06 2020].

(Wangsness et al., 2020), concerning trade balance (since electricity is produced normally with domestic sources), noise, business investments, employment, health care costs, and GHG emissions - highlighted in green - and exacerbated other - stressed in red in Figure 5.2.

However, as emphasized by Lamjon (2012), GHG emissions and local air pollution significant reduction require a non-polluting energy source, as renewable electricity production. It is valuable to note that not all European countries rely only on this kind of energy source, but the tendency is a progressive move away from oil.

Figure 5-2 - EV Negative Externalities



Source: Own elaboration

Additionally, EVs involve a major transformation in the infrastructure network, regarding battery charging and switching in the network and human capital, concerning EV repair and maintenance.

EVs are exacerbating other road transport negative externalities, as stated by Wangsness et al. (2020), regarding vehicular congestion. The bus lane allowance, EV parking charges and toll road exemption, non-economic EV incentives given normally by local government, create more traffic congestion during peak hours and crowding on public transport, phenome that is happening already in Norway- in Oslo city. Thus, these authors defend a trade-off exists between climate goals and welfare maximation.

In brief, the EV transition is not just an environmental issue, but also an economic and social challenge, since these new zero-emission vehicles will not solve all the external costs of driving and especially traffic congestion and infrastructure network problem.

OECD/IEA (2019a), Adam and Stroud (2019), and Transport&Environment (2019) defend an adoption of long-term solutions for car taxation created by the transition towards zero-emission vehicles, which includes revenue stability in long-run, negative externalities management, and implementation simplicity before technological change percolates through the entire car fleet.

If nothing is done, car tax revenue will be reduced dramatically and citizens will have low-tax car expectations. However, it is important to have in mind that this tax break can be offset by Government savings related to the reduction of negative externalities associated with EVs, compared to ICEVs. However, this is not done in our study.

Hence, national governments could:

- Implement higher taxes on a car purchase or ownership;

- Replace fuel taxes to alternative fuels, such as electricity, as apply to petrol and diesel nowadays. This is especially challenging since electricity used for a car should have a higher tax rate than other household uses, and most EV consumers charge their vehicles at home. This will be made for Spain in section 5.4.

In summary, governments are facing a problematic trade-off, since, in the long time horizon, low-emissions vehicles should be taxed to maintain some disincentives related to negative externalities of driving (as congestion and infrastructure maintenance and charging adaptation) and in the short run, governments want to encourage the energy transition and these low taxes on low emission vehicles are a common way in Europe to do that.

5.2. CAR TAX COLLECTION BY POWERTRAIN SYSTEMS (PETROL AND DIESEL ICEVS, BEVS, AND PHEVS)

In this section, an attempt is made to understand the total taxes collected over the useful life of a car by a powertrain system, divided into two moments: at the time of purchase and when using the vehicle. It should be noted that we only performed the analysis for petrol and diesel ICEVs, PHEVs, and BEVs powertrain systems.

The main objective of this subchapter is to understand the different levels of tax collection throughout the different powertrain technologies and to achieve the annual tax value per moment – our fiscal model - and to carry out a simulation of Spanish Car Taxation evolution from 2018-2050, maintaining 2019/2020 taxes, in next section. It is important to highlight that Sanz and Ventosa (2019) conducted a study focused on car taxation related to EVs and the historical evolution of each car tax. Thus, our greatest contribution is to quantify the losses of government revenue for the future.

In order to do this, we calculate the taxes that are collected at the time of vehicle purchase and those that are recurring - the annual costs until the end of the vehicle's life. Valuable to note that company car taxation is not considered here for simplification purposes. However, it was not possible to include all taxes and charges associated, but we believe the main ones are included **(Table 5-1)**. More specifically, our vehicle use calculation does not include revenues collected from toll roads, ferries, and municipal parking.

Table 5-1 - Different Car taxation on vehicle purchase and its use

Vehicle Purchase	Vehicle Use (per year)
Registration Tax	Circulation Tax
VAT (21%)	Fuel Tax + VAT on fuel
Individual Purchase Subsidy	Electricity Tax + VAT on Electricity

Source: Own elaboration

With this in mind, some hypotheses had to be created, in order to simplify the context. Our assumptions in our model are:

- Volkswagen Golf 2020 is the car model for the different powertrains in the entire Spanish car fleet **(Table 5-2)**. This car model was chosen by analogy to previous studies as OECD/IEA (2018a) and ICCT (2018), since it encompasses various types of powertrain systems (combustion and electric), is the best-selling car in Europe, and symbolizes a good middle point in the average consumer market with regard of price and size.

Table 5-2 – Different Golf models per each powertrain system: ICEV petrol, diesel, PHEV, and BEV.

Volkswagen Golf	Powertrain system	Horse Power	Engine Size	Electric Range	Fuel Consumption L/100 km	Electricity Consumption kWh/100km	Emissions
Volkswagen Golf Last Edition	ICE (Petrol)	130 cv (96 kW)	1.5	-	5,6	-	126 g/km
Volkswagen Golf Last Edition	ICE (Diesel)	115cv (85 kW)	1.6	-	5	-	131 g/km
Volkswagen Golf GTE (petrol)	PHEV	150 cv (kW)	1.4	40 km	2	13,6	45 g/km
Volkswagen e-Golf	BEVs	136 cv (100 Kw)	-	275 km	-	15,4	0 g/km

Source: Own elaboration based on (Volkwagen.ES, 2020c, Volkwagen.ES, 2020d, Volkwagen.ES, 2020b, Volkwagen.ES, 2020a)

As can be seen in **Table 5-2**, we considered the car manufacturers – Volkswagen – configurations throughout our study. As we are analyzing a vehicle purchase in 2020, consumption and CO_2 emissions are calculated based on the official EU test procedure called the Worldwide Harmonized Light Vehicle Test Procedure (WLTP), which is more realistic than the previous model New European Driving Cycle (NEDC), replaced in January 2019. These values are relevant since the official CO_2 figure is the basis for car tax calculation. However, car tax will be calculated until April 2020 based on NEDC test results or will be 'NEDC equivalent' calculated from the WLTP (AA, 2018). Thus, the emissions considered in the calculation of taxes are underestimated[12].

[12] According to AA. 2018. *Official fuel consumption figures* [Online]. Automobile Association Developments. Available: https://www.theaa.com/driving-advice/fuels-environment/official-fuel-consumption-figures [Accessed 14.06 2020]., NEDC does not properly represent modern driving patterns or vehicle performance. It was created in 1970 and does not take into account air-conditioning, lights,

Nevertheless, some differences should be expected, even with this new official EU test procedure - WLTP, since laboratory tests do not reproduce completely the driving styles, road (changes in traffic), and weather conditions experienced in real-world (AA, 2018).

However, in our study, we are considering values based on WLTP. As we saw earlier, even these values are also underestimated, but by far less than NEDC tests.

- We assumed an expected car useful life[13] in Spain of 18 years to be aligned with Casado (2020) simulation modeling used in the next subchapter 5.3. However, it is important to highlight the difference between the car's useful life and the average age of the Spanish car fleet.

  Since the average age of the Spanish car fleet is about 12 years in the first years of the simulation model and ends up being 15 years. Therefore, this value is aligned with reality, since the average age of passenger cars in Spain was of 12,4 years in 2018 (Autoalan, 2020).
- Car prices and taxes are between 2019 and 2020:

i. <u>Car prices</u>

Car prices were collected in May 2020 regarding prices of the same year (Volkwagen.ES, 2020c, Volkwagen.ES, 2020d, Volkwagen.ES, 2020b, Volkwagen.ES, 2020a) **(Table 5-3)**.

Table 5-3 - Different Golf sale price per each powertrain system: ICEV petrol, diesel, PHEV, and BEV.

	ICEV petrol	**ICEV diesel**	**PHEVs**	**BEVs**
Sale price before taxes	18 233,15 €	19 891,99 €	35 520,00 €	27 60,00 €

Source: Own elaboration based on (Volkwagen.ES, 2020c, Volkwagen.ES, 2020d, Volkwagen.ES, 2020b, Volkwagen.ES, 2020a)

electrical loads and passengers or other loads. In addition, NEDC is only short in duration and dominated by periods of idling and low engine load and briefly reaches highways speed.

[13] Estimation of the number of years that a car is likely to remain in service.

ii. **Car Taxes**

a. Value Added Tax - *Impuesto sobre el Valor Añadido* – 21% – applied to most of the goods and services that are bought and sold for use or consumption in Spain **(Table 5-4)**. This data was provided by ACEA (2019).

Table 5-4 - VAT share in Spain.

VAT
21%

Source: (ACEA, 2019)

b. **Registration Tax** – *Impuesto especial sobre determinados medios de transporte* (*Impuesto de matriculación)* – is a percentage of the sale price before taxes for the respective car model plus VAT (21%) – it is implemented in an *ad valorem*[14] way (Sanz and Ventosa, 2019). It is collected at the local level (autonomous communities) and this percentage varies according to g/Km of CO_2 emissions (calculated based on NEDC) **(Table 5-5)**. It should be noted that the autonomous communities in Spain can adapt these percentages, but we consider the percentages recommended by the national government. This tax data was taken from Diariomotor (2019).

As can be seen in **Table 5-5** below, BEVs and PHEVs do not pay any registration tax, since their emissions are below 120 g/km of CO_2. It is valuable to highlight that this 120 g/km of CO_2 emissions requirement allows 70% passenger cars registered in Spain not to pay this tax, since most recent ICEV vehicles emit less CO_2 (Autobild.es, 2020). Thus, taxation obtained in 2017 for this tax represented 36% of that has been obtained in 2008 (Sanz and Ventosa, 2019).

Alternatively, we consider CO_2 emissions based on WLTP (**Table 5-2**) of our selected car models, which are above to the previous requirement, which can create an overestimation in our model, since this tax is calculated based on NEDC.

[14] Is a tax based on the assessed value of an item.

Our petrol and diesel vehicles with emissions between 121 and 159 g/km of CO_2 pay a tax that corresponds to 4.75% of the sale price plus VAT.

Table 5-5 - Different registration tax shares according to CO_2 emission level

Registration tax	CO_2 Emissions (NEDC)
0%	Until 120 g/km of CO_2
4,75%	Between 121 and 159 g/km of CO_2
9,75%	Between 160 and 199 g/km of CO_2
14,75%	Above 200 g/km de CO_2

Source: (Diariomotor, 2019)

At the same time, Spain has an additional registration fee of 97,80€ per passenger car (ACEA, 2020a). However, we do not consider this value in our analysis.

c. **Individual purchase subsidies** are given to electric vehicles as the ones of Moves 2019 Plan - the latest Spanish electric mobility incentive program – €5 500 for BEVs and 2 600€ for PHEVs (Autobild.es (2019). As a matter of fact, we are not considering the discount of the € 1 000 provided by the car manufacturer nor the requirement to have a vehicle scrappage over 10 years old that has been in its possession for at least 12 months.

d. **Circulation Tax -** *Impuesto sobre Vehículos de Tracción Mecánica (IVTM)* **-** is an annual tax collected at the local level (municipal level) and therefore differs across Spain **(Table 5-6)**. It is calculated based on *caballos fiscales* – Tax horsepower. Thus, we selected the taxes collected by Madrid, which is the capital of the country. Therefore, we consider that the circulation tax is the same for all other counties. Additionally, Sanz and Ventosa (2019) stated that Madrid and Barcelona, in 2017, accounted for more than 50% of the Spanish passenger car fleet. The values were collected in Dieselogasolina (2020).

Table 5-6 - Different circulation tax according to the powertrain system – Example of the autonomous community of Madrid

	ICEV petrol	ICEV diesel	PHEVs	BEVs
Circulation Tax	€ 59	€ 59	€ 59	€ 14,75

Source: Own elaboration based on (Dieselogasolina, 2020)

As you can see in **Table 5-6**, petrol and diesel ICEVs pay the same amount as PHEVs. However, BEVs pay 25% of this amount.

e. **Fuel Tax** - *Impuesto especial sobre hidrocarburos* – is the tax charged for each petrol or diesel liter consumed. To simplify the calculation of this tax, we consider the price of petrol and diesel over the life of the car as the same as on January 1st, 2019. These data were obtained through ACEA (2019).

However, it is important to emphasize again that this tax is 35% for petrol and 30% for diesel (Autobild.es, 2020).

As you can see in **Table 5-7**, we have the product cost, plus the taxes that correspond to the fuel tax and the associated VAT per liter for petrol and diesel. Fuel taxes represent about 60% of the fuel sale price. Since we have to add the VAT - 21% - previously mentioned.

Additionally, the cost (of the product plus distribution profit) of diesel is higher than petrol, but diesel pays fewer taxes. Making diesel cheaper per liter, compared to petrol.

Table 5-7 - Fuel Taxes and price on January 1st, 2019

Fuel Taxes	Cost of product plus distribution profit	Excise and other taxes	VAT (21%)	€/ per L	January 1st 2019
Petrol	0,54 €	0,47 €	0,21 €	1,22 €	
Diesel	0,59 €	0,38 €	0,20 €	1,18 €	

Source: Own elaboration based on (ACEA, 2019)

f. **Electricity Tax** - Impuesto Especial sobre la Electricidad - is the tax per kWh consumed. Corresponds to a percentage of 5.11269632% on the electricity household price **(Table 5-8)**. It is important to highlight that the electricity tax was obtained from Sanz (2016) and electricity household price was collected from Statista (2018). Again, to simplify the calculation, we consider that the electricity household price will remain constant throughout the life of the vehicle at the value of the first semester of 2018. It should be noted that the price of electricity is higher for households than for industrial activity. However, as Sanz and Ventosa (2019) refer, EVs are likely subjected to a lower price per kWh than domestic consumers, but like us, these authors were unable to obtain data.

Table 5-8 - Electricity Tax and electricity household price on the 1st semester 2018.

Electricity household price per kWh (without any taxes)	thereof **Electricity Tax per kWh**	**Electricity household price per kWh (without VAT)**	thereof **VAT per kWh**	**Total Electricity household price per kWh (including all taxes and VAT)**	**Electricity Tax**
0,1874 €	0,0096 €	0,1969 €	0,0414 €	0,2383 €	5,11269632%

Source: Own elaboration based on Sanz (2016) and Statista (2018).

As you can see, there is a big gap between the percentage of taxes collected between electricity and fuel.

Please note that we do not take into account in our model, the Electricity Tax collected on electricity generation – *Impuesto sobre el valor de la producción de la energía eléctrica*. It is an 7% *ad valorem* tax. Additionally, we also do not consider tax related to nuclear power generation - *Impuesto sobre la producción de combustible nuclear,* nuclear waste management tax - *Impuesto sobre la producción de combustible nuclear gastado y residuos radiactivos resultantes de la generación de energía nucleoeléctrica* and nuclear storage management tax - *Impuesto sobre el almacenamiento de combustible nuclear gastado y residuos radiactivos en instalaciones centralizadas.*

- To calculate the taxes associated with vehicle usage, that is related with fuel and electricity, we assumed the average kilometers made over the life of car data provided by INE (2008). Note that the life of the car has been divided into three categories: i) Vehicles from 0 to 4 years; ii) Vehicles from 5 to 10 years; iii) Vehicles from 11 to 20 years;

  As you can see in **Table 5-9**, cars with the fewest years of life are the ones that travel most average kilometers (km) per year and as we consider the useful life of a car of 18 years, the first three columns are the ones that interest us.

Table 5-9 - Average km traveled per year

Km per year	**Vehicles from 0 to 4 years**	**Vehicles from 5 to 10 years**	**Vehicles from 11 to 20 years**	**Vehicles from 21 to 50 years**	**Average**
TOTAL	13 889,5	12 784,1	9 729,9	7 891,8	11 073,8

Source: Own elaboration based on (INE, 2008).

For simplification purposes, we consider that all powertrains do the same average km per year. However, for future work, it would be useful to differentiate between the different powertrains, since EVs currently travel fewer kilometers, but in the future, they could do the same as ICEVs.

Thus, this hypothesis largely hinders the penetration of new powertrain technologies, since these technologies have lower operating and maintenance costs than ICE technology and, in the future, might travel more kilometers.

In addition, another limitation of our model is not to differentiate the km made on highways, where fuel consumption is lower and the kilometers traveled in urban areas that require a higher fuel consumption.

Afterward, the exposure of the results obtained in this initial analysis begins.

a. **Car tax collection per powertrain system on purchase moment**

Table 5-10 shows a systematization of the car tax collection associated with the car purchase moment in the different powertrain systems. As you can see, the taxes collected at this time are associated with the registration tax and VAT. These taxes considered are from 2019 and 2020, but we assume that they remain constant for 18 years, that is, throughout the life of the vehicle.

Regarding the registration tax, BEVs and PHEVs are exempt due to their CO_2 emissions below 120 g/km. However, petrol and diesel ICEVs are subject to a percentage - 4,75% - of the sales price plus VAT, due to its emissions between 121 and 159 g / km of CO_2.

With respect to VAT, Spain has no incentive associated with this tax. Therefore, all powertrain systems pay 21% of the sale price before tax plus registration tax. It should be noted that here, PHEVs and BEVs pay more due to their higher sale price. This trend will be reversed in the future, since EVs will have an increasingly lower selling price, due to technological innovations and economies of scale associated with batteries. Thus, when we add these two taxes, we realize the Government collects at purchase moment more or less the same value in ICEV petrol and diesel and BEVs, approximately € 5 000. However, PHEVs pay almost € 7 500, due to its high selling price.

Table 5-10 - Car tax collected on purchase moment in Spain for ICEV petrol and diesel, PHEVs, and BEVs.

Vehicle Purchase					
Policy Instruments	**Tax collection**	**ICEV petrol**	**ICEV diesel**	**PHEVs**	**BEVs**
	Sale price before taxes	18 233,15 €	19 891,99 €	35 520,00 €	27 460,00 €
Impuesto de matriculación	+ Registration tax*	1 111,85 €	1 213,01 €	-	-
Impuesto sobre el Valor Añadido	+ VAT (21%)**	4 062,45 €	4 432,05 €	7 459,20 €	5 766,60 €
	Sale price after taxes	23 407,45 €	25 537,05 €	42 979,20 €	33 226,60 €
Without subsidy	**Taxes collected per car sold (1)**	**5 174,30 €**	**5 645,06 €**	**7 459,20 €**	**5 766,60 €**
MOVES Plan 2019	Individual Purchase Subsidy	-	-	2 600,00 €	5 500,00 €
	TOTAL purchase subsidy budget	-	-	?	?
With subsidy	**Taxes collected per car sold (2)**	**5 174,30 €**	**5 645,06 €**	**4 859,20 €**	**266,60 €**

Source: Own elaboration

On the other hand, when we consider the individual purchase subsidy given to PHEVs and BEVs as a cost to the Government at the time of purchase, we subtract from the registration tax and VAT. In this way, the Spanish government still collects about € 5000 per petrol and diesel ICEVs and PHEVs car sold. Nevertheless, BEVs only collect around € 300 on the purchase moment. This corresponds to a great loss of government revenue with the increase in the BEVs market penetration.

In brief, the Spanish Government collects more or less the same amount of taxes on the purchase moment between ICEV petrol and diesel and BEVs. However, PHEVs are the vehicles that collect the majority of taxes, due to their considerably higher sale price. However, this scenario changes, when we are considering the incentives given by the

MOVES 2019 Plan - an individual purchase subsidy, which represents a cost to the State. Thus, ICEV petrol, diesel, and PHEVs collect more or less the same taxes, while BEVs pay a residual amount.

It is important to consider that these individual purchase subsidy incentives are given by annual programs that are not very constant over time, have a maximum budget per year, and therefore may or may not exist. In addition, the trend is for BEVs and PHEVs to have lower costs and later to match the sale price of ICEVs. Therefore, when we have to consider the taxes collected at the purchase moment, we will not consider the subsidy given.

b. Car tax collection per powertrain system on vehicle use

With regard to car tax related to vehicle usage, which is costs that are repeated every year or monthly, we consider the circulation tax, fuel tax, electricity tax, and the associated VAT paid per year.

To start with the circulation tax, it was decided to select the city of Madrid, as an example for the entire national territory. As you can see, ICEV petrol and diesel pay annually, as much tax as PHEVs. However, BEVs pay a residual value - about 25% of the remaining powertrain systems.

To calculate fuel taxes, we had to figure out the total fuel liters consumed per year, in order to the average kilometer traveled per year defined previously per each powertrain. So, we had to calculate it for vehicles aged 0-4 years; between 5-10 years, and lastly between 11-20 years. Although, in our study, only a lifetime of 18 years is considered for a light passenger vehicle.

To calculate the total liters consumed per year, we divide the average total of kilometers per vehicle age (**Table 5-9**) per 100 km and then multiply by the number of liters of fuel consumption on average for each 100 km traveled (**Table 5-2**). It should be noted that these average fuel and electricity consumption per 100 km were obtained through the car manufacturer. However, as emphasized by Sanz and Ventosa (2019), in the case of EVs, the energy consumption also depends on the type of charging made, that is, whether it is slow, semi-fast, or fast, this differentiation was not carried out in our model.

All things considered, petrol cars are the ones that collect the majority of fuel taxes, followed by diesel cars and lastly PHEVs. In addition, there is also a small difference between the newer cars that do the most kilometers and the oldest ones with the least kilometers traveled per year. Consequently, VAT on fuel is also higher for petrol cars.

In addition, it was also necessary to carry out a similar procedure to fuel taxes to arrive at the electricity tax obtained over a year. We divide the average total of kilometers per vehicle age (**Table 5-9**) per 100 km and then multiply by the number of electricity consumption on average for each 100 km traveled (**Table 5-11**).

Table 5-11 - Car tax collected on vehicle use in Spain for ICEV petrol and diesel, PHEVs and BEVs.

Vehicle Use (per year)					
Tax collection type	**Vehicle age**	**ICEV petrol**	**ICEV diesel**	**PHEVs**	**BEVs**
Circulation tax - Impuesto sobre Vehículos de Tracción Mecánica (IVTM)	Entire lifetime	59,00 €	59,00 €	59,00 €	14,75 €
Fuel tax - Impuesto especial sobre hidrocarburos	0 - 4 years	367,66 €	263,21 €	131,31 €	-
	5 - 10 years	338,40 €	242,26 €	120,86 €	-
	11 - 20 years	257,56 €	184,38 €	91,98 €	-
VAT on fuel - Impuesto sobre el Valor Añadido	0 - 4 years	164,98 €	141,94 €	58,92 €	-
	5 - 10 years	151,85 €	130,65 €	54,23 €	-
	11 - 20 years	115,57 €	99,43 €	41,28 €	-
Electricity tax - Impuesto Especial sobre la Electricidad	0 - 4 years	-	-	18,10 €	20,49 €
	5 - 10 years	-	-	16,65 €	18,86 €
	11 - 20 years	-	-	12,68 €	14,35 €
VAT on Electricity - Impuesto sobre el Valor Añadido	0 - 4 years	-	-	78,12 €	88,46 €
	5 - 10 years	-	-	71,91 €	81,42 €
	11 - 20 years	-	-	54,73 €	61,97 €

Source: Own elaboration

Thus, when looking at electricity taxes in **Table 5-11**, we see that the total taxes are not very different between PHEVs and BEVs, since they have similar consumption per 100 km. This tax also reflects the difference in mileage achieved by vehicles in their different stages of aging. In addition, EVs are more efficient when compared to ICEVs.

In conclusion, conventional vehicles continue to pay more taxes during its use compared to electric vehicles. In addition, EVs are more energy-efficient, and electricity is proportionally much less taxed.

Now, in **Table 5-12**, we see the totality of taxes paid at the time of purchase and in the following years of use. Once again, the taxes collected on the purchase of the vehicle are considered here: registration taxes and VAT, then with regard to the use of the vehicle, the circulation tax is added, with the fuel tax, electricity tax, and the VAT associated with each of them for each age category of vehicles.

Finally, in order to arrive at the total value collected over the lifetime of passenger car for each powertrain, the taxes collected on the purchase of the vehicle are added to the taxes on vehicle use per year and these values are multiplied by the number of years within the years' category. That is, the first category, vehicles between 0-4 years old are 4 years, the second is 6 years and the third is 8 years, assuming a car life of 18 years.

To sum up, petrol and diesel ICEVs and PHEVs allow the State to raise around € 13 000 during its lifetime. On the other hand, BEVs allow a collection of around half the value when compared with other powertrain systems – 7680,21 €. The situation gets worse if we take into account the subsidy offered in 2019 for BEVs and PHEVs.

It is important to note that another of the limitations of our model is the consideration of only four powertrains. However, the main powertrains of ICEV vehicles and EVs were selected in our model.

Now, in the next subchapter, we will consider these tax values obtained for 2019 and 2020 for a simulation modeling of the passenger car fleet evolution, keeping the taxes constant over time for three different BEV market penetration scenarios.

Table 5-12 - Car tax collected during its useful life in Spain for ICEV petrol and diesel, PHEVs, and BEVs.

	Vehicle age	ICEV petrol	ICEV diesel	PHEVs	BEVs	Years
on Purchase moment	Year 0	5 174,30 €	5 645,06 €	7 459,20 €	5 766,60 €	-
on Vehicle Use	0 - 4 years	591,65 €	464,15 €	345,45 €	123,70 €	4
	5 - 10 years	549,25 €	431,91 €	322,65 €	115,03 €	6
	11 - 20 years	432,13 €	342,82 €	259,66 €	91,07 €	8
	Average	**524,34 €**	**412,96 €**	**309,26 €**	**109,94 €**	**18 years**
	Car Taxes collected on Expected Car Life (18 years)	14 293,46 €	12 835,62 €	12 854,22 €	7 680,21 €	

Source: Own elaboration

5.3. CAR TAX COLLECTION ON A YEARLY BASIS UNTIL 2050 WITH THREE BEV MARKET PENETRATION SCENARIOS

As we have seen in the previous subchapter, BEVs pay about half of the taxes over its lifetime, compared to the other three powertrain systems, and can still receive a considerable subsidy, which is considered an extra charge for the government.

In this subchapter, we intend to understand the impact of different BEVs market penetration levels in 2050 on government revenue on a yearly basis, maintaining taxation, as we know it today.

To understand the behavior of the Spanish fleet of passenger cars until 2050, we used three possible scenarios for the BEV market penetration, using a simulation model built by Professor Andrés Diego Diaz Casado.

- Radical BEV penetration: 100% BEV sales in 2040;
- Intermediate BEV penetration: 50% BEV sales in 2040;
- No BEV penetration: 0% BEV sales in 2035.

These scenarios were built based on the statement made by the Spanish government in 2019 that in 2040 all car sales should be 100% ZEV (Spain, 2019). It is important to highlight that ZEV is zero-emission vehicles and we considered here only the pure battery-powered electric vehicles - BEVs. Therefore, we used this scenario and then the other two more conservative.

In this subchapter, we intend to answer these questions: How much will be the tax reduction in the 100% / 50% / 0% BEV sales scenarios for 2050 if we maintain taxation as we know it today? How will the Spanish passenger car fleet be characterized by the 2050 horizon in the three different scenarios?

In order to answer these questions, in section 5.3.1., we analyze the evolution of the Spanish car fleet, its car sales (equivalent to the new car registrations), and its scrappage. In section 5.3.2., we examine the evolution of tax collection per year from 2018 to 2050 in each scenario, dividing them into purchase moment and vehicle usage. Finally, in section 5.3.3, we compare our taxes in 2018 with actual taxes from 2019/2020 with real values available in ACEA (2020a).

5.3.1. Spanish Passenger car evolution in three scenarios

To answer these questions, we begin by analyzing the evolution of the passenger car fleet in Spain per year, as well as the new registrations and scrappage vehicles for the three different scenarios.

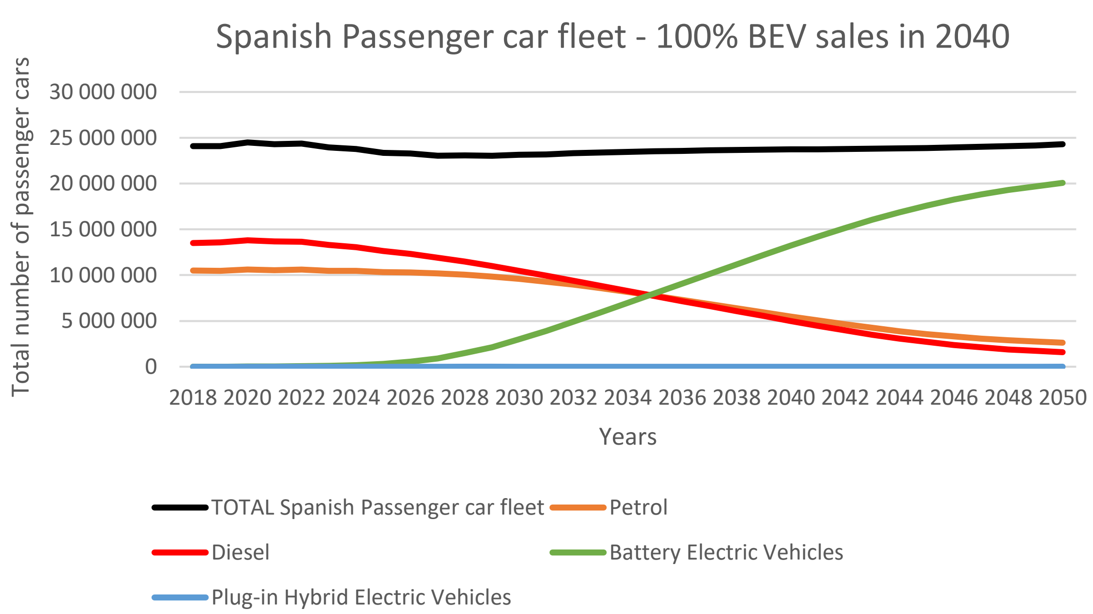
In addition, the model considers: petrol and diesel ICEV, LPG (Liquefied Petroleum Gas), diesel, NGV (Natural Gas vehicle) BEV, PHEV, and also HEV powertrain systems. However, we will only examine the values of petrol and diesel ICEVs and BEVs and PHEVs, because they are the relevant powertrains for our analysis.

It is important to remind that for simplification of the model, we consider that PHEVs sales in all scenarios would be 0%, in order to better capture the BEVs market penetration effects and not of hybrid technology.

5.3.1.1. Spanish Passenger car evolution

As can be seen in the first scenario **(Figure 5-3)**, 100% BEV sales in 2040, the total passenger car fleet in Spain remained more or less constant from 2018 to 2050. Thus, the Spanish fleet consists of approximately 25 million cars (black line).

Figure 5-3 - Spanish Passenger car fleet evolution from 2018-2050 – 100% BEV sales in 2040 scenario



Source: Own elaboration

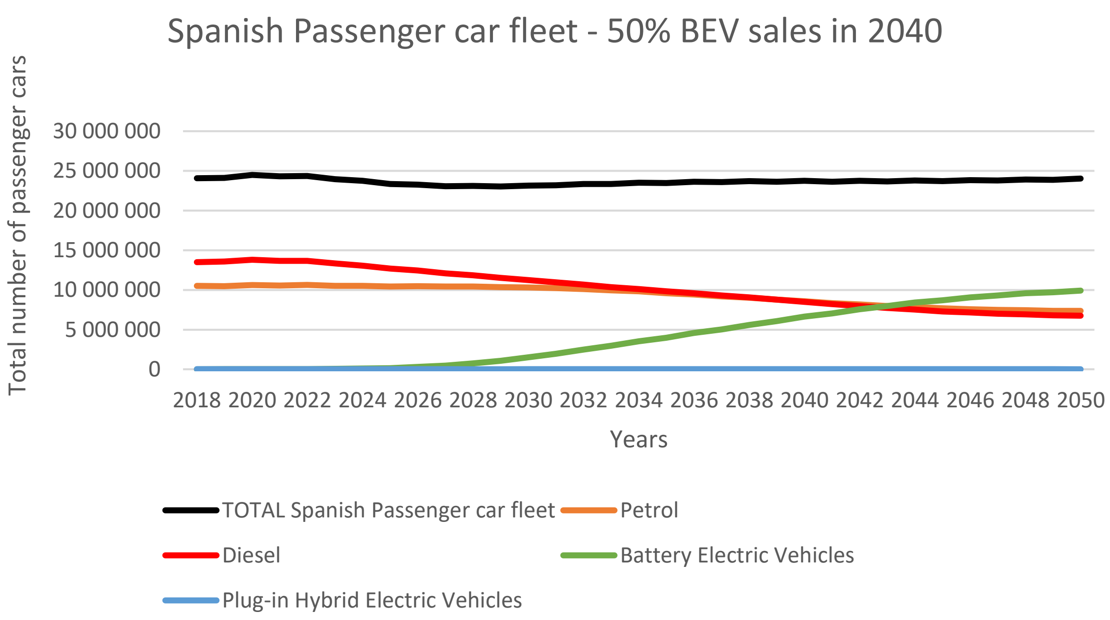
While in early 2018, the car fleet was mostly composed of diesel vehicles (red line), followed by petrol (orange line), the electric vehicles (BEVs + PHEVs) were residual until 2026. But then, BEVs (green line) began to increase their penetration in the car fleet until 2035, when BEVs matched petrol and diesel vehicles and even exceeded it, with a BEV stock of around 8 million cars. In 2050, around 20 million cars were BEVs.

At the same time, ICEV continues to decline until 2050, and in 2037 petrol will outperform diesel vehicles, reversing the results of the promotion policies of vehicles that use diesel from the 90s (Sanz and Ventosa, 2019). Finally, in 2050, ICEVs was residual in the fleet, representing petrol ICEVs around 2,5 million cars and diesel ICEVs about 1,5 million cars.

As can be seen in the graph in figure 5-3, PHEVs (blue line) remain almost null from 2018 until 2050, since their sales are zero.

In the second scenario more conservative **(Figure 5-4),** 50% BEV sales in 2040, the volume of the Spanish passenger car fleet remains constant at approximately 25 million from 2018 to 2050 (black line), which is in line with the previous scenario.

Figure 5-4 - Spanish Passenger car fleet evolution from 2018-2050 – 50% BEV sales in 2040 scenario



Source: Own elaboration

Unlike the first scenario, the BEV (green line) stock will only match petrol and diesel ICEV in 2043, 8 years later than the first model, with approximately 8 million cars each. BEVs start to be representative in the fleet from 2028 and in 2050 they reach 10 million cars.

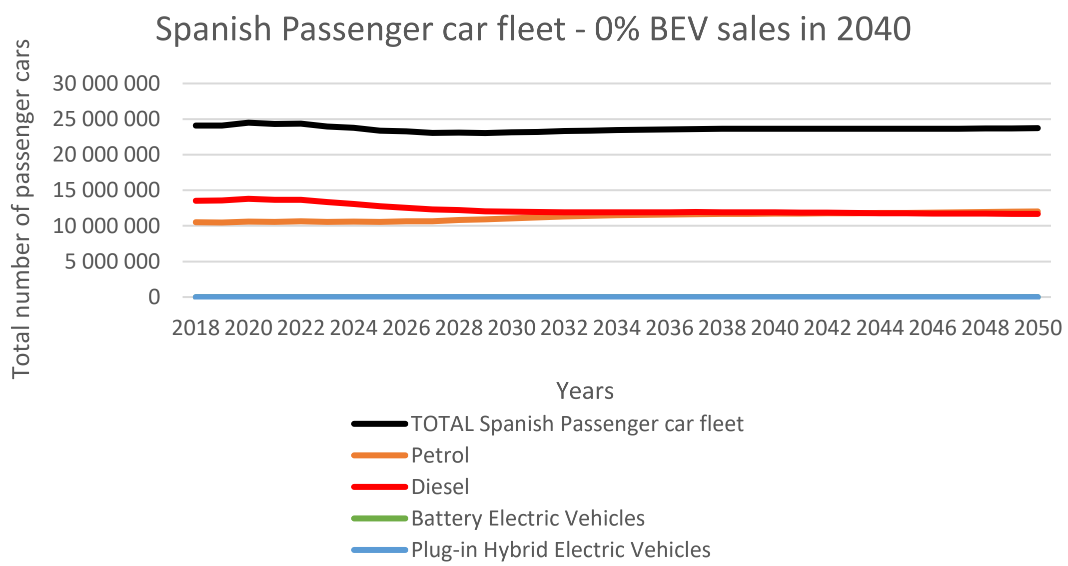
Additionally, the drop in petrol (orange line) and diesel (red line) ICEV stock will be less abrupt, causing these vehicles to represent each one around 7 million cars in 2050 and not 2,5 and 1,5 million as the previous scenario. Note that in 2018, diesel vehicles were the majority of powertrain car stock, however this stock will approach petrol progressively, as previously seen. It should be noted that diesel vehicles will only match petrol vehicles later in this scenario around 2033.

In the third scenario **(Figure 5-5)**, which is highly conservative, as it considers no BEV sales between 2018 and 2050, the stock of passenger cars (black line) in Spain also remains constant with approximately 25 million cars, as previously seen in the last two graphs.

This model also starts with the preponderance of diesel vehicles, compared to other powertrains. However, their reduction will approach petrol ICEV stock in 2035. In 2050, petrol vehicles will outnumber diesel vehicles with approximately 12 million cars and diesel vehicles with 11.5 million.

As there will be no BEV sales in this scenario, its stock (green line) in 2050 will be residual, as PHEVs.

Figure 5-5 - Spanish Passenger car fleet evolution from 2018-2050 – 0 % BEV sales in 2040 scenario



Source: Own elaboration

In brief, the stock of passenger cars in Spain will remain at approximately 25 million cars in the three BEV scenarios. Additionally, in all scenarios, exists a diesel ICEV preponderance over ICEV petrol and this difference has been overcome around 2030.

With regard to BEVs, they outperform ICEVs in the first scenario in 2035 and in the second scenario in 2043 - 8 years later, corresponding in 2050, respectively to 20 and 10 million car stock. The third scenario assumes that there will be no BEV sales. In both scenarios, PHEVs remain residual, since in this model we intend to understand the impact of BEVs on Government revenue.

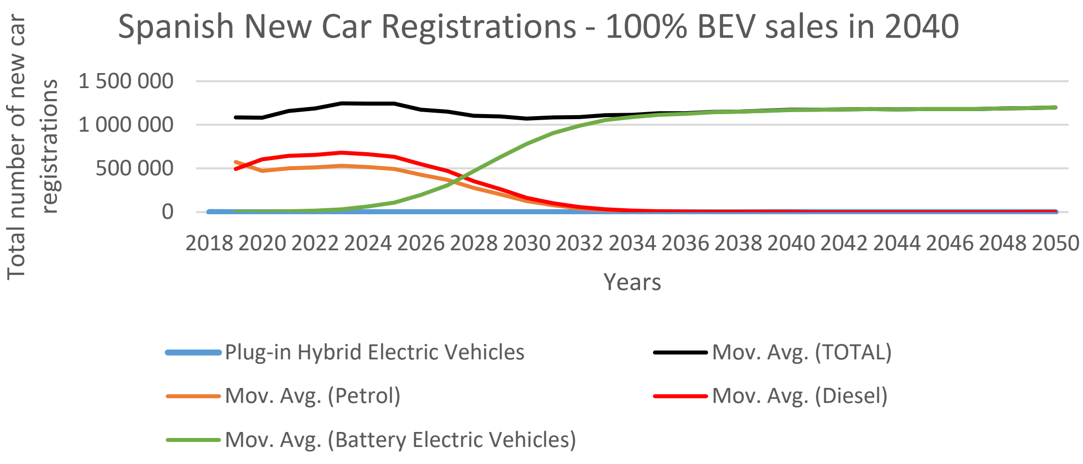
5.3.1.2. Spanish New Car Registrations evolution

Regarding the new car registrations, which normally represent annual sales, the three scenarios offer different characteristics. It is valuable to note that Casado (2020) Spanish Passenger Car Fleet simulation modeling has new car registrations per year not steady, but oscillating, due to the starting point of the time-series. Therefore, in order to provide a flatten pathway, we use a Moving Average (Mov. Avg.) 2 periods Excel tool to smooth out peaks and valleys and to be able to recognized trends in our graphs.

In the first scenario **(Figure 5-6)**, the new car registrations start to be mostly petrol ICEVs in 2018, but between 2019 and 2032, diesel ICEV will surpass the new petrol registrations. In addition, between 2018 and 2050, there is a reduction in new car registrations in Spain associated with ICEVs.

However, in 2023, the new BEV registrations will increase considerably until 2028, when they surpass the petrol and diesel ICEV new registrations. From 2028 onwards, new BEV registrations will grow dramatically until they reach 100% new car registrations in 2040. Becoming the only powertrain in the new registrations until 2050.

Figure 5-6 - Spanish New car registrations evolution per powertrain system from 2018-2050 – 100 % BEV sales in 2040 scenario



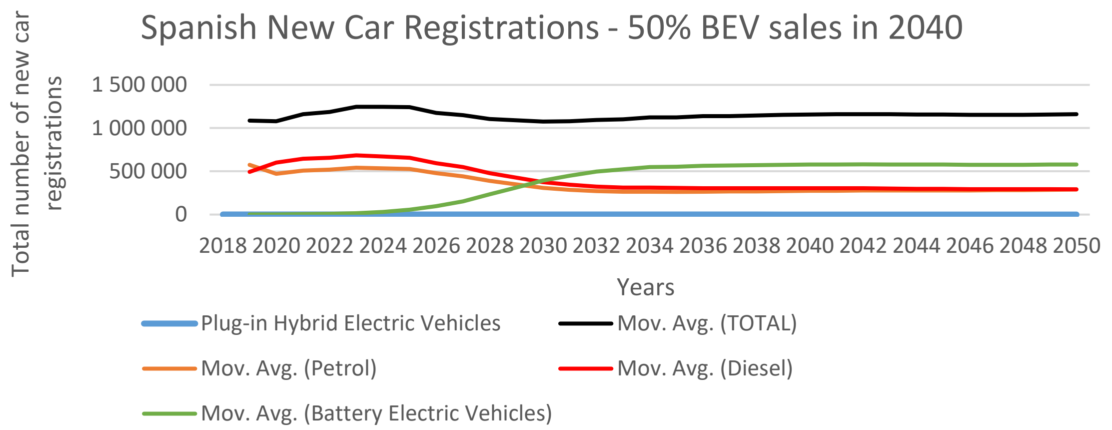
Source: Own elaboration

With regard to the second scenario **(Figure 5-7)**, there is a preponderance of diesel ICEV new registrations in relation to petrol, which has grown over time, especially since 2031, as previously seen in the last section. The reduction in new ICEV registrations is greater between 2018 and 2030, remaining almost constant thereafter until 2050.

With regard to BEVs, they remain residual between 2018 and 2022, starting to grow rapidly until 2032. Note that the new records of BEVs surpass the ICEV in 2030 and remain almost constant from 2033 onwards. As in 2040, new BEV registrations represent 50% of the total new passenger car registrations in Spain.

Contrary to the previous scenario, there are still sales of ICEV vehicles that have remained more or less constant since 2032 and thus, BEVs do not dominate the new registrations.

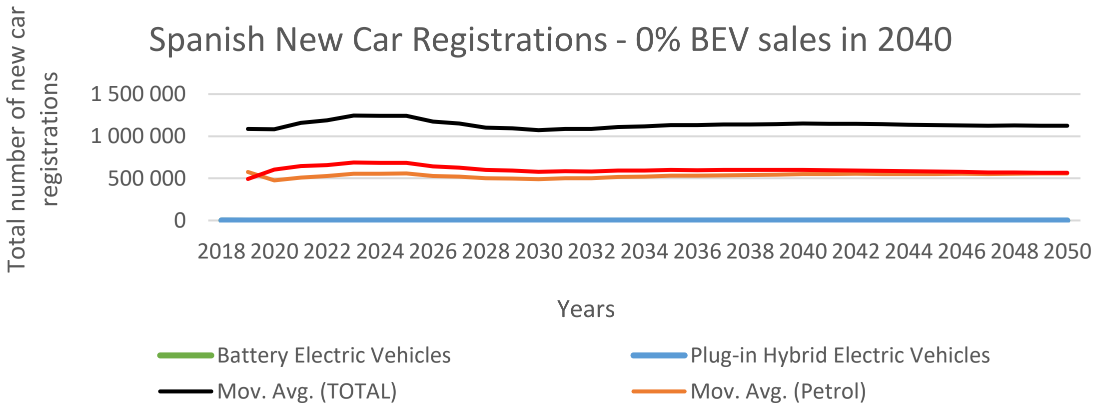
Figure 5-7 - Spanish New car registrations evolution per powertrain system from 2018-2050 – 50 % BEV sales in 2040 scenario



Source: Own elaboration

In the last scenario **(Figure 5-8)**, as previously mentioned, there are no new registration of BEVs, as well as PHEVs, between 2018 and 2050. As in the previous scenarios, starts with preponderance diesel ICEVs and then they approach petrol ICEV registrations, keeping almost constant over time.

Figure 5-8 - Spanish New car registrations evolution per powertrain system from 2018-2050 – 0 % BEV sales in 2040 scenario



Source: Own elaboration

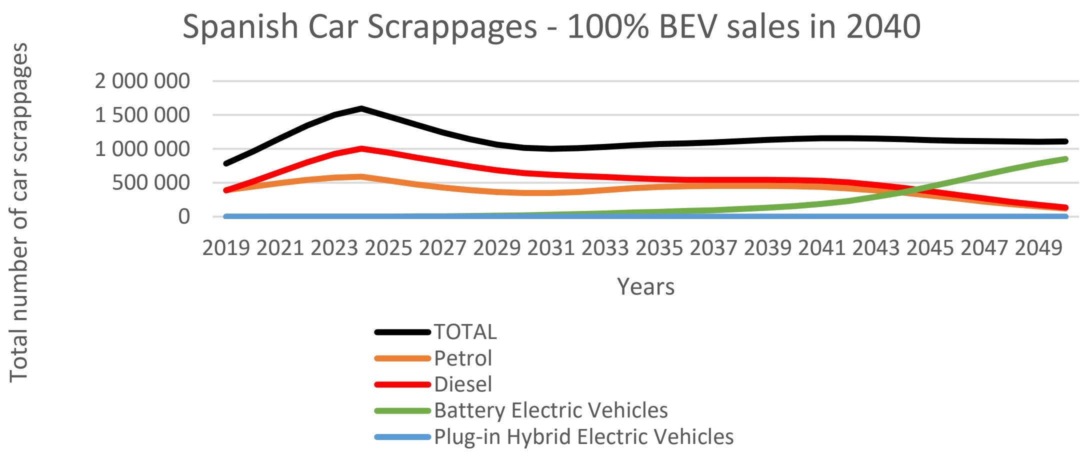
According to what was realized in the three previous graphs, the pace of new BEV registrations varies radically, between BEV scenarios and between 2018 and 2050. In addition, the new diesel car registrations will approximate the values of petrol ICEVs in the three models.

5.3.1.3. Spanish Car Scrappage evolution

Finally, with regard to the Spanish car scrappage between 2019 and 2050, there is also a variance in the three scenarios.

In the first scenario, in **Figure 5-9**, most scrapped cars are diesel ICEVs until 2045, when they equal the value of petrol ICEVs. It should be noted that in this scenario, the scrappage of the BEVs begins to be representative in 2030 and exceeds petrol and diesel ICEVs scrappage in 2045, with the majority being from then on. This can be explained by the preponderance of BEVs in sales since 2040.

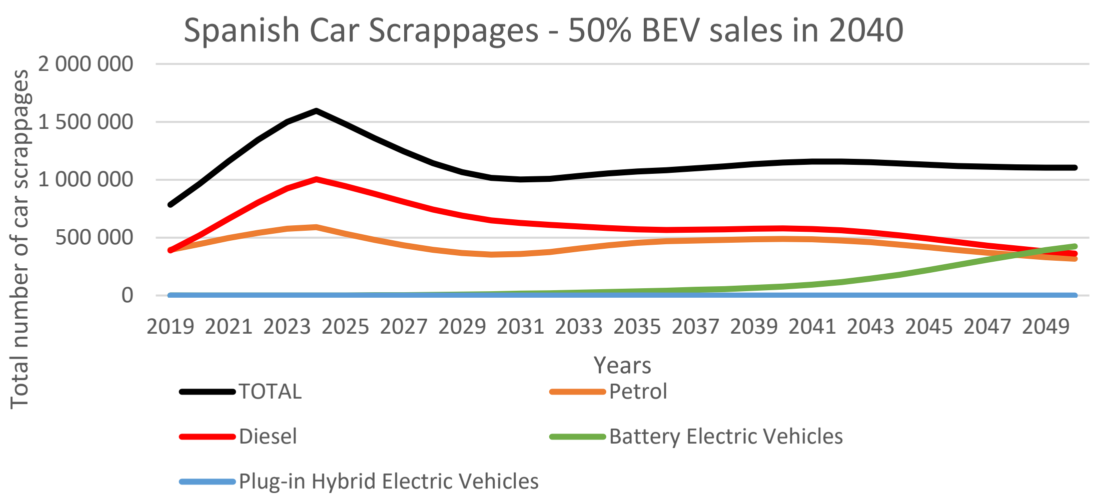
Figure 5-9 - Spanish Car Scrappages evolution per powertrain system from 2018-2050 – 100 % BEV sales in 2040 scenario



Source: Own elaboration

In the second scenario, **Figure 5-10**, most scrappage car is concentrated on diesel ICEVs, followed by petrol ICEVs, as previously perceived in the last scenario. The BEVs scrappage becomes relevant in 2031 and surpasses petrol ICEV scrappage in 2048 and diesel in 2049. The same occurred in the previous scenario, but the BEV scrappage was much higher in the first case, since in the second scenario it only exceeded, but was close to the values of the ICEV scrappage.

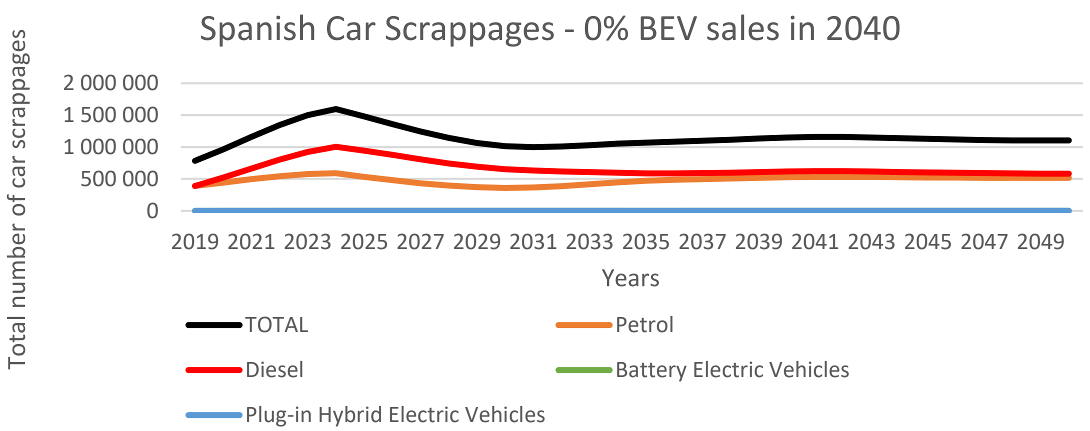
Figure 5-10 - Spanish Car Scrappages evolution per powertrain system from 2018-2050 – 50 % BEV sales in 2040 scenario



Source: Own elaboration

As previously mentioned, as there was no sale of BEVs in the last scenario, they are not slaughtered either **(Figure 5-11)**. Thus, in this scenario there is also a predominance of the slaughter of diesel vehicles but remains close to the values of petrol vehicles.

Figure 5-11 - Spanish Car Scrappages evolution per powertrain system from 2018-2050 – 0 % BEV sales in 2040 scenario



Source: Own elaboration

All things considered, scrappage cars reflect the evolution of sales in previous years, which is why there is greater diesel vehicles scrappage in both scenarios. In addition, in the first scenario, we see a strong predominance of BEV vehicles in the 40s, and in the second scenario, BEVs only surpass ICEV without departing from them. Finally, in the last scenario, BEV vehicles are almost not scrapped, since there were no BEV sales.

5.3.2. Spanish Car Tax Evolution in three BEV scenarios

After analyzing the passenger car fleet structure evolution in Spain for the three different scenarios, the analysis of the impact of this change on the total tax collection begins.

It should be noted that the values of the car tax used were obtained based on the values of the previous subchapter 5.2. As you can see, taxes were only obtained for petrol and diesel ICEVs, BEVs, and PHEVs powertrain systems. Although other powertrains are relevant, our analysis will only focus on these because they are the main powertrains for ICEV and EV. Therefore, one of the limitations of our model is to consider only these four powertrains and ignore the other ones.

Thus, to get the car tax associated with cars, we divide the tax by the time of vehicle purchase and its use (recurring taxes), as earlier emphasized.

As identified in **Table 5-13** below, the purchase moment is equivalent to the new registrations and the use of the vehicle is associated with the car passenger fleet. Consequently, for each scenario, we multiply these tax values respectively by the registrations and the fleet in the respective powertrain.

Table 5-13 -Individual tax collected per powertrain system on vehicle purchase moment and use

	Vehicle age	ICEV petrol	ICEV diesel	PHEVs	BEVs	
on Purchase moment	0	5 174,30 €	5 645,06 €	7 459,20 €	5 766,60 €	New Car Registrations
on Vehicle Use	0-18	524,34 €	412,96 €	309,26 €	**109,94 €**	Car passenger Fleet

Source: Own elaboration

As can be seen in the previous table, it is expected that the major fluctuations will be in the vehicle use category, since it is here that there is a greater reduction in tax collection, since the tax collected at the time of purchase are more or less identical over the different powertrains. Especially because these three scenarios consider the new registrations of PHEVs to be null over time and therefore we cannot understand the impact of the taxation over PHEVs. This was done to understand the impact of BEVs penetration in the Spanish car fleet, since, in 2019, Spain declared that it intended that in 2040 its car sales would be ZEV and for that, it would have to be only the BEVs sales.

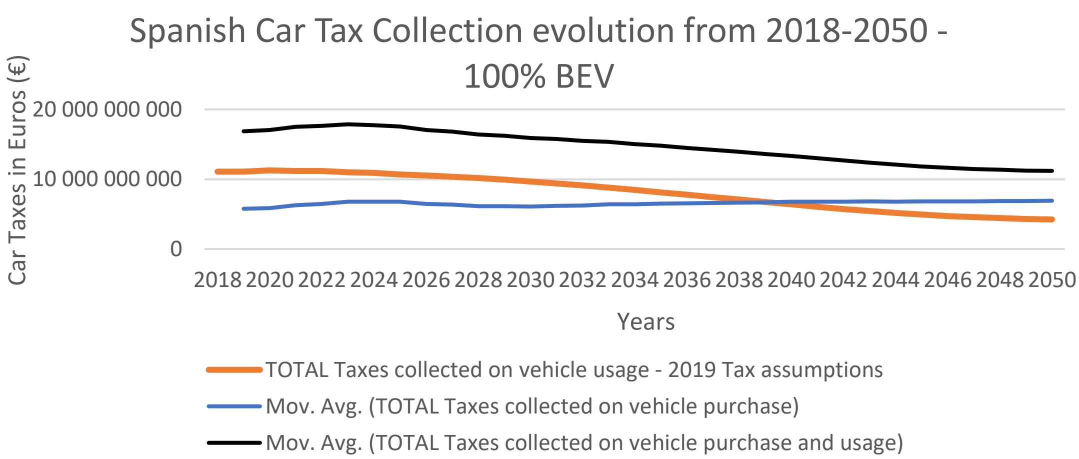
5.3.2.1.100% BEV sales in 2040

As expected there was a reduction in the total tax collection associated with passenger cars in Spain (black line) in the first BEV radical scenario **(Figure 5-12)**. As we are analyzing the scenario that assumes that all new registrations will be BEVs in 2040, the tax collected with the use of the vehicle is experiencing a substantial fall (orange line), when compared to the evolution of the tax collected with the new registrations (blue line).

Perhaps these results would be different if we consider an increase in the new registrations of PHEVs, since this powertrain has a much higher purchase price and this is reflected in the taxes collected in the new registrations.

Thus, this drop in tax collection is mainly due to the result of a drop in tax collection associated with the use of the vehicle (orange line) and not in purchase moment (blue line). However, as we saw in the previous chapter, most government initiatives are focused on the vehicle purchase and not on use. These results were also obtained because we are not considering the impact of cash purchase subsidies given by Spain on the EV purchase.

Figure 5-12 - Spanish Car Tax collection evolution from 2018-2050 - 100% BEV Scenario

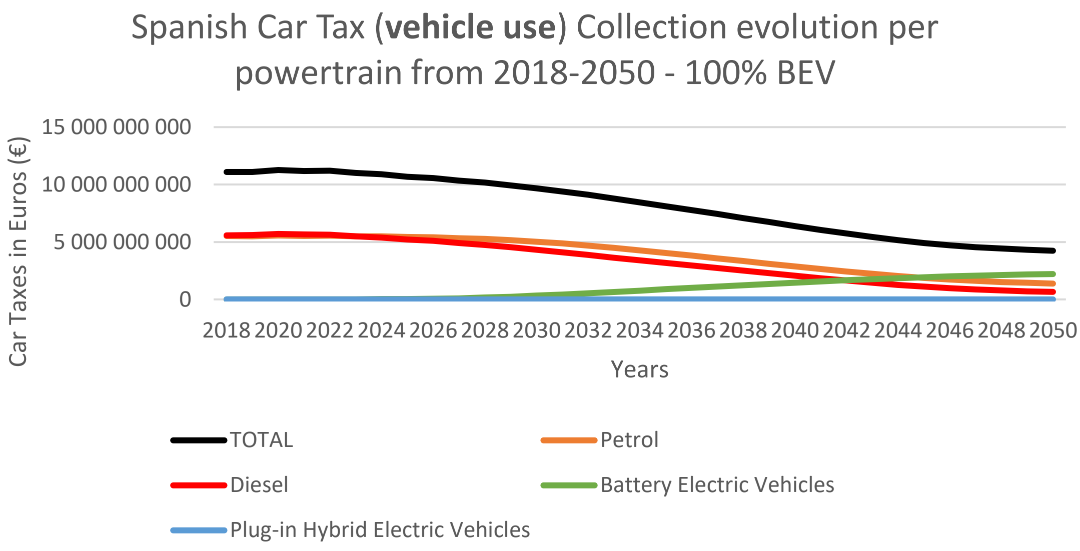


Source: Own elaboration

As we showed earlier, the great change in car tax collection is associated with taxes collected over the vehicle life, so it is worth analyzing the evolution of these vehicle usage tax collected by each powertrains system overtime.

As can be seen in **Figure 5-13**, the drop in total tax collected over time associated with the use of the vehicle (black line) suffers a sharp drop associated with the drop in taxes collected by ICEV petrol and diesel (orange and red line) across time. However, from 2030 onwards, BEVs begin to increase their contribution to this tax (green line), associated with the increase in market share. By contrast, as BEVs pay considerably less tax than ICEVs, increasing their market share does not allow the Government to maintain the same level of tax collection and revenue.

Figure 5-13 - Spanish Car Tax (vehicle use) collection per powertrain system evolution from 2018-2050 - 100% BEV Scenario



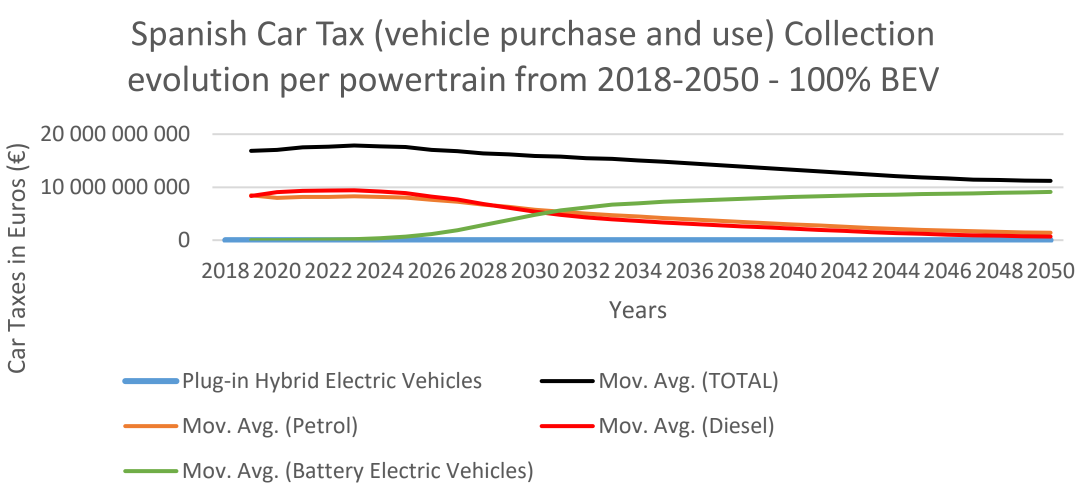
Source: Own elaboration

After analyzing the effect of BEV market penetration on vehicle usage tax collected over time, it is worthwhile to understand the tax behavior (purchase and use) collected over time by the powertrain system.

As you can see in **Figure 5-14**, there is a reduction in the total tax collected per year in the entire fleet, considering all powertrains – ICEVs and EVs (black line). This drop reflects the reductions in tax collection associated with petrol and diesel vehicles (orange and red line) scrappage and new BEV registrations. However, here the increase in tax collection associated with BEVs begins in 2024 and exceeds ICEVs in 2030.

It is clear then that the effect of BEV market penetration on the fleet begins to be seen even before reaching 100% of sales. This is because every time an ICEV car was scrapped, it was replaced by a vehicle paying less than € 300 per year – a BEV.

Figure 5-14 - Spanish Car Tax (vehicle purchase and use) collection per powertrain system evolution from 2018-2050 - 100% BEV Scenario

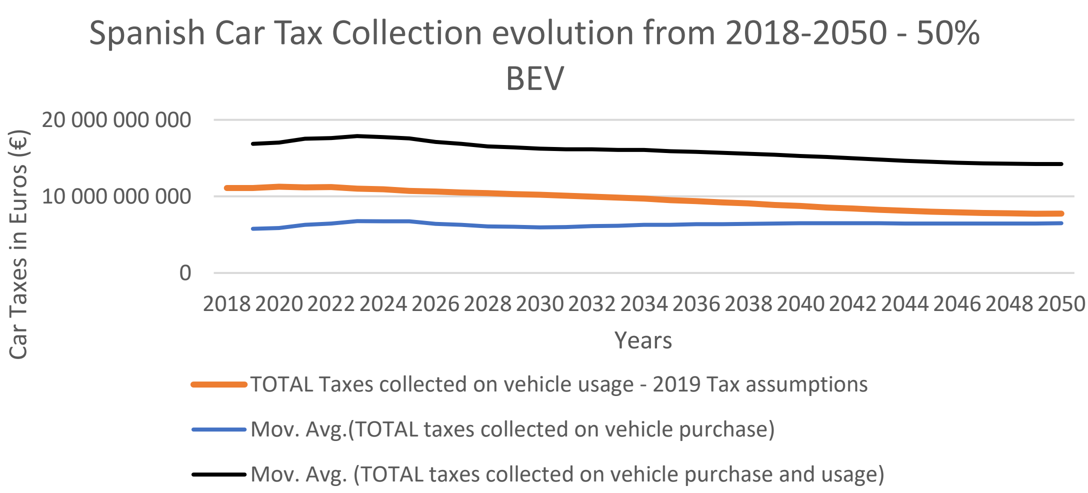


Source: Own elaboration

5.3.2.2.50% BEV sales in 2040

The same analysis will be done as in the previous section, but for a different scenario, when the new registrations after 2040 are 50% BEVs. As previously seen in **Figure 5-13**, the total tax collected during the vehicle purchase and usage suffers a break (black line). However, as can be seen in **Figure 5-15**, this drop is not as sharp as that one of 100% BEV scenario. This drop is mainly due to taxes associated with the use of the vehicle (orange line), since the taxes collected on the purchase of the vehicle remain almost constant (blue line) over time, consistent with the results obtained for the previous scenario.

Figure 5-15 - Spanish Car Tax collection evolution from 2018-2050 - 50% BEV Scenario



Source: Own elaboration

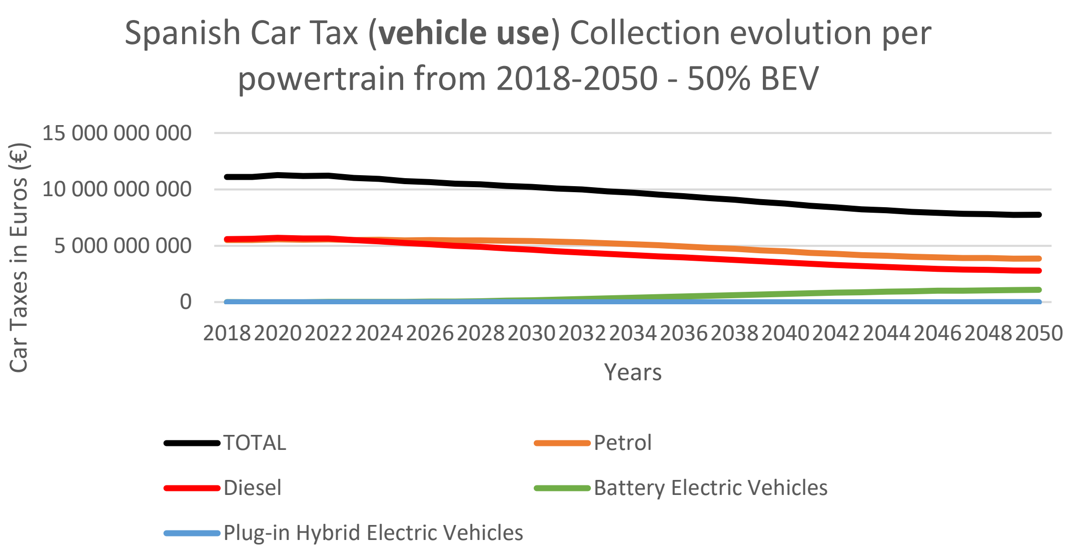
Consequently, it is important to understand the reason why the taxes associated with the use of the vehicle suffered such a drop. Therefore, it is fundamental to analyze the tax data collected during vehicle usage by the powertrain.

As you are able to see in **Figure 5-16** below, there is also a drop in taxes associated with the vehicle usage (black line) over time. Unlike the previous scenario in which the drop in ICEV is exponential because sales are 100% BEVs, here the tax drop is much smaller because there are still more ICEVs that pay much more taxes than BEVs proportionately.

At the same time, there is a slower reduction in the tax collection associated with the petrol and diesel ICEVs (orange and red line). However, petrol ICEVs end up surpassing diesel ICEVs in tax collection.

On the other hand, BEVs are beginning to be relevant to the tribulation in this category from 2032 onwards, but never exceed ICEVs, because their contribution is very small as mentioned above.

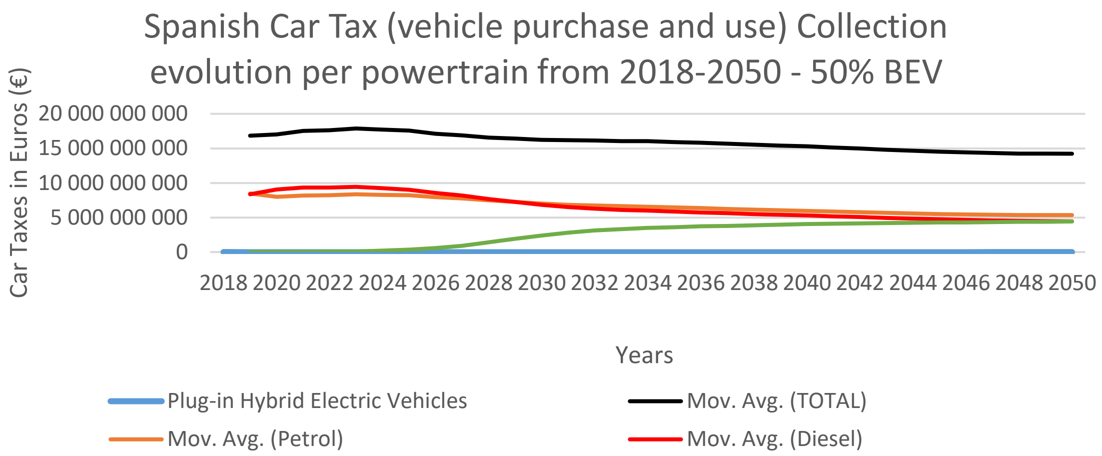
Figure 5-16 - Spanish Car Tax (vehicle use) collection per powertrain system evolution from 2018-2050 – 50% BEV Scenario



Source: Own elaboration

In **Figure 5-17**, different results can be seen, although there is a less pronounced drop in taxes collected by the total powertrain fleet (black line). However, the fall in taxes collected associated with ICEVs (orange and red line) is smaller and is never surpassed by BEVs (green line), contrary to the previous scenario. Thus, although there has been an increase in tax collection associated with BEVs since 2026, they cannot overcome the collection of ICEVs, because they pay much less although at that moment they represent 50% of sales.

Figure 5-17 - Spanish Car Tax (vehicle purchase and use) collection per powertrain system evolution from 2018-2050 - 50% BEV Scenario



Source: Own elaboration

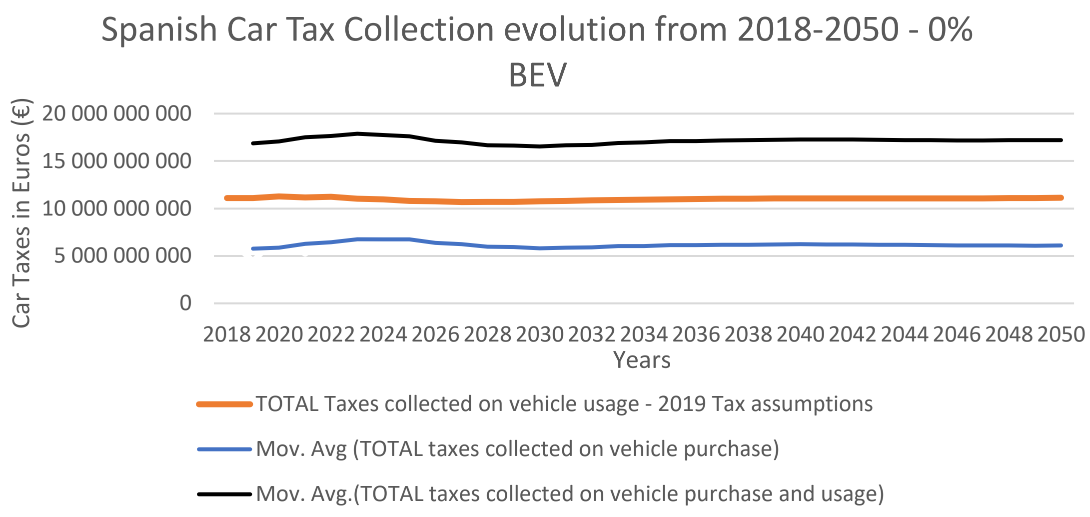
To summarize, as we have realized in these two previous scenarios that admit different BEV market penetration rhythms, the drop in total car tax collected is the result of taxes related to the use of the vehicle.

This can be explained because petrol and diesel ICEV pays an average of € 468.65 per year, while a BEV pays about € 109,94 € in taxes related to vehicle usage. This means that with higher BEV market penetration, more ICEV were scrapped and therefore less tax collection was obtained. Thus, each BEV represents a € 358,71 reduction in taxes collected on vehicle usage per year.

5.3.2.3.0% BEV sales in 2040

Finally, in the last scenario, 0% BEV sales, we see in **Figure 5-18,** that car tax collection remains constant (black line) over time, even when we analyze taxes associated with vehicle usage (orange line). This can be explained because there was no BEV sale and therefore, no BEV market penetration.

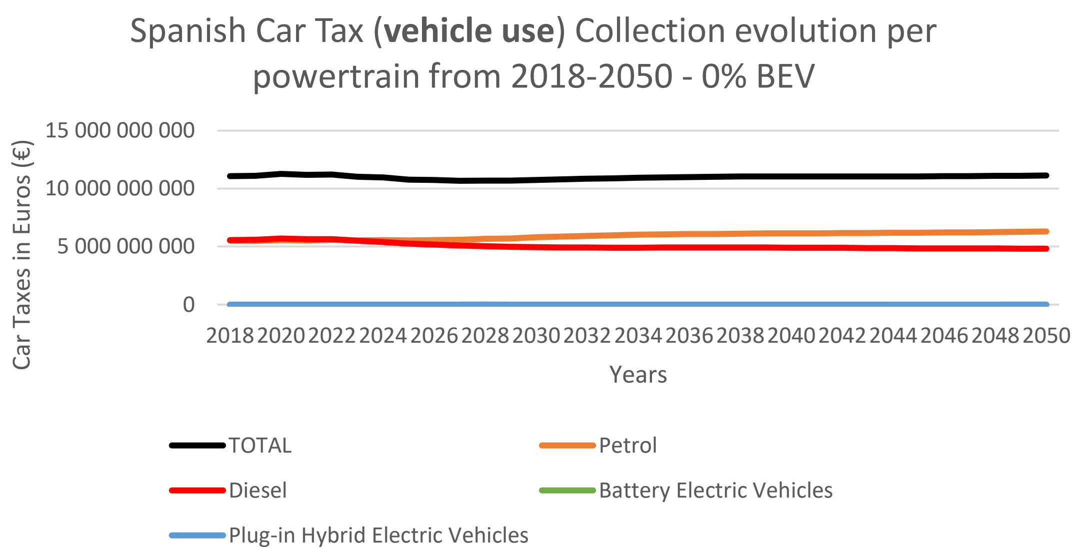
Figure 5-18 - Spanish Car Tax collection evolution from 2018-2050 - 0% BEV Scenario



Source: Own elaboration

This is a continuous trend in taxation level overtime, since remains constant when we face the values collected by each powertrain and in-vehicle use category **(Figure 5-19)**.

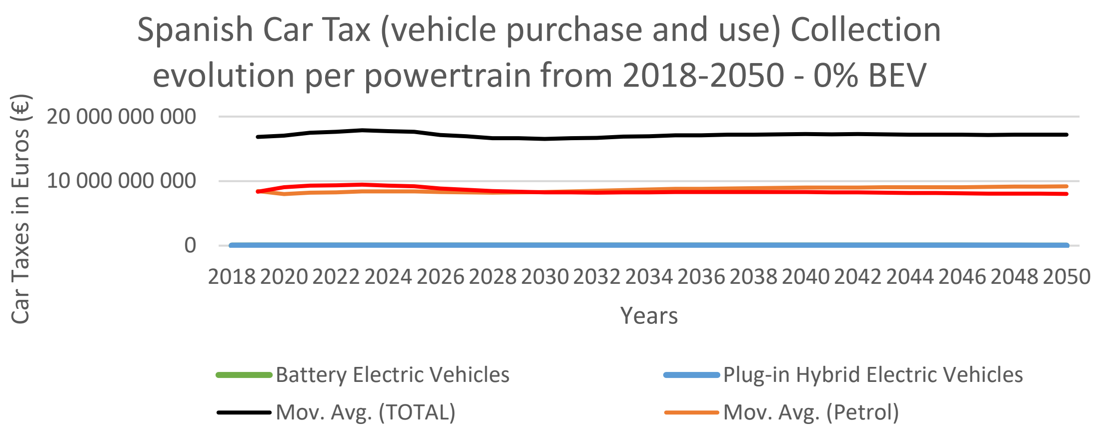
Figure 5-19 - Spanish Car Tax (vehicle use) collection per powertrain system evolution from 2018-2050 – 0% BEV Scenario



Source: Own elaboration

And the same happens when we are facing the total tax collection (purchase and use), **Figure 5-20**, since the values do not suffer major changes, due to the maintenance of the current scenario of the Spanish car fleet.

Figure 5-20 - Spanish Car Tax (vehicle purchase and use) collection per powertrain system evolution from 2018-2050 - 50% BEV Scenario



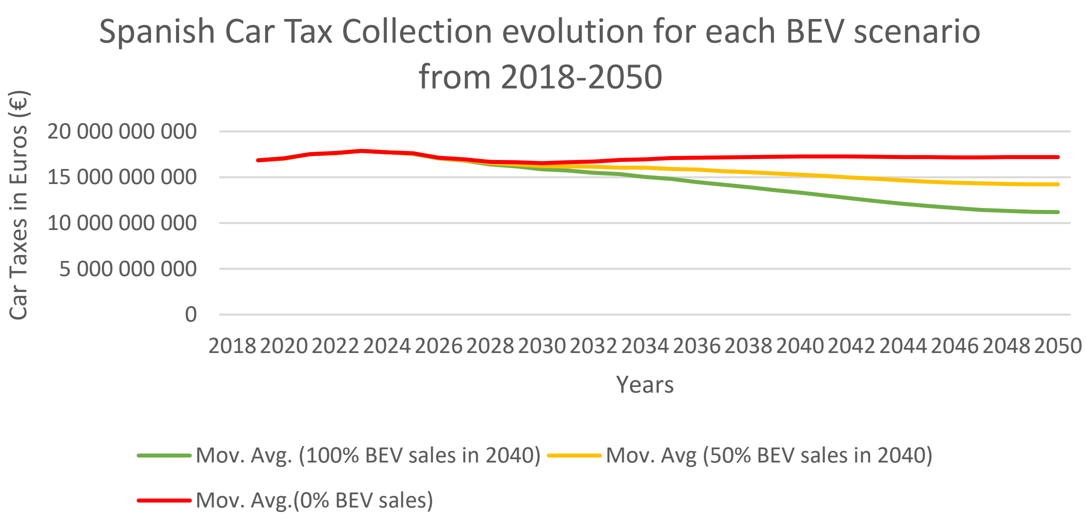
Source: Own elaboration

Now, that we have analyzed the different levels of tax collection obtained over the three scenarios, we will compare them.

5.3.2.4. Comparison of results from different scenarios

When we see the total tax (vehicle purchase and use) collected per year and for each BEV penetration scenario, we realize that the values are maintained until 2030, but then the values change according to the degree of BEVs penetration **(Figure 5-21)**.

Figure 5-21 - Spanish Car Tax collection evolution from 2018-2050 in the three different BEV scenarios



Source: Own elaboration

This can be explained, because until 2030, there were not enough BEVs in the passenger car fleet to translate a tax break, representing about 13% of market in the first scenario, 7% in the second, and 0% in the third in 2030.

First, in the radical scenario of electric mobility promotion (green line), 100% BEV sales in 2040, we see that it is the scenario that offers a higher break in the car tax collection. This is because greater BEV market penetration requires greater ICEV scrappage. This is clear from 2030 onwards.

In the intermediate situation with a penetration of 50% BEV sales in 2040 (yellow line), the total tax break between 2030 and 2050 are lower but bigger than in the scenario where we do not have BEVs.

Finally, when we came to cross with the more conservative scenario (red line) with 0% BEV sales, the tax collection associated with automobiles remains more or less constant over time.

Table 5-14 below shows the total tax (vehicle purchase and usage) collection breakdown between 2018 and 2050 for the three scenarios. It is noticed that in the scenario 100% BEV sales in 2040 there is a drop of 38%, 19% for the scenario of 50% BEV sales in 2040, and for the scenario without BEVs a decrease of 5%.

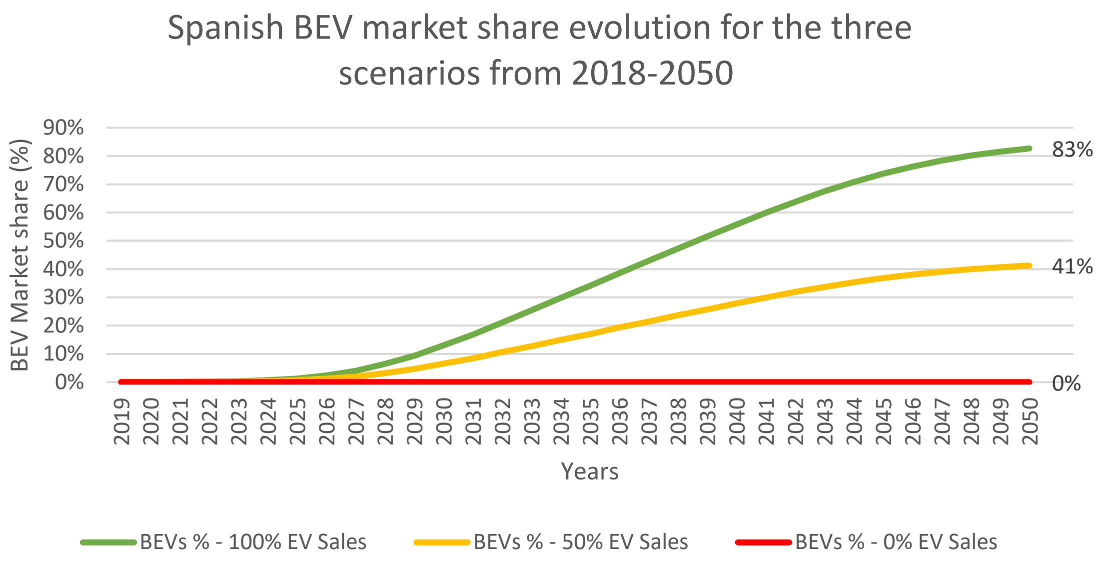
Table 5-14 - Total Car Tax Collection Losses between 2018 and 2050 for the three BEV scenarios

	Scenarios	**2018**	**2050**	**The Variation between 2050 and 2018**	**Annual Average Break in total Tax Collection**
Total Car Tax Collection (vehicle purchase and usage)	100% BEV sales in 2040	**18 213 700 058**	11 288 615 882 €	**-38%**	**-1,24%**
	50% BEV sales in 2040		14 768 620 773 €	**-19%**	**-0.28%**
	0% BEV sales in 2040		17 328 301 989 €	**-5%**	**0,08%**

Source: Own elaboration

Therefore, it is important to realize if this tax collection break allowed a BEV penetration **(Figure 5-22)**. Thus, in scenario, where there was a higher tax break (100% BEV sales) has a greater BEV market penetration, higher than 80% in 2050. The intermediate scenario - yellow line – has in 2050 - 41% of the Spanish car fleet, while in the third scenario - red line – 0% BEV market share.

Figure 5-22 - Spanish BEV Market share evolution from 2018-2050 in the three different BEV scenarios



Source: Own elaboration

In brief, in scenarios where there was a greater tax break in 2050, compared to 2018, there is a greater BEV market penetration. Now, we will compare the values obtained in the taxation of our base year – 2018 - with the real values of ACEA (2020a) to understand the tax data limitations.

5.3.3. Tax data Limitations

As seen earlier, the base year of the simulation model is 2018, while we are using tax values from 2019/2020. However, as such values are quite stables, we could compare them with the values obtained in our data with ACEA (2020a), in order to better understand the model limitations impact **(Table 5-15)**.

As previously mentioned, our model is a simplification of reality and therefore has limitations that culminate in a difference of 11.97 billion euros in the taxes collected by Spain associated with its passenger car fleet in 2018.

One of the main reasons for this difference is the annual number of new car registrations considered in Casado (2020) model are not in line with the real ones, available in DGT (2018).

Table 5-15 - Tax data Limitation

	In billion €			
2018	**ACEA 2020**	**Our values**	**Difference**	
VAT on vehicle sales, servicing, repair, and parts	5,00 €	5,60 €	0,60 €	Considered only Sales
Sales and Registration taxes	0,50 €	1,53 €	1,03 €	Considered only registration tax
Annual Ownership Taxes	2,90 €	1,42 €	-1,48 €	Considered
Fuel and lubricants	20,80 €	9,67 €	-11,13 €	With VAT on fuel
Other driving license fees	0,10 €	-	-0,10 €	No considered
Insurance taxes	-	-	-	No considered
Tolls	-	-	-	No considered
Customs duties	-	-	-	No considered
Other taxes	0,70 €	-	-0,70 €	No considered
TOTAL Spanish Car Tax in 2018	**30,00 €**	**18,21 €**	-11,79 €	

Source: Own elaboration

Another reason for this difference is that for the tax collection formulas in our model, it is only taken into account four powertrains, although they are the main ones for ICEV and EVs. Therefore, there is always a residual amount of powertrains that are not collecting taxes on our model and that are actually doing so.

On a more detailed level, we can see:

1. **VAT** of 5.6 billion euros obtained, took only into account sales and is therefore overestimated. Additionally, the annual number of new car registrations considered in Casado (2020) model is not the same as the real ones in 2018 available in DGT (2018), which may explain this trend. Another possible explanation might be due to the Volkswagen Golf model considered for the entire fleet, while in reality could have on average cheaper models in new car registrations in 2018.

2. This trend seems to be in line with **registration taxes**, which are also overestimated, again the difference in the annual number of new car registrations considered of Casado (2020) model and DGT (2018) may explain this tendency. In addition, the average price of cars in 2018 for new car registrations may be lower than Golf in Spain.

   Another possible explanation is that new Spanish car registrations may have an average of CO_2 emissions below 120 g/km, being exempt from this tax, unlike our ICEVs Golf models, which has higher emissions (calculated based and therefore are subject to registration tax.

   To make matters worse, the emissions considered in the calculation of taxes until April 2020 are obtained through the previous calculation method (NEDC), that underestimates emissions even more than the new calculation model (WLTP), which was what we took into account, as car manufacturers should provide emissions based on WLTP, since January 2019. This seems to be the most plausible justification for our overestimation.

   Furthermore, our model does not consider the registration fee, which represents a Government revenue of approximately € 97 per car sold, indicating an even stronger overestimation of this value.

3. The **annual ownership taxes or circulation taxes** are underestimated, indicating that the city of Madrid has lower taxation than other local authorities. Therefore, since Madrid and Barcelona, in 2017, had over 50% of the car fleet, for future studies it would be important to do the average the taxes collected by these two cities.

4. However, the biggest underestimation of our model is associated with the **Fuel tax**, which shows under 50% of the value stated in ACEA (2020a). This is mostly associated with the possible underestimation of fuel consumption announced by the car manufacturer – Volkswagen - or even of the average kilometer traveled per year since the INE values are for 2008. In addition, we considered fuel prices for 2019 and not 2018, which may have been higher than those defined in the model, and fuel prices are not constant over time.

5. On the other hand, we did not take into account taxes collected from driving licenses and other fees.

It should be noted that although this model is not truly consistent with reality, it allows us to understand the impact that BEVs create on the Government revenues associated with the Spanish car fleet, maintaining taxation as it is today. Therefore, the model fulfills its main objective, which is providing the overall tendencies.

Now, that we understand the limitation of the 2019/2020 tax data obtained, in subchapter 5.3., we try to understand if by changing the electricity tax rate, we can reduce the car tax collection breakdown across time with higher BEVs market penetration. This is potentially relevant, as previously identified in chapter 5.3.1, the majority of the tax contraction was due to vehicle usage, which in our model is influenced by the value of electricity tax, VAT on electricity, and circulation tax previously seen in section 5.2. As the fuel tax rate represents 30% of the cost per liter of petrol and 35% in the case of diesel, while the electricity tax is 5%, we believe it could be relevant, since the fuel category is where Spain collects the most of their car taxation.

5.4. CHANGE IN ELECTRICITY TAX RATE TO DECREASE LOSSES OF CAR TAXATION WITH HIGHER BEV MARKET PENETRATION

As previously mentioned in section 5.1., passenger cars are taxed not only to promote the infrastructure creation and maintenance but to internalize part of the negative externalities.

Electric vehicles are not free from negative externalities, although they have less than conventional ICEV powertrains. Thus, BEVs do not emit air pollution, GHG emissions, and noise during their circulation, but they are subject to accidents, they contribute to traffic congestion, and also need the transport infrastructure and the creation of public charging infrastructure, especially the fast one for more distant travels.

Therefore, the low taxation used to promote its penetration into the passenger car fleet has to be adapted before consumers are expected to maintain their current taxation in the long-term.

In this subchapter, we will see if, with a change in the electricity tax rate, we are able to maintain the same level of taxation over time in our scenarios which admit electric mobility penetration. It should be noted that this increase in electricity tax rate is potentially problematic because unlike fuels, electricity is used widely in households and if we increase taxes only for EVs, these vehicles are often charged at home. In addition, the industrial activity has access to a lower electricity per kWh, compared with households in Spain, creating additional social and equity challenges.

As you can see, electricity taxation has not yet been adapted for electric transportation and national tax rates vary widely between European countries (Transport&Environment, 2019). Consequently, electricity is taxed at much lower tax rate (5,11269632%) than fuel (petrol - 35% and diesel - 30%). This is particularly relevant, since Fuel Taxes are the main source of car taxation revenue in most European countries **(Table 5-16)**, accounting in Spain for around 20,80 of 30 billion euros in 2018 estimated by ACEA (2020a). This is particularly problematic since EVs eliminate most of this source of income.

Table 5-16 - National Government revenue from car taxation in the EU

Purchase or transfer	AT (€ bn) 2017	BE (€ bn) 2018	DE (€ bn) 2018	DK (DKK bn) 2018	ES (€ bn) 2018	FI (€ bn) 2018	FR (€ bn) 2018	GR (€ bn) 2019	IE (€ bn) 2019	IT (€ bn) 2018	NL (€ bn) 2019	PT (€ bn) 2019	SE (SEK bn) 2019	UK (£ bn) 2018/2019[4]
1.VAT on vehicle sales, servicing, repair & parts	3.1	7.4	31.3	–	5.0	1.7	18.5	0.3	0.7	18.6	1.2	4.5	25.0	12.5
2. Sales & registration taxes	0.5	0.5	–	20.7	0.5	1.0	2.3	0.3	1.0	1.8	2.2	0.7	–	–
3. Annual ownership taxes	2.4	1.7	9.0	9.9	2.9	1.2	0.9	1.2	0.9	6.8	4.3	0.7	13.9	6.5
4. Fuels & lubricants	5.4	8.8	41.7	17.5	20.8	3.9	42.8	5.6	3.5	37.8	10.4	3.5	45.0	28.0
5. Others														
Driving license fees	–	0.0	0.2	–	0.1	–	–	–	0.0	–	0.3	–	–	–
Insurance taxes	0.4	1.0	5.3	1.5	–	0.4	5.1	–	0.1	3.9	1.2	–	2.8	–
Tolls	2.1	0.7	5.7	0.5	–	–	12.6	–	–	2.2	0.2	0.2	2.7	–
Customs duties	–	–	0.2	–	–	–	–	–	–	–	–	–	–	–
Other taxes	0.4	0.7	–	–	0.7	–	1.7	0.1	–	5.3	1.8	–	–	1.5
TOTAL (national currencies)	14.3	20.7	93.4	50.1	30.0	8.1	83.9	7.4	6.2	76.3	21.5	9.6	89.4	48.1
TOTAL (€)[5]	14.3	20.7	93.4	6.7	30.0	8.1	83.9	7.4	6.2	76.3	21.5	9.6	8.1	54.1
GRAND TOTAL = €440.4 billion														

Source: ACEA (2020a)

However, we are not going to develop this problem in detail, but try to understand the impact of the increase in electricity on the maintenance of car taxation in Spain between 2018 and 2050. As was emphasized in the previous subchapter, the scenario with the highest BEV penetration is the one with the greatest loss of car taxation in the vehicle usage category over time and in 2050.

Indeed, the total annual tax break associated with the BEV penetration in the scenario 100% BEV sales in 2040 is of -38% in 2050, compared to 2018. This corresponds to an average loss of 1,24 % per annum. In the case of the 50% BEV sales in 2040 scenario, the total annual car taxation drop in 2050 compared to 2018 is -19% while the average tax break per year is 0.28%. Indeed, this car taxation break was mainly due to the category of taxes associated with the use of the vehicle.

To understand the impact of this change in electricity tax, we are going to look at the current annual cost of supplying a vehicle with fuel and electricity, with a fuel tax of 35% for petrol and 30% for diesel and an electricity tax of 5,11269632% **(Table 5-17)**.

As you can see in the Table 5-17, BEVs have the lowest operating costs (445,31€), mainly associated with much lower taxation – electricity tax which influences VAT level[15]. It should be noted that the amount paid for electricity is equivalent to the petrol and diesel cost, emphasizing the household high cost of electricity in Spain when compared to the rest of the European Union **(Figure 5-23)**.

[15] Electricity final price (after taxes) = (Electricity Price before taxes + Electricity Tax) x VAT (21%)

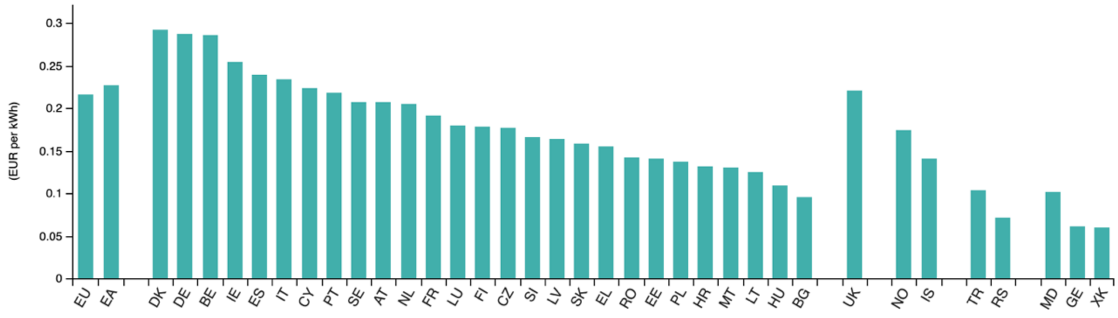
Table 5-17 - Current Annual Car Fuel and Electricity Cost

	Vehicle age	ICEV petrol	ICEV diesel	PHEVs	BEVs
Fuel Price (without taxes)	0 - 4 years	417,95 €	412,72 €	149,27 €	
	5 - 10 years	384,69 €	379,87 €	137,39 €	
	11 - 20 years	292,78 €	289,12 €	104,57 €	
Fuel tax - Impuesto especial sobre hidrocarburos	0 - 4 years	367,66 €	263,21 €	131,31 €	
	5 - 10 years	338,40 €	242,26 €	120,86 €	
	11 - 20 years	257,56 €	184,38 €	91,98 €	
VAT on fuel - Impuesto sobre el Valor Añadido	0 - 4 years	164,98 €	141,94 €	58,92 €	
	5 - 10 years	151,85 €	130,65 €	54,23 €	
	11 - 20 years	115,57 €	99,43 €	41,28 €	
Electricity household price	0 - 4 years			353,92 €	400,77 €
	5 - 10 years			325,76 €	368,87 €
	11 - 20 years			247,93 €	280,75 €
Electricity tax - Impuesto Especial sobre la Electricidad	0 - 4 years			18,10 €	20,49 €
	5 - 10 years			16,65 €	18,86 €
	11 - 20 years			12,68 €	14,35 €
VAT on Electricity - Impuesto sobre el Valor Añadido	0 - 4 years			78,12 €	88,46 €
	5 - 10 years			71,91 €	81,42 €
	11 - 20 years			54,73 €	61,97 €

	Vehicle age	ICEV petrol	ICEV diesel	PHEVs	BEVs
Annual Car Fuel or Electricity Cost (plus taxes)	0 - 4 years	950,60 €	817,87 €	789,64 €	509,72 €
	5 - 10 years	874,94 €	752,78 €	726,80 €	469,15 €
	11 - 20 years	665,91 €	572,94 €	553,16 €	357,07 €
	Average	**830,48 €**	**714,53 €**	**689,87 €**	**445,31 €**

Source: Own elaboration

Figure 5-23 - Electricity Prices (including taxes) for households consumers (2019)



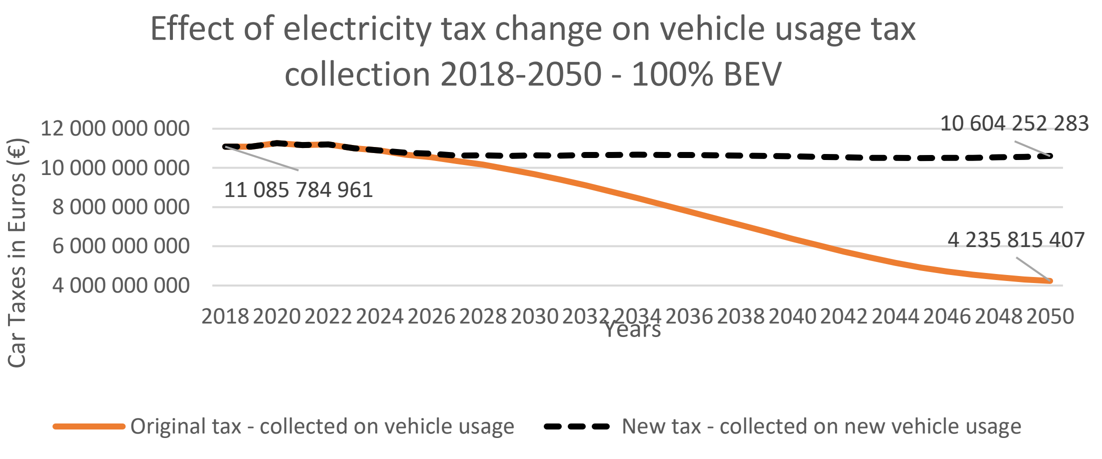
Source: (Eurostat, 2020)

Thus, in order to maintain the car taxation over time, that is, an annual variation of the total taxes collected from 2018 – 2050 close to zero is necessary. In order to achieve this, we built a model in excel, in which we analyze these variations for different levels of electricity tax.

We noticed that a change in electricity tax from approximately 5% to 80% in 2025 onwards in the two BEV scenarios allows a reduction in the total annual tax collection of about 5% compared to 2018 and an almost zero annual variation in the total tax collected. It should be noted that this rate could be lower if we consider, in our model, taxes on electricity production, which currently have a rate of 7%.

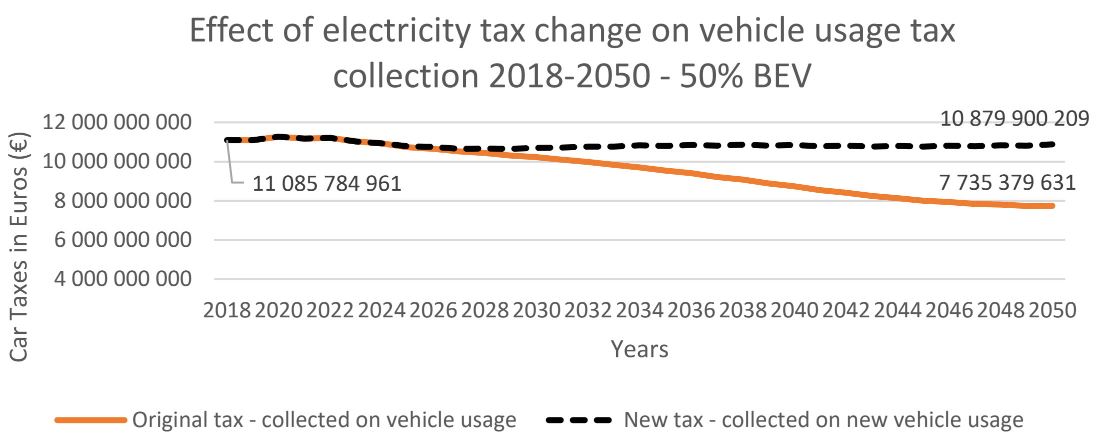
As can be seen in the following graphics **(Figure 5-24 and 5-25)**, this new electricity tax permits the maintenance of the total annual tax collected on vehicle usage in Spain. This value can be explained based on the annual tax difference collected by the State in the vehicle usage between powertrains (in section 5.2). As we saw earlier, ICEV pays an average of € 468.65 in annual taxes associated with the vehicle use, while BEVs pay € 109, 94. So, each ICEV that is scrapped and replaced by a BEV represents an average loss of € 358.71 per year.

Figure 5-24 - Effect of electricity Tax on vehicle usage tax collection 2018-2050 - 100% BEV



Source: Own elaboration

Figure 5-25 - Effect of electricity Tax on vehicle usage tax collection 2018-2050 - 50% BEV



Source: Own elaboration

However, it is important to understand the impact of this increase in electricity tax on the total cost of fueling the vehicle. Does the annual operating cost of the BEV remain lower? As we can see in **Table 5-18** below, the annual BEV operating cost remains slightly cheaper than ICEV petrol, but it is more expensive than diesel ICEV.

In short, changing the electricity tax rate from approximately 5% to 80% solves the problem of loss of taxation on BEVs, but makes operating costs higher, reducing one of BEV's main advantages.

Table 5-18 - Effect of a higher electricity tax on annual Car Fuel and Electricity Cost

	Vehicle age	ICEV petrol	ICEV diesel	PHEVs	BEVs
Fuel Price (without taxes)	0 - 4 years	417,95 €	412,72 €	149,27 €	
	5 - 10 years	384,69 €	379,87 €	137,39 €	
	11 - 20 years	292,78 €	289,12 €	104,57 €	
Fuel tax - Impuesto especial sobre hidrocarburos	0 - 4 years	367,66 €	263,21 €	131,31 €	
	5 - 10 years	338,40 €	242,26 €	120,86 €	
	11 - 20 years	257,56 €	184,38 €	91,98 €	
VAT on fuel - Impuesto sobre el Valor Añadido	0 - 4 years	164,98 €	141,94 €	58,92 €	
	5 - 10 years	151,85 €	130,65 €	54,23 €	
	11 - 20 years	115,57 €	99,43 €	41,28 €	
Electricity household price	0 - 4 years			353,92 €	400,77 €
	5 - 10 years			325,76 €	368,87 €
	11 - 20 years			247,93 €	280,75 €
Electricity tax - Impuesto Especial sobre la Electricidad	0 - 4 years			283,14 €	320,61 €
	5 - 10 years			260,60 €	295,10 €
	11 - 20 years			198,34 €	224,60 €
VAT on Electricity - Impuesto sobre el Valor Añadido	0 - 4 years			133,78 €	151,49 €
	5 - 10 years			123,14 €	139,43 €
	11 - 20 years			93,72 €	106,12 €

	Vehicle age	ICEV petrol	ICEV diesel	PHEVs	BEVs
Annual Car Fuel or Electricity Cost (plus taxes)	0 - 4 years	950,60 €	817,87 €	1 110,34 €	872,87 €
	5 - 10 years	874,94 €	752,78 €	1 021,98 €	803,40 €
	11 - 20 years	665,91 €	572,94 €	777,82 €	611,46 €
	Average	**830,48 €**	**714,53 €**	**970,05 €**	**762,58 €**

Source: Own elaboration

Additionally, as defend by Sanz and Ventosa (2019), the EV taxation must be changed, so that it can change consumer consumption habits in real-time, especially associated with the recharge time of vehicle, as well as the kind of charge, in order to avoid the consequences of sharp demand peaks in the local electricity distribution networks. Thus, these authors suggest a change in taxes on electricity consumed and also on the generation of *ad valorem* should be changed for a physical basis – kWh. Sanz and Ventosa (2019) also state that these electricity taxes should be based on CO_2 emissions, to encourage the generation and consumption of electricity from renewable sources.

At the same time, as emphasized by Transport&Environment (2019) and (OECD/IEA, 2019a), in the long-run, electric mobility will require a shift to new road financing models, as intelligent road pricing based on Km traveled and not in the asset (car), as the previous national and local tax model.

5.5. CHAPTER CONCLUSIONS

In Chapter 5, we analyzed the current car taxation regime in Spain, which is mainly concentrated on the asset (car) and not in its use (km), resulting in the encouragement of personal ownership and the selection of bigger and heavier vehicles.

Nowadays, car taxes are all the taxes associated with ownership and vehicle usage, as well as infrastructure usage. Additionally, this car tax revenue typically goes to a general budget, which funds infrastructure deployment and maintenance and non-auto related projects.

This government revenue is important since represents a significant source of income from national and local governments. Indeed, car taxation internalizes some of the negative externalities associated with transportation: as air pollution, greenhouse gas emissions, noise, accidents, and traffic congestion and funds the construction, maintenance, and managing of transport infrastructure, which are not paid by transport users, since they do not take into account these costs in their economic decisions.

With a higher EV market penetration, government revenue collected through car taxation is at risk, if we maintain a "business-as-usual" car tax scenario. As previously seen, EVs do not solve all negative externalities related to individual mobility, especially traffic congestion and infrastructure costs, but are currently subjected to lower tax rates in order to promote the transition towards zero-emission vehicles.

With a simulation model of the evolution of the passenger car fleet in Spain from 2018 to 2050, which admits three different BEV market penetrations scenarios - 100% BEV sales in 2040, 50% BEV sales in 2040, and 0% BEV sales - and maintaining the current taxation, we conclude that the total car tax collection is more or less preserved until 2030. In 2030, starts a substantial annual drop that accompanies BEV penetration growth in the passenger car fleet until 2050.

Therefore, in the scenario that admits 100% BEV sales in 2040, the fall in the total taxes collected is 38% in 2050 compared to 2018 and in the scenario of 50% BEV sales in 2040 are 19%.

This can be explained, because this tax break happens in our model especially during vehicle usage and not on purchase moment, since the Spanish Government collects more or less the same amount of taxes on the purchase moment between ICEV petrol and diesel and BEVs if we do not take into account the individual purchase subsidy given annually, due to EV higher selling price, which allows for greater VAT collection.

In Spain, conventional vehicles continue to pay more taxes during its usage compared to EVs, especially because of the difference between Fuel tax (30% Petrol and 35% Diesel) and Electricity tax (5%) rate. This is particularly relevant, since Fuel Tax is the main source of car taxation revenue, accounting for around 20,80 of 30 billion euros in 2018 estimated by ACEA (2020a).

Spain, like most countries in the world, has not yet adapted its electricity tax rate to the new reality of electromobility. Therefore, we changed the electricity tax rate in order to reduce the breakdown in car tax collection over time with higher BEV market penetration.

We noticed that a change in electricity tax rate from approximately 5% to 80% in 2025 onwards for the two BEV scenarios allows a reduction in 2050 in the total annual tax collection drop of about 5% compared to 2018 and an approximately zero annual variation in the total tax collected.

Due to BEVs energy efficiency, we reached the conclusion that this would mean an extremely higher percentage of taxation would be necessary to reach the taxations values of ICEVs, Therefore, it is suggested that the electricity tax is a plausible way of having higher revenues from these vehicles, however in order to not reach such an extreme measure, with a higher market share of BEVs, other factors would need to be considered as a way to raise government revenues from taxes on transportation, since this electricity tax rate increase makes the BEV operating costs higher, reducing one the main advantages of buying a BEV.

In sum, the growth in BEV market share means the long-term stabilization of transport-related fiscal revenues cannot depend exclusively on marginal adjustments of vehicle and fuel taxes and electric mobility will require a shift to new road tax financing models based on Km traveled and not on the asset.

CHAPTER 6 - CONCLUSIONS

Currently, private car transport accounts for three-quarters of all passenger mobility, representing the largest modal share of the world's passenger transport. Consequently, its transformation is particularly problematic, concerning that the transport sector has a significant contribution to national GDP, employment, national and local government revenue. Besides GHG emissions, noise, and local air pollution, road transport is also responsible for dependence on foreign energy sources, compromising energy security and for road safety issues.

EVs are perceived as best suited to reduce emissions from light-duty vehicles, but their diffusion is still dependent on Government support since their market penetration in passenger car fleet is residual. Thus, literature has focused on the role of public policies in promoting the EV market penetration, given the current EV technological and cost advances.

Transport policies are coming in complex packages and comprehending the nature of their design is increasingly important, creating multi-policy, multi-objective and multi-instrument mixes. Thus, Policy mix literature seems pertinent to address this great challenge, despite this theory has benefited from little attention by the transportation literature, since has been widely used in the climate and energy field for the transition of the decarbonized energy system.

The Policy mix is a concept under-conceptualized and has an inconsistent terminology, but in our study, we adopted the concept of Flanagan et al. (2011) and Rogge and Reichardt (2016), which defend that policy mixes are more than just a combination of policy instruments, since this concept also includes the dynamic processes of creation and interaction of such instruments.

Although the policy mix concept has multiple components, we will focus on the elements - policy strategy and instrument mix - and vertical governance dimension. The first Element component is the Policy strategy, which provides the direction given to actions and decisions by policy objectives and plans. It is valuable to note that policy objectives consist of long-term environmental, social, and economic targets.

The second Elements component is the instrument mix that is the combination of policy instruments, which are tools or techniques of governance adopted by a governing body and can be called measures, programs, or policies in the studies.

Finally, the vertical governance dimension is compatible with the definition of the modern state, where there is a dispersion of power, both upwards and downwards, since governments operate on various scales of jurisdiction and in different areas. Therefore, vertical governance level is the existence of international, supranational, national, and local levels in public policies, which can create more conflicts and coordination issues between policy instruments and objectives implemented by each vertical governance level. This happens because certain vertical governments may promote some actions without taking into account their impact on other elements of a policy mix.

Consequently, each vertical governance level has its policy objectives, which can have something in common with the other jurisdictions, as well as different policy objectives and preferences. For example, the international level is concerned with the environmental degradation and climate change and has been trying to promote sustainable mobility, while the supranational level is also worried about the previous policy objectives, plus EU's external dependency on imported fossil fuels, efficiency and secure and affordable energy to consumers. The national level tries to transpose European measures into its national legislation but is more apprehensive with GDP and the level of employment. Lastly, the local level is focused on increase urban livability.

In Chapter 2, different vertical governance levels add additional challenges to EV promotion associated with conflicts and coordination problems in policy objectives and consequently in the policy instruments implemented by each vertical governance level. Therefore, each vertical governance level has a role in promoting electric mobility in Europe.

We conclude that Paris Agreement on Climate Change and Sustainable Development Goals helped by Sum4All are the main forces behind the international level, pressuring the Supranational (European Union for the Member States and European Economic Area for non-Member States) and national governance levels to act, fostering the electric mobility in Chapter 3.

In the second section of this chapter, we find that the European Union is at the forefront of the global transition towards a low-carbon. Although, in 2018, Europe represented the second-largest electric car market. This leadership may be explained by the definition of regulations, directives, targets, and industrial policies that should be transposed into national legislation within defined deadlines by the European Union and some of them by the European Economic Area. The main areas of intervention to boost electromobility are the vehicles, the charging infrastructure, and energy. Thus, these vertical governance levels provide the main guidelines for the national and local level.

In the last section, we discover that European countries that are characterized by a strong traditional automobile industry are those that are still lagging behind in electric mobility since this industry creates extra challenges in coordination activities and difficult the implementation of certain incentives. This resistance can be explained since EV penetration embodies a large challenge to this conventional sector, requiring a redesign of its value chain, investment priorities, and technological choice.

Consequently, European countries were divided into three different clusters according to the importance of the automobile industry in country's GDP (high, medium, low) and three representative countries from each cluster were selected to carry out an analysis in Chapter 4 of the initiatives carried out at national and local governance level. The selected countries were Spain, Portugal, and Norway, based on data availability.

The first cluster of European countries with high economic dependence of the Automobile industry is characterized mostly by countries with low penetration of renewable sources and with high energy dependence. All of these countries comply with the European Alternative Fuels Infrastructure Directive, which are populous countries with their citizens concentrated in urban areas that mainly use private transport for their daily commuting. Therefore, they are more polluted and more traffic congested. Spain was chosen as a representative country of this cluster, as it has a considerable tradition in this industry (10% of GDP), but with the advantage of not hosting the headquarters of the main car companies. In addition, it has an EV share of less than 1 percent and an EV market share of less than 2 percent.

The second cluster of European countries is described by an average automotive industry (less than 9% of GDP) with an EV share of less than 1%, but with a market share of more than 2% in some countries. In addition, they are countries that also comply with the European Alternative Fuels Infrastructure Directive and some of them use private transportation for the daily commute, having an intermediate level of pollution. Portugal was selected as a representative country, since has invested in electric mobility recently and has an EV market share above 5 percent, despite its certain dependency on the Volkswagen Autoeuropa factory.

Finally, the latter cluster is illustrated by countries with no tradition in the auto industry, which consequently are also the leaders in electric mobility in Europe. It consists of the Nordic countries and the Netherlands. These are the countries with the lowest energy dependence and the highest penetration of renewable sources. However, a sufficient charging infrastructure deployment was not reached so far and does not comply with the European Alternative Fuels Infrastructure Directive. Norway was the country chosen for being the leader of the electromobility in Europe and the Nordic region. Besides, it has a network of varied policy instruments implemented since the mid90s at the national and local levels.

In Chapter 4, we accomplish that for a more widespread EV adoption is important to implement combined policy support with a mix of policy instruments. These policy instruments have an impact on EV market share and consequently on EV share in total passenger car fleet. Additionally, one key factor is the national electricity price.

Norway has the greatest incentives associated with the vehicle purchase, but with tax benefits and not direct subsidies since it allows registration tax, import duty tax, and VAT exemption, and ICEV vehicles are much more taxed in this country. In addition, Norway uses the majority of non-economic incentives implemented at the local level that increase the advantages of this type of vehicle.

Portugal and Spain have more or less the same type of economic and non-economic incentives, but Portugal and Spain have a measure that Norway does not adopt, relating to a direct purchase subsidy implemented annually. It should be noted that Spain offers a much higher subsidy, including PHEVs and Portugal offers a timid subsidy just for BEVs. Thus, Portugal and Norway distinguish more the acquisition incentives for BEVs, compared to PHEVs, paralleled to Spain.

Consequently, we discover that national and local levels are where the great European EV market penetration disparity occurs, since it is where most of the direct policy instruments for consumers are implemented, despite all these European countries benefited from an international and supranational level pressure that help EV promotion, even when the countries are not UE member-states, but part of European Economic Area – like Norway.

The existence of the automobile industry dominance or not in the country's GDP relevance was illustrated here by Spain and Norway's case because their lobbying groups can complicate the EV promotion and jeopardize the collaboration between actors. Consequently, some national measures can be contra-productive, since are supporting these industry interests. In sum, the collaboration between national and local agents, car manufactures, importers, electricity producers, grid operators is fundamental, as have been happening in Norway.

In Chapter 5, we realize that the current framework of vehicle and fuel taxation is not prepared for the individual road transport revolution, since are driving to an unsustainable transport system characterized by personally owned cars powered by engines with high negative externalities on society, since is centered mainly on the asset (car) and not on the driving distance.

Nowadays, car taxes are all the taxes associated with ownership and vehicle usage, as well as infrastructure usage. Additionally, this car tax revenue typically goes to a general budget, which funds infrastructure deployment and maintenance and non-auto related projects.

This government revenue is important since represents a significant source of income from national and local governments. Indeed, car taxation internalizes some of the negative externalities associated with transportation: as air pollution, greenhouse gas emissions, noise, accidents, and traffic congestion and funds the construction, maintenance, and managing of transport infrastructure, which are not paid by transport users, since they do not take into account these costs in their economic decisions.

With a higher EV market penetration, government revenue collected through car taxation is at risk, if we maintain a "business-as-usual" car tax scenario. As previously seen, EVs do not solve all negative externalities related to individual mobility, especially traffic congestion and infrastructure costs, but are currently subjected to lower tax rates in order to promote the transition towards zero-emission vehicles.

With a simulation model of the evolution of the passenger car fleet in Spain from 2018 to 2050, which admits three different BEV market penetrations scenarios - 100% BEV sales in 2040, 50% BEV sales in 2040, and 0% BEV sales - and maintaining the current taxation, we conclude that the total car tax collection is more or less preserved until 2030. In 2030, starts a substantial annual drop that accompanies BEV penetration growth in the passenger car fleet until 2050.

Therefore, in the scenario that admits 100% BEV sales in 2040, the fall in the total taxes collected is 38% in 2050 compared to 2018 and in the scenario of 50% BEV sales in 2040 are 19%.

This can be explained, since this tax break happens in our model especially during vehicle usage and not on purchase moment, since the Spanish Government collects more or less the same amount of taxes on the purchase moment between ICEV petrol and diesel and BEVs, if we do not take into account the individual purchase subsidy given annually, due to EV higher selling price, which allows for greater VAT collection.

In Spain, conventional vehicles continue to pay more taxes during its usage compared to EVs, especially because of the difference between Fuel tax (30% Petrol and 35% Diesel) and Electricity tax (5%) rate. This is particularly relevant since Fuel Taxes are the main source of car taxation revenue in most European countries and EVs almost eliminate this source of Government revenue.

Spain, like most countries in the world, has not yet adapted its electricity tax rate to the new reality of electromobility. Therefore, we changed the electricity tax rate in order to reduce the breakdown in car tax collection over time with higher BEV market penetration. **From € 18 213 700 058 in 2018 to:**

- **100% BEV Sales scenario:** € 11 288 615 882 (5%) and € 17 657 052 757 (80% from 2025 onwards) in 2050;
- **50% BEV Sales scenario:** € 14 768 620 773 (5%) and € 17 913 141 351 (80% from 2025 onwards) in 2050.

Due to BEVs energy efficiency, we concluded that this would mean an extremely higher percentage of taxation would be necessary to reach the taxations values of ICEVs. Therefore, it is suggested that the electricity tax is a plausible way of having higher revenues from these vehicles, however in order to not reach such an extreme measure, with a higher market share of BEVs, other factors would need to be considered as a way to raise government revenues from taxes on transportation, since this electricity tax rate increase makes the BEV operating costs higher - annual electricity cost for BEVs from € 445,31 (5%) to € 762,58 (80%), while petrol ICEVs pays annually € 830,48 and diesel ICEV €714,53 - reducing one the main advantages of buying a BEV.

In sum, growth in BEV market share means the long-term stabilization of transport-related fiscal revenues cannot depend exclusively on marginal adjustments of vehicle and fuel taxes and electric mobility will require a shift to new road tax financing models based on distance travel and not on the asset.

Research limitations and suggestions for future work

In the first part of the study, it would be important for future studies to relate the initiatives carried out at the Supranational level with the fulfillment of deadlines for national transposition.

Regarding the selection of representative countries, it would be useful to promote the study of other representative countries in each European cluster and add a section dedicated exclusively to lessons for other countries with the same characteristics - members of the same cluster.

In the second part of the study, when using the quantitative approach, it is important to consider the impact of purchase subsidies given to EVs. Additionally, future work should consider more powertrain systems, besides petrol and diesel ICEVs, BEVs, and PHEVs or at least develop a combination of BEV and PHEV market penetration at the same time, not done in our study.

In addition, it would be important to consider a different driving distance for each powertrain system and more accurate fuel and energy consumption, since our assumptions underestimate real energy consumption. At the same time, electricity tax on generation should be included in our fiscal model, besides the electricity tax on energy consumption.

It should be noted that by keeping the price of BEVs and PHEVs constant over time, we are masking possible future losses associated with tax collection at the purchase moment. This is because until now the high selling price of BEVs and PHEVs compensates the loss of tax collection related registration tax exemption or benefit, with VAT. However, the tendency is for EV price to be equal to ICEVs in the next decade, announcing extra challenges beyond electricity tax - fuel tax.

It also would be interesting to further develop the topic associated with car taxation schemes in the future that are more based on driving distance and not on assets.

Finally, it is important to have in mind that if EV market penetration increases and we maintain the taxation regime, this will lead to substantial falls in national and local government revenues in the future. However, EVs have less negative externalities with respect to GHG emissions, air pollution, and noise (section 5.1), which could lead to substantial savings in spending by national and local governments, for example, on Health. For future work, it would be very noteworthy to try to quantify this gain in negative externalities and compare it to government revenue drops, since theoretically, the state would have fewer expenses.

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APPENDIXES

APPENDIX A- ANALYSIS OF EV PROMOTION IN THE EUROPEAN COUNTRIES

i. Electric Passenger car stock in Europe

Table A-1 - Electric Passengers Cars Market Share

		2019			2017	2019/2017
		STOCK - PASSENGERS CARS				
	Countries	BEVs	PHEV	Total EVs (BEVs and PHEVs)	Registered passengers cars - 2017	Total EVs % of registered passenger cars
1	Austria	28 327	7 258	35 585	4 899 000	0,73%
2	Belgium	19 191	38 577	57 768	5 799 000	1,00%
3	Bulgaria	394	237	631	2 771 000	0,02%
4	Croatia	491	139	630	1 596 000	0,04%
5	Cyprus	195	228	423	526 600	0,08%
6	Czech Republic	2 647	1 105	3 752	5 538 000	0,07%
7	Denmark	14 851	7 305	22 156	2 530 000	0,88%
8	Estonia	1 315	129	1 444	726 000	0,20%
9	Finland	3 649	13 263	16 912	3 423 000	0,49%
10	France	153 695	54 481	208 176	32 006 000	0,65%
11	Germany	148 086	117 893	265 979	46 475 000	0,57%
12	Greece	376	480	856	5 283 000	0,02%
13	Hungary	3 191	1 722	4 913	3 472 000	0,14%
14	Iceland	3 561	7 152	10 713	250 000	4,29%
15	Ireland	6 787	2 848	9 635	2 087 000	0,46%
16	Italy	19 963	41 341	61 304	38 520 000	0,16%
17	Latvia	537	110	647	690 000	0,09%
18	Lithuania	385	276	661	1 357 000	0,05%
19	Luxembourg	2 364	2 181	4 545	403 000	1,13%
20	Malta	330	14	344	292 000	0,12%
21	Netherlands	77 392	96 046	173 438	8 373 000	2,07%
22	Norway	211 796	98 374	310 170	2 719 000	11,41%
23	Poland	2 607	2 081	4 688	22 503 000	0,02%
24	Portugal	13 763	11 323	25 086	5 059 000	0,50%
25	Romania	2 224	582	2 806	5 998 000	0,05%
26	Slovakia	915	766	1 681	2 223 000	0,08%
27	Slovenia	1 581	629	2 210	1 118 000	0,20%
28	Spain	24 180	17 280	41 460	23 500 000	0,18%
29	Sweden	31 565	74 023	105 588	4 845 000	2,18%
30	Switzerland	28 417	16 547	44 964	4 571 000	0,98%
31	Turkey	1 260	366	1 626	12 036 000	0,01%
31	United Kingdom	86 777	160 715	247 492	32 201 000	0,77%
32	Liechtenstein	159	1	160	29 000	0,55%
						> 1%
						0,75%-1%
	TOTAL	892 971	775 472	1 668 443		
	Data Source	EAFO (2019)	EAFO (2019)		Statista (2017)	

Data Sources:(Statista, 2017, EAFO, 2019a)

As mentioned above, we adopted OECD/IEA (2019a) definition for EVs share, regarding the share of electric car stock as a percentage of total passenger light-duty car stock. In other words, it represents the total electric cars in the total passenger light-duty car stock, showing the EV penetration in Europe.

This data has been collected mostly through EAFO (2019a) for the electric passenger cars and to obtain the total passenger light-duty car stock we used Statista (2017) database. Additionally, in our study, EVs are seen as the sum of PHEVS and BEVs, and the EVs share is calculated by the division between EVs and the total passenger light-duty car stock. However, the passenger car fleet is from 2017 and the values related to electric mobility are from 2019, which may cause deviations in the results.

As we have seen in **Table A-1**, in 2019, electric vehicles were residual, considering the total registered passenger cars. EVs represented, in the majority, less than 1% of the passenger car fleet in Europe. Thus, European countries with a percentage of electric passenger cars over 1% are concentrated mainly in the Nordic region - Norway (11.41%), Iceland (4.29%) and Sweden (2.18 %) - and in the Netherlands (2.07%), Luxembourg (1.13%) and Belgium (1%). There is a second group of countries with a share between 0.75% and 1% - Belgium (1%), Denmark (0.88%), Switzerland (0.98%), and the United Kingdom (0.77%). Lastly, the remaining countries have an EV share less of than 0,75%.

ii. Electric Passenger car Market Share

Table A-2 - Electric Passengers Cars Market Share

		2019 MARKET SHARE - PASSENGERS CARS			
	Countries	EVs % Market share	PHEVs % Market share	BEVs % Market share	BEVs > PHEVs (% Market share)
1	Austria	3,50%	0,70%	2,80%	Yes
2	Belgium	3,00%	1,50%	1,50%	No
3	Bulgaria	0,90%	0,30%	0,60%	Yes
4	Croatia	0,50%	0,10%	0,40%	Yes
5	Cyprus	1,30%	0,70%	0,60%	No
6	Czech Republic	0,50%	0,20%	0,30%	Yes
7	Denmark	3,90%	1,70%	2,20%	Yes
8	Estonia	0,40%	0,10%	0,30%	Yes
9	Finland	6,50%	4,90%	1,60%	No
10	France	2,70%	0,80%	1,90%	Yes
11	Germany	2,90%	1,20%	1,70%	Yes
12	Greece	0,40%	0,20%	0,20%	No
13	Hungary	1,70%	0,60%	1,10%	Yes
14	Iceland	24,40%	14,80%	9,60%	No
15	Ireland	4,30%	1,20%	3,10%	Yes
16	Italy	0,90%	0,30%	0,60%	Yes
17	Latvia	0,90%	0,20%	0,70%	Yes
18	Lithuania	0,50%	0,10%	0,40%	Yes
19	Luxembourg	3,40%	1,80%	1,60%	No
20	Malta	N/A	N/A	N/A	N/A
21	Netherlands	10,80%	1,20%	9,60%	Yes
22	Norway	56,00%	12,70%	43,30%	Yes
23	Poland	0,50%	0,20%	0,30%	Yes
24	Portugal	5,50%	2,50%	3%	Yes
25	Romania	1,10%	0,20%	0,90%	Yes
26	Slovakia	0,40%	0,20%	0,20%	No
27	Slovenia	1,10%	0,10%	1,00%	Yes
28	Spain	1,30%	0,50%	0,80%	Yes
29	Sweden	9,20%	4,70%	4,50%	No
30	Switzerland	N/A	N/A	3,70%	N/A
31	Turkey	N/A	N/A	N/A	N/A
31	United Kingdom	N/A	N/A	1,50%	No
32	Liechtenstein	N/A	N/A	N/A	N/A
		> 9%			
		> 2%			
	Data Source		EAFO (2019)	EAFO (2019)	

Data Sources: (EAFO, 2019b)

As stated before, we adopted OECD/IEA (2019a) definition of EVs market share, meaning that the share of new electric car registrations as a percentage of new passengers light-duty car registrations. EV market share is relevant to demonstrate the short-trend in new passenger light-duty car sales.

This data was collected on EAFO (2019b) to have the PHEVs market share and BEVs market share per each European country. Then, we combined these two variables to get the EV market share.

Regarding the new passenger car sales in 2019, illustrated in **Table A-2**, the EV market share was also more representative in Norway (56%), Iceland (24%), the Netherlands (10.80%), and Sweden (9.92%). Although the percentage of electric vehicles in the total stock of registered passenger cars is less than 0,75%, it seems that this trend is reversing in the short term, as the EVs market share is over 2% in many European countries: Finland (6.5%), Portugal (5.5%), Ireland (4.3%), Denmark (3.9%), Germany (2.9%) and France (2.7%).

It should be noted that this trend occurs mainly due to the increase in pure electric vehicles (BEVs) market share. BEVs represented 31.2% of the 46.42% of the EVs market share in Norway and 5.4% of 5.57% in the Netherlands. Nonetheless, in Iceland, Sweden, Finland, United Kingdom, Luxembourg, and Cyprus this market share was due to the majority presence of PHEVs.

iii. Automobile Industry

Table A-3 - Automobile Industry

		2018	2013	2013
		AUTOMOBILE INDUSTRY		
	Countries	% Automobile Industry in GDP	Automobile Industry % of Gross Value Added	Automobile Industry % total employment
1	Austria	N/A	1,30%	0,75%
2	Belgium	1% (2016)	0,80%	0,80%
3	Bulgaria	5% (2017)	0,40%	0,30%
4	Croatia	N/A	0,05%	0,25%
5	Cyprus	N/A	0,01%	0,10%
6	Czech Republic	7% (2016)	4,30%	3,10%
7	Denmark	0,10%	0,10%	0,10%
8	Estonia	N/A	0,55%	0,60%
9	Finland	N/A	0,20%	0,23%
10	France	N/A	0,50%	0,40%
11	Germany	14% (2018)	4,00%	1,95%
12	Greece	N/A	0,03%	0,05%
13	Hungary	9% (2017)	3,90%	2,60%
14	Iceland	N/A	N/A	N/A
15	Ireland	N/A	0,10%	0,15%
16	Italy	11,6% (2012)	0,65%	0,75%
17	Latvia	N/A	0,20%	0,20%
18	Lithuania	N/A	0,25%	0,10%
19	Luxembourg	N/A	N/A	N/A
20	Malta	N/A	N/A	N/A
21	Netherlands	0,4% (2016)	0,30%	0,20%
22	Norway	N/A	N/A	N/A
23	Poland	4% (2010)	1,40%	1,45%
24	Portugal	4%	0,75%	0,65%
25	Romania	14%	1,65%	1,65%
26	Slovakia	12% (2013)	3,60%	2,75%
27	Slovenia	N/A	1,75%	1,35%
28	Spain	10%	0,90%	0,85%
29	Sweden	N/A	1,65%	1,30%
30	Switzerland	N/A	N/A	N/A
31	Turkey	N/A	N/A	N/A
31	United Kingdom	4% (2016)	0,65%	0,40%
32	Liechtenstein	N/A	N/A	N/A
		> 9%	> 1%	
		4%-9%	4%-9%	
	Data Source		Bank of Finland (2013)	Bank of Finland (2013)

Data Sources from GDP:(Reuters, 2013, Atradius, 2017a, Atradius, 2017b, Aznar, 2017, Evans, 2017, Novinite, 2017, Hrivnák, 2018, PWC, 2018, Saberi, 2018, Dragan, 2019, Wikipedia, 2020)

Data Sources from Gross Value Added and Total Employment:(Finland, 2013)

The automobile industry is one of the most powerful forces in Europe and this can be seen by the weight that this industry has in the GDP, in the gross added value, and in the share of total employment, shown by **Table A-3**.

We suffered from a lack of data, regarding the importance of this industry in GDP. In fact, this data was collected through a search on local newspapers and websites (Reuters, 2013, Atradius, 2017a, Atradius, 2017b, Aznar, 2017, Evans, 2017, Novinite, 2017, Hrivnák, 2018, PWC, 2018, Saberi, 2018, Dragan, 2019, Wikipedia, 2020). On the other hand, the automobile industry contribution to gross value added and employment was obtained through Finland (2013).

Germany (14%), Romania (14%), Slovakia (12%), Italy (11.6%), Spain (10%), and Hungary (9%) are the European countries with the greater weight of the automotive industry in its GDP, from the countries that we found data. We believe that France and Sweden should be in this group, but we did not find data for these countries. Please note that this industry accounts for more than 9% of these countries' GDP.

The automobile's industry importance in these countries can also be explained by the fact that this sector has an important share in the gross added value and in the share of total employment (> 1%) in these countries. Thus, it seems that countries with a strong automobile sector tradition are not the leaders in electric mobility. These countries have a low EV share in their passenger car fleet and even considering EVs market share, they also have a low share with the exception of Germany and France, with market shares above 2%.

There is an intermediate level of countries - Czech Republic (7%), Bulgaria (5%), Poland (4%), the United Kingdom (4%), and Portugal (4%) - which automotive industry represent less than 7% of GDP. This cluster has a low EV share in its passenger car fleet and in the EVs market share. The exceptions here are Portugal and the United Kingdom with EVs market share above 1%, but with a lower share of the car industry in GDP (only 4%).

Due to the lack of available data, we believe that the third group would have the countries where the auto industry is not relevant and where the EVs share and EV market share are high.

iv. Tax Revenues

Table A-4 - Tax Revenues - Centralization + Decentralization Data

		2017 TAX REVENUES as percentage of total general government tax revenue			
	Countries	**Central**	**State**	**Local**	**Decentralized governance**
1	Austria	94,97%	1,59%	3,01%	-
2	Belgium	83,39%	10,78%	4,85%	-
3	Bulgaria	N/A	N/A	N/A	-
4	Croatia	N/A	N/A	N/A	-
5	Cyprus	N/A	N/A	N/A	-
6	Czech Republic	98,46%		1,07%	-
7	Denmark	73,28%		26,41%	Yes
8	Estonia	98,54%		0,91%	-
9	Finland	76,20%		23,49%	Yes
10	France	86,33%		13,29%	-
11	Germany	67,41%	23,47%	8,56%	Yes
12	Greece	97,08%		2,42%	-
13	Hungary	93,90%		5,78%	-
14	Iceland	73,54%		26,46%	Yes
15	Ireland	97,19%		2,17%	-
16	Italy	83,88%		15,49%	-
17	Latvia	80,14%		19,23%	-
18	Lithuania	97,94%		1,18%	-
19	Luxembourg	95,34%		4,07%	-
20	Malta	N/A	N/A	N/A	-
21	Netherlands	95,88%		3,00%	-
22	Norway	84,12%		15,88%	-
23	Poland	86,78%		12,70%	-
24	Portugal	92,43%		7,10%	-
25	Romania	N/A	N/A	N/A	-
26	Slovakia	97,53%		1,93%	-
27	Slovenia	90,23%		9,36%	-
28	Spain	74,46%	15,19%	9,69%	Yes
29	Sweden	64,41%		35,28%	Yes
30	Switzerland	60,06%	24,62%	15,32%	Yes
31	Turkey	90,50%		9,50%	-
31	United Kingdom	94,64%		4,86%	-
32	Liechtenstein	N/A	N/A	N/A	-
	Data Source	**OECD (2017)**	**OECD (2017)**	**OECD (2017)**	

Source: (OECD, 2017b)

The tax revenues are collected at various government levels. This is relevant to understand the impact that economic tax incentives have at the national and local levels, normally implemented to promote electromobility.

The data was collected in OECD (2017b), but we also faced a lack of data for some European countries, like Bulgaria, Croatia, Cyprus, Malta, Romania, and Liechtenstein.

Most European countries have a very centralized government (central level), as exposed in **Table A-4.** This can be shown by the percentage of total general government tax revenues collected at the central level higher than 80%.

However, there are some countries where tax revenues are only collected up to 80% at the central level. This shows a certain tendency towards the decentralization of tax collection. This is the case of Denmark, Finland, Germany, Iceland, Spain, Sweden, and Switzerland.

Even though, Germany, Spain, and Switzerland have a truly decentralized government structure with three levels, representing the more decentralized structure in Europe.

v. Power Sector

Table A-5 - Power Sector

		2017	2018
		POWER SECTOR	
	Countries	Energy Dependecy Rate (%) - 2017	% RES in gross final energy consumption
1	Austria	64,43%	33,43%
2	Belgium	74,84%	9,42%
3	Bulgaria	39,51%	20,53%
4	Croatia	53,25%	28,02%
5	Cyprus	96,33%	13,88%
6	Czech Republic	37,19%	15,15%
7	Denmark	11,66%	36,13%
8	Estonia	4,07%	30,00%
9	Finland	43,98%	41,16%
10	France	48,59%	16,59%
11	Germany	63,91%	16,48%
12	Greece	71,07%	18,00%
13	Hungary	62,57%	12,49%
14	Iceland	18,65%	71,57%
15	Ireland	67,14%	11,06%
16	Italy	76,98%	17,78%
17	Latvia	44,06%	40,29%
18	Lithuania	75,61%	24,45%
19	Luxembourg	95,40%	9,06%
20	Malta	102,94%	7,98%
21	Netherlands	51,81%	7,39%
22	Norway	-597,22%	72,75%
23	Poland	38,31%	11,28%
24	Portugal	79,87%	30,32%
25	Romania	23,12%	23,88%
26	Slovakia	64,85%	11,90%
27	Slovenia	50,38%	21,15%
28	Spain	73,94%	17,41%
29	Sweden	26,57%	54,65%
30	Switzerland	N/A	N/A
31	Turkey	77,16%	13,66%
31	United Kingdom	35,35%	11,02%
32	Liechtenstein	N/A	N/A
		< 25%	> 30%
			20%-30%
	Data Source	Eurostat (2017)	Eurostat (2018)

Data sources:(Eurostat, 2017, Eurostat, 2018)

The power sector is relevant for the penetration of electric mobility since the potential of electric vehicles is exponential with the combination of electricity, which is carbon neutral - generated through RES (Renewable Energy Sources). In addition, electric vehicles are an important tool to reduce oil dependence, reducing energy dependency of the European countries.

The data was obtained respectively through Eurostat (2017) and Eurostat (2018).

As indicated in **Table A-5**, European countries with a RES share higher than 50% in final energy consumption are Norway (72.75%), Iceland (71.57%), and Sweden

(54.65%). It should be noted that these countries have the largest EVs fleets in their registered passenger vehicles.

Finally, countries with a percentage of RES higher than 30%, such as Finland (41.16%), Denmark (36.13%), Austria (33.43%), Portugal (30.31%) correspond to the countries with the largest EV market shares (above 2%), showing a short-term effort in electrification (%EVs market sale).

Countries that are less energy-dependent, i.e. with an energy dependence rate less of than 25%, are: Norway (-597.22%), Estonia (4%), Denmark (11%) Iceland (19%), and Romania (23%).

With the exception of Estonia and Romania, the remaining countries are leaders in electric mobility. Estonia and Romania are far behind in transport electrification and in the case of Romania, it has a great contribution of the automotive industry in GDP (% EVs and % EVs market share).

Therefore, we found a contradiction, since countries with less energy dependency are the ones investing more in Electromobility.

On the other hand, countries with a less than 50% energy dependency are Sweden (27%), the United Kingdom (33%), Czech Republic (37%), Poland (38%), Bulgaria (40%), Finland (44%)), Latvia (44%) and Germany (49%).

Sweden and Finland, which are advanced countries in electric mobility, have an intermediate level of energy dependence. Germany is trying to advance in electric mobility in the short term (% market share), but it has an energy dependence rate of almost 50%.

Other countries with intermediate energy dependence do not have major initiatives in the promotion of electric mobility.

vi. Charging Infrastructure

Table A-6 - Charging Infrastructure

		2019						
		CHARGING INFRASTRUTURE						
	Countries	Total Number of Normal Chargers	Total Number of Fast Chargers	Normal + Fast Chargers	Fast Chargers per 100 km highway	%Fast Chargers per 100 km highway per total number of chargers (normal +fast)	%Fast Chargers per 100 km highway per total number of fast chargers	Number of Vehicles per charging point
1	Austria	3 696	576	4 272	34	1%	6%	8
2	Belgium	5 860	353	6 213	20	0%	6%	9
3	Bulgaria	70	54	124	7	6%	13%	5
4	Croatia	509	135	644	11	2%	8%	1
5	Cyprus	38	0	38				11
6	Czech Republic	400	342	742	38	5%	11%	5
7	Denmark	2 244	431	2 675	35	1%	8%	8
8	Estonia	193	201	394	132	34%	66%	4
9	Finland	706	319	1 025	50	5%	16%	16
10	France	27 661	1937	29 598	18	0%	1%	7
11	Germany	28 382	5040	33 422	47	0%	1%	8
12	Greece	40	18	58	1	2%	6%	15
13	Hungary	592	103	695	7	1%	7%	7
14	Iceland	40	84	124	232	187%	276%	86
15	Ireland	845	205	1 050	23	2%	11%	9
16	Italy	3 542	799	4 341	13	0%	2%	8
17	Latvia	83	155	238			0%	3
18	Lithuania	114	82	196	65	33%	79%	3
19	Luxembourg	949	13	962	8	1%	62%	5
20	Malta	102		102				3
21	Netherlands	49 343	1072	50 415	35	0%	3%	3
22	Norway	10 337	3426	13 763	655	5%	19%	23
23	Poland	584	358	942	15	2%	4%	5
24	Portugal	2 732	359	3 091	12	0%	3%	8
25	Romania	288	91	379	14	4%	15%	7
26	Slovakia	350	187	537	50	9%	27%	3
27	Slovenia	452	123	575	16	3%	13%	4
28	Spain	7 576	1244	8 820	8	0%	1%	5
29	Sweden	4 036	1030	5 066	48	1%	5%	21
30	Switzerland	5 099	841	5 940	67	1%	8%	8
31	Turkey	750	82	832	3	0%	4%	2
31	United Kingdom	22 759	4960	27 719	130	0%	3%	9
32	Liechtenstein			0				
								<10
	Data Source	EAFO (2019)	EAFO (2019)		EAFO (2019)			EAFO (2019)

Data sources:(EAFO, 2019d, EAFO, 2019c, EAFO, 2019e)

The development of the charging infrastructure is essential for the penetration of electric vehicles, especially for long trips. Otherwise, electric cars will always be seen as a second family car.

The data were taken again from EAFO (2019d), EAFO (2019c), and EAFO (2019e).

The European Union Alternative Fuels Infrastructure Directive has set a ratio of 10 electric vehicles per 1 charging point. Most European countries comply with this requirement, with the exception of Iceland (86), Norway (23), Sweden (21), Finland (16), Greece (15), and Cyprus (11), as illustrate in **Table A-6**. These countries which have worse ratios are the leading countries in electric mobility (EV%), showing that this trend is in line with the idea that these vehicles work as the second family car. Thus, actually, EVs are mainly used for commuting and are charged at home.

There seems to be no need for the deployment of charging infrastructure, in order to start the penetration of electric vehicles, especially in the beginning. This may answer the question of the Chicken and Egg dilemma since this theory states that it is not known where to start the electric mobility promotion, whether by the increase in vehicle penetration or by the development of the charging infrastructure.

However, the urgency to create a charging infrastructure is dependent on factors such as the size of the country, its geographic characteristics, the average distance from the daily commute, as well as cultural factors. Therefore, the installation of fast chargers can be an answer to long-distance travel and have been a bet set by national governments, especially on highways.

vii. Urban Population and Commute per workday

Table A-7 - Urban Population and Commute per workday

		2018	2020		2020			
		Urban Population	COMMUTE PER WORKDAY		MODES OF TRANSPORT USE ON COMMUTE			
	Countries	% urban polulation	Commute - Distance km - round trip	Average of Minutes spent on commuting in a weekday	Private Transportation (Car + Moto)	Public Transportion (bus + metro + tram)	Non-Motorized modes (Walk + Bike)	Main mode of tranposrt
1	Austria	58,20%	20	70	25%	39%	36%	Public
2	Belgium	98,00%	34	72	40%	26%	29%	Private
3	Bulgaria	75,00%	17	59	40%	27%	30%	Private
4	Croatia	56,95%	19	58	47%	22%	28%	Private
5	Cyprus	66,81%	25	47	71%	5%	20%	Private
6	Czech Republic	73,79%	21	59	25%	49%	24%	Public
7	Denmark	87,87%	21	58	16%	27%	55%	Non-Motorized
8	Estonia	68,88%	16	49	30%	35%	32%	Public
9	Finland	85,38%	25	60	26%	42%	31%	Public
10	France	80,44%	27	70	32%	34%	28%	Public
11	Germany	77,31%	26	63	27%	33%	35%	Non-Motorized
12	Greece	79,06%	25	68	53%	23%	20%	Private
13	Hungary	71,35%	22	72	27%	43%	29%	Public
14	Iceland	93,81%	22	40	73%	8%	17%	Private
15	Ireland	63,17%	27	76	37%	27%	33%	Private
16	Italy	70,44%	30	69	51%	24%	20%	Private
17	Latvia	68,14%	21	64	42%	23%	29%	Private
18	Lithuania	67,68%	17	51	49%	25%	24%	Private
19	Luxembourg	90,98%	30	65	40%	38%	18%	Private
20	Malta	94,61%	12	59	35%	19%	41%	Non-Motorized
21	Netherlands	91,49%	33	58	24%	17%	56%	Non-Motorized
22	Norway	82,25%	20	53	36%	32%	30%	Private
23	Poland	60,06%	20	63	35%	37%	23%	Public
24	Portugal	65,21%	26	60	53%	20%	22%	Private
25	Romania	54,00%	17	69	38%	26%	32%	Private
26	Slovakia	53,73%	22	58	35%	36%	23%	Public
27	Slovenia	54,54%	29	55	39%	22%	31%	Private
28	Spain	80,32%	26	58	45%	21%	28%	Private
29	Sweden	87,43%	31	61	29%	37%	30%	Public
30	Switzerland	73,80%	26	58	27%	39%	30%	Public
31	Turkey	75,14%	37	90	51%	31%	14%	Private
31	United Kingdom	83,40%	28	69	45%	24%	26%	Private
32	Liechtenstein	14,34%	N/A	N/A	N/A	N/A	N/A	Private
		72,8%	> 24,09	> 61,9 km	18 Nº of Countries	10 Nº of Countries	4 Nº of Countries	
	Data Source	UN (2018)	Numbeo (2018)	Numbeo (2018)	Numbeo (2018)	Numbeo (2018)	Numbeo (2018)	

Data Sources:(UN, 2018, Numbeo, 2020)

As we have mentioned early, most EV drivers live in the electromobility leaders countries and are concentrated in the urban areas, which represent the main cities. Nowadays, EVs are mostly used for daily travel related to commuting. Therefore, it is important to understand that the commute patterns of each country, based on time and distance travel. Additionally, we tried to comprehend the main modes of transport used by each country in the daily commute.

The data was collected through UN (2018) to obtain the share of people concentrated in urban areas. Then, the data related to commuting was obtained by a survey databased, named Numbeo (2020). Please note that the reliability of these data vary between countries since some countries have a higher number of answers.

Most European citizens live in urban areas, mostly in major capitals. Most countries have an urban population higher than 75%, as shown in **Table A-7**. The exemptions are Austria, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia, Slovenia, and Switzerland. It seems like the electromobility leaders are the ones with a higher share of the urban population (Norway, Denmark, Finland, Iceland, Netherlands, and Sweden). However, some countries with low EV penetration have a high urban population, such as Spain, France, Germany, Greece, and Luxemburg.

Accordingly to what we have seen earlier, the commuters of more than half of the European countries (18 countries) rely mainly on private transportation as their main mode of transportation, with 10 countries using mainly public transports, and only 4 of them using non-motorized modes (Denmark, Germany, Luxembourg and the Netherlands), as their main mode of transportation.

Additionally, some countries that have less urban population are using private transportation as their main mode of transportation, for instance, Bulgaria, Croatia, Cyprus, Ireland, Italy, Latvia, Lithuania, Portugal, Romania, Slovenia. Nevertheless, some of the higher urban population countries rely on private transport as the main mode of transportation and some of them are the leaders in EV penetration, take the case of Norway and Iceland.

viii. Population, Pollution, and traffic congestion

Table A-8 - Population, Pollution and traffic congestion

		2018	2017	2017	2019
		POPULATION	C02 EMISSIONS	GHG EMISSIONS	CITIES TRAFFIC
	Countries	Population	CO2 emissons from passengers cars (in grams per km)	Greenhouse gas emissions by country (in thousand tonnes)	Traffic Index - nº of cities with a congestion level => 25%
1	Austria	8 955 102	121	84 526,64	3
2	Belgium	11 539 328	116	119 382,64	3
3	Bulgaria	7 000 119	126	62 085,59	1
4	Croatia	4 130 304	113	25 472,57	N/A
5	Cyprus	1 198 575	122	9 952,09	N/A
6	Czech Republic	10 689 209	124	130 466,42	2
7	Denmark	5 771 876	107	50 827,51	0
8	Estonia	1 325 648	133	21 060,75	1
9	Finland	5 532 156	118	57 502,03	0
10	France	65 129 728	110	481 984,74	13
11	Germany	83 517 045	127	936 003,17	13
12	Greece	10 473 455	109	98 884,54	2
13	Hungary	9 684 679	126	64 488,77	1
14	Iceland	339 031	N/A	5 911,12	0
15	Ireland	4 882 495	112	63 805,48	3
16	Italy	60 550 075	113	438 959,09	12
17	Latvia	1 906 743	129	11 755,88	1
18	Lithuania	2 759 627	127	20 737,67	1
19	Luxembourg	615 729	N/A	11 933,48	1
20	Malta	440 372	110	2 582,71	N/A
21	Netherlands	17 097 130	N/A	205 829,43	7
22	Norway	5 378 857	N/A	54 397,49	0
23	Poland	37 887 768	128	416 298,55	10
24	Portugal	10 226 187	105	74 606,49	2
25	Romania	19 364 557	N/A	114 811,43	1
26	Slovakia	5 457 013	N/A	43 482,84	2
27	Slovenia	2 078 654	120	17 527,80	1
28	Spain	46 736 776	115	357 296,69	2
29	Sweden	10 036 379	122	55 451,33	1
30	Switzerland	8 591 365	N/A	52 600,05	5
31	Turkey	83 429 615	N/A	537 361,54	6
31	United Kingdom	67 530 172	121	505 420,37	23
32	Liechtenstein	38 019	N/A	194,49	N/A
		> 30 000 000		> 200 000	> 3 cities

Data Source	Worldometer (2018)	ACEA (2017)	OECD (2017)	Tomtom (2019)

Data Sources:(ACEA, 2017, OECD, 2017a, Worldometer, 2018, Tomtom, 2019)

Finally, in this last section, we analyze the total number of population, the level of pollution, and traffic congestion for each European country, illustrated in **Table A-8**. This is especially relevant because EVs are a possible answer to the problems related to urban mobility and their local air and noise pollution. Notwithstanding, EVs do not solve the traffic congestion problems, only combined with carsharing, carpooling, or autonomous cars.

The population data was collected through Worldometer (2018) database and GHG emissions data was obtained by OECD (2017). Lastly, the traffic congestion index was gathered on Tomtom (2019) and we decided to count the number of congested cities (congestion level higher than 25%) per each country.

The most populous European countries (over 30 million inhabitants) are France, Germany, Italy, Poland, Spain, Turkey, and the United Kingdom. It should be noted that these countries are the ones that have the largest concentration of the automotive industry. At the same time, most polluted countries are the ones more populous with the exemption of the Netherlands, which has a high level of pollution and do not reach 30 million inhabitants.

Similarly, the most polluted countries (emissions levels above 200 000 thousand tones) are also the ones with a larger number of traffic-congested cities. Spain is the only exemption with few traffic-congested cities (only 2).

In sum, most European Countries with strong automotive industry are highly populated, polluted, and congested. Nevertheless, these countries should be incenting heavily in the electromobility, but are the ones farther behind.

APPENDIX B - THE THREE DIFFERENT EUROPEAN COUNTRIES CLUSTERS IN EVS PENETRATION

In **Table B-1**, systematization of the European scenario is carried out in the adoption of EVs, taking into account the importance of the automobile industry in GDP (high, medium, and low share). There also appears to have a correlation between EV share and market penetration and the importance of the auto industry in national GDP.

Table B-1 - Characterization of the three European Countries cluster in the EV adoption based on their Automotive industry share in GDP.

Automobile Industry	**High share in GDP**	**Medium share in GDP**	**Low share in GDP**
Countries	Germany, Romania, Slovakia, Italy, Spain and Hungary. France and Sweden should be in this cluster (lack of data).	Czech Republic, Bulgaria, Poland, United Kingdom and Portugal.	Norway, Iceland, Denmark, Finland, Netherlands and Belgium.
%EVs Stock	< 0,75% Exceptions: Sweden (2,18%)	< 1%	> 1% (11%)
EVs Market share	Most of them < 2% Exceptions: Sweden 9,2% Germany 2,9% France 2,7%.	Most of them < 2% Exceptions: Portugal 5,5%, United Kingdom 1,5%.	> 9% Norway 56%, Iceland 24%, Netherlands 10,8%.
Higher % BEVs Market share	France Germany	Portugal	Norway
Higher %PHEVs Market share	Sweden		Iceland Finland

Tax Revenues – Centralization (> 80%)	France 86,33%, Hungary 93,90%, Italy 83,88%.	Portugal 92,43%	Norway 84,12%, Netherlands 95,88%.
Tax Revenues – Decentralization	Germany 67,41% Spain 74,46%		
% RES	**<20%** Germany France Italy Spain Slovakia Hungary Exceptions: Sweden	**20-30%** Portugal (30.31%) Exceptions: Poland	**> 50%** Norway (72.75%), Iceland (71.57%), Finland Denmark Exceptions: Netherlands
% Energy Dependency	**> 65%** Italy Spain **Exceptions:** Romania (23,12%)		**<25%** Norway (-597,22%) Iceland (18,65%) Denmark
Number of Vehicles per charging point < 10	All Except for Sweden	All	None **Exception:** Denmark, Netherlands, Belgium
Majority use of Non-motorized modes on Commute	Germany		Netherlands Denmark

Majority use of Private Transportation on Commute	Italy Spain Romania	Portugal United Kingdom	Belgium Iceland Norway
More populated countries (> 30 000 000)	France Germany Italy Poland Spain	United Kingdom	
GHG emissions	**High > 200 000 000** France Germany Italy Spain **Exception: Medium 50 000 000 – 200 000 000** Sweden, Romania Hungary **Low < 50 000 000** Slovakia	**Medium 50 000 000 – 200 000 000** Portugal Bulgaria Czech Republic **High > 200 000 000** Poland United Kingdom	**Medium 50 000 000 – 200 000 000** Belgium Denmark Finland Norway Exception: **Low < 50 000 000** Iceland **High > 200 000 000** Netherlands
Number of traffic-congested cities (> 3 cities)	France Germany Italy Poland	United Kingdom	Netherlands

Source: Own elaboration.

APPENDIX C - OVERVIEW OF MAIN POLICY INSTRUMENTS IMPLEMENTED AT NATIONAL AND LOCAL LEVEL – NORWAY, PORTUGAL, AND SPAIN

i. Norway

EV SUPPORT POLICIES	NORWAY				
Policy Type	Tax Name	Starting Year	Amendments	Powertrain	Details
Vehicle Acquisition - Private owned					
Exemption on import taxes		1990	-	BEVs	
Exemption from registration costs		1990	-	BEVs	
Reduced registration costs		2013	-	PHEVs	
Reduced private use tax		2000	2017	BEVs	15% till 2017, 18% in 2018
Exemption from VAT	Fritak fra merverdiavgift (mva)	2001	-	BEVs	25% VAT
Vehicle Acquisition - Company owned					
Exemption on import taxes		1990	-	BEVs	
Exemption from registration costs		1990	-	BEVs	
Reduced registration costs		2013	-	PHEVs	
Reduced company use tax	Firmabilbeskatning	2000	2018	BEVs	50% reduction to 40% in 2018
Exemption from VAT	Fritak fra merverdiavgift (mva)	2001	-	BEVs	25% VAT
Exemption from VAT on leasing	Fritak fra merverdiavgift (mva)	2015	-		25% VAT
Recurring or Use of Vehicle - Private and company owned					
Reduced circulation taxes/annual road tax		1996	-	BEVs + PHEVs	50€ for BEVs, instead of 350-410 € annually
None or reduced charges on toll roads	Bompenger	1997	2019	BEVs	Free toll roads until 2017. Then, maximum of 50% of the total amount
None or reduced charges on ferries	Elbil på ferjer	1997	2018	BEVs	Free ferries until 2017.Maximum of 50% of the total amount
None or reduced charges on municipal parking	Parkering for elbil	1997	2018	2017	Free parking until 2017. Then, parking fee for EVs defined locally a maximum of 50% of the total amount
Access to bus lanes		2005	2016	BEVs	Since 2016, local authorities can limit the access to BEVs carry one or more passengers.
Driver license class B allows to drive electric vans class C1 up to 4250 kg		2019	-		
Charging Infrastruture					
Subsidies		2007	BEVs + PHEVs		Governmental incentives for the deployment of home and public charging infrastructure
Program		2017	BEVs + PHEVs		Finance the creation of at least two multi-standard fast charging each 50 km on all principal roads

Figure C-1 - EV Support policies – Norway

Source: Own elaboration based on (Figenbaum, 2017, Deuten et al., 2020, Elbil, 2020)

ii. **Portugal**

EV SUPPORT POLICIES	PORTUGAL				
Policy Type	Tax Name	Starting Year	Amendments	Powertrain	Details
Vehicle Acquisition - Private owned					
Exemption from registration costs	Imposto sobre veículos - ISV	2007	2014+2016	BEVs	€ 0
Reduced registration costs	Imposto sobre veículos - ISV	2007	2014+2016	PHEVs	25% of total value paid by ICEV
Scrapping Scheme	Incentivo ao Abate de Veículos em fim de vida	2014	-	BEVs + PHEVs	Increase of vehicle replacement through new acquisitions. Since 2014, add a new requirement for new car, demanding low-emission vehicle
Acquisition Subsidy	Incentivo pela Introdução no Consumo de Veículos de Baixas Emissões	2016	-	BEVs	Subsidy amount varies annually and is limited in number. Without the necessity to deliver an old vehicle
Vehicle Acquisition - Company owned					
Exemption from registration costs	Imposto sobre veículos - ISV	2007	2014+2016	BEVs	€ 0
Reduced registration costs	Imposto sobre veículos - ISV	2007	2014+2016	PHEVs	25% of total value paid by ICEV
Scrapping Scheme	Incentivo ao Abate de Veículos em fim de vida	2014	-	BEVs + PHEVs	Increase of vehicle replacement through new acquisitions. Since 2014, add a new requirement for new car, demanding low-emission vehicle
Acquistion Subsidy	Incentivo pela Introdução no Consumo de Veículos de Baixas Emissões	2016	-	BEVs	Subsidy amount varies annually and is limited in number. Without the necessity to deliver an old vehicle
Exemption from Autonomous Taxation	Tributação Autónoma	2014	-	BEVs	€ 0
Reduced Autonomous Taxation	Tributação Autónoma	2014	-	PHEVs	Up to € 25,000 pay 5% instead of 10%, between € 25,000 and € 35,000 pay 10% instead of 27.5% and over € 35,000 pay 17.5%.
VAT deductible	Imposto sobre o valor acrescentado (IVA)	2014	-	BEVs	For total sale price until € 62.500
VAT deductible	Imposto sobre o valor acrescentado (IVA)	2014	-	PHEVs	For total sale price until € 50.000
Recurring or Use of Vehicle - Private and company owned					
Exemption from circulation taxes/annual road tax	Imposto Único de Circulação - IUC	2007	2014+2016	BEVs	PHEVs have to pay ICEV equivalently
Reduced or Exemption from parking fee	Desconto ou isenção no estacionamento	Definition at local level, varies by municipality	-	BEVs + PHEVs	Some municipalities make distinctions between BEVs and PHEVS
Access to areas with traffic restrictions - Reduced emissions zone	Zona de Emissões Reduzidas (ZER)	2020	-	BEVs	In this area, circulation will be limited to authorized vehicles only - it is mandatory to have a badge - during the daytime, established between 06:30 and 00:00.
State passenger cars fleet - Acquisition + charging infrastructure					
Electric Mobility Support Program in Public Administration	Programa de Apoio à Mobilidade Elétrica na Administração Pública	2015	-		Finances 50% of the expenditure (including VAT) with the rents of the purchased EVs, under an operating and financial lease regime over a period of 48 months and 50% of the acquisition and installation of charging stations (from €1 000 normal chargers to €4 000 fast chargers)
Charging Infrastruture					
Establishment of electric grid management	Programa Mobi.E	2009	2013+2014+2015	BEVs + PHEVs	-
Electric Mobility Support Program in Public Administration	Programa de Apoio à Mobilidade Elétrica na Administração Pública - ECO. mob	2015		BEVs + PHEVs	State finances 50% of the acquisition and installation of charging stations, up to a maximum number of chargers equal to the number of vehicles assigned to each entity and up to a limit of € 2,000 per station, in the case of conventional chargers, or € 4,000 per charger, in case of semi-fast charging point

Figure C-2 - EV Support policies – Portugal

Source: Own elaboration based on (Magueta et al., 2018, UVE, 2020c, UVE, 2020a, UVE, 2018, impostosobreveiculos.info, 2020)

iii. Spain

EV SUPPORT POLICIES	SPAIN				
Policy Type	Tax Name	Starting Year	Amendments	Powertrain	Details
Vehicle Acquistion - Private owned					
Exemption from registration costs	Impuesto de Matriculación			BEVs	0 € - emissions up to 120 g / km of CO_2
Exemption registration costs	Impuesto de Matriculación			PHEVs	0 € - emissions up to 120 g / km of CO_2
Acquistion Subsidy + Scrapping Scheme	MOVES Plan 2019	2019	-	BEVs + PHEVs	Subsidy amount varies annually and is limited in number, with the necessity to deliver an old vehicle (10 years owned at least at one year)
Vehicle Acquistion - Company owned					
Exemption from registration costs	Impuesto de Matriculación			BEVs	€ 0
Reduced registration costs	Impuesto de Matriculación			PHEVs	€ 0
Acquistion Subsidy + Scrapping Scheme	MOVES Plan 2019	2019	-	BEVs + PHEVs	Subsidy amount varies annually and is limited in number, with the necessity to deliver an old vehicle (10 years owned at least at one year)
Recurring or Use of Vehicle - Private and company owned					
Reduced circulation taxes/annual road tax	Impuesto sobre Vehículos de Tracción Mecánica (IVTM)	Definition at local level, varies by municipality		BEVs	Reduction up to a maximum of 75% on the fuel that consumes the vehicle for BEVs - PHEVs have to pay ICEV equivalently
Reduced or Exemption from parking fee	Regulación del aparcamiento	Definition at local level, varies by municipality	-	BEVs + PHEVs	In many Spanish cities electric cars can park for free and without a time limit, as is the case in Madrid and Barcelona
Access to bus lanes	Infraestructura Reservada	Definition at local level, varies by municipality		BEVs + PHEVs	Madrid will allow the use of BUS-VAO-ECO lanes by BEVs - PHEVs
None or reduced charges on toll roads	Norma de peajes catalanes	Definition at local level, only in Catalonia	2020	BEVs + PHEVs	BEVS reduction up to 75%. PHEVs reduction up to 30%.
Access to areas with traffic restrictions - Reduced emissions zone	Restricción de Acceso	Definition at local level, varies by municipality	-	BEVs	In this area, circulation will be limited to authorized vehicles only - it is mandatory to have a badge - Case of Madrid
Charging Infrastruture					
MOVES Plan 2019	Plan MOVES 2019			BEVs + PHEVs	Aid for the installation of charging points is 30% for private companies and 40% for individuals, communities of owners and public entities without commercial or mercantile activity.

Figure C-3 - EV Support policies – Spain

Source: Own elaboration based on (Energiaysociedad, 2010, Sanz, 2016, ElMotor, 2019, IDAE, 2019, Autopista, 2020, IDAE, 2020, Nissan, 2020b, Nissan, 2020a, Movilidadeléctrica, 2020)