UNIVERSIDAD PONTIFICIA COMILLAS

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

OFFICIAL MASTER'S DEGREE IN THE ELECTRIC POWER INDUSTRY

ANALYSIS OF THE FACTORS THAT AFFECT PUBLIC Charge PRICES IN SPAIN

Master´s Thesis

Autor: Gabriela Orisell Gastelum Fernández

Supervisor: Dr. José Pablo Chaves Ávila

Co-Supervisor: Dr. Manuel Pérez Bravo

Madrid, 2024

Declaro, bajo mi responsabilidad, que el Proyecto presentado con el título

Analysis of the factors that affect public charge prices in Spain la ETS de Ingeniería - ICAI de la Universidad Pontificia Comillas en el

curso académico 2024 es de mi autoría, original e inédito y

no ha sido presentado con anterioridad a otros efectos.

El Proyecto no es plagio de otro, ni total ni parcialmente y la información que ha sido

tomada de otros documentos está debidamente referenciada.

Fdo.: Gabriela Orisell Gastelum Fernández Fecha: 01/ 02/ 2024

Autorizada la entrega del proyecto

EL DIRECTOR DEL PROYECTO

José Pablo Chaves Ávila

Fdo.: Dr. José Pablo Chaves Ávila Fecha: 08/ 02/ 2024

Firmado digitalmente
por PEREZ BRAVO
MANUEL - 49114355V
Fecha: 2024.02.07
18:00:04 +01'00'

ANALYSIS OF THE FACTORS THAT AFFECT PUBLIC CHARGE PRICES IN SPAIN

Author: Gastelum Fernández, Gabriela Orisell
Supervisor: Chaves Ávila, José Pablo
Collaborating Entity: Iberdrola España.

ABSTRACT

This work presents the results obtained after analyzing the public charging market for electric vehicles, on how the different agents of the current market interact, which current regulations must be respected, and which sector must pay attention to be regulated efficiently, ensuring a fair and sustainable transition to electromobility, as well as to evaluate the evolution of competition and prices in the public charging market. This is due to the rapid growth and boom that this sector has acquired in the last three years.

Keywords: *decarbonization, e-mobility, CPO, EMP, public charging infrastructure.*

I. Introduction

Nowadays, the automotive industry is undergoing profound changes, since about 29% of all gases emitted globally are caused by the transportation sector (Rode & Schulz, 2022). One of the most viable solutions is the improvement of vehicles that are independent of the use of fossil fuels, making electromobility an efficient option applicable today.

The deployment of public charging is held back by the high installation costs for the current low use of electric vehicles, in addition to the time-consuming and laborious process of processing licenses and connecting new installations to the grid, with a total time of 2 years until commissioning.

Based on calculations by the charging operators integrated in AEDIVE[1], an infrastructure deployment would be needed to reach 70,000 in 2025 and 255,000 in 2030 (ANFAC, 2023). However, it is important to mention that the deployment should is complex and depends on locations and types of charging in each of them, with priority being given to the user and fair competition.

II. Description model

The research is complemented by the explanatory method, since it will determine how different variables related to charging infrastructure and agents' strategies are related, establishing factors that can explain the possible future behaviors that are studied, as well as the possible evolution of a market that is structuring and evolving rapidly and constantly.

During the research and the compilation of information on public charging, the charging price was established by the charging service provider (EMP).

Once the research was completed, two possible analyses of interest were conisdered:

1) *Infrastructure public charge development*

To develop this analysis, it was necessary to compile three different sources where the projections of installed chargers for 2030 were published: official data from the Spanish government, AEDIVE and ANFAC, based on the annual report *Barómetro de ectro-movilidad* published every year by ANFAC.

[1] Asociación Empresarial para el Desarrollo e Impulso de la Movilidad Eléctrica

Once we have the historical data, we will proceed to choose the type of regression that best fits the data. Analysis of the prices over the years and identify which factors are involved.

2) *Analysis of factors influencing public charge prices*.

Therefore, it is proposed to compile a list of the charging points in the center of Madrid, to delimit the research area, relating the location with the power of the charger. An analysis was performed on the main EMPs in the Spanish market, as well as the products they offer and the price per charge.

For this, it was necessary to track the charging points in different sources: Google Maps, Electromaps and in the applications of each EMP. This was done validate the information of each charging point, because currently there is no complete database for all charging points.

III. Results

1) Infrastructure public charge development

The charging speed of charging points is classified in different levels, in terms of power, which defines the charge time of the battery. It is important to mention that the speed at which the battery charges depends not only on the available power of the charger, but also on the charging capacity of the battery and the temperature control of the battery.

Once the chargers installed at the time of the research are identified, a panel was drawn up to perform the analysis in a more visual way. The result is shown in Fig. 1 which shows the distribution of public chargers in Madrid center, this shows the current state of the way in which electric chargers are distributed, to project in a better way the future locations and to identify which are the main participants in the market.

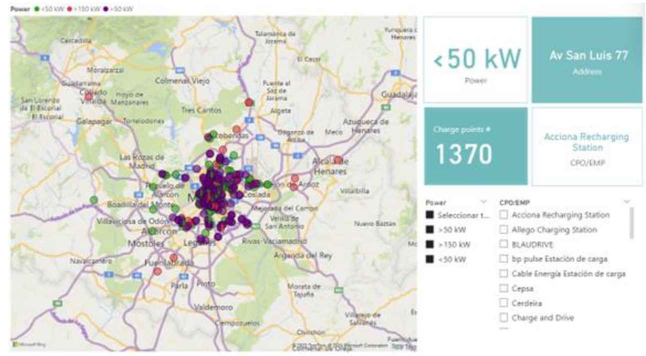

Figure 1. Public chargers' distribution in Madrid center by E-Mobility Provider and power capacity.

The chargers installed in the center of Madrid were analyzed and classified as listed below, according to the prices found in the market.

Home charging <3,7 kW. Full battery charge time can take several hours; however, it is the most used among the different modes.

Semi-Fast charging <50 kW. This is the most common type of chargers in the public charging network since they were the first points to be installed. To be attractive to users, they must be in shopping centers, restaurants, hotels or near housing complexes, due to the time of rest to be able to charge the battery to a considerable percentage.

As can be seen in Figure 2, there are about 649 charging stations in Madrid, most of them located in the downtown area, which demonstrates that the best strategy for the installation of this type of equipment is close to areas where there are shopping malls, neighborhoods and restaurants, as this is a sign that users have enough time to charge the battery sufficiently to continue their route and use the waiting time for other activities.

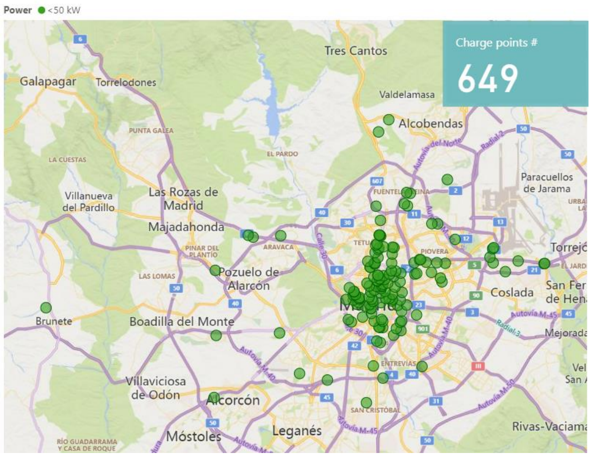

Figure 2. Charging station located in Madrid under 50 kW.

Furthermore, the price of the installation of these devices is much lower than the fast-charging ones, which makes the technology more accessible to users and more attractive to the owners of establishments.

Fast charging >50 kW. These are the ideal chargers for public charging, as they offer a fast-charging speed, and the installation costs of the equipment are not as high as those of the superchargers.

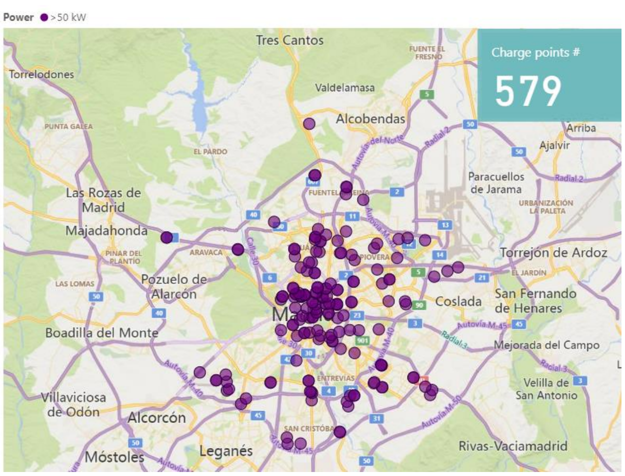

Figure 3. Charging stations more than 50kW but less than 150kW available in Madrid.

As we can see, the major concentration of stations is in the downtown, close to the commercial areas. The number in the corner refers to the charging stations.

Ultra-fast charging >150 kW. They are ideal to be located on roads or in places far away from stores and businesses because they require specialized high-voltage DC power sources, so they need some additional works to prepare the installation. The charging speed is up to 3,6 times faster than fast-charging ones, it means that it takes around 30 minutes for an 80% charge but depends on the battery technology.

Figure 4 shows the actual infrastructure installed in Madrid, as we can see, it is expanding but not as widespread as AC charging.

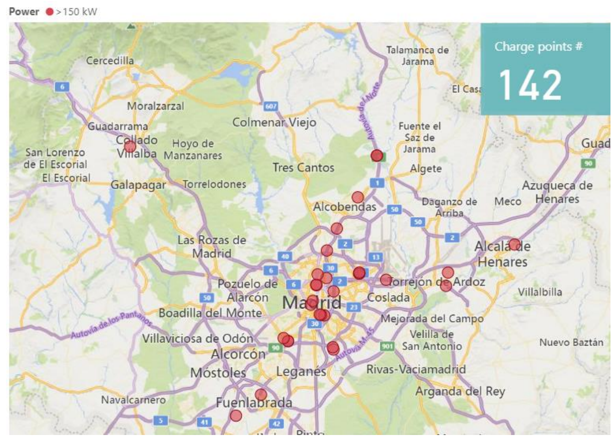

Figure 4. Charging stations more than 150kW.

When analyzing the location of the stations, it can be observed that although the locations are less than the previous ones, the strategy for the establishment of the stations is different than with the previous power ranges, because for these it is chosen to install more connections, which makes sense when taking in consideration the preparation that must be done and the requirements that the distribution network to which the station will be connected must have.

It is important that this type of stations is located on highways, because in this way, the barrier that EVs have for long trips would be demolished, opening the possibility of making fewer stops and increasing the reliability of the technology, since betting on better batteries is a viable option, although it represents more time and higher costs.

The previous figures show how the charging stations and the EMPs that have access to them are spread out, so it should be remembered that the fact that an EMP has a charging point within its network does not exclude the rest from not having one, since there is an interoperability agreement, and the charging service can be offered by different EMPs at different prices and offering different services.

Figure 5 shows the percentage of locations for each CPO. The charging stations are highly diversified in the services offered.

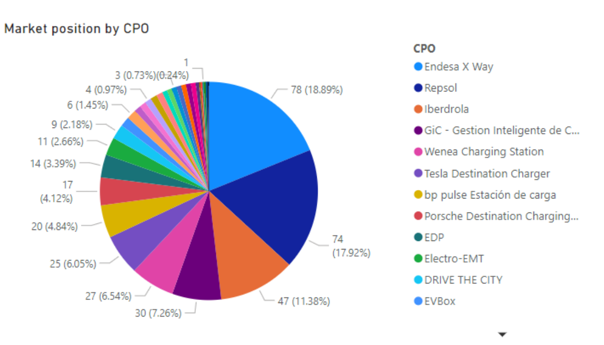

Figure 5. Market position by CPO.

The big square gives us a better understanding of the main CPO in the market, using this information, we can compare it with the type of technology they installed and give us an idea about the strategy of each one.

While some CPOs are inclined to expand their charging network with fast chargers, others have focused on developing and improving super-fast technology, and another sector is inclined only to offer home charging.

With such diversified competition, there must be well-defined regulations that consider standardization and interoperability between charging stations and the network. This challenge must be considered for the CPOs to ensure that EV users have access to their charging stations without having problems with the compatibility of the chargers (connectors, charging speed) with the vehicle batteries.

There are established goals for the number of charging points installed by 2030, so for Spain, four different scenarios have been proposed to understand the number of chargers needed to be installed per year to meet the expected demand.

The greater the number of chargers, the greater the adoption of this technology and, in addition to the number of cars, more chargers will be needed over time, which is why a polynomial regression is the best fit, figure 6 shows the result obtained. However, as can be seen in the blue line, if the rate of growth of points continues at the current rate, by 2030 there will be less than half the number of points installed.

This suggests that investment in the public charging sector is urgent, and support mechanisms for CPOs are essential to grow the public infrastructure.

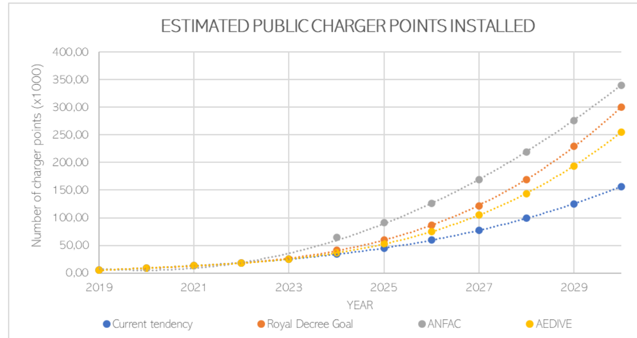

Figure 6. Estimate public chargers' points installed to achieve the goals established by Royal Decree, ANFAC and AEDIVE.

In this case, a third-degree polynomial model of the form was proposed:

$$Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \varepsilon$$

Solving for each case and substituting the model of the resulting equations, it was obtained that the best projection to reach the goals set in each scenario is shown in table 3, the closest to reality is the one proposed by AEDIVE.

Table 1. Total number of chargers installed at the end of each year to meet the demand proposed by the institutions, including the current growth scenario.

	Current tendency	Royal Decree	ANFAC	AEDIVE
2019	5.000	5.000	5.000	5.000
2020	8.545	8.545	8.545	8.545
2021	13.411	13.411	13.411	13.411
2022	18.128	18.128	18.128	18.128
2023	25.180	25.180	25.180	25.180
2024	33.888	41.789	64.000	36.340
2025	45.154	60.024	91.000	52.386
2026	59.429	86.172	125.984	74.803
2027	77.219	121.955	169.430	104.933
2028	99.033	169.093	219.605	144.116
2029	125.376	229.309	276.536	193.690
2030	156.755	300.000	340.000	255.000

2) Analysis of factors influencing public charge prices.

For this analysis, it is important to mention the fees applicable to electricity for a standard user. The tariff in Spain is composed of the power term and the energy term. The first is a fixed amount that depends on the power contracted by the subscriber and a fixed amount is paid each month for each kW contracted.

The second term is the amount of electrical energy, which is measured in kWh, the price per kWh varies according to the electricity market. The market price or marginal price is set through an auction organized by the Iberian Energy Market Operator (OMIE).

Prices for electric chargers can be separated into regulated and competitive charges. Regulated charges today are the cost of electricity, transmission and distribution tolls. While the costs that are free to competition are any extra costs that an EMP wants to charge for, such as a subscription or a parking fee, among others.

Daily energy prices are divided into 6 periods, which depend on the hour, day, and month. These are published by REE at the end of the immediate previous year, for the 3.0 tariff the peninsular calendar.

The network tolls (peajes) are regulated by the Resolution of CNMC 21/12/2023. BOE 25/12/2023 and the other regulated tolls (cargos) by the Orden TED/1312/2022. The table 2 below shows the fees and charges for energy and power established by 2024.

Table 2. Network tolls and other regulated tolls by 2024 for power and energy term for electricity.

	NETWORK TOLLS AND OTHER TOLLS €/kW year (POWER)					
€/kW año	P1	P2	P3	P4	P5	P6
2.0TD	25,39	0,97				
3.0TD	15,71	9,55	4,66	4,14	2,29	1,55
6.1TD	24,41	14,69	11,33	9,25	1,73	0,97
6.2TD	15,40	9,88	6,44	5,49	1,06	0,62
6.3TD	12,29	7,42	5,90	4,80	1,00	0,64
6.4TD	8,20	4,56	3,48	3,20	0,52	0,34

	NETWORK TOLLS AND OTHER TOLLS €/kW year (ENERGY)					
€/MWh cc	P1	P2	P3	P4	P5	P6
2.0TD	76,97	27,96	2,75			
3.0TD	48,44	30,94	17,36	10,39	3,56	2,19
6.1TD	35,19	21,53	12,72	8,04	2,11	1,28
6.2TD	18,12	11,15	6,18	4,02	1,05	0,59
6.3TD	15,52	9,44	5,65	3,68	0,89	0,55
6.4TD	10,70	6,25	3,85	2,60	0,39	0,25

There is a regulated market, called PVPC (Precio Voluntario al Pequeño Consumidor) where contracts reflect hourly variations in the price of electricity. The hourly rates are grouped to give three periods: peak, flat and off-peak.

The CNMC Resolution of December 21, 2023 specifically mentions the transmission and distribution fees applicable to public access electric vehicle charging points and also to domestic charging points, shown in table 3. The Circular unifies all fees into one for contracted power of less than 15 kW (domestic and SMEs).

Table 3. Tolls by 2024 for power and energy term for electric vehicles chargers vs. regular consumers

	TRANSPORT AND DISTRIBUTION TOLLS €/kW year (POWER)					
Tariff	P1	P2	P3	P4	P5	P6
3.0 TD	11,99783	7,68781	3,30744	2,79179	0,93444	0,93444
3.0 TDVE	3,04255	1,95053	0,83950	0,70788	0,23271	0,23271
6.1 TD	20,55785	12,76288	9,92625	7,84838	0,32514	0,32514
6.1 TDVE	4,65631	2,89079	2,24832	1,77767	0,07365	0,07365

	TRANSPORT AND DISTRIBUTION TOLLS €/kW year (ENERGY)					
Tariff	P1	P2	P3	P4	P5	P6
3.0 TD	0,02397	0,01282	0,00757	0,00550	0,00042	0,00023
3.0 TDVE	0,09097	0,04880	0,02878	0,02087	0,00164	0,00089
6.1 TD	0,02190	0,01168	0,00739	0,00538	0,00041	0,00021
6.1 TDVE	0,14975	0,07982	0,05056	0,03676	0,00277	0,00145

The tables above show that in the case of distribution and transmission tolls for the power term, there is a variation of 25% less in terms of the fees applied for electric chargers. The opposite is the case for the energy term, which is 26% higher for EV chargers with tariff 3.0 and 14% higher for tariff 6.1. In general terms, the regulated tariffs for the charging point are lower.

Regarding the transmission and distribution tolls applicable to public access electric vehicle charging points, the owner of a charging point for public access electric vehicle charging may request the application of the fee regulated in this provision from the distributor, directly or through its distributor, as an alternative to the general fees. To this end, it must prove that the supply point will be used exclusively for electric vehicle charging and that it will be publicly accessible. These fees may be applied to those supply points with contracted power exceeding 15 kWh.

Fees must be applicable to electric vehicle charging: amortization, initial equipment investment (known as CAPEX), contracted power cost, operating cost, maintenance cost, average supply cost (known as OPEX).

In the actual charging price, there is no clear procedure for the determination of prices by CPO or EMP for the public charge, which implies a problem for the end user to understand the prices he/she is paying, as well as complicating competition among market participants.

Once we have all those components and factors, the estimated tariff calculation proposed for each charger station group is:

$$\frac{C_O + C_m + I_O + A}{ES} + C_p + C_e = mean\ tariff$$

Where:

- Initial investment (I_0): the initial investment for each type of charger.
- Power cost (Cp): regulated tariff by CNMC
- Energy cost (Ce): regulated tariff by CNMC
- Annual amortization (A)
- Operation cost (Co)
- Maintenance cost (Cm)
- Energy supply (ES)

The highest costs in this proposed formula are the initial investment costs for the installation of the equipment and the cost of the regulated tariffs, however, as the number of electric vehicles increases in registration, the energy supply by the charging points will increase, which implies that the prices will reduce (both OPEX and CAPEX), in addition to mitigating the consumer barrier for the acquisition of the EV.

IV. Conclusions

The increasing need to foster the electromobility market is clear. However, the key points to drive the development of this market must be carefully identified, as this will drive the use of electric cars along with it.

While the government has an important role to play in this, implementing incentives for EV acquisition, as well as for the installation of home electric chargers, public charging needs to be regularized. This is where one of the barriers lies: in the deployment of public chargers.

The difference in prices between competitors, the high tariffs on super-fast chargers and the complexity of how each market player sets the prices is a combination to keep users from taking the decisive step to the transition.

With the data obtained and the analysis carried out, it can be concluded that the best strategy for the installation of charging points should be to promote chargers with power less than or equal to 50kW within the city and near residential units, as this guarantees the peace of mind of users who cannot install a charger at home to have accessibility to public chargers at a reasonable price.

However, in commercial establishments or restaurants, the installation of more powerful chargers is more attractive because users do not have so much waiting time, while on roads and places far from stores or residential units, the installation of ultra-fast chargers is the best alternative to boost EV use outside cities without sacrificing travel time from one point to another.

At the same time, regulations for the installation of points must be established, as the current procedure involves many months of waiting for the approval of the necessary permits for the construction of charging stations. This is a major barrier to infrastructure growth; therefore, to meet the objectives, it is necessary to establish mechanisms to accelerate the procedures and improve the structure of the public charging market.

Regarding charging prices, it is concluded that the highest correlation between the factors is found between price and power of the charger, followed by the number of points installed and the CPO to which they belong. The location of the charging point does not influence the price directly, but it does influence the power of the charger. As the market is constantly expanding and, at the same time, demand is growing, both home charging and public charging will be needed to satisfy it.

V. References

Abel Rosales-Tristamcho, Raúl Brey, Ana F. Carazo, & J. Javier Brey. (2022). *Analysis of the barriers to the adoption of zero-emission vehicles in Spain.* Transportation Research Part A: Policy and Practice, 19-43.

ANFAC. (2022). *Informe Anual.* Madrid, España: ANFAC.

ANFAC. (2023). *Barómetro de la electromovilidad, segundo trimestre 2023*. Madrid, españa: ANFAC.

IEA. (2023). *Global EV Outlook 2023*. Paris: IEA.

Ministerio para la Transición Ecológica y el Reto Demográfico. (2020). *Plan Nacional Integrado de Energía y Clima (PNIEC) 2021-2030*. España: MITECO.

Ministerio para la transición ecológica y el reto demográfico. (2021). *Proyecto de Real Decreto por el que se regula la actividad de prestación de servicios de recarga energética de vehículos eléctricos.* Madrid.

Ministerio para la transición ecológica y reto demográfico. (2023*). Disposiciones generales. Real Decreto 184/2022, de 8 de marzo*. Boletín Oficial del Estado(67).

MITECO. (2020). *Estrategia de descarbonización a largo plazo 2050*. MITECO. Madrid: Ministerio para la transición ecológica y el reto demográfico.

Rode, J., & Schulz, F. (2022). *Public charging infrastructure and electric vehicles in Norway*. Energy Policy, 1-12

Ruiz Barrientos, F. M., Gámiz Martínez, E., Román Calvo, C., & Sallent Bayo, H. (2021). *Estudio sobre el despliegue de la infraestructura de carga del vehículo eléctrico en España.* Bruselas: Transport & Environment

DEDICATION

To my sisters, because even at a distance they give me their love, their support and continue to be my engine to move forward day by day and always seek to improve myself a little more. I hope to be able to give them back that great feeling they give me for always being there.

To my parents and family, for always believing in me, giving me confidence and reminding me that dreams can always come true, it just takes a little effort.

To my lifelong friends in Mexico and the new ones in Spain, I have found incredible people who always find a way to make me feel at home, even when I am far away. Above all, I want to thank Miguel and Ernesto, for all those full days and nights studying or doing some work, for not letting my spirits drop and for being my little family in Madrid, I hope we continue having more adventures together.

Life is about taking advantage of everything that happens in front of us, but if we let something pass us by and we want it... we can always run after it until we reach it.

ACKNOWLEDGMENTS

I want to thank IBERDROLA México for trusting me and giving me the opportunity to study a quality Master and outside my country, it is a vote of confidence that they gave me, for which I will be deeply grateful.

Thanks to José Pablo and Manuel for all their support during this process, for all your patience and time dedicated to me and this work, especially for pushing me and encouraging me when I needed it the most. Without their mentoring I would not have been able to develop all this.

TABLE OF CONTENTS

DEDICATION..x

ACKNOWLEDGMENTS xi

TABLE OF CONTENTS xii

LIST OF FIGURES 14

GLOSARY..16

CHAPTER I. INTRODUCTION...17

1.1 Introduction...17

1.2 Motivation...19

1.3 Objective...20

1.3.2 Main Objective..20

1.3.3 Secondary Objectives...21

CHAPTER II. STATE OF ART...22

2.1 E-Mobility: state of the art of the public charging market in the Iberian Peninsula...23

2.1.1 Regulation...27

2.2 Main Market Players...31

2.2.1 CPOs 31

2.2.2 EMPs...33

2.2.3 EV USERS...35

Spanish vehicle fleet evolution in the next years.. 37

2.3 Evolution of prices in public electric chargers 38

2.5 EMP Services..42

CHAPTER III. METHODOLOGY 45

3.1 Model 47

CHAPTER IV. RESULT ANALYSIS 50

4.1 Infrastructure public charge development 50

4.2 Analysis of factors influencing public charge prices. 58

CHAPTER V. CONCLUSIONS 68

FUTURE WORKS..70

Bibliography 72

LIST OF FIGURES

Figure 1. Charge infrastructure indicator. 24

Figure 2. Distribution of public chargers installed in Spain at the end of the second trimester of 2023. 26

Figure 3. Registered vehicles by fuel type until the first trimester of 2023. 36

Figure 4. Evolution of electric vehicle fleet in Spain by 2030. 37

Figure 5. Evolution of public charging prices. 41

Figure 6. Public chargers' distribution in Madrid center by EMP and power capacity 50

Figure 7. Charging station located in Madrid under 50 kW. 52

Figure 8. Charging stations more than 50kW but less than 150kW available in Madrid. .53

Figure 9. Charging stations more than 150kW. 54

Figure 10. Market position by CPO. 55

Figure 12. Estimate public chargers' points installed to achieve the goals established by Royal Decree, ANFAC and AEDIVE. 57

Figura 13. Energy peninsular calendar. 59

Figure 14. Correlation matrix of factors influencing the final price of the public charge to the end user. 65

Indeed, the linear regression between the price of charging points and their power (capacity, in kW) is not negligeable and prices can vary from 0.3 €/kWh to 0.7 €/kWh for charging capacities between 20 and 150 kW, as we can see in figure 15. With further development of more fast charging points and even faster equipment, prices of public charging could rise. The increase in prices could lead to higher average price of energy for EVs, deincentivizing the purchase of zero-emission vehicles. 65

Figure 15. linear regression between the price of charging points and their power (capacity, in kW) 66

Figure 16. Relation between the location of the charging point with the average price of energy...67

For that reason, it is crucial to promote both home charging (which provides the cheapest charging energy) as well as cheaper but also faster public charging facilities. In the following years, charging points will have to become faster to attract drivers towards EVs, while demand will still be very low. During this time, an increasing charging capacity can lead to an increasing average price of energy for EV users (as we can see in the Figure 16), which can jeopardize their adoption. Hence, the importance of regulatory measures to boost the adoption of zero-emissions vehicles helping overcome price barriers. 67

GLOSARY

AEDIVE: Asociación Empresarial para el Desarrollo e Impulso de la Movilidad Eléctrica.

ANFAC: Asociación Española de Fabricación de Automóviles y Camiones.

BOE: Boletín Oficial del Estado.

CAPEX: Capital Expenditure.

CNMC: Comisión Nacional del Mercado y la Competencia.

CPO: Charging Point Operator.

E-Mobility: Electric Mobility.

EMP: E-Mobility Provider.

EV: Electric Vehicle.

GHG: Green House Gases.

ICE: Internal Combustion Engine.

kW: Kilowatt.

kWh: Kilowatt hour.

MITECO: Ministerio de Transición Ecológica y el Reto Demográfico.

MOVES: Movilidad Vehicular Eléctrica Sostenible.

OMIE: Operador del Mercado Ibérico de Energía.

OPEX: Operational Expenditure.

PNIEC: Plan Nacional Integrado de Energía y Clima.

PVPC: Precio Voluntario al Pequeño Consumidor.

REE: Red Eléctrica de España

TD: Tarifa de Acceso.

TDVE: Tarifa de Acceso para Vehículo Eléctrico.

CHAPTER I.

INTRODUCTION

1.1 Introduction

Nowadays, the automotive industry is undergoing profound changes, since about 29% of all gases emitted globally are caused by the transportation sector (Rode & Schulz, 2022). One of the most viable solutions is the improvement of vehicles that are independent of the use of fossil fuels, making electromobility an efficient option applicable today.

In this context, in 2022, Spain reinforced its commitment to promote the use of electric vehicles, setting a target of five million in circulation by 2030 (Ministerio para la Transición Ecológica y el Reto Demográfico, 2020). The deployment of public charging is held back by the high installation costs for the current low use of electric vehicles, in addition to the time-consuming and laborious process of processing licenses and connecting new installations to the grid, with a total time of 2 years until commissioning.

Based on calculations by the charging operators integrated in AEDIVE[2], an infrastructure deployment would be needed to reach 70,000 in 2025 and 255,000 in 2030 (ANFAC, 2023). However, it is important to mention that the deployment should not be based on "numbers", but on locations and type of charging in each of them, with priority being given to the user and fair competition.

[2] Asociación Empresarial para el Desarrollo e Impulso de la Movilidad Eléctrica

According to the 2022 Annual Report by ANFAC, sales of electric vehicles increased by 31.3% compared to the previous year, and plug-in hybrids reported a growth of 11.3%. While non-plug-in hybrids, with 25.3%, were the technology with the highest number of sales recorded.

The above is the result of the perception of users who consider that there is still a lack of autonomy in electric vehicles, in addition to the fact that, despite the MOVES III Plan, the market remains low. The plans are a valuable instrument, but they need to be more effective, due to a lack of diffusion but also due to the relative facility with which these plans can channel funds towards consumers others than the target (free-riding).

To address the perceived lack of autonomy, it is necessary to promote the development of public access charging infrastructure, because although Spain had a growth of 18,128 charging points (4,717 more than the previous year), it is still below the target of 45,000 that should have been at the end of 2022. (ANFAC, 2022)

To ensure an adequate transition from ICE vehicle re-fueling stations (gas stations) to EV charging stations (electric charging stations), it is necessary to analyze and study the different contexts that help the respective institutions to carry out a correct forecast to establish the right legislative instruments to promote the optimal location of public charging stations.

This research first includes the explanation of the current state of charging points, since it will be determined how the variables and agents are related, establishing factors that can explain the possible future behaviors that are studied, as well as the possible evolution of a market that is structuring and evolving rapidly and constantly.

After the descriptive study, a data analysis is proposed, making a linear regression model to describe prices as a function of to several explanatory variables such as location, types of chargers and power of each one of them.

Therefore, the main methodology used to obtain information is the literature review. In this sense, most of the information comes from official bodies such as the Official State Gazette (BOE), Royal Decrees, websites of suppliers and installers of charging points, and the use of articles and useful reports.

The analysis of the results and conclusions are presented at the end.

1.2 Motivation

In 2015, the United Nations Member States created the 17 Sustainable Development Goals (SDGs) as a universal call to end poverty, protect the planet and ensure that by 2030 all people enjoy a sustainable and just world. To achieve a just and sustainable EV, the actions to be created must be attached to the goals:

- 7: Affordable and clean energy
- 9: Industry, innovation, and infrastructure
- 11: Sustainable cities and communities

One of the main barriers for consumers to adopt EVs is the lack and sometimes the price of the public charging infrastructure, especially in places (cities) where private infrastructure is not as common.

The transition towards electromobility could need policies (mechanisms) guiding the economics of the EVs, for which we must know the charging market needs and trends. That is why, in this thesis work, an investigation is proposed on how the different agents of the current market interact, which current regulations must be respected, and which sector must pay attention to be regulated efficiently, ensuring a fair and sustainable transition to electromobility, as well as to evaluate the evolution of competition and prices in the public charging market. This is due to the rapid growth and boom that this sector has acquired in the last three years.

1.3 Objective

For the development of this work, an analysis of the current e-mobility market is proposed, as well as the current and future impacts on the electricity sector market. The above to propose lines of research and policy development to regulate the market and ensure a transition with the least possible negative impact on the operation of distribution networks and the market in general.

1.3.2 Main Objective

To understand the variation of prices in public charging points, according to the attributes of the charging points and the services offered by competitors in the market.

1.3.3 Secondary Objectives

- To analyze the main players involved in the e-mobility market.
- Analyze current market prices.
  - Identification of variables that define the price of charging.
  - Price differences according to each variable
- Analyze the expected demand of EV users.
- Identify the electromobility economics barriers for EV users, assess the impact of the public charging services in the decision-making of drivers.

CHAPTER II.

STATE OF ART

To understand the current political context in Spain in the international framework, I must begin by talking about the PNIEC 2021-2030[3]. The evolution of the investment in renewable technologies from 2021 to 2030 depends on the evolution of cost and the viability and flexibility to install them.

By 2030, 74% of the energy produced will be renewable and trying to achieve a 100% in 2050 (MITECO, 2020). In the mobility sector, the idea is to reduce 27 Mt CO2 between 2020-2030 reducing 33%. With the idea of making big cities (more than 50,000 habitants) set zones of low emissions prohibiting access to the most polluting vehicles. The main idea in mobility is to increase the electrification of vehicles to 28%.

One important thing is to increase energy efficiency from 32% to 39.5% in 2030. For 2050 the idea is to achieve climate neutrality. By 2050 the purpose of the Spanish government is to produce 100% with renewable energies, 97% of the heating and cooling sector also with renewable energies and in the transport sector 79%.

The transport sector is a sector that is already with great advances and a lot of programs like subsidies by the government and reduction of taxes, nowadays also implemented the installation of chargers. For 2030 it is necessary to make more profitable

[3] Plan Nacional Integrado de Energía y Clima

cars since nowadays they are expensive and not all the population can buy them. This also is reducing the GHG emissions of this sector.

To achieve the goal of 2050, it is necessary to make the same transition as when the energy sector starts to set a year when it is prohibited to sell more combustion cars around the year 2040. So, the amount of these cars will be reduced by the year 2050 and the emissions can be reduced. By the 2040 its expected that the cost of an electricity vehicle reduced a lot so more people can buy it with the incentives and subsidies given by the government.

2.1 E-Mobility: state of the art of the public charging market in the Iberian Peninsula

Despite the government's efforts to promote electromobility, Spain still lags in the development of public access charging infrastructure. Every 3 months, ANFAC prepares a "barometer" which is composed of indicators that measure the level of penetration of electrified and pure electric passenger car vehicles, as well as the level of charging infrastructures.

For the report of the second trimester of 2023, which is summarized in Figure 1, Spain ranks eighth in the European Union. The charging infrastructure in Europe is still progressing slowly compared to the previous trimester. (ANFAC, 2023).

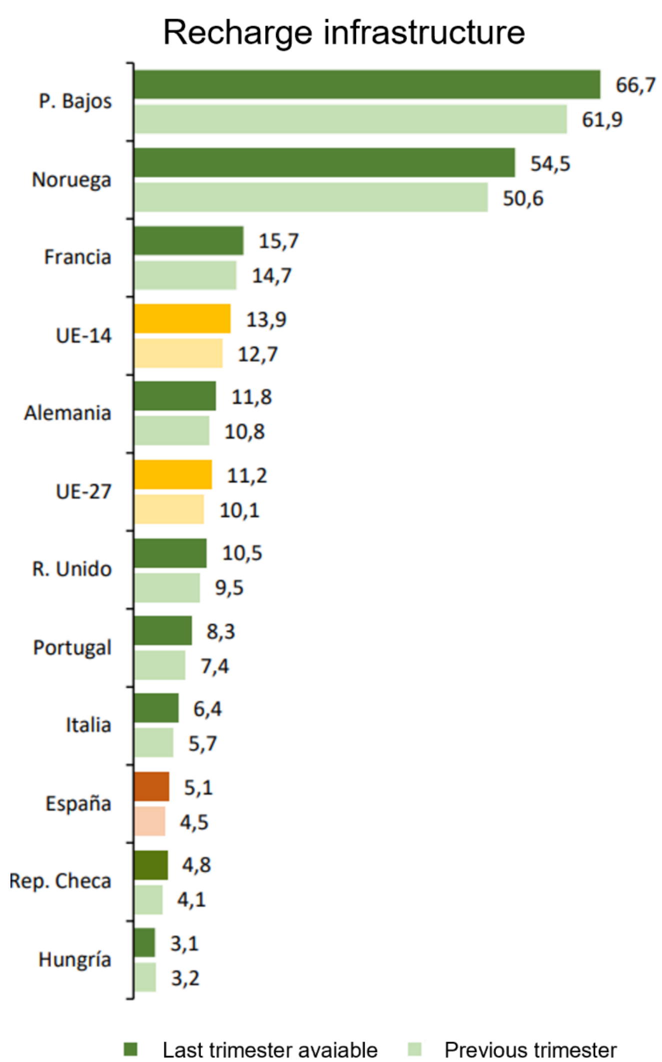

Figure 1. Charge infrastructure indicator.

Index in base 100. The value of the indicator determines the distance to a predetermined target for 2030 in line with the Fit for 55 package of measures of the European Commission. The indicator evaluates the status considering a target of 9.1 charging points per 1,000 motorized. Source: ANFAC.

In Spain this year is projected 45.063 public charging points of which only 29.464 have been installed and 22% of the public access charging infrastructure in Spain corresponds to charging with power greater than 22kW. It is important to mention that, compared to last trimester report by ANFAC, the public charging infrastructure has increased by 2.517 points.

However, about 22,75% are out of service. This is due to complications in the interconnection to the electricity grid, due to poor condition or breakdowns in the equipment installed because of the difficulties in the development of this type of projects.

The main barrier that companies in charge of installing public charging points face today is the lack of a clear, fast and efficient procedure for the commissioning of equipment, which will not be possible until an adequate regulated procedure is established.

Figure 2 shows a comparison of active charging points and those out of service at the time of the report published by ANFAC, Cataluña is the autonomous community with the highest growth compared to the rest. This may be due to the high demand for electric vehicles in the autonomous community, although this is not a determining factor in choosing the location of the chargers, the demand for public charging and the routes usually taken by users should be considered.

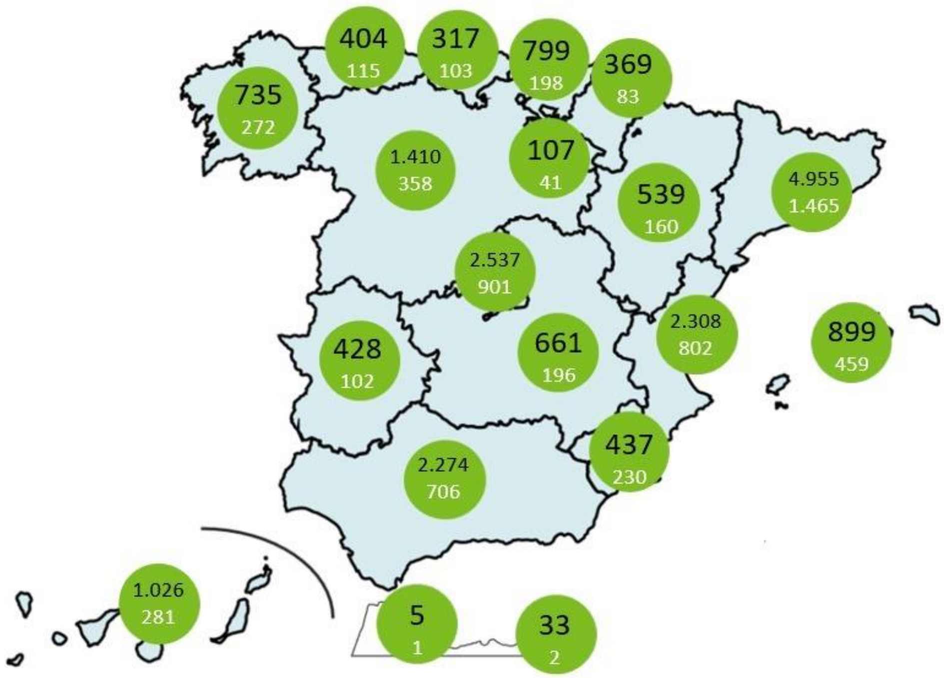

Figure 2. Distribution of public chargers installed in Spain at the end of the second trimester of 2023.

Chargers that are out of service for various reasons are shown in white. Source: own elaboration with ANFAC data.

Although the greatest demand for charging is in home charging, it is imperative that public charging continues to grow in order to provide the same level of conviction and motivation to vehicle users to switch to electric mobility. While the pandemic was the main cause of the marked decline in growth, the numbers needed to meet demand have not yet been achieved.

This chapter is focus on analyzing the current state of the art of electromobility, going through the main actors, the key values related to the topic, important to understand the context and to ground the topic in a realistic way to understand the market that was studied.

2.1.1 Regulation.

In the regulatory framework, during the period 2008-2013 public charging was not among the priorities of the Spanish government. However, a basic regulatory framework was established that allowed the installation of electric charging points on public roads, focusing on technical and safety aspects. One of the plans promoted by the government was the MOVELE Plan in which incentives were offered for the acquisition of EVs as well as for the installation of electric infrastructure (Abel Rosales-Tristamcho, Raúl Brey, Ana F. Carazo, & J. Javier Brey, 2022).

In 2014, Royal Decree 1053/2014 was published establishing the technical and safety conditions for EV charging facilities, as well as the procedure and requirements to be met for connection to the electricity grid. It was until 2018 when interoperability[4] began to be promoted in Spain, facilitating access to the infrastructure between different grid operators.

[4] Ability of information systems to share data.

Royal Decree 647/2021, which established important aspects such as rights of access and use of the charging infrastructure, transparent billing, promotion of interoperability and protection of user data.

The adaptation of the Technical Building Code to the provisions of Directive (EU) 2018/844 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency was carried out, establishing the conditions of the minimum infrastructures necessary for the smart charging of electric vehicles in the parking lots of buildings.

Following on the above, Royal Decree 29/2021 was published, in which the measures mentioned contemplate those buildings for private residential use be prepared with pre-charging in the totality of their parking spaces. In the case of the rest of new buildings and those subject to refurbishment, it contemplates that it will be for 20% of the available parking spaces.

For public parking, one charging station for every 40 parking places and, for the buildings of the General State Administration, it increases to one charging station for every 20 parking places. The autonomous communities will be responsible for notifying service station owners of their obligation to install at least one charging point for electric vehicles.

According to order TED/1009/2022, the electric vehicle charging point may be located on the land adjacent to the service station, at a maximum distance of 300 meters from the fuel supply facility.

While in 2022, with the publication of Royal Decree 184/2022, the regulatory framework for the activity of providing public charging services for EVs (called charging stations) was established, defining transparent billing methods, security at charging stations, reinforces the protection of user data and sets as a goal the installation of the 100,000 public chargers for electric cars it needs to meet the target set by the government by 2023.

A point to be mentioned is article 3.e and 3.f of RD 184/2022, which establishes the definition of the figures of charge point operator and electric mobility service provider company. This subject will be discussed in more detail in later chapters.

Instead, the article 4 of RD 184/2022 establishes a series of principles that must govern the activity of the energy charging service. Among these principles, the following can be highlighted:

- Principle of efficiency and minimum cost for the user and for the electricity system.
- Freedom to provide the service by any consumer.
- Companies providing services for electric mobility shall carry out their activity under fair and non-discriminatory market conditions. Operators of charging points shall not grant preferential treatment to them by applying an unjustified price differential that may hinder competition and ultimately lead to higher prices for consumers or any other practice involving undue preferential treatment.

- Establishment of reasonable easily comparable, transparent and non-discriminatory prices by the providers of energy charging services. In this point it mentions that service providers may apply discounts, special offers and promotions to the users of charge services, as long as these do not contravene the principles mentioned in the previous point.
- Principle of cooperation between the distribution network operator and the provider of energy charging services on the basis of non-discrimination.
- Principle of universal access to electric vehicle charging point infrastructures with public access.

Article 11 establishes the authorization regime for the electric infrastructure of electric vehicle charging points with a power of more than 250 kW:

1. The electrical infrastructures of electric vehicle charging stations with a power of more than 250 kW are subject to the authorization procedure applicable, in accordance with Article 53 of Law 24/2013, of December 26, of the Electricity Sector.
2. When the competence for the authorization of the referred facilities corresponds to the General State Administration, the provisions of Royal Decree 1955/2000, of December 1, which regulates the activities of transport, distribution, commercialization, supply and procedures for the authorization of electric energy facilities shall apply.

The trend in the coming years for the displacement of charging points is expected to be fast and ultra-fast charging stations, especially on highways and for heavy vehicles. It is necessary to promote stations of this type to ensure the reliability of users in terms of the autonomy of electric vehicles, which is why the impact of Article 11 is so important, which should not be a barrier but a watershed to ensure the proper planning of charging points.

Continuing with the measures to boost the EV market, in 2022 the government launched the MOVES III program, which consists of aid for both individuals and companies wishing to purchase a pure electric vehicle, a hybrid or an extended-range vehicle.

In 2023, the Spanish government set a target of 300.000 charging points installed by 2030, in order to meet the expected demand for electric vehicles.

2.2 Main Market Players

The transition to electromobility implies a set of actions involving different actors, being part of a technological revolution where combustion engines are replaced by electric motors and batteries. The main market players will be described below, followed by an in-depth analysis of their relationship with each other and their interaction with the market.

2.2.1 CPOs

Charge Port Operators (CPOs) are responsible for the installation and operation of the charge points, in other words, they are the owners of the hardware. CPOs are also in charge of the maintenance of the points.

In relation to the regulation of the participants in the provision of this service, in April 2021 the Draft Royal Decree regulating the activity of providing energy charging services for electric vehicles was published, which was developed under the protection of Article 48.2 of Law 24/2013 of the Electricity Sector.

This publication establishes that the charging point operator must assume certain obligations whose ultimate ratio is the provision of a charging service under conditions of minimum cost and efficiency from which electric vehicle users can benefit.

Likewise, it defines that the charging point operator is constituted, in general, as the consumer of electric energy, in accordance with the provisions of Article 6 of Law 24/2013, of December 26, of the Electricity Sector. Alternatively, the consumer may assign or transfer, for the purposes of this royal decree, the rights to operate the electric vehicle charging point infrastructure to third parties, who shall assume the rights and obligations of the charging point operator in accordance with the provisions of this royal decree (Ministerio para la transición ecológica y el reto demográfico, 2021).

The CPO market has been growing significantly in the last years. In Europe, the strong companies that have establish a presence in EV charging industry are:

- Kempower (Finland). They design, manufacture, and sell DC fast charging devices, services for EVs and different solutions.
- Allego (Netherlands). Was founded in 2018 and is growing very fast across the European network. They build an international charging network with more than 34.000 operation charge points in all the continent. Something interesting is that they try to have their public facilities close to coffee shops, restaurants or grocery store, as well as ensuring WIFI and toilet for short and long stay.

- BP p.l.c. (England). In 2018, it acquired Chargemaster that is the UK's largest EV charging network. And in this point is important to say that they are commitment to install more than 100.00' EV charge points worldwide, 90% of them must be rapid or ultra-fast, one strategy they have could be the JV signed with Iberdrola in June 2023.
- Efacec (Portugal). Was founded in 1948 and is a major player in the EV charging station market.
- EVbox (Netherlands). They offer only fast charging devices and they ensure that the energy comes from renewable sources.
- IONITY (Germany). Is a high-power station network from EVs, its technologies enable long-distance travel across Europe.
- Wallbox (Spain). Was establish in 2015 and nowadays is one of the most important companies in the sector.

Of those CPO, the one who has more installed equipment in Spain, is Wallbox.

2.2.2 EMPs

E-Mobility providers refer to the companies that offer the charging service, in Spain they are known as the charging manager. They are responsible for creating the platforms that connect the CPOs with the users, so that the former can establish their rates and the users can charge. In other words, the EMPs oversee charging and additional services.

In Europe, the best EV charging apps who are the EMPs nowadays revolutionized the charging experience for the EV users, because they offer different services and different pay methods, the race to offer the best, coverage and efficiency in the status of the chargers shown has already begun. The main EMPs in Europe are as follows:

- Iberdrola. More than 94.000 points in Spain, being one of the apps with the highest growth and coverage in the country.
- ElectroMaps. It is one of the most popular and complete apps in the market, as it allows locating electric gas stations, type of chargers, rates and payment options. It currently has more than 240,000 chargers registered.
- Endesa X way. Offers around 1,305 charging stations available in its app.
- Charge Map. With around 5,000 charging points in Spain, it is one of the most complete applications, in addition to offering different payment methods through its app.
- Place to charge. This one has a different scheme, since in addition to finding public charging points, it is possible to share and use charging points in private homes.

In Spain, the EMP with the largest network of chargers in its public charging APP is Iberdrola, which offers around 94,000 chargers to its app users. However, with the royal decree published in 2023 it could change the rules of the game, as it envisages a public map where all CPOs provide the data of their public chargers to feed the database, which will be owned by the government. This will prevent users from having different APPs to compare prices, charging speed and search for the nearest chargers according to their needs.

2.2.3 EV USERS

The transition to electromobility implies a set of actions involving different actors, being part of a technological revolution where combustion engines are replaced by electric motors and batteries. The population's interest in meeting the goals set for 2023 is growing, as the effects of climate change begin to really affect people's daily lives.

In Europe, electric car sales increased by ore 15% in 2022 relative to 2021 to reach 2.7 million. When compared to previous years, a slower growth can be noted, as an average annual growth of 40% was recorded between 2017-2019. To the foregoing, it can be attributed that in 2020 and 2021 there was a remarkably rapid growth since manufacturers quickly adjusted corporate strategy to meet the CO2 emission standards approved in 2019. European countries continued to rank highly for the sales share of electric cars, led by Norway at 88%, Sweden at 54%, the Netherlands at 35%, Germany at 31%, the United Kingdom at 23% and France at 21% in 2022.

In volume terms, Germany is the biggest market in Europe with sales of 830 000 in 2022, followed by the United Kingdom with 370 000 and France with 330 000 (IEA, 2023). Sales also exceeded 80 000 in Spain and in the first trimester of 2023, there has been a slow but steady growth in the number of electric and hybrid vehicles, which is the opposite of the acquisition of combustion vehicles, as shown in the Figure 3.

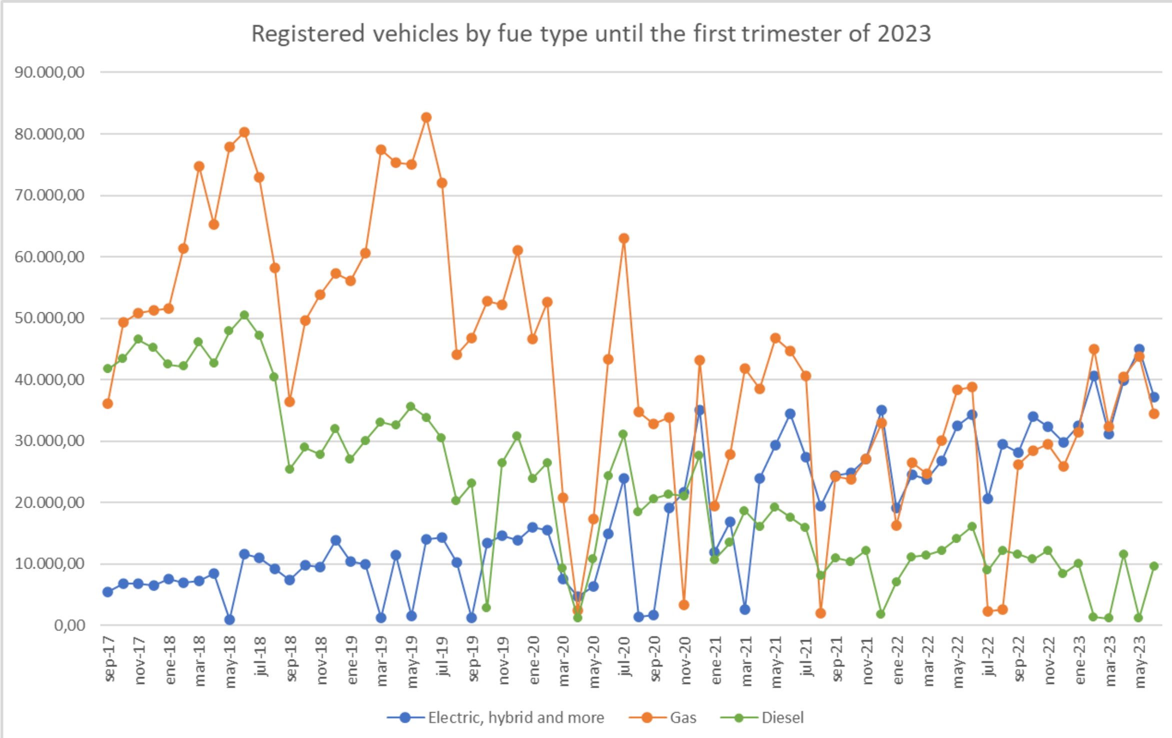

Figure 3. Registered vehicles by fuel type until the first trimester of 2023.
In this graphic we can see the comparative between the acquisition of hybrid (or electric), gasoline and diesel vehicles. We can note that while electric vehicles are increasing, fossil fuel vehicles have decreased considerably in the last two to three years. Source: ANFAC/ / Faconauto / Ganvam.

Another sector that is important is the users like the drivers of taxi and car sharing, delivery people, transporters, medical representatives and salespeople, since they are the vehicle users who spend the most time driving, they travel more km than an average user (who only uses the home-work-home vehicle, for example) they are the most interested in public charging, taking into account that their route daily varies and night (home) charging may not be sufficient.

Spanish vehicle fleet evolution in the next years

In the case of Spain, there has been a constant growth in the number of electric vehicles, however, it has been as explained above. That is why an accelerated growth is expected in the coming years, since taking into account the goal of 5 million electric vehicles established by the PNIEC and based on data from the DGT, an evolution of each of the segments has been projected until 2030, as we can see in the Figure 4, managing to estimate the goal for each type of vehicle since everything that allows electric mobility, called micro mobility (electric scooters and bicycles), must be considered. This is due to the importance they have acquired in the last year for urban mobility.

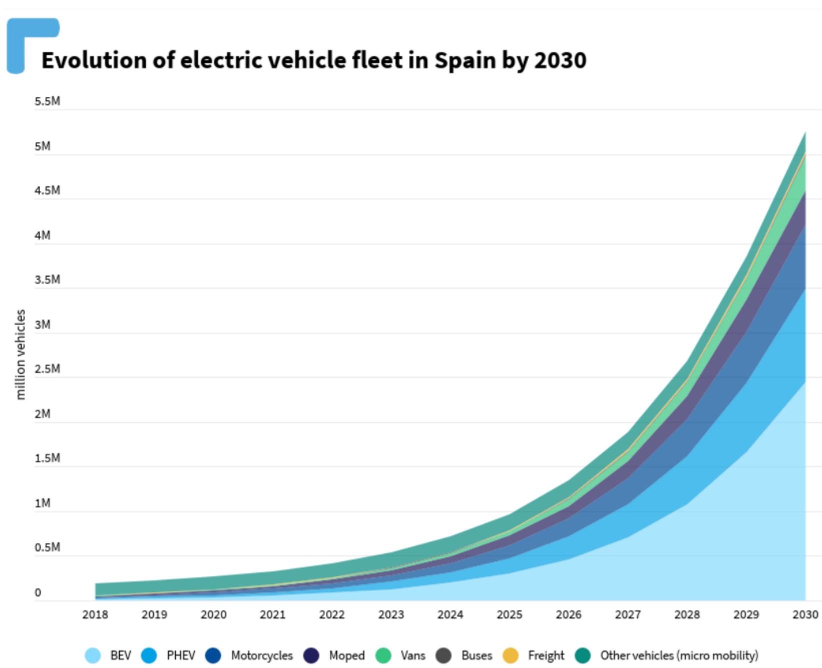

Figure 4. Evolution of electric vehicle fleet in Spain by 2030.

Here, we can see the estimation of the increase by obtaining the vehicle fleet in 2030, it is possible to estimate the daily and annual energy consumption equivalent to the planned fleet. To do this, it is necessary to divide consumption by segment and average values of battery capacity, considering energy efficiency (kWh/km), autonomy, trips made annually, average number of kilometers traveled daily. Source: Electric vehicle charging point deployment plan for Spain by Transport & Environment, 2021.

Transport & Environment made an estimate in 2019, considering the improvement of batteries over the years, in this way and taking as input variables the named parameters, estimated the total energy consumption of the electric vehicle fleet year by year until 2030. With all this, an estimate of an average daily energy consumption of the electric vehicle fleet of 42,970 MWh was published, which is equivalent to a total annual consumption of 11,215 GWh.

2.3 Evolution of prices in public electric chargers

The rates established at public access charging points are usually related to the price per kWh charged to the consumer, varying according to the power and sometimes a fixed amount regardless of the consumption produced. It is important to note that there are certain charging points in places such as supermarkets, hotels and malls where the service is offered free of charge, however, this only happens in the case of low power chargers (or slow charging).

However, this only happens in the case of low-power chargers (or slow charging). In comparison with tariffs contracted at home (at private domestic points) where the price varies according to the time of consumption. In this case, many suppliers offer preferential prices in periods when demand is not high (i.e. in flat or low periods).

Establishing a methodology to determine the price of public charging is not simple, since different factors are involved, such as: the operator of the charging point (whether it is public or private sector), the power of the installed equipment, the site where the charger is placed and its availability to the electric grid, since it may be that it is located on a road without a nearby distribution line, being necessary to supply it by means of a mix of battery storage and renewable production (such as solar).

Table 1 shows a comparison of the evolution of tariffs offered by EMPs (some CPOs as well) in the last 4 years. It can also be seen how charging point operators as well as service providers have been added to the list.

Table 1. Evolution of charging prices €/kWh.

	YEAR	2019	2020		2021			2022				2023			
	POWER	50kW	50kW	>100kW	50kW	<100kW	>100kW	22 kW	50 kW	>100 kW	>150 kW	22 kW	50 kW	90-120 kW	150-180 kW
CPO/EMP	Ionity	0,79 €	0,79 €	0,79 €			0,79 €				0,79 €			0,79 €	
	Endesa	0,49 €	0,40 €		0,40 €			0,33 €	0,35 €	0,43 €		0,39 €	0,45 €	0,55 €	
	Repsol	0,47 €	0,47 €	0,54 €	0,47 €				0,47 €	0,54 €	0,54 €	0,35 €	0,47 €	0,54 €	
	Wenea	0,45 €	0,30 €		0,39 €		0,49 €					0,38 €	0,42 €	0,56 €	0,59 €
	GIC	0,45 €	0,45 €		0,45 €			0,45 €	0,45 €			0,45 €	0,45 €		
	EMT Madrid	0,40 €			0,40 €			0,35 €	0,35 €			0,35 €	0,40 €		
	Cargacoches	0,38 €	0,38 €		0,29 €	0,40 €	0,40 €								
	EDP	0,36 €	0,45 €		0,45 €			0,39 €	0,45 €			0,39 €	0,45 €		
	Iberdrola	0,30 €	0,30 €		0,30 €	0,40 €	0,50 €	0,39 €	0,45 €	0,54 €	0,69 €	0,39 €	0,45 €	0,54 €	0,69 €
	Easycharger	0,30 €	0,30 €		0,30 €	0,40 €	0,55 €								
	Tesla (uso exclusivo)	0,29 €	0,34 €	0,34 €			0,36 €				0,57 €				0,58 €
	Easycharger (Nissan)	0,15 €	0,30 €												
	Tesla S/X (free SuC)	0,00 €	0,00 €	0,00 €											
	Honest Charging	0,00 €	0,00 €												
	Acciona							0,20 €	0,43 €	0,54 €	0,57 €	0,20 €	0,38 €	0,48 €	0,57 €
	Electromaps							0,18 €		0,45 €		0,20 €	0,30 €	0,50 €	0,60 €
	TotalEnergies							0,24 €	0,36 €	0,53 €	0,53 €	0,24 €	0,36 €	0,53 €	0,53 €
	Zunder							0,42 €	0,42 €	0,55 €	0,55 €	0,42 €	0,42 €	0,55 €	0,55 €

As can be seen, classifying the prices of each CPO or EMP is a complex task, since each one handles different powers, types of tariffs and charges. For example, in the case of fast and ultra-fast charging, there are only eight CPOs with the capacity to supply in that power range, which are shown in Table 1.

It is to be noted that Tesla is not considered a competitor at all, since only Tesla models can use its charging network, being free and unlimited for Tesla Model X and Tesla Model X. Currently, the costs necessary to provide electric service to consumers are directly affected by the electricity tariff, which considers liberalized costs, regulated prices and taxes.

In the graph below, the evolution of fast and ultra-fast charging prices over the last three years is shown. As for the most powerful chargers (350kW) only three of the CPOs have them:

- The most expensive one is Ionity with a price of 0,79€ and 100 charge points in Spain is the most expensive EMP, they offer subsidies (provided by affiliated car dealers) or a fixed fee of 17.99 € per month resulting in kWh at 0,35 €.
- The next one is Iberdrola with 0,69€; however, it offers different types of promotions and packages that make the contracting of the service attractive, especially for the company level, as it usually handles fixed rates below what is established in the APP at the time of signing a long-term contract.
- Finally, we note that Repsol has a price of 0,54 € because they began installing ultra-fast charging equipment at the end of 2019.

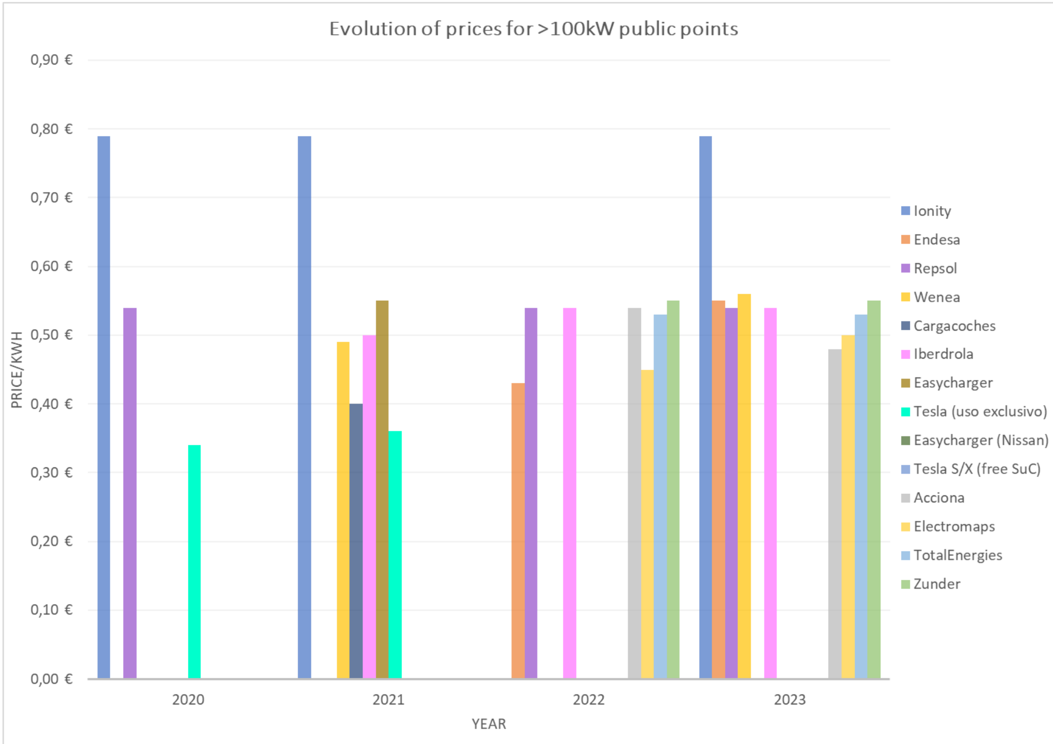

Figure 5. Evolution of public charging prices.

The graph shows the different prices for fast and ultra-fast charging. It is important to note that slow charging is not included, since the price evolution has not been significant (as shown in table 1). Providers such as Ionity have remained with the same price as the most expensive in the market. This gives us a glimpse of the complexity and variety of services found in the market, as each EMP offers its customers offers and packages to lower the kWh price of charging.

2.5 EMP Services

With so much variety in the market of public charging service providers, they have diversified the services offered by each EMP, not only limiting the services to facilitating electric charging.

Some of these services are described below:

- Subscription. This service provides the user with the facility to subscribe to the application, which will facilitate each charge. Many of the EMPs offer seasonal special offers to users, as well as free kWh when subscribing. This is the most common service, as it has been detected that companies are increasingly interested in having more registered users per application.
  This could be since it is a way to ensure certain user behavior for future actions to be developed, such as the installation of new chargers.
- Monthly plan. Relates to monthly plans for users. It can be presented in two ways: fixed monthly fees, which are limited to a certain amount of kWh consumed at the end of the month. And the second is a preferential price depending on the time of charge, since EMPs that are also CPOs can offer lower prices in the evenings, when the price of electricity is usually lower.
- Super-fast chargers. The power of the chargers is another factor that divides the market, as there are CPOs that install only super or ultra-fast chargers, making their rates more expensive. Therefore, EMPs that are also CPOs offer exclusively this type of charging, making it easier for users who prefer

this type of services to find them, since they do not usually negotiate interoperability[5] agreements for all their installed points with the rest of the EMPs.

- Charge card. One of the barriers detected is the payment method, since most EMPs require the user to have a smart phone with the capacity to download the application, as well as internet access. Which for many are complicated conditions, especially for companies wishing to change their fleet to EV. That is why some EMPs offer the charge service through cards, which are synchronized with an internal user number so that the user can charge without the need to use their mobile device.
- Hourly prices. This service applies to the CPOs that are also EMPs, allowing them to offer a lower nighttime rate. This is appealing to carsharing or taxi companies since they can access public chargers at a lower price during the night, coordinating their trips among their vehicles.
- Parking fee. Probably this is another barrier for EV users. This type of fee is usually applied at slow-charging points. One possible explanation is the location of the chargers, as they are often situated near malls, stores, or restaurants where parking spaces are limited. Therefore, it represents an additional profit for the charge service providers. This fee is typically applied after 2 hours of service.

[5] Refers to the ability of different systems, infrastructures and components related to electric vehicles (EVs) to work together efficiently. In this case, it is the possibility that a CPO or EMP can make an agreement with another EMP so that certain charge points appear in its application, making it easier for the user to use a single application to charge.

- Company prices. By detecting the increase in companies with electric vehicles fleets, EMPs offer fixed-term contracts to these companies. These agreements specify the number of registered vehicles and provide unlimited charges at a fixed price during that period or a limited amount of kWh at very low rates. The second option is designed for fleets that consistently follow the same route and can estimate the monthly kWh requirements.

Therefore, the initial price difference of each EMP can be explained. However, it is important to consider that within these rates, users can access various types of contracts, subscriptions, or agreements depending on the application they choose to use. Table 2 displays the main EMPs and the services provided by each one.

Table 2. Services offer to the public charging users of the principals EMP in Spain.

As can be seen, the EMPs with the most services offered are those that are also CPOs, which gives them a greater margin to be able to offer offers in the charge prices or different tariffs based on electricity off-peak hours.

EMP	Subscription	Monthly Plan	Special Prices for Some Chargers	Special Price for Fast Chargers	Fast & Super Fast chargers	Recharge Card	Hourly prices	Parking fee	Company prices
Easycharger (Zunder)	x	x		x					
Iberdrola	x	x	x	x	x	x	x		x
Wenea	x							x	x
Tesla		x	x	x	x				
Endesa X	x	x	x	x			x		x
EMT Madrid								x	
EDP Moveon	x	x	x	x		x	x		x
GIC-ETRA-ACS					x				
Repsol	x	x							x
Ionity	x				x				
ChargeMaps	x		x	x	x			x	
Electromaps	x		x	x	x			x	
Acciona (Cargacoches)	x				x				x
VW (Elli)	x	x							

CHAPTER III.

METHODOLOGY

The public charging market for electric vehicles is a new, complex market with areas of opportunity to develop policies to regulate and ensure fair competition for all participants, as well as to protect users who are now in a transition and adaptation stage to this new technology (the adoption of electric vehicles).

It was decided to focus on two problems:

1) **Infrastructure public charge development.** The concern of users to ensure that the autonomy of electric vehicles is equal to that of conventional vehicles is one of the main barriers that we find. The lack of private parking spaces at users' homes makes it necessary to develop a public charging infrastructure for all those who cannot charge their vehicles at home.
   To encourage the acquisition of EVs, users must be certain that charging their vehicles is not a problem. Without forgetting that the needs must be analyzed depending on the area where the equipment is to be installed, so that the prices are sufficiently affordable for all users. In the case of long distances, such as highways, care must be taken in the strategic points for the installation of charging points, as well as the power of the same, to avoid that the travel time increases to a point that is an impediment to the adoption of EV.

Once we have the historical data, we will proceed to choose the type of regression that best fits the reality of the data. Analysis of the price among the years and identify which factors are involved. According to the expected evolution, the most suitable regression is a polynomial regression, since the growth will change depending on the needs and evolution of the electric car market, where the increase in the circulation of these vehicles is expected to occur in the next few years.

2) **Analysis of factors influencing public charge prices.** The price per charge is without doubt a subject that must be clear, defined, and affordable for the user. Without posing a risk for the service providers and for the owners of the charge point. Nowadays, some of the main concerns and challenges associated with pricing are a) **Lack of standardization**: the absence of uniform standards to establish prices makes it difficult to compare different EMPs. b) **Equity and accessibility**: the variation of prices may affect differently segments of the population, facing one of the biggest economic barriers to EV adoption, because although there are incentives for purchase, there are no incentives for public charging. c) **Regulatory challenges**: Regulation around charging prices may vary and, in some cases, may not be sufficiently clear to address current issues, which may result in unfair practices and increase uncertainty among consumers.

3.1 Model

The research is complemented by a regression analysis, since it will be determined how the variables and agents are related, establishing factors that can explain the possible future behaviors that are studied, as well as the possible evolution of a market that is structuring and evolving rapidly and constantly.

Regarding the evolutionary development, the sources used are information published by the *Asociación Empresarial para el Desarrollo e Impuso de la Movilidad Eléctrica (AEDIVE), the Asociación Española de Fabricantes de Automóviles y Camiones (ANFAC*), and information provided by *Iberdrola España*.

At the beginning of the research, the initial hypothesis was that public charge prices varied depending on the location of the charge point. During the research and the compilation of information on public charging, it was found that there was no such relationship since the price was established by the charging service provider (EMP). For this reason, it was necessary to establish new objectives oriented to two of the problems that were detected.

Once the research was completed, two possible analyses of interest were found to be developed:

1) Infrastructure public charge development

To develop this analysis, it was necessary to compile three different sources where the projections of installed chargers for 2030 were published: official data from the

Spanish government, AEDIVE and ANFAC, based on the annual report *Barómetro de ectro-movilidad* published every year by ANFAC.

As explained in the methodology, the model used for the charger installation regression was a 3rd degree polynomial regression, since this regression was the most appropriate for this model, giving an R of 0.99 for the equation used:

$$Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \varepsilon$$

Where:

Y= This represents the dependent variable (number of installation points).

x= This is the independent variable, feature variable using to predict the dependent variable.

β_0= This is the y-intercept, the constant term that represents the value of *Y* when *x* is 0.

β_{1-3}= This is the coefficient associated with the linear, quadratic and cubic term, represents the change in the rate of change of *Y* with respect to *x*.

$\varepsilon =$ This represents the error term, which accounts for unobserved factors that may affect the dependent variable but are not included in the model. It represents the difference between the actual and predicted values of *Y*.

This type of regression is useful when the relationship between the dependent and independent variables is not linear but follows a polynomial pattern, like the one we have.

2) Analysis of factors influencing public charge prices.

Therefore, it is proposed to compile a list of the charging points in the center of Madrid, to delimit the research area, relating the location with the power of the charger. To analyze the main EMPs in the Spanish market, as well as the products they offer and the price per charge. For this it was necessary to track the points in different sources: google maps, electro maps and in the applications of each EMP, this to validate the information of each point, because currently there is no complete database with the data of the charging points.

Although MITECO has published a website (https://geoportalgasolineras.es/geoportal-instalaciones/Inicio) with the public charging points available in Spain, only the super-fast and ultra-fast charging points of some CPOs are published. It is a useful tool for planning long journeys, however, there is a lot of data to be updated and points to be added. In addition, the page is slow compared to those offered by the EMPs.

CHAPTER IV.

RESULT ANALYSIS

4.1 Infrastructure public charge development

The charging speed of electric vehicles is classified in different levels, in terms of power, which defines the charge time of the battery. The speed at which the battery charges depend not only on the available power of the charger, but also on the charging capacity of the battery and the temperature control of the battery.

Once the chargers installed at the time of the research were identified, a panel was drawn up to perform the analysis in a more visual way, the result is shown in Fig. 6 which shows the distribution of public chargers in Madrid center. This was done to make a visual analysis of the current state of the way in which electric chargers are distributed, to project in a better way the future locations and to identify which are the main participants in the market.

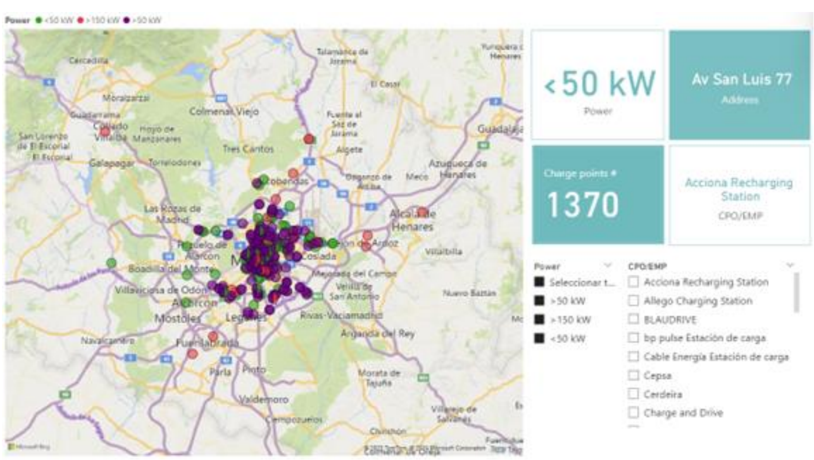

Figure 6. Public chargers' distribution in Madrid center by EMP and power capacity.

In the panel is divided by 3, in the first square we can see a map with the charging points, he second square (upper right corner) shows the specification of the selected charging point and the number of existing points of the selected power. In the lower right corner are shown the modules to select the power of the chargers to be displayed and the CPO/EMP to be displayed on the map.

The chargers installed in the center of Madrid were analyzed and classified as listed below, according to the prices found in the market.

Home charging <3,7 kW. Full battery charge time can take several hours; however, it is the most recommended by EV manufacturers.

Semi-Fast charging <50 kW. This is the most common type of chargers in the public charging network since they were the first points to be installed. To be attractive to users, they must be in shopping centers, restaurants, hotels or near housing complexes, due to the time of rest to be able to charge the battery to a considerable percentage.

As can be seen in Figure 7, there are about 649 charging stations in Madrid, most of them located in the downtown area, which demonstrates that the best strategy for the installation of this type of equipment is close to areas where there are shopping malls, neighborhoods and restaurants, as this is a sign that users have enough time to charge the battery sufficiently to continue their route and use the waiting time for other activities.

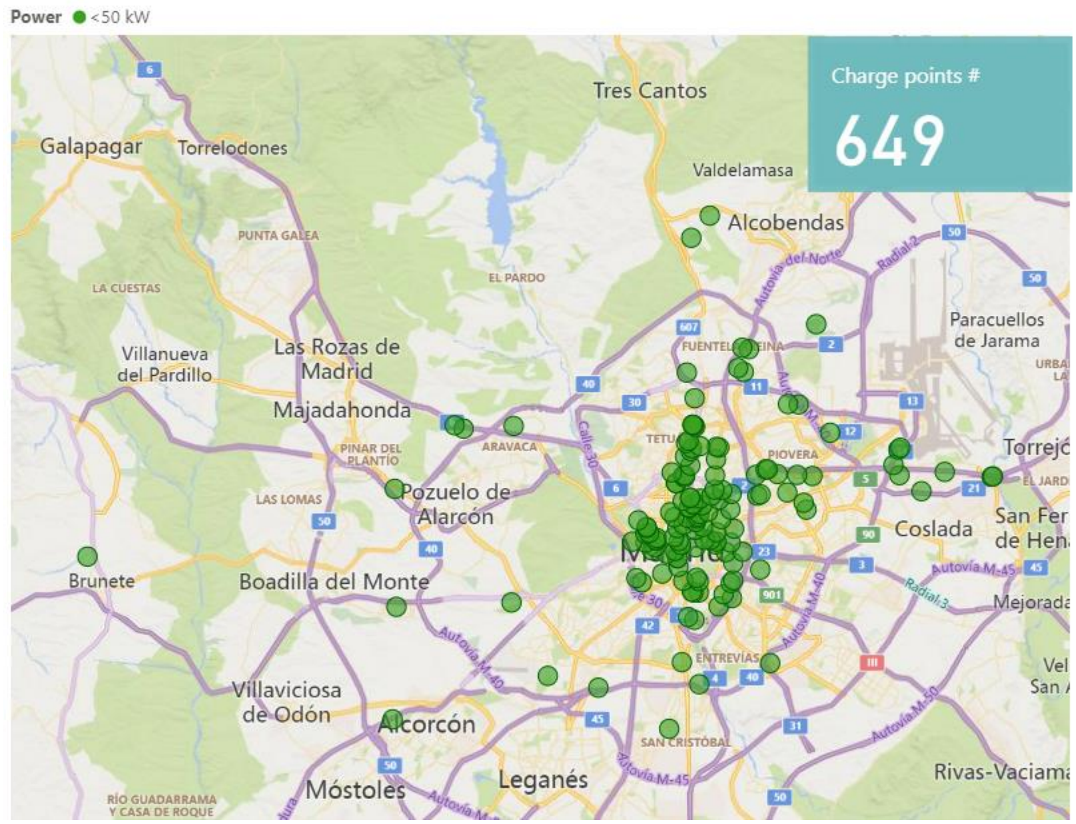

Figure 7. Charging station located in Madrid under 50 kW.

The database for the mapping of the available stations was collected from Google Maps, Electro Maps, MITECO Geoportal and Madrid City Council's Open Data Portal.

Furthermore, the price of the installation of these devices is much lower than the fast-charging ones, which makes the technology more accessible to users and more attractive to the owners of establishments.

Fast charging >50 kW. These are the ideal chargers for public charging, as they offer a fast-charging speed, and the installation costs of the equipment are not as high as those of the super chargers.

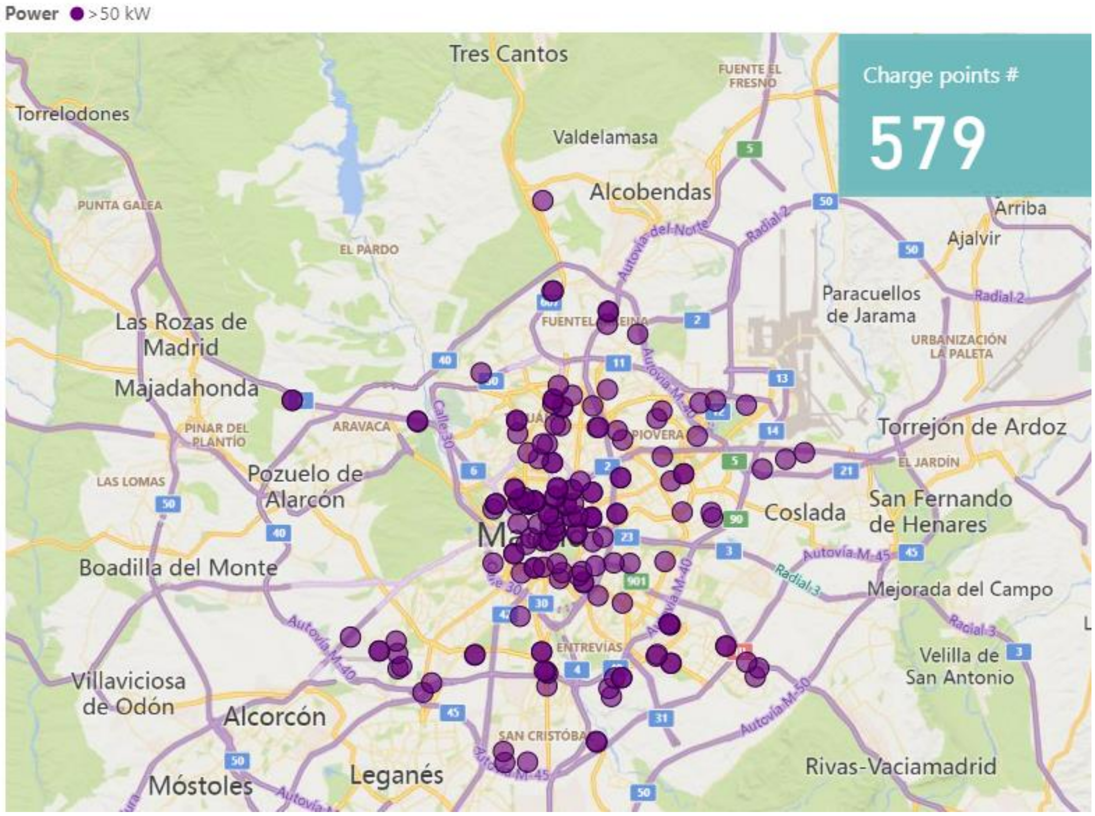

Figure 8. Charging stations more than 50kW but less than 150kW available in Madrid.

As we can see, the major concentration of station is in the downtown, close to the commercial areas. The number in the corner refers to the charging stations.

Ultra-fast charging >150 kW. They are ideal to be located on roads or in places far away from stores and businesses because requires specialized high-voltage DC power sources, so needs some additional works to prepare the installation. The charging speed is up to 3,6 times faster than fast-charging ones, it means that around 30 minutes for an 80% charge but depends on the battery technology.

The Figure 9 shows the actual infrastructure installed in Madrid, as we can see is expanding but not as widespread as AC charging.

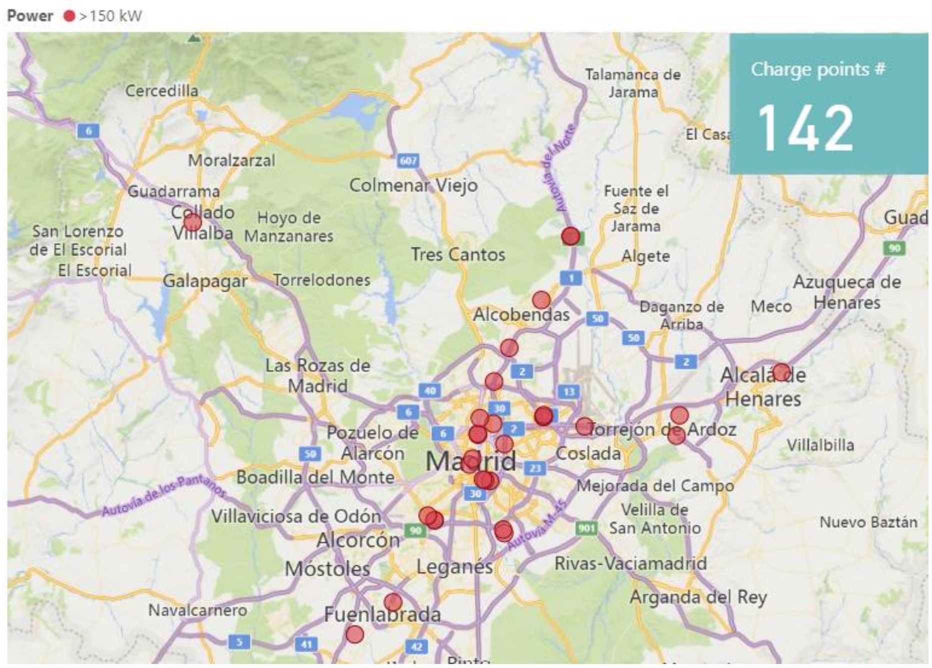

Figure 9. Charging stations more than 150kW.

When analyzing the location of the stations, it can be observed that although the locations are less than the previous ones, the strategy for the establishment of the stations is different than with the previous powers, because for these it is chosen to install more logical connections, which makes sense when taking in consideration the preparation that must be done and the requirements that the distribution network to which the station will be connected must have.

It is important that this type of stations is located on highways, because in this way the barrier that EVs have for long trips would be demolished, opening the possibility of making fewer stops and increasing the reliability of the technology, since betting on better batteries is a viable option, although it represents more time and higher costs.

The previous figures show how the charging stations and the EMPs that have access to them are spread out, so it should be remembered that the fact that an EMP has a charging point within its network does not exclude the rest from not having one, since there is an interoperability agreement, and the charging service can be offered by different EMPs at different prices and offering different services.

The results are shown in Figure 10, where the percentage of locations for each CPO can be better perceived. This is important and makes sense when combined with the data presented above on charging stations as the market is, so far, highly diversified in the services offered, ensuring greater competition compared to other markets.

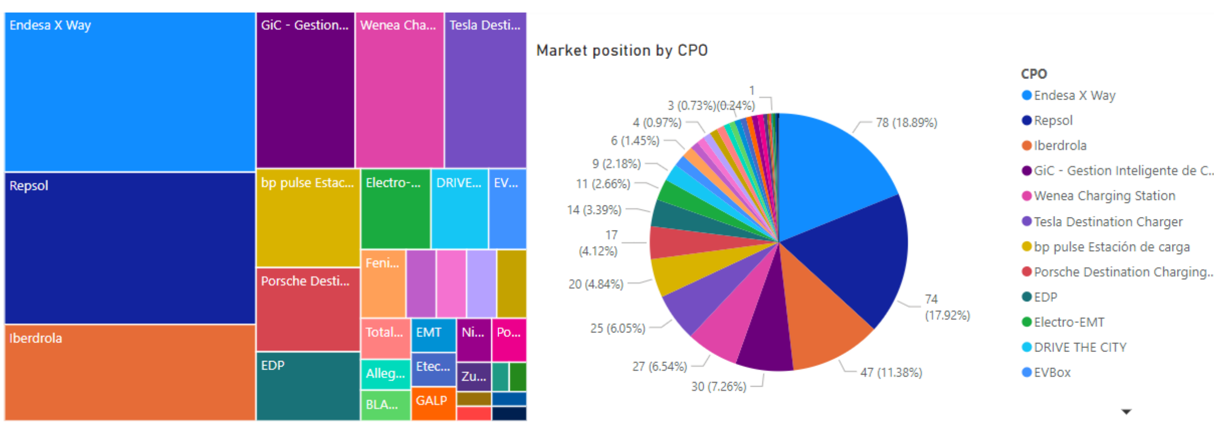

Figure 10. Market position by CPO.

The big square presented in Figure 10 gives us a better understanding of the main CPO in the market, using this information we can compare with the type of technology they installed and give us an idea about the strategy of each one.

While some CPOs are inclined to expand their charging network with fast chargers, others have focused on developing and improving super-fast technology, and another sector is inclined only to offer home charging.

With such diversified competition, there must be well-defined regulations that take into consideration standardization and interoperability between charging stations and the network. This challenge must be considered for the CPOs to ensure that EV users have access to their charging stations without having problems in the compatibility of the chargers (connectors, charging speed) with the vehicle batteries.

As mentioned in Chapter I, there are established goals for the number of charging points installed by 2030, so for Spain four different scenarios have been proposed to understand the number of chargers needed to be installed per year to meet the expected demand.

The greater the number of chargers, the greater the adoption of this technology and, in addition to the number of cars, more chargers will be needed over time, which is why a polynomial regression is the best fit, figure 12 shows the result obtained. However, as can be seen in the blue line, if the rate of growth of points continues at the current rate, by 2030 there will be less than half the number of points installed. This suggests that investment in the public charging sector is urgent, and support mechanisms for CPOs are essential to grow the public infrastructure.

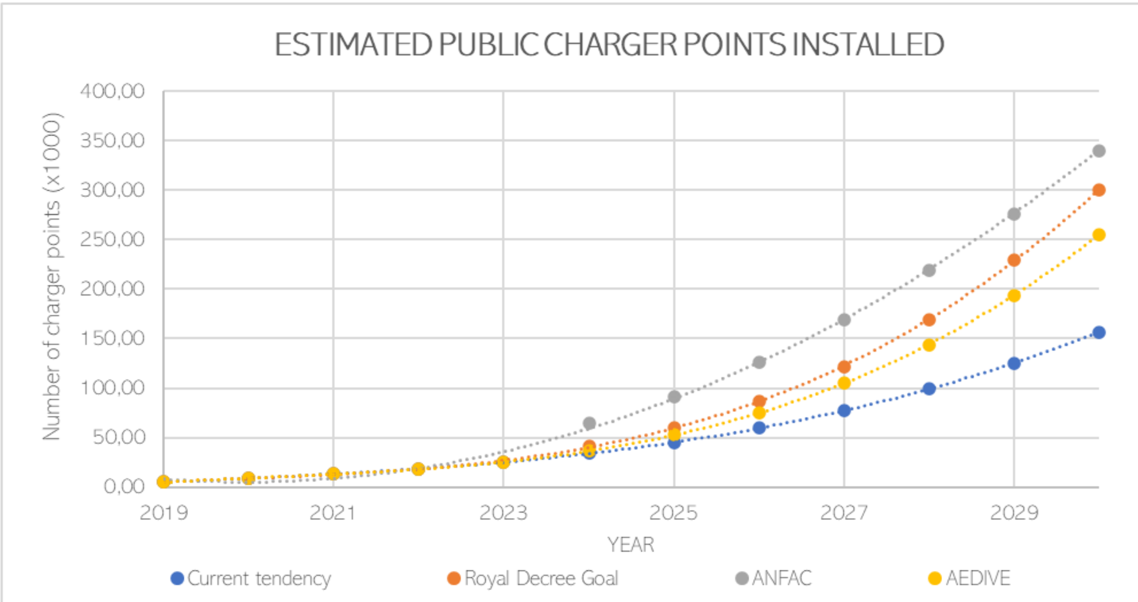

Figure 12. Estimate public chargers' points installed to achieve the goals established by Royal Decree, ANFAC and AEDIVE.

In this case, a third-degree model of the form as as it is explained in the methodology:

$$Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \varepsilon$$

Solving for each case and substituting the model of the resulting equations, it was obtained that the best projection to reach the goals set in each scenario is shown in the table 3, the closest to reality is the one proposed by AEDIVE.

Table 3. Total number of chargers installed at the end of each year to meet the demand proposed by the institutions, including the current growth scenario.

	Current tendency	Royal Decree	ANFAC	AEDIVE
2019	5.000	5.000	5.000	5.000
2020	8.545	8.545	8.545	8.545
2021	13.411	13.411	13.411	13.411
2022	18.128	18.128	18.128	18.128
2023	25.180	25.180	25.180	25.180
2024	33.888	41.789	64.000	36.340
2025	45.154	60.024	91.000	52.386
2026	59.429	86.172	125.984	74.803
2027	77.219	121.955	169.430	104.933
2028	99.033	169.093	219.605	144.116
2029	125.376	229.309	276.536	193.690
2030	156.755	300.000	340.000	255.000

4.2 Analysis of factors influencing public charge prices.

For this analysis it is important to mention the tolls applicable to electricity for a standard user. The tariff in Spain is composed of the power term and the energy term. The first is a fixed amount that depends on the power contracted by the subscriber and a fixed amount is paid each month for each kW contracted. The second term is the amount of electrical energy, which is measured in kWh, the price per kWh varies according to the electricity market which is governed by supply and demand. The market price or marginal price is set through an auction organized by the Iberian Energy Market Operator (OMIE).

Daily energy prices are divided into 6 periods, which depend on the hour, day, and month. These are published by REE at the end of the immediate previous year, for the 3.0 tariff the peninsular calendar is shown in Figure 13.

	0_1	1_2	2_3	3_4	4_5	5_6	6_7	7_8	8_9	9_10	10_11	11_12	12_13	13_14	14_15	15_16	16_17	17_18	18_19	19_20	20_21	21_22	22_23	23_24
Enero	P6	P6	P6	P6	P6	P6	P6	P6	P2	P1	P1	P1	P1	P1	P2	P2	P2	P2	P1	P1	P1	P1	P2	P2
Febrero	P6	P6	P6	P6	P6	P6	P6	P6	P2	P1	P1	P1	P1	P1	P2	P2	P2	P2	P1	P1	P1	P1	P2	P2
Marzo	P6	P6	P6	P6	P6	P6	P6	P6	P3	P2	P2	P2	P2	P2	P3	P3	P3	P3	P2	P2	P2	P2	P3	P3
Abril	P6	P6	P6	P6	P6	P6	P6	P6	P5	P4	P4	P4	P4	P4	P5	P5	P5	P5	P4	P4	P4	P4	P5	P5
Mayo	P6	P6	P6	P6	P6	P6	P6	P6	P5	P4	P4	P4	P4	P4	P5	P5	P5	P5	P4	P4	P4	P4	P5	P5
Junio	P6	P6	P6	P6	P6	P6	P6	P6	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P3	P3	P3	P3	P4	P4
Julio	P6	P6	P6	P6	P6	P6	P6	P6	P2	P1	P1	P1	P1	P1	P2	P2	P2	P2	P1	P1	P1	P1	P2	P2
Agosto	P6	P6	P6	P6	P6	P6	P6	P6	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P3	P3	P3	P3	P4	P4
Septiembre	P6	P6	P6	P6	P6	P6	P6	P6	P4	P3	P3	P3	P3	P3	P4	P4	P4	P4	P3	P3	P3	P3	P4	P4
Octubre	P6	P6	P6	P6	P6	P6	P6	P6	P5	P4	P4	P4	P4	P4	P5	P5	P5	P5	P4	P4	P4	P4	P5	P5
Noviembre	P6	P6	P6	P6	P6	P6	P6	P6	P3	P2	P2	P2	P2	P2	P3	P3	P3	P3	P2	P2	P2	P2	P3	P3
Diciembre	P6	P6	P6	P6	P6	P6	P6	P6	P2	P1	P1	P1	P1	P1	P2	P2	P2	P2	P1	P1	P1	P1	P2	P2
Sab, Dom y Festivos Nacionales + (6-ene)	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6

Figura 13. Energy peninsular calendar.

The heading of each column shows the hours of the day, while the first column shows the months of the year. Source: Atlas Energía.

The network tolls (peajes) are regulated by the Resolution of CNMC 21/12/2023. BOE 25/12/2023 and the other tolls (cargos) by the Orden TED/1312/2022. The table 3 below shows the tolls and other tolls for energy and power established by 2024.

Table 3. Network tolls and other tolls by 2024 for power and energy term for electricity.

	NETWORK TOLLS AND OTHER TOLLS €/kW year (POWER)					
€/kW año	P1	P2	P3	P4	P5	P6
2.0TD	25,39	0,97				
3.0TD	15,71	9,55	4,66	4,14	2,29	1,55
6.1TD	24,41	14,69	11,33	9,25	1,73	0,97
6.2TD	15,40	9,88	6,44	5,49	1,06	0,62
6.3TD	12,29	7,42	5,90	4,80	1,00	0,64
6.4TD	8,20	4,56	3,48	3,20	0,52	0,34

	NETWORK TOLLS AND OTHER TOLLS €/kW year (ENERGY)					
€/MWh cc	P1	P2	P3	P4	P5	P6
2.0TD	76,97	27,96	2,75			
3.0TD	48,44	30,94	17,36	10,39	3,56	2,19
6.1TD	35,19	21,53	12,72	8,04	2,11	1,28
6.2TD	18,12	11,15	6,18	4,02	1,05	0,59
6.3TD	15,52	9,44	5,65	3,68	0,89	0,55
6.4TD	10,70	6,25	3,85	2,60	0,39	0,25

There is a regulated market, called PVPC (Precio Voluntario al Pequeño Consumidor) where contracts reflect hourly variations in the price of electricity. The hourly rates are grouped to give three periods: peak, flat and off-peak.

The CNMC Resolution of December 21, 2023 of the CNMC specifically mentions the transmission and distribution fees applicable to public access electric vehicle charging points and also to domestic charging points, that is shown in the table 4. The Circular unifies all fees into one for contracted power of less than 15 kW (domestic and SMEs).

Table 4. Network tolls by 2024 for power and energy term for electric vehicles chargers vs. regular consumers.

	TRANSPORT AND DISTRIBUTION TOLLS €/kW year (POWER)					
Tariff	P1	P2	P3	P4	P5	P6
3.0 TD	11,99783	7,68781	3,30744	2,79179	0,93444	0,93444
3.0 TDVE	3,04255	1,95053	0,83950	0,70788	0,23271	0,23271
6.1 TD	20,55785	12,76288	9,92625	7,84838	0,32514	0,32514
6.1 TDVE	4,65631	2,89079	2,24832	1,77767	0,07365	0,07365

	TRANSPORT AND DISTRIBUTION TOLLS €/kW year (ENERGY)					
Tariff	P1	P2	P3	P4	P5	P6
3.0 TD	0,02397	0,01282	0,00757	0,00550	0,00042	0,00023
3.0 TDVE	0,09097	0,04880	0,02878	0,02087	0,00164	0,00089
6.1 TD	0,02190	0,01168	0,00739	0,00538	0,00041	0,00021
6.1 TDVE	0,14975	0,07982	0,05056	0,03676	0,00277	0,00145

The tables above show that in the case of distribution and transport tolls for the power term, there is a variation of 25% less in terms of the tolls applied for electric chargers. The opposite is the case for the energy term, which is 26% higher for EV chargers with tariff 3.0 and 14% higher for tariff 6.1. In general terms, the regulated tariffs for the charging point are lower.

Regarding the transmission and distribution tolls applicable to public access electric vehicle charging points, the owner of a charging point for public access electric vehicle charging may request the application of the fee regulated in this provision from the distributor, directly or through its distributor, as an alternative to the general fees. To this end, it must prove that the supply point will be used exclusively for electric vehicle charging and that it will be public accessible. These tolls may be applied to those supply points with contracted power exceeding 15 kWh.

Fees must be applicable to electric vehicle charging: amortization, initial equipment investment (known as CAPEX), power cost, operating cost, maintenance cost, average supply cost (known as OPEX).

In the actual charging price is no clear procedure for the determination of prices by CPO or EMP for public charge, which implies a problem for the end user to understand the prices he/she is paying, as well as complicating competition among market participants. In order to determine the prices for each group of chargers, it is proposed that the following parameters be used to standardize the prices.

- Initial investment (I_0): the initial investment for each type of charger must be estimated, as it depends on the power it can deliver. For fast and ultra-fast charging points, the supply point must be registered, which implies an extra cost.
- Power cost (Cp): this is a regulated cost, the one published by the CNMC.
- Energy cost (Ce): regulated tariff by CNMC
- Annual amortization (A): The amortization should be estimated for 10 years, which is an estimate of the duration of the infrastructure.
- Operation cost (Co): This must be estimated by charging point, because depends on the location and the conditions of the infrastructure.
- Maintenance cost (Cm): This must be estimated by charging point, depends on the location and the additional cost to arrive at the point.

- Energy supply (ES): the approximate kWh consumption per year per charge point should be known.

Once we have all those components and factors, the estimated tariff calculation propose for each charger station group is:

$$\frac{C_O + C_m + I_O + A}{ES} + C_p + C_e = media\ tariff$$

The highest costs in this proposed formula are the initial investment costs for the installation of the equipment and the cost of the regulated tariffs, however, as the number of electric vehicles increases in registration, the energy supply by the charging points will increase, which implies that the prices will reduce (both OPEX and CAPEX), in addition to mitigating the consumer barrier for the acquisition of the EV.

By having the complete database, relating each charging point with the prices that the user must pay, a correlation matrix can be calculated with the prices of each service available per EMP, as this is the price that the user must pay for each charge. In order to analyze this, it was necessary to add the following variables to the location database:

- Base price
- Subscription price
- Monthly plan price (if applicable)
- Price for inactivity after recharge.
- Interoperability price (an average of the price of third-party applications)
- Company price

The result is the matrix shown in figure 14, where we can see that the highest correlation is found between price and capacity (power, in kW), followed by quantity (-0.51), and power (0.35). We can see that the distance to the downtown does not significantly influence the price, but it has some importance on the power (0.25), because as observed in Figures 7, 8 and 9, the further away the load point is from the downtown, the higher the power will be, so the higher the price will be. This is how we can conclude that the biggest price barrier to entry is in power, so home charging is needed at the same time as public charging.

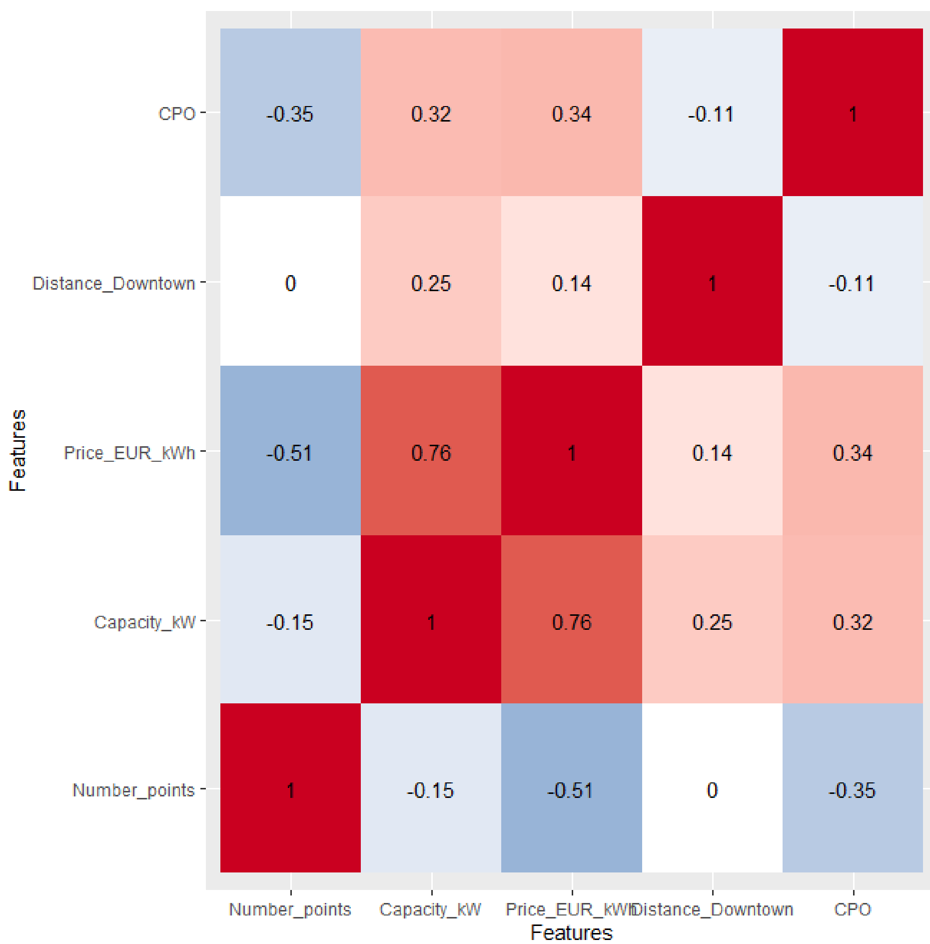

Figure 14. Correlation matrix of factors influencing the final price of the public charge to the end user.

Indeed, the linear regression between the price of charging points and their power (capacity, in kW) is not negligeable and prices can vary from 0.3 €/kWh to 0.7 €/kWh for charging capacities between 20 and 150 kW, as we can see in figure 15. With further development of more fast charging points and even faster equipment, prices of public charging could rise. The increase in prices could lead to higher average price of energy for EVs, deincentivizing the purchase of zero-emission vehicles.

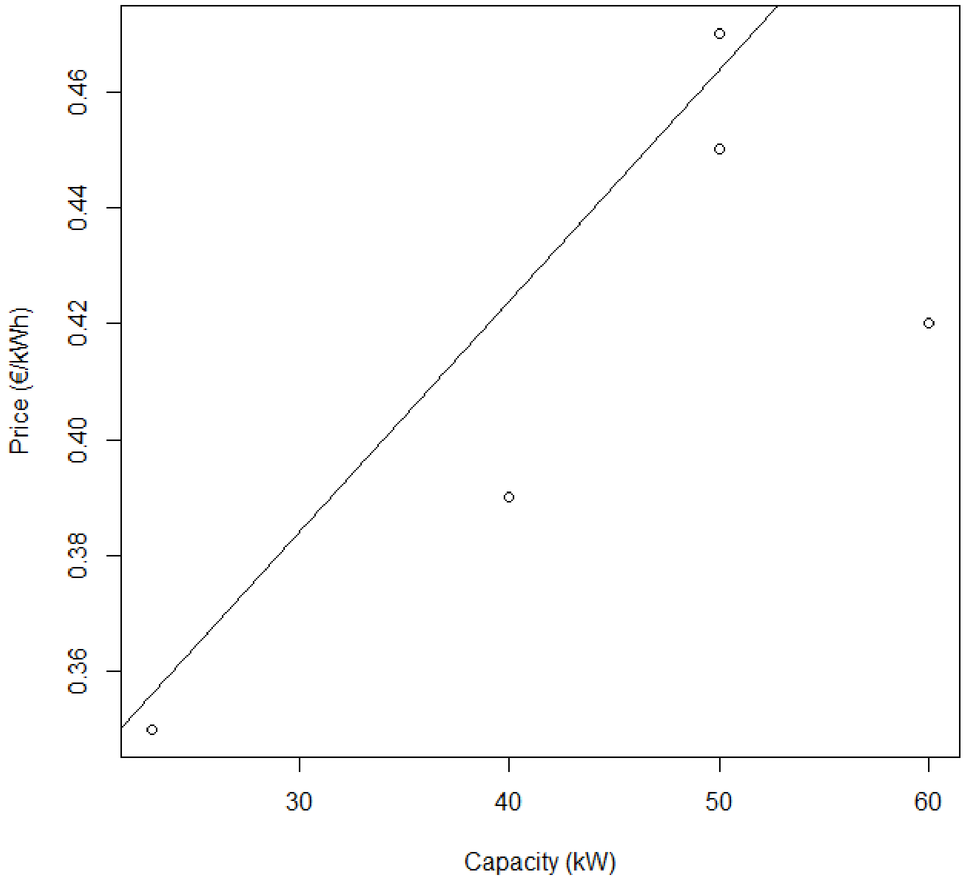

Figure 15. linear regression between the price of charging points and their power (capacity, in kW)

In this decade, the charging habits of EV users are expected to change: a higher portion of the total amount of energy used in their vehicles in public charging points. If technology costs of fast chargers remain intact (therefore, their price per kWh sold), the average price of public charging could indeed go up, even over the diesel benchmark.

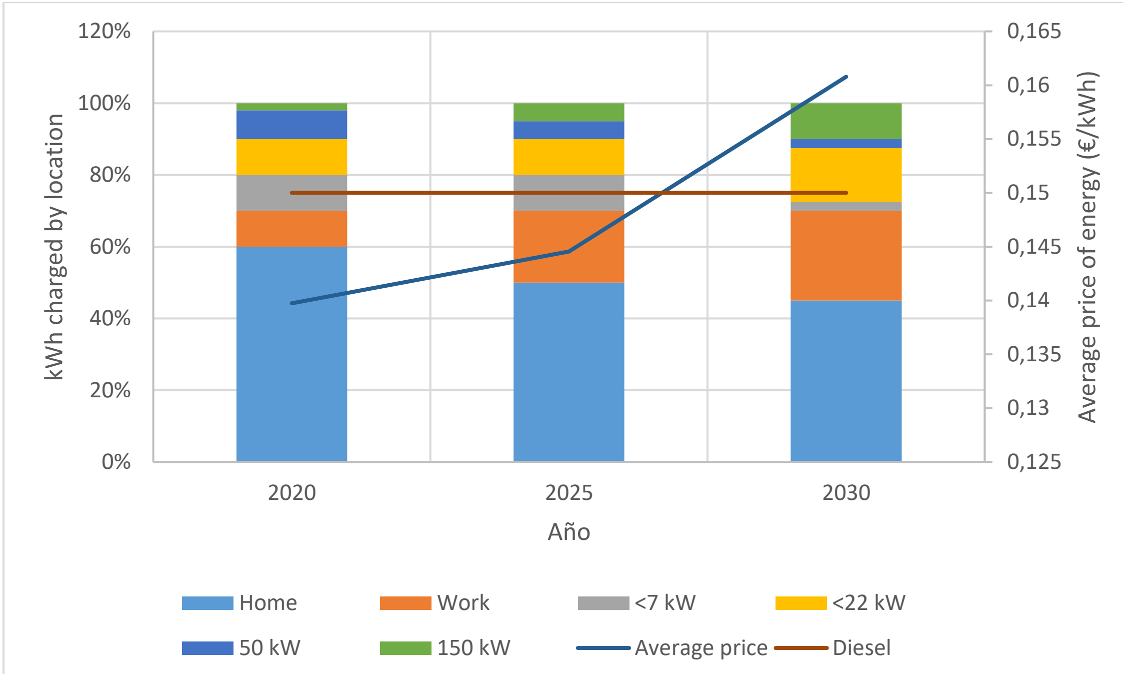

Figure 16. Relation between the location of the charging point with the average price of energy.

For that reason, it is crucial to promote both home charging (which provides the cheapest charging energy) as well as cheaper but also faster public charging facilities. In the following years, charging points will have to become faster to attract drivers towards EVs, while demand will still be very low. During this time, an increasing charging capacity can lead to an increasing average price of energy for EV users (as we can see in the Figure 16), which can jeopardize their adoption. Hence, the importance of regulatory measures to boost the adoption of zero-emissions vehicles helping overcome price barriers.

CHAPTER V.

CONCLUSIONS

As mentioned throughout this paper, the increasing need to establish the rules of the electromobility market is clear. However, the key points to drive the development of this market must be carefully identified, as this will drive the use of electric cars along with it.

In the research, two of the key issues were found to represent a major barrier to the deployment of the electric vehicle fleet. While the government has an important role to play in this, implementing incentives for EV acquisition, as well as for the installation of home electric chargers, public charging needs to be regularized. This is where one of the barriers lies: in the deployment of public chargers.

The difference in costs between competitors, the high tariffs on super-fast chargers and the complexity of how each market player sets the prices is a combination to keep users from taking the decisive step to the transition.

With the data obtained and the analysis carried out, it can be concluded that the best strategy for the installation of charging points in the short term should be to promote chargers with power less than or equal to 50kW within the city and near residential units, as this guarantees the peace of mind of users who cannot install a charger at home to have accessibility to public chargers at a reasonable price.

However, in commercial establishments or restaurants, the installation of more powerful chargers is more attractive because users do not have so much waiting time, while on roads and places far from stores or residential units, the installation of ultra-fast chargers is the best alternative to boost EV use outside cities without sacrificing travel time from one point to another.

At the same time, regulations for the installation of points must be established, as the current procedure involves many months of waiting for the approval of the necessary permits for the construction of charging stations. This is a major barrier to infrastructure growth; therefore, in order to meet the objectives, it is necessary to establish mechanisms to accelerate the procedures and improve the structure of the public charging market.

Regarding charging prices, it is concluded that the highest correlation between the factors is found between price and power, followed by the number of points installed and the CPO to which they belong. As can be seen in table 1 the location of the charging point does not influence the price directly, but it does influence the power of the charger. However, as the market is constantly expanding and, at the same time, demand is growing, both home charging and public charging will be needed to satisfy it.

If the technology costs of fast chargers remain unchanged (thus maintaining their price per kWh sold), there is a possibility that the average price of public charging could surpass that of diesel. Therefore, it is imperative to encourage both home charging, which offers the most cost-effective energy, and the development of cheaper yet faster public charging facilities. In the coming years, charging infrastructure must evolve to become faster in order to attract more drivers to electric vehicles (EVs), especially while demand remains relatively low. However, during this transitional period, an increase in charging capacity may lead to a rise in the average energy price for EV users, potentially hindering their adoption. This underscores the importance of regulatory measures aimed at incentivizing the uptake of zero-emissions vehicles to overcome cost barriers.

Still there is a lot of work to be done, but with the cooperation of government and companies the goals are still achievable, especially with the development of the right policies, the electrification of fleets and the installation of public charging points can be achieved.

FUTURE WORKS

- Develop a programme to monitor the development of charging stations, with real commitments to achieve the targets set for 2023.
- Analyse the impact of charging points on the grid, in particular superfast and ultrafast charging points, in order to be sure of the need for investment in the electricity grid and to avoid congestion in the future.
- Identifying the barriers to speeding up approvals for the installation of charging points in order to create specific approvals and policies for this technology and reduce waiting times.
- Create a national map of public charging points to identify the specific areas where it is appropriate to install new points, compare this with the electricity

demand of that area and carry out the technical and economic evaluation of the installation of battery banks.

Bibliography

Abel Rosales-Tristamcho, Raúl Brey, Ana F. Carazo, & J. Javier Brey. (2022). Analysis of the barriers to the adoption of zero-emission vehicles in Spain. *Transportation Research Part A: Policy and Prractice*, 19-43.

ANFAC. (2022). *Informe Anual.* Madrid, España: ANFAC.

ANFAC. (2023). *Barómetro de la electromovilidad, segundo trimestre 2023.* Madrid, españa: ANFAC. Obtenido de https://anfac.com/wp-content/uploads/2023/05/Barometro-Electromovilidad-2023-T1.pdf

IEA. (2023). *Global EV Outlook 2023.* Paris: IEA. Recuperado el 2023, de https://www.iea.org/reports/global-ev-outlook-2023, License: CC BY 4.0

Ministerio para la Transición Ecológica y el Reto Demográfico. (2020). *Plan Nacional Integrado de Energía y Clima (PNIEC) 2021-2030.* España: MITECO. Recuperado el 2023, de https://www.miteco.gob.es/content/dam/miteco/es/ministerio/planes-estrategias/plan-nacional-integrado-energia-clima/plannacionalintegradodeenergiayclima2021-2030_tcm30-546623.pdf

Ministerio para la transición ecológica y el reto demográfico. (2021). *Proyecto de Real Decreto por el que se regula la actividad de prestación de servicios de recarga energética de vehículos eléctricos.* Madrid. Obtenido de https://energia.gob.es/es-es/participacion/paginas/detalleparticipacionpublica.aspx?k=408

Ministerio para la transición ecológica y reto demográfico. (2023). Disposiciones generales. Real Decreto 184/2022, de 8 de marzo. *Boletín Oficial del Estado*(67). Obtenido de https://www.boe.es/boe/dias/2022/03/19/pdfs/BOE-A-2022-4361.pdf

MITECO. (2020). *Estrategia de descarbonización a largo plazo 2050.* MITECO. Madrid: Ministerio para la transición ecológica y el reto demográfico.

Rode, J., & Schulz, F. (2022). Public charging infrastructure and electric vehicles in Norway . *Energy Policy*, 1-12.

Ruiz Barrientos, F. M., Gámiz Martínez, E., Román Calvo, C., & Sallent Bayo, H. (2021). *Estudio sobre el despliegue de la infraestructura de carga del vehículo eléctrico en España.* Bruselas: Transport & Environment.