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MASTER OF SCIENCE IN ENGINEERING AND MANAGEMENT

STUDY OF THE IMPLEMENTATION OF THE RECHARGING INFRASTRUCTURE FOR ELECTRIC VEHICLES - THE BIELLA PROJECT

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To my parents and brothers, my safe haven.

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“Go, confront the problem. Fight! Win!”

- Edna Mode

ABSTRACT

The electromobility industry has been exponentially growing and is expected to become every year larger in the future. The environmental aspects related to this issue are unquestionable but, in order to be fully spread, this industry needs the cities to be prepared. The presence (or absence) of charging points is still one of the greatest bottle necks found by that segment, specially outside of big urban centers. The objective of this thesis is to evaluate the feasibility and the economical aspects related to the implementation of a complete infrastructure in the province of Biella, Italy, until 2030.

That assessment was achieved first by a broad literature review on the market, that concerned different subjects such as types and modes of electric vehicles charging and governance structures for charging stations. After that, a collection of important data was made, using both the information present in the literature and a benchmarking made with existing companies acting in the sector.

The third part consisted in the Biella province case study. A business model was developed for the region, detailing the possible governance structures expected. The two main governance model options were separated evaluated and compared. A complete costs structure was assessed, detailing the capital expenditure and the operational costs. Then, the estimated revenues for each of the scenarios studied were obtained.

With capital expenditure, operational costs and revenues, the net present values were analyzed for all the different possible models and scenarios. The breakeven years and payback times were also calculated. The next step was to develop an analysis on the possibility of co-financing of the project with public funds.

All the calculations obtained were compared for each scenario in each model studied. The governance model in which the responsible company acts only as infrastructure provider showed to be less risky and more profitable.

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1. INTRODUCTION

1.1. CONTEXT

In the past years the concern about global warming and pollution by greenhouse gas emissions has been growing. Being almost twenty five percent of Europe's greenhouse gas emissions from transport, and 70% of that from road transport (EUROPEAN COMMISSION, 2016) this theme must be considered a priority. However, approximately 95% of vehicles driven in Europe still have an internal combustion engine (EUROPEAN COMMISSION, 2017). That is why the study of implementation of new technologies is necessary nowadays.

The development of technologies related to electromobility comes from a long time ago but is increasing drastically in the last years. Back in 1997, the Toyota Prius was released in the Japanese market as one of the first hybrid cars developed. Today, there are already nearly fifty different hybrid models in the US market and by 2015, hybrid electric vehicles were 30% of the cars bought in Japan and were already above 6% of the market share of road cars in California, making Japan and California two of the biggest markets for electric vehicles in the world (PALMER, TATE, *et al.*, 2017). Besides the Hybrid Electric Vehicles (HEVs), the number and development of models have grown mostly in other two main approaches of electric driving: the Plug-in Hybrid Vehicles (PHEVs) and the Battery Electric Vehicle (BEVs) (VLIET, BROUWER, *et al.*, 2010). It is expected that, in 2018, global sales for electric vehicles achieve the mark of 1.6 million and, in 2019, 2 million (GLOBAL AUTOMOTIVE & TRANSPORTATION TEAM AT FROST & SULLIVAN, 2018). That shows the growing importance and participation of electric mobility not only in environmental issues, but also in economy and society.

However, this industry is still finding some obstacles for growing, showing results in market share below expectations. That is due to some issues like the electric vehicles cost. Even though the running costs are often lower for this type of cars, the buying cost is still very high because the technologies are still very recent, and the market is still small, prejudicing economies of scale (PALMER, TATE, *et al.*, 2017). The growth in the energy consumption is also a worry when dealing with electric mobility, it is known that it may increase the consumption of a household by 50% (VLIET, BROUWER, *et al.*, 2010). Besides those, the dissemination of electric cars finds obstacles like the early technology's limitations (low driving range) and a lack of an infrastructure for charging (with specific plugs and adequate electrical wiring) (ANDRENACCI, RAGONA e VALENTI, 2016). Projections and planning for infrastructure installation in large population centers are multiple and constantly updated, but in small volume of consumers regions there is a lack of interest from the industry and a consequent research gap.

With all these barriers to grow, governments all over the world have been developing policies as incentives, like purchase subsidies and exemptions (MIRHEDAYATIAN e YAN, 2017). In December 2015, in the Paris Agreement, it was made clear that this is a subject of interest for politicians in the entire world. In order to achieve the commitments made by the European Union's countries on that date and knowing that the main cause of air pollution in cities is transport, it was organized the European Commission. In 2016, and again in 2017, this commission met to asses a strategy for low emission mobility and define goals, helping to modernize the EU's economy and reduce emissions from the transport sector (EUROPEAN COMMISSION, 2016).

Electromobility is a trending topic and a very important subject all over the world nowadays. It is a theme of interest for environment, societies, economies and politics, and represents a growing market that will definitely have an always higher importance and presence in everyone's lives. Public electric vehicles charging stations are a key factor for this market growth, but the information on this sector are still scarce and its attractiveness for investor is questioned, and these characteristics are potentialized in regions with small volume of consumers.

1.2. OBJECTIVE AND STRUCTURE

Having the broad importance of electric mobility in diverse sectors of society (economy, politics, environment), its constant growth and the research gap of infrastructure in regions with small volume of consumers, the main objective of this work is to develop a business model adequate to this industry and apply its structure on the specific case of the province of Biella, Italy. It will be assessed the viability and financial impacts and consequences of the implementation of the infrastructure for charging electric vehicles in the province. The study will be divided in three parts: literature review, data collection and case study.

In the first part (literature review) a complete framework of the industry will be developed. Starting from basic concepts and going through the existing and predicted technologies, the projects of charging infrastructure, the interested players and governance models and contractual relationships, this part's goal is to offer a broad view and understanding of how the social, economical and political issues relate and act on the industry.

The second part (data collection and assumptions) consists in assessing a general framework for the charging stations and infrastructure market, including quantitative information about costs, revenues and capital expenditure, as well as information on some qualitative important information like policies applied to the specific region and technology dominant design for charging infrastructure. This part will offer a complete business model based on literature review, the data from the province of Biella and some assumptions needed for the final part.

The third and final part (case study) will take in consideration the Biella specific case and its data will be applied in the business model assessed before. This part has a more quantitative approach and will result in financial reports and analysis of the economic issues concerning the implementation of charging infrastructure for electric vehicles in the Italian province.

This study shows much importance in future society once this theme has a big impact in environment, economies and politics and there is a research gap for small population and demand regions.

2. LITERATURE REVIEW

2.1. VEHICLE TECHNOLOGIES

Firstly, it is important to have a clear understanding of the main concepts related to the electric mobility industry. In this section the existing and predicted main technologies for electric vehicles will be exposed and explained.

As previously mentioned, there are three main technology approaches of electric vehicles. The first one will be called Battery Electric Vehicle (BEV), that is fully powered by a big electric battery, having the autonomy for long trips (VLIET, BROUWER, *et al.*, 2010). This model found more difficulty in meeting competitive prices due to the cost of a battery that guarantees a high drive range with a fast charging system. It now depends on a development on that technology and a consequent decrease in price to be widely bought (PALMER, TATE, *et al.*, 2017). As an example of BEV, it can be considered the New Nissan Leaf Electric, that has a battery capacity of 40.0 kWh and a driving range of approximately 270 km (NISSAN, 2018).

The second approach is the Plug-in Hybrid Electric Vehicle (PHEV), that includes an electric battery for low distance trips (approximately 50 km) and an internal combustion engine (ICE) for longer trips (VLIET, BROUWER, *et al.*, 2010). This technology is a great option for urban centers, once it has the same environmental impact of the battery electric vehicle in short distance journeys. It is known that 70% of the trips in USA are under 16.10 km (PALMER, TATE, *et al.*, 2017), but on average, only 26% of PHEV kilometers travelled are battery-driving only (TAL, NICHOLAS e DAVIES, 2014). This model requires a smaller and simpler battery when comparing to the first one due to the lower driving range required, what leads to more competitive prices. As an example of PHEV, it can be considered the Toyota Prius plug-in, that has a battery capacity of 6.4 kWh and an all-electric driving range of 19.80 km (PALMER, TATE, *et al.*, 2017).

The last one is the Hybrid Electric Vehicle (HEV), that has both an electric motor and an internal combustion engine connected to the wheels. They work supplementing each other when needed (VLIET, BROUWER, *et al.*, 2010). This model has a bigger environmental impact due to the use of the fossil fuel powered engine but represents still a great advance when compared to traditional cars. This technology has achieved a considerable market share once it has already reached competitive prices because of the smaller and simpler battery needed. As an example of HEV, it can be considered the Toyota Prius, with a battery capacity of 1.3 kWh (PALMER, TATE, *et al.*, 2017).

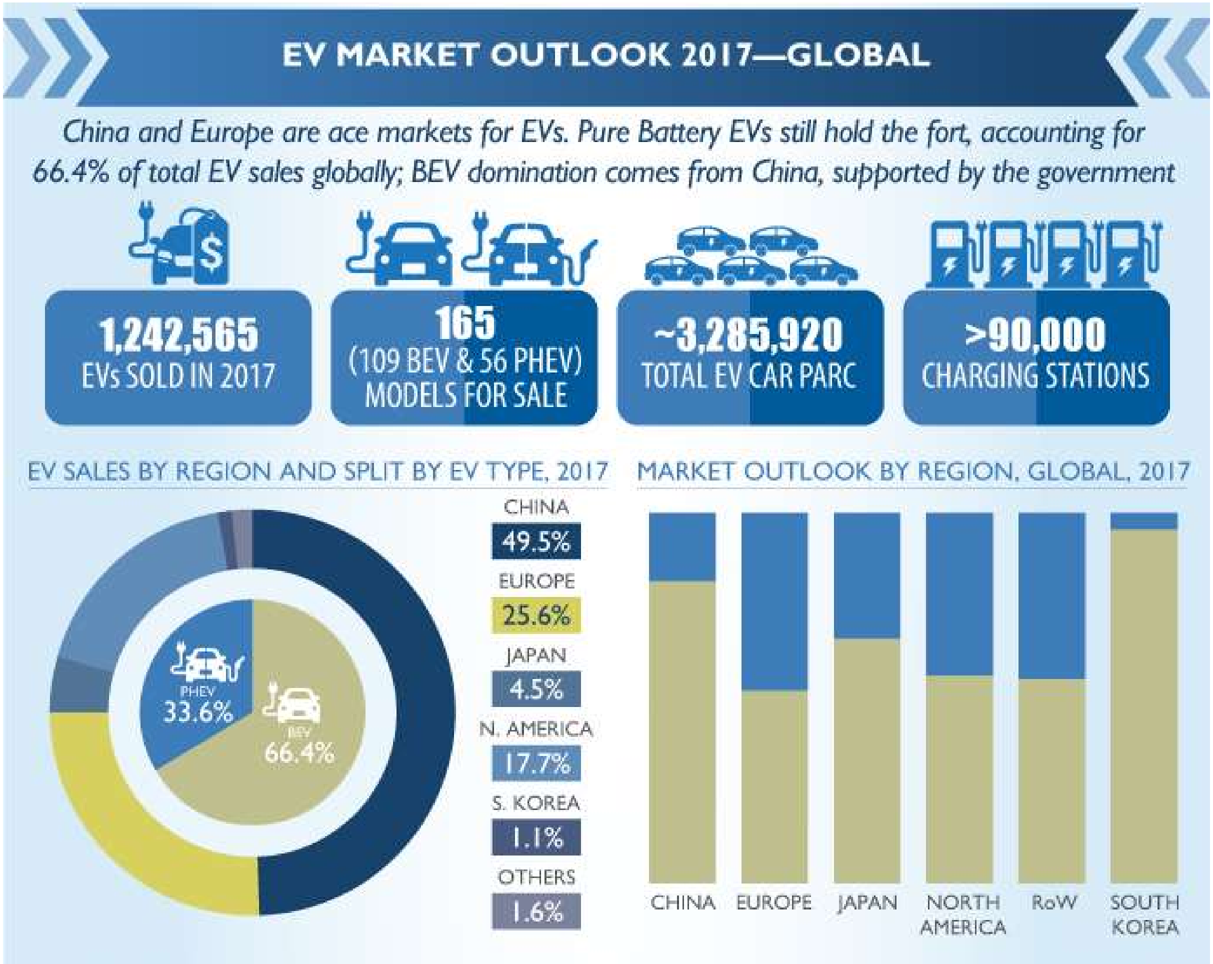

Figure 1 - EV Market Outlook 2017 - Global (Global Automotive & Transportation Team at Frost & Sullivan, 2018)

It is known that in 2017 more than 1.2 million electric vehicles were sold and that Europe is the second biggest market for them in the world, representing a market share of 25.6%. Staying only behind China, that had a 49.5% market share in 2017 (Figure 1 - EV Market Outlook 2017 - Global (Global Automotive & Transportation Team at Frost & Sullivan, 2018) (GLOBAL AUTOMOTIVE & TRANSPORTATION TEAM AT FROST & SULLIVAN, 2018).

As for predictions, it is expected that, by 2015, the global market for electric mobility until meets some heterogeneity. While China's main technology adopted will probably be the battery electric vehicle, in Europe, it is expected that the hybrid electric vehicle be the dominant model (Figure 2) (GLOBAL AUTOMOTIVE & TRANSPORTATION TEAM AT FROST & SULLIVAN, 2018).

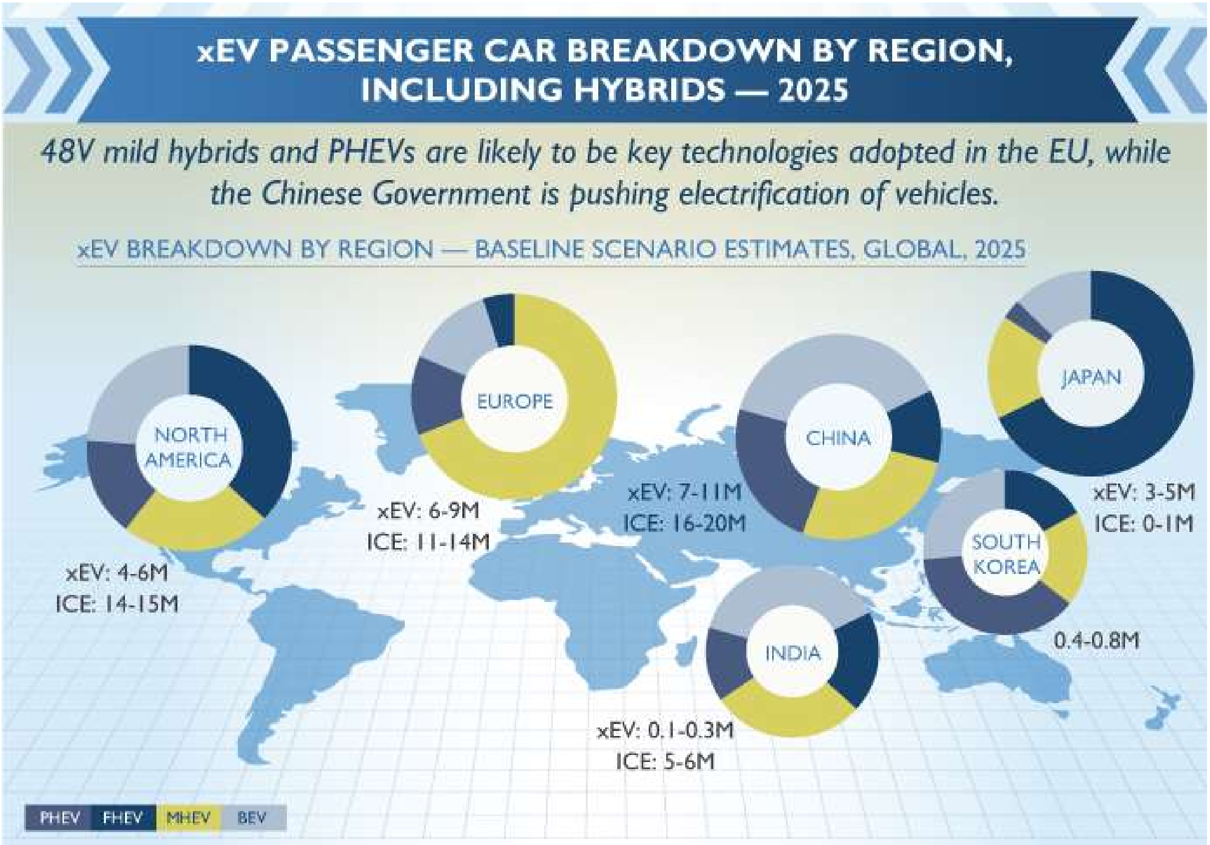

Figure 2 - xEV Passenger Car Breakdown by Region, including Hybrids - 2025 (Global Automotive & Transportation Team at Frost & Sullivan, 2018)

2.2. BATTERY TECHNOLOGIES

It is known that one of the biggest challenges for the electric mobility industry are the batteries. There is a need of a technology that achieve a necessary driving range, with a significantly fast charging and a small cost to the electric vehicles to become competitive (PALMER, TATE, *et al.*, 2017). The cost of electric vehicles in general are predicted to become competitive by 2026, when the cost of lithium-ion batteries is expected to fall to $100 per kilowatt hour (Figure 3). While today the battery cost represents circa 50% of the electric cars total cost, it is expected that by 2030 that amount decreases to only 18% (Figure 4) (WATANABE, 2017).

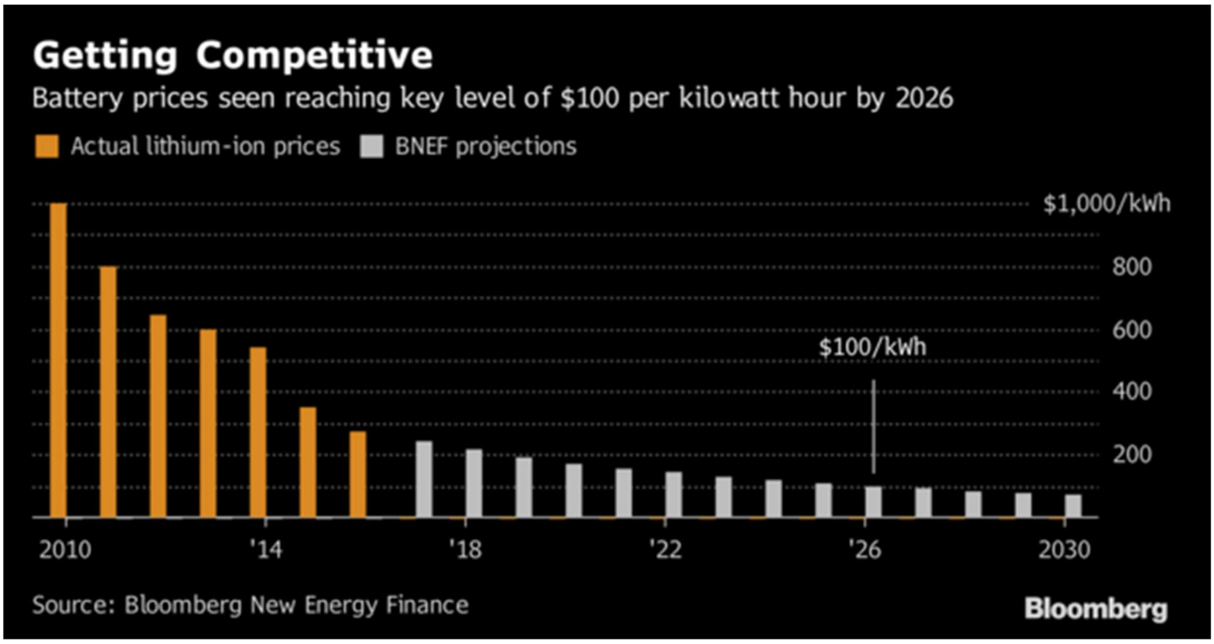

Figure 3 - Battery prices prediction in time (WATANABE, 2017)

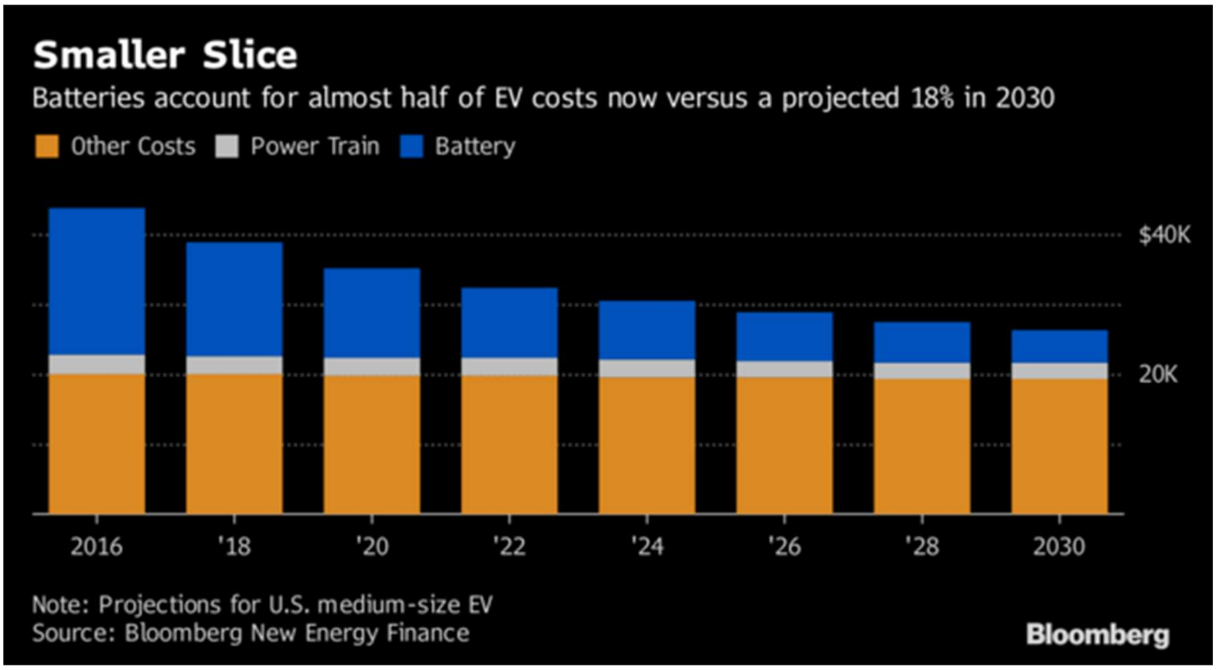

Figure 4 - Battery price proportion in electric vehicle prices in time (WATANABE, 2017)

The focus of the industry was on lithium-ion batteries using liquid electrolytes but, due to recent discoveries, the investments are shifting to the lithium-ion solid-state ones. Toyota Motor Corp. intends to start commercializing this technology in the early

2020s and The British company plans to invest $1.3 billion to create solid-state batteries for its car (WATANABE, 2017). This technology is expected to be the game changer in the batteries chemistry industry, once it has 2.5 times higher density when compared to the older one (GLOBAL AUTOMOTIVE & TRANSPORTATION TEAM AT FROST & SULLIVAN, 2018) and is claimed to be safer (SINGH, 2018).

Besides that, batteries in general are a very important piece in today's world, so the research on that field comes from a big number of diverse industries. As an example, in 2017, the Samsung Advanced Institute of Technology developed a graphene ball battery that could increase by 45% the power density and make the charging speed five times faster when compared to lithium-ion ones. With that, a Tesla Model S 90 kWh version could fully charge in 15 minutes, opposed to the 75 minutes it actually takes (LEATHER, 2017).

The electric vehicles batteries industry is expected to become one of the biggest ones in the future world. Only in China, there are already more than 140 EV battery manufacturers and this industry is expected to reach a value of $240 billion worldwide in the next 20 years (PERKOWSKI, 2017).

2.3. CHARGING TECHNOLOGIES

In this section the important information about the charging system are going to be exposed and explained. It is very important to understand how the charging of electric vehicles happen to assess the infrastructure necessary for a city to embrace this technology.

The "point-of-fueling" infrastructure, used to deliver electrical energy to the electric vehicle charging is known as Electric Vehicle Supply Equipment (or EVSE). It is basically the name given to an electric vehicle recharging station (RAMER, 2013). The EVSE concept incorporates all the grounding and non-grounding equipment, the connectors, the attachment plugs and every accessory necessary for charging EVs (BANSAL, 2015).

2.3.1. Charging levels

EVSEs are categorized according to its power levels. Power configurations are diverse in each country, depending on frequency, voltage, electrical grid connections and transmission standards. The most common and used categorization of charging levels is the one proposed by the Electric Power Research Institute (EPRI) and utilized by the Society of Automotive Engineers (SAE). According to it, there are three charging levels for EVSE, that are: alternating current (AC) Level 1; alternating current (AC) Level 2; and direct current (DC) Level 3 (SHAREEF, MAINULISLAM e MOHAMED, 2015). These levels are going to be explained in more details below.

2.3.1.1. Charging level 1

The Level 1 represents a power level of 120V AC, that is equivalent to a basic household electrical outlet. Its current handling capacity is of 15 A (12 A usable) or 20 A (16 A usable) (SHAREEF, MAINULISLAM e MOHAMED, 2015). It provides a slow charging, taking 10 to 20 hours to achieve a full charging. It is ideal for smaller batteries, like the PHEV ones or when charging time available is longer (RAMER, 2013). This level is the cheapest because it can be home-based and need no additional infrastructure. However, it gives a very slow charging and, therefore, is the lowest common level found (SHAREEF, MAINULISLAM e MOHAMED, 2015).

2.3.1.2. Charging level 2

The Level 2 is equivalent of plugging to a household electric clothes dryer socket (RAMER, 2013). It has, for private installations, a single-phase 240V AC with current handling capacity of 40 A, and, for public installations, a three-phased 400V AC with a current handling capacity of 80 A (SHAREEF, MAINULISLAM e MOHAMED, 2015). This level presents a quick charging, being able to full charge a vehicle in 4 to 8 hours (RAMER, 2013). It has a standard connector and receptacle developed by SAE International and it demands a more expansive installation than Level 1 EVSEs, due to the necessity of safety procedures and equipment to avoid over-current and over-heating. This is the most common level of EVSE used because of its fast charging, giving the drivers the possibility to charge their vehicles overnight (SHAREEF, MAINULISLAM e MOHAMED, 2015).

There are two most popular options of Level 2 charging: Basic AC Charging and Destination SC Charging.

- Basic AC Charging

This charging option is destined to long-parking places, like homes and workplaces. Its equipment can be installed by a licensed electrician on a common dedicated circuit. It is usually placed close to the main switchboard, to reduce cable runs and consequently installation costs (STATE OF QUEENSLAND, 2018). Table 1 shows the main characteristics for this charging model.

Table 1 - Basic AC Charging characteristics

Power	2.4 - 7 kW
Electric potential	240 V
Electric current	10 - 32 A
Charging rates	10 - 45 km range per hour
Charging time	2h - overnight
Max. electricity consumption per charge	10 - 35 kWh

(STATE OF QUEENSLAND, 2018)

- Destination AC Charging

This option is ideal to places where the users can take part in an activity while their vehicles charge, like restaurants or tourist locations. It also can be installed by a licensed electrician and it is recommended a review of the property’s electrical infrastructure in advance. However, a network impact is unlikely for this type of charging (STATE OF QUEENSLAND, 2018). Table 2 shows the main characteristics for this charging model.

Table 2 - Destination AC Charging characteristics

Power	11 - 22 kW
Electric potential	415 V
Electric current	16 - 32 A

Charging rates	50 - 130 km range per hour
Charging time	30 minutes - 2h
Max. electricity consumption per charge	8 - 32 kWh

(STATE OF QUEENSLAND, 2018)

2.3.1.3. Charging level 3

The third and last level converts three-phased AC to DC, offering a very fast charging that can full charge a vehicle in 20 to 30 minutes (RAMER, 2013). It is suited for fast turnaround locations, proportioning to the client an experience similar to a commercial filling station with oil-based fuel. This EVSE level is still very rare because of its high installation prices and is suitable for commercial areas. The three-phased circuit has a power level of 600V DC that supports up to 200A. In this level, the conversion from AC to DC is performed in an off-board charger, providing the vehicle directly with DC power and reducing the overall weight of the electric vehicle (SHAREEF, MAINULISLAM e MOHAMED, 2015).

Figure 5 and Figure 6 represent, respectively, a schematic arrangement for on-board AC slow charging and off-board DC fast charging.

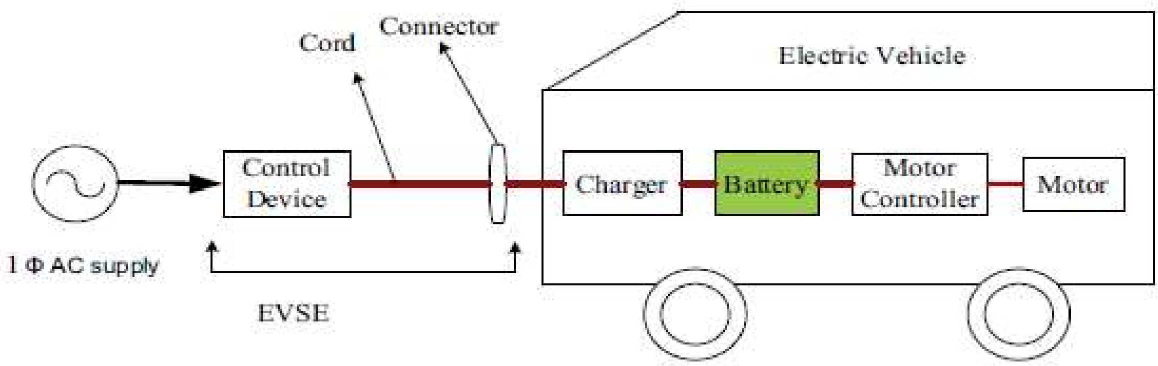

Figure 5 - EVSE arrangement for on-board AC slow charging (SHAREEF, MAINULISLAM e MOHAMED, 2015)

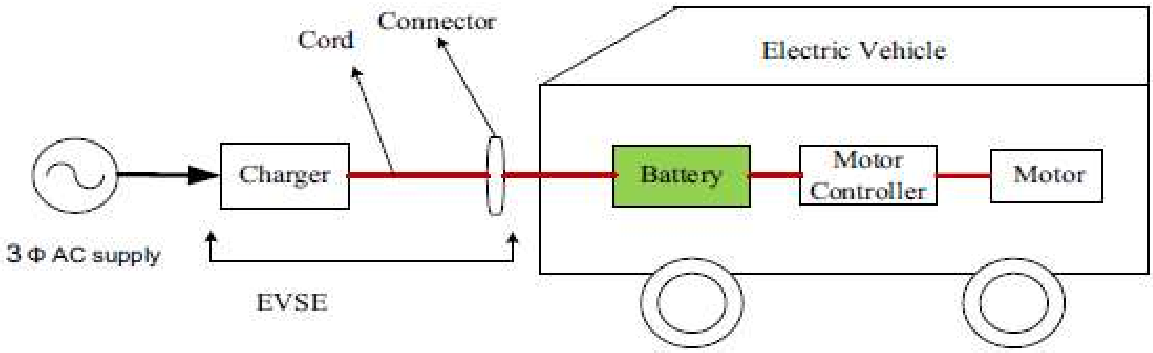

Figure 6 - EVSE arrangement for off-board DC fast charging (SHAREEF, MAINULISLAM e MOHAMED, 2015)

There are two most popular options of Level 3 charging: Fast DC Charging and Ultra-fast DC Charging.

- Fast DC Charging

The Fast DC Charging is suitable for strategic locations such as those along major routes or in areas of high demand. It is recommended its installment near places with basic amenities such as coffees and restrooms. It is critical to determine its location according to the surrounding electrical infrastructure, it is recommended near high power transformer, guaranteeing sufficient capacity. It requires a more complex installation that should be done by a specialized company (STATE OF QUEENSLAND, 2018). Table 3 shows the main characteristics for this charging model.

Table 3 - Fast DC Charging characteristics

Power	50 - 150 kW
Electric potential	415 V
Charging rates	100 - 300 km range per hour
Charging time	20 minutes - 1h
Max. electricity consumption per charge	15 - 90 kWh

(STATE OF QUEENSLAND, 2018)

- Ultra-fast DC Charging

This technology is still evolving, but it is expected that it makes it possible to add 300 km of range in 5 to 10 minutes. Its installation is recommended in highly strategically selected locations, like highly trafficked major highways. The site will need an extensive review of the serving electrical network, and the installation is recommended by professional and specialized personnel near to high power transformers to guarantee sufficient capacity. Its estimated main characteristics include 150 – 350 kW of power, 5 – 20 minutes charging time and a maximum electricity consumption per charge of 20 – 100 kWh (STATE OF QUEENSLAND, 2018).

2.3.2. Charging systems

An electric vehicle battery charger is a device used to transfer energy from an electrical energy source to the EV rechargeable battery by converting AC to DC (SHAREEF, MAINULISLAM e MOHAMED, 2015). It can be on-board or off-board (as shown in the section “Charging levels”). The on-board model makes it possible for drivers to charge wherever a suitable power source is available, but on the other hand has limited power because of the constraints in weight, space and cost due to its presence in the vehicle design. The off-board type can be designed for high-charging rates but creates a dependency on an existing charging infrastructure (SBORDONE, BERTINI, *et al.*, 2014).

When talking about the energy transfer mode, the three existing types of charging systems are: conductive charging, inductive charging and battery swapping (SHAREEF, MAINULISLAM e MOHAMED, 2015).

2.3.2.1. Conductive charging

This type of charging system consists in the transferring of energy by direct contact. It can be on-board (usually for slow charging) and off-board (usually for fast charging) and is a very simple and efficient charging, being the most commonly used in electric mobility nowadays (SHAREEF, MAINULISLAM e MOHAMED, 2015).

2.3.2.2. Inductive charging

Inductive charging is the also known “wireless charging”, in which the energy is transferred to the EV battery with the use of an electromagnetic field. Its advantages are the much bigger electric safety under any weather condition and the possibility of a non-stationary charging. However, this is a very complex technology, that is still very expensive and still presents a very low efficiency, with a high power loss (SHAREEF, MAINULISLAM e MOHAMED, 2015).

Audi announced the release of the first commercial electric vehicle using inductive charging in 2019, the 2019 Audi A8 quattro. However, this technology is very far from being widely spread in the industry. It is still at a very initial phase of its development and has no standardization by now, while the plug-in technology is much ahead in dissemination and progress. Besides that, there is no prediction for a fast-charging inductive system for the next few years (WILLIAMS, 2018).

There are studies also on dynamic electric vehicle charging (DEVC) in progress, like the chip-maker Qualcomm Halo DEVC project, subsidized by the European Commission, in Versailles, France. This model, however is much more further from becoming commercially viable. Even the researchers involved with it are skeptical about its usage, once the infrastructure necessary would be very complex and expensive. Besides that, cars usually spend 90 to 95 percent of its time parked, so a wireless static charging technology would already be enough if developed and spread (WILLIAMS, 2018).

2.3.2.3. Battery swapping

The third and last type of charging system is the battery swapping, that consists in swapping an empty battery with a fully charged one in a battery swapping station. Benefits for this method include longer battery lives, minimal cost to manage, shorter time to get the EV fully charged and possibility of charging batteries outside of the peak demands of the grid. As main drawbacks are the necessity of a large investment, the lower battery safety and the use of large spaces for stations, once there is the need to storage a big number of batteries in one place (SHAREEF, MAINULISLAM e MOHAMED, 2015).

This model lost much of its popularity when Better Place went to bankruptcy in 2013. The company had installed more than 50 battery swapping stations by that time. After that, the big majority of EV models do not support battery swapping, with some exceptions like Tesla’s Model S (AMSTERDAM ROUNDTABLES FOUNDATION; MCKINSEY & COMPANY, 2014)

2.3.3. Standards for EV charging

In order to make it easier for electric mobility industry to grow and spread, many organizations around the world developed standards for EV charging. Taking in consideration safety, reliability, durability, rated power and cost of different charging methods, they have decided for a pattern that must be followed. The charger must be efficient, reliable, affordable and adaptable for diverse models of electric vehicles. The carmakers use these standards to guide their production and research (SBORDONE, BERTINI, *et al.*, 2014).

In EU, the standardization is indispensable for driver’s convenience, avoiding the necessity for different cables and adaptors when traveling internationally. For that matter, the IEC 61851 was issued providing a standardization of charging systems, plugs and sockets. (SBORDONE, BERTINI, *et al.*, 2014).

In Europe, for AC charging, the IEC 62196 (Type 2), known as Mennekes connector (Figure 7), is the most used type and can deliver up to 43 kW. While in Japan and the USA, the SAE J1772 (Type 1) is commonplace for Level 1 and 2 charging. For DC charging, the European Union adopted the CCS Combo 2 Type 2, that is very similar to the Mennekes connector, but with two additional pins for supporting fast-charging. For that level of charging, the USA standard is the CCS Combo 1 Type 1 and the Japanese is the CHAdeMO connector (STATE OF QUEENSLAND, 2018).

Figure 7 - Type 2 Mennekes connector (STATE OF QUEENSLAND, 2018)

2.3.4. Vehicle-to-grid (V2G) technology

One rising trend in the electric vehicles charging technologies is the vehicle-to-grid (V2G) model. It works by making it possible for the EV to provide electricity to the grid, and not only the other way around (AMSTERDAM ROUNDTABLES FOUNDATION; MCKINSEY & COMPANY, 2014). When activated, the V2G transforms the vehicle in a generation source, using the power stored in it when charged. By discharging stored energy from the cars to the distribution network, this technology increases reliability and reduces system costs of the power system (SHAREEF, MAINULISLAM e MOHAMED, 2015).

The benefits are diverse: mitigating voltage fluctuations, offering participant drivers some revenue, contributing to power quality improvement and frequency control for a decentralized power supply, reducing the use of voltage regulators in distribution networks, reducing distribution line loss and stabilizing grids in terms of peak-load shaving (SHAREEF, MAINULISLAM e MOHAMED, 2015). However, the biggest concern when talking about V2G technology is the degradation of lithium-ion batteries. Studies show that the discharging of the EV battery is detrimental to its performance. This obstacle can be the key factor for defining the economic viability of vehicle-to-grid use (UDDIN, DUBARRY e GLICK, 2017).

2.4. POLICY

As the electric mobility is showing to be an important industry to maintain the sustainability of the modern urban mobility model in all the world, governments have been pursuing policies that serve as incentive for this growing market. The creation and adoption of these regulations are being made mainly because of the main obstacles that the electric vehicles find to spread. One of them is the high cost of production and development of the new technologies, that makes it impracticable for the regular buyer to adopt the electric alternative (MIRHEDAYATIAN e YAN, 2017).

Some examples of common measures taken by governments are purchase subsidies, limited access to congestion or low-emission zones and taxes exemptions. The purchase subsidies are simply direct subsidies to purchase of electric vehicles. The limited access to congestion or low-emission zones is a limitation for high-emission or heavy vehicles to access some areas of the cities. It can be made, for example, by a fee charging or simply by prohibiting access on specified dates (or even everyday) and intend to reduce the emissions. The last one (tax exemptions) is about creating a differentiated taxation for electric vehicles. It can be made either by eliminating a tax (vehicle registration tax or annual circulation tax) or by making them reduced only for EV owners (MIRHEDAYATIAN e YAN, 2017).

Other known policies that are related to traffic regulations include free use of bus lanes and/or fast lanes and free parking in selected zones. The California's Zero Emission Vehicle program makes it mandatory for manufacturers to produce a certain percentage of zero emission vehicles. (LIEVEN, 2015).

The European Commission, in order to achieve its long-term goals of electric vehicles participation in the market, suggested some ways the governments might influence the industry, creating a conducive environment for low-emission mobility. These suggestions are directed not only to governors, but also for big companies that have impact on these sectors. Between the policies discussed, there is linking the transport and the energy systems. One of the main challenges in this area is at the distribution level at peak times, once the existing infrastructure generally has already the capacity to provide for a widespread electricity in transport. The policies suggested include encouraging charging at off-peak times or at high supply moments, by managing price differentiation for different time intervals during the day. Another suggestion is to reduce barriers for self-generation, storage and consumption of renewable energy and also the development of vehicle-to-grid technologies that make it possible for charged vehicles to provide energy to the grid (EUROPEAN COMMISSION, 2016).

According to Kley, Wietschel & Dallinger (2010), the electric mobility support instruments can be regulatory, economic, “suasive” and organizational. Regulatory instruments are the ones that impose restrictions on automotive manufacturers. Economic instruments are those that influence the natural market outcomes, using quantity and/or price changes. “Suasive” instruments are the ones that aims on persuading buyers or producers to adopt the new technologies by non-economic means. And lastly, organizational instruments are those that reduce the obstacles for the industry to grow. Governments often use diverse types of support mechanisms combined to incentive both the buyers and the sellers to adopt new technologies in electric mobility (KLEY, WIETSCHEL e DALLINGER, 2010).

2.5. ITALIAN POLICY

One of the main regulatory authorities in the Italian electricity market is the Authority for Energy, Gas and Water (*Autorità per l”Energia Elettrica, il Gas e il Sistema Idrico* - AEEGSI). It was established in 1995 and is intended to protect customer’s interests, promote competition and ensure efficiency and profitability in the industry. ARERA regulates distribution and transmission tariffs, but prices and contractual conditions for parties that are not under enhanced protection regime (*maggior tutela*) are freely determined by the parties involved. The *maggior tutela* applies to low voltage users and small enterprises only (MONTELLA e MARTORANA, 2017).

The European Parliament and the Council of the European Union released in 2014 the Directive 2014/94/EU on Alternative Fuel Infrastructure (AFI) with the objective to establish a common framework as incentive for the EV charger market development. The document defended, among other things, that this activity should be carried out under competitive conditions. It also declared that the governments should ensure that the users of the charging infrastructure should be able to use the chargers without the need for a contract with the electricity vendor or the charging point operator (requiring the known as “*ad hoc*” payment) (THE EUROPEAN PARLIAMENT AND

THE COUNCIL OF THE EUROPEAN UNION, 2014). In 2016, the European Commission revised that statement and declared that DSOs should be able to operate charging stations only under the conditions that other parties have not expressed interest in the activity and that the authority approved it (EUROPEAN COMMISSION, 2016).

In 2010, AEEGSI launched a project that took place from 2011 to 2015 to decide on efficient and pro-competitive regulatory solutions for the development of RV charging infrastructure in public places. The pilot projects were open in three different business models with the objective to gather the information necessary for developing a regulatory framework. The business models tested were: Area-licensed Service Provider model, Service Provider in Competition model and Distribution System Operator (DSO) model (SCHIAVO, BONAFEDE, *et al.*, 2017).

In the Area-licensed Service Provider model the operation of the recharging network is of responsibility of a single industrial player selected by a public tender in a given area according to a local license for public service. And in the Service Provider in Competition model works like the traditional fuel stations market, in which many industrial players compete in the same area (SCHIAVO, BONAFEDE, *et al.*, 2017).

In the DSO model, the electricity utility develops and manage the recharging infrastructure in concession area. Two special requirements were made by the authorities to guarantee adequate competition and avoid that the DSO investment in EV charging affects the tariffs for energy final consumers. These requirements were: the “multivendor” approach gives the EV owner to choose his or her electricity supplier at each recharge station; and the “accounting separation” that demands for the DSO not to merge the recharge activity assets with the electricity distribution. This model worked with long-term contracts and access to the charging stations by radio-frequency identification cards (SCHIAVO, BONAFEDE, *et al.*, 2017).

This last model was the one that showed poorer results and that had more problems among the users. Besides that, the Directive 2014/94/EU on Alternative Fuel Infrastructure (AFI) released in 2014 made it an impracticable option and AEEGSI took the position that it should no longer be adopted. Even with the revision of the Directive by the European Commission in 2016, the Authority maintained its decision due to the growing number of commercial players that were appearing in the market (SCHIAVO, BONAFEDE, *et al.*, 2017).

According to the AFI Directive, the prices charged by the public located charging stations operators have to be reasonable, easily and clearly comparable, transparent and no-discriminatory (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2014). Adding to that, AEEGSI stated that the price for charging should not be considered as just the price of the energy, but for the whole service of charging (SCHIAVO, BONAFEDE, *et al.*, 2017).

The activity should not be considered just a re-selling of electricity due to the many value-adding aspects related to the process. With that, the Authority affirmed that prices expressed only in "€/kWh" could be misleading and that it was likely a fixed monthly payment to be a structural part of pricing. As the "*ad hoc*" payment is a minimum service required by the AFI Directive, this suggestion could imply in loyalty programs or flat-rate subscriptions for frequent customers. Another possibility is the conscient use of the equipment, charging higher fees for vehicles that remain connected after its full charging, for example (SCHIAVO, BONAFEDE, *et al.*, 2017).

The regulation for plugs and connectors, in the Directive 2014/94/EU on Alternative Fuel Infrastructure (AFI) states that the charging points for AC need to be equipped with at least a Type 2 socket outlet, and those for DC with at least a Combo 2 connector. This decision was made based on the European Union standards and its objective was to guarantee interoperability for customers (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2014).

2.6. ELECTRIC VEHICLES CHARGING PLAYERS

In order to understand the relationships in this growing industry it is important to study the players involved in the electric vehicles charging system. They are going to be divided in existing players and new players. The first group represents agents that already existed in the electricity industry before the development of the electric mobility industry. The second one is about those agents that appeared as a consequence of the development of electric vehicles.

2.6.1. Existing players

2.6.1.1. Distribution System Operator (DSO)

According to the Directive 2009/72/EC of EU electricity market legislation, European Union Member States should ensure the separation of vertically integrated energy companies to avoid monopolies and guarantee incentives to adequate investments in the networks. The various stages of energy supply, such as generation, distribution, transmission and supply, were separated and regulated individually. While generation and supply were open to free competition, transmission and distribution were subjected to regulatory control (PRETTICO, GANGALE, *et al.*, 2016).

A Distribution System Operator (DSO) is a natural or legal person who owns and operates an electricity distribution grid. It is responsible for the maintenance and development of the system in a given area. They are designated by European Union Member States, who are responsible that the DSOs act according to the regulations (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2009). The DSOs should guarantee non-discriminatory access to the grid and provide all the information needed to an efficient use of the energy. However, with the development of new technologies and the constant transformation in the electricity industry, the role of the DSOs began to be reconsidered and new tasks, responsibilities and opportunities are being discussed (PRETTICO, GANGALE, *et al.*, 2016).

2.6.1.2. Supplier

The supplier (or retailer) is the company responsible for selling the energy to the final customer. It can be unbundled from the DSO or integrated. In the first case, it receives the payment for the energy by the final customer and procures it and pays the regulated charges and system costs to the DSO. When integrated, the supply and distribution are made by the same agent, consisting in a vertically integrated model (ROMÁN, MOMBER, *et al.*, 2010).

2.6.1.3. Final customer

The final customers are residential, commercial or industrial customers who purchase electricity for their own use (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2009). This is the agent that requires the energy and pays the supplier for it. The final customer is not allowed to resell the electricity purchased (ROMÁN, MOMBER, *et al.*, 2010).

2.6.1.4. Transmission System Operator (TSO)

A Transmission System Operator (TSO) or Independent System Operator (ISO) is a natural or legal person responsible for the operation, maintenance and development of the transmission system in a given area (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2009).

The difference between transmission and distribution systems is in the moment of the energy supply process they happen. The transmission system connects generating sites, like a power plant, to large substations. Its operating voltage exceeds 230 kV. In the other hand, the distribution system connects local substations to individual households. Its operating voltage is lower than 34.5 kV (MCGRAW-HILL, 2005).

2.6.2. New players

2.6.2.1. EV owner

Electric vehicle owner is the owner of an EV that requires energy for its charging. He or she can be a final customer, when he or she only receives the electricity and pays for it. But in V2G cases, the EV owner does not work solely as final customer, once the energy bought is redistributed and the owner can receive a remuneration (ROMÁN, MOMBER, *et al.*, 2010).

2.6.2.2. EV supplier-aggregator

The EV supplier is the retailer that sells electricity to the EV owner. In the cases of domestic charging, it is the same as the traditional supplier. However, in some cases it assumes different roles. When talking about public EV charging, the EV supplier cannot be considered a traditional supplier because its domain is not location based or bound to a single final outlet. The EV supplier can also act as an aggregator in V2G cases, in which the EVs also provide electricity to the grid (ROMÁN, MOMBER, *et al.*, 2010).

2.6.2.3. Charging Point Manager (CPM)

The charging point manager (CPM) is the agent that owns and manages a charging station. It can be a final customer, when it is the EV owner who installs a charging point at his private property, or not, reselling the energy to different EV owners (ROMÁN, MOMBER, *et al.*, 2010). In the sections “Charging modes” (2.7.2), “Alternative charging modes” (2.7.3) and “EV charging modes variations with V2G services” (2.7.4) various types of CPMs are described and explained.

2.6.2.4. Mobility Service Provider (MSP)

The Mobility Service Provider is a player that facilitates interoperability among charging points with different CPMs. This player works by making contractual partnerships with various charger operators in an area and by offering to the customer an unified contract that allows him access to all the partner operators’ charging stations (SCHIAVO, BONAFEDE, *et al.*, 2017).

The contractual relationships among the actors in a generic case are represented on Figure 8.

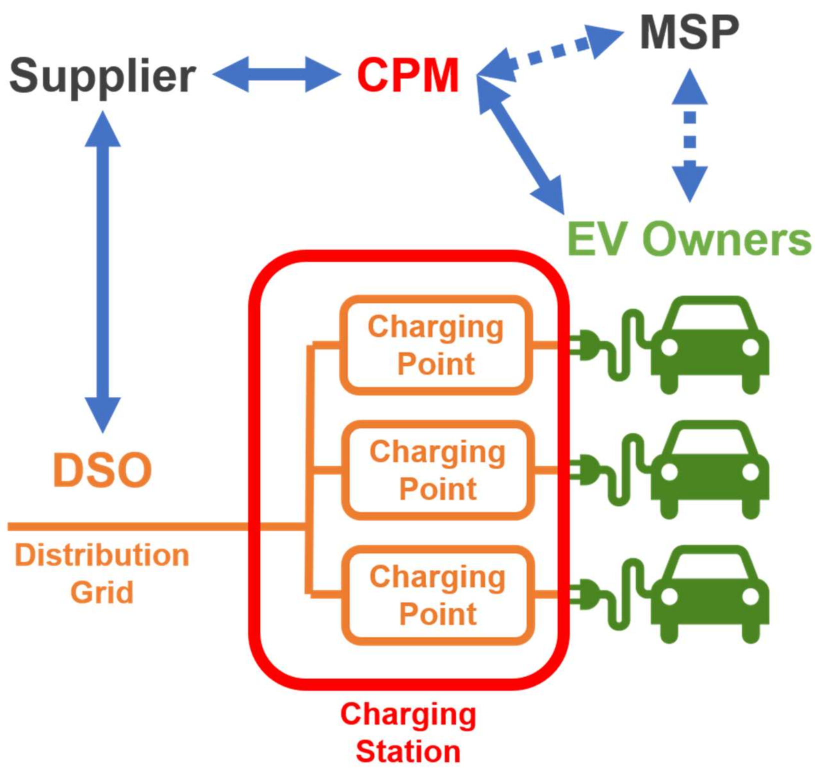

Figure 8 - Schematic representation of the contractual relationships among players in a charging station – adapted from (SCHIAVO, BONAFEDE, et al.*, 2017)*

2.7. CHARGING INFRASTRUCTURE

2.7.1. Charging points uses

To initiate an assessment of the charging points needed in a city, it is possible to define two different uses for charging points: residential use and public use. The charging point for residential use is that located in a residential home or a private property location and is owned and used by the car owner. It consists in a standard EV plug connected directly to the household power. It is intended only for normal charging rates, usually for charging power level 2. In this model, the vehicle has an on-board charger and the connector and cables are bought by the owner, with the energy being charged with the household's energy bill (ROMÁN, MOMBER, *et al.*, 2010).

The charging points for public use, instead, are the ones located in public areas or in private areas with public access. It is suitable for charging power levels 2 or 3 and needs some other resources like an interface for user identification, energy flow measuring and billing, as well as physical lock after payment and a protection against vandalism. It can be owned by the government, by the distribution system operator or by a charging point manager (ROMÁN, MOMBER, *et al.*, 2010).

2.7.2. Charging modes

With that in mind, it is possible to assess the main charging modes, that is, the most common ways that charging occurs. There are three main big divisions with many variables within them. They are: EV home charging; public street charging and charging stations on private property with public access. Derived from these three modes, there are many alternative ones, including ones with V2G services. (ROMÁN, MOMBER, *et al.*, 2010). The three basic cases and some of the more important alternative ones are going to be more deeply explored and discussed in the following topics.

2.7.2.1. EV home charging

This is a case of charging point for residential use in which the electric vehicle supply equipment is installed by the home owner and the electricity comes from a unique supply contract for the house. The billing occurs along with the total household consumption with all the other home appliances (ROMÁN, MOMBER, *et al.*, 2010).

This model involves the energy distribution system owner and operator, the supplier and the final residential costumer, where the two last ones have a contract with at least a peak and off-peak prices or hourly prices differentiation as an incentive for off-peak charging. The supplier, then, pays for the energy grid owner according to the network charges. In this case, it is not possible for the electric vehicle charging to have differentiated prices when compared to usual household consumption. As an incentive for electric vehicles adoption, some policies propose an alternative pricing for the electricity consumption in charging, that would need a different supply contract and some equipment for differentiated energy flow measuring (ROMÁN, MOMBER, *et al.*, 2010).

In Figure 9 and Figure 10, there are schemes for contractual relationships and physical system for EV home charging. Figure 9 represents the case in which the energy used for charging electric vehicles is charged as usual domestic electrical appliance. Figure 10 represents the case in which there is a separate billing for EV usage of electrical energy. DSO represents the “distribution system operator”; FCM represents the “final customer meter”, that is, the energy flow measuring equipment for final customer; CP is for “charging point”; and SoC is the on-board “state of charge” indicator (ROMÁN, MOMBER, *et al.*, 2010).

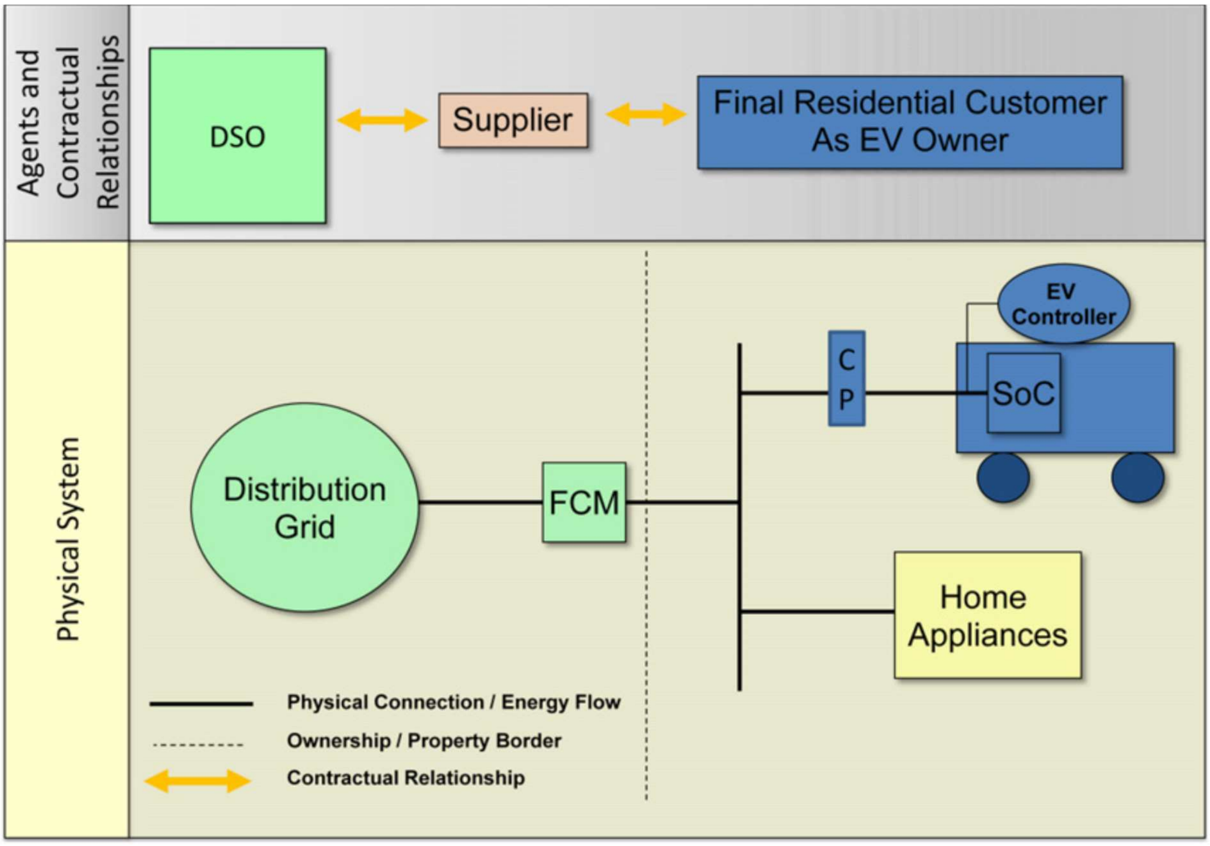

Figure 9 - EV charged at home as domestic electrical appliance (Román, Momber, Abbad, & Miralles, 2010)

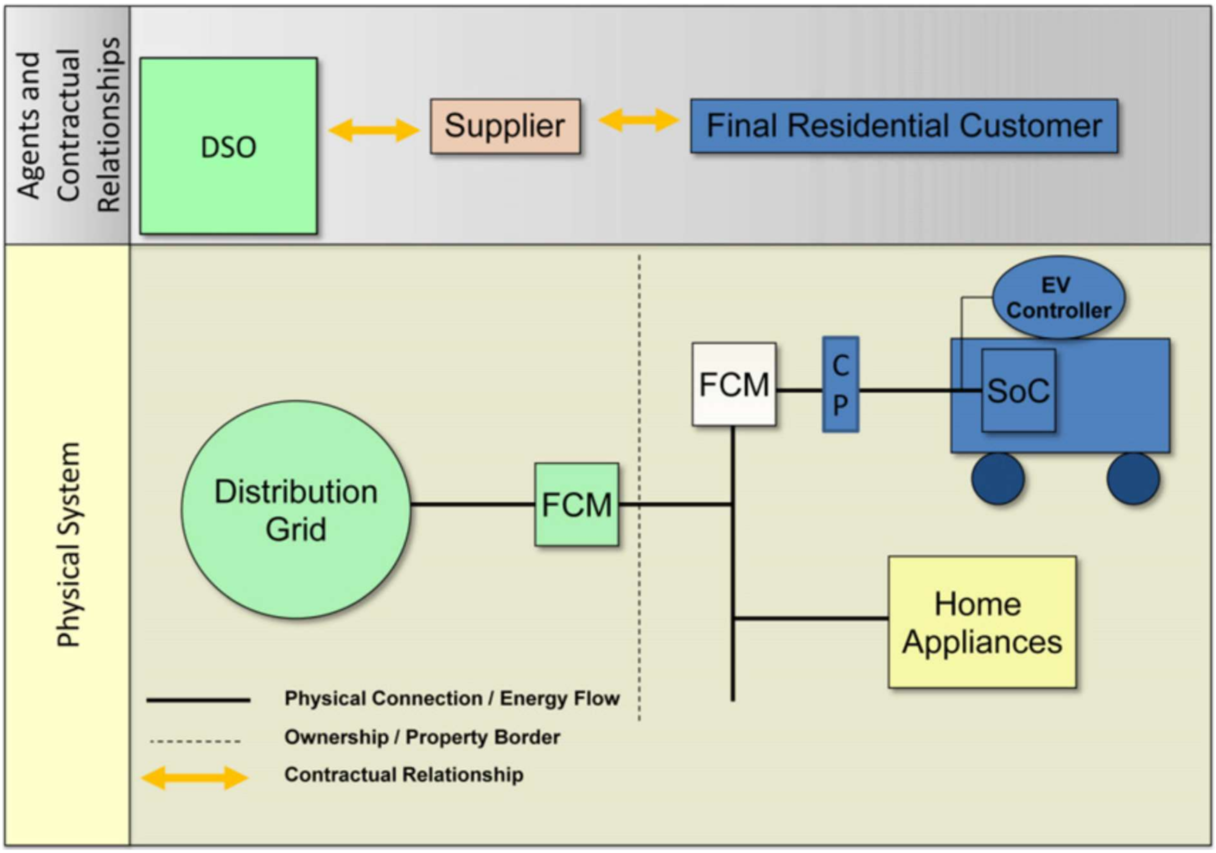

Figure 10 - EV charged at home with sub-meter for separate EV electricity billing (Román, Momber, Abbad, & Miralles, 2010)

2.7.2.2. Public street charging

This scenario consists of charging points of public property for public use. The charging stations are located in public facilities such as streets or public parking lots and can be used by any EV owner. The local distribution system operator (DSO) is responsible for installing the infrastructure and an electric vehicle supply aggregator (EVSA) is defined to intermediate the charging between the final customer and the DSO. This model has complex contract relationships and involves multiple players, including local governments and authorities. The allocation and management of the stations have to be well thought and planned once big public investments are involved and different policies and regulations must be issued to guarantee the functioning and maintenance of the system (ROMÁN, MOMBER, *et al.*, 2010).

The agents involved in this model are the distribution system owner and operator (DSO), the electric vehicle supply aggregators (EVSAs) and the electric vehicle owners. The contractual relationships in this scenario are very similar to those on the EV home charging: the DSO installs charging points through the city as part of its distribution network. The EVSA act as the supplier, mediating the transaction. There must be a fair accessibility to the charging points in order to avoid an EVSA monopoly situation. The aggregators then, sign contracts with the final customer (EV owner), who can charge their cars in the public spots and have it billed for them. The EVSA, then, pays for the energy grid owner according to the network charges (ROMÁN, MOMBER, *et al.*, 2010).

In Figure 11, a scheme of the public street charging is represented. In the figure, EVM represents "electric vehicle meter", that is the equipment used to measure the energy flow and times for billing purposes (ROMÁN, MOMBER, *et al.*, 2010).

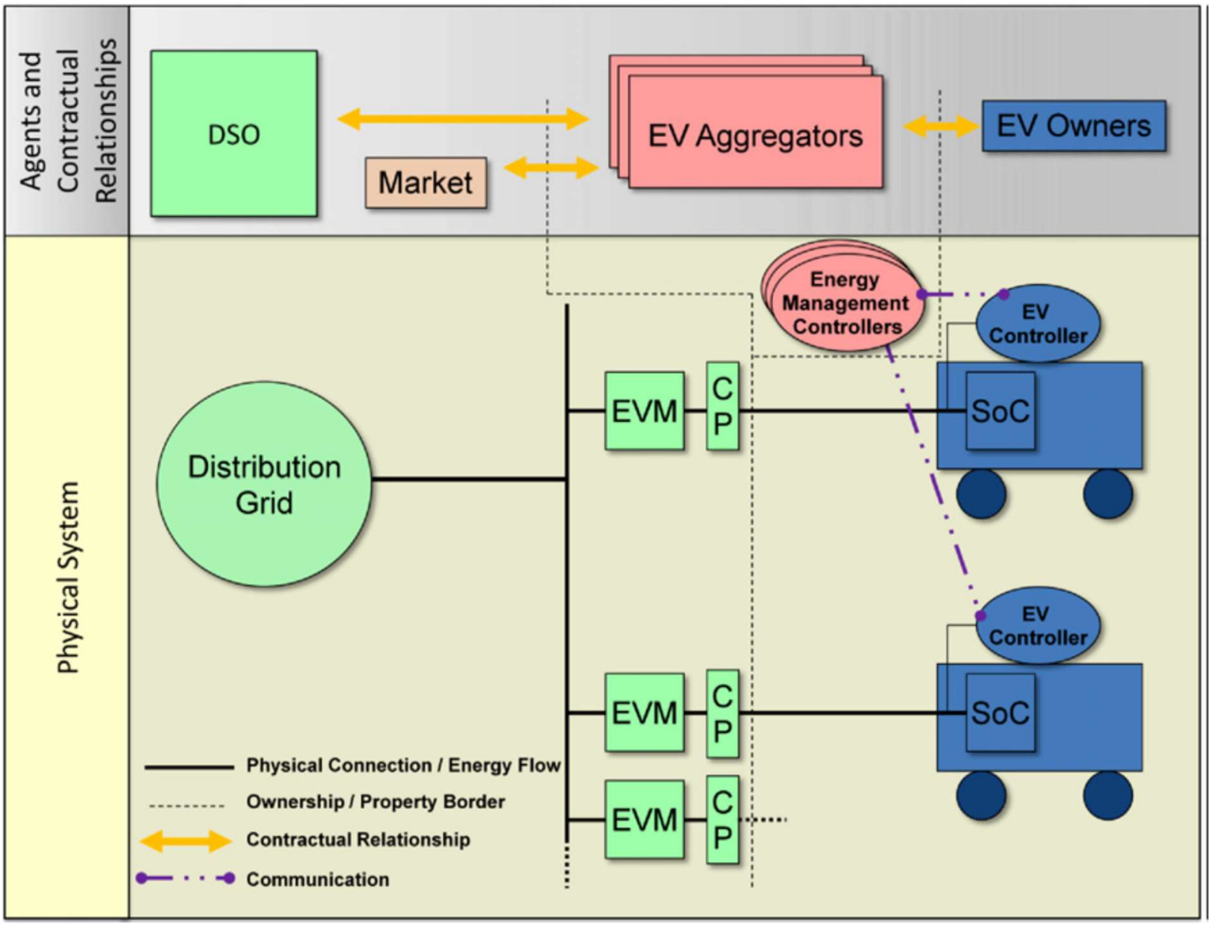

Figure 11 - Public street parking area with multiple EV suppliers (ROMÁN, MOMBER, et al.*, 2010)*

2.7.2.3. Stations on private property with public access

This charging mode represents the situations in which the charging point is located in a private property that is open for customer's vehicles. Examples of this situation would be shopping facilities, private parking lots, various kind of commercial office buildings and private roadside charging stations. In this model, the charging station owner is responsible for the installment and maintenance of the charging equipment. He or she buys the energy from a supplier and provides drivers with charging services. Along with the basic equipment for charging, the charging point manager (CPM) can have additional equipment to convert, store and produce electricity. With that, it is possible for the CPM to provide optimized and diversified services, like DC fast-charging (Level 3), that is very useful for places where the driver doesn't remain parked for long periods or roadside stations. It is also possible for the charging station owner to store electricity during off-peak hours when its price is lower, maximizing profits and making more competitive prices possible for the final customer (ROMÁN, MOMBER, *et al.*, 2010).

The agents involved in this scenario are the distribution system owner and operator (DSO), the supplier, the charging point manager (CPM) and the EV owner. The CPM acts as final costumer in the contract with the supplier, who mediates the transaction with the DSO. The CPM buys electricity and then resells it to the EV owners, having the possibility to convert, store and generate energy to increase profits, diversify services and reach lowest prices (ROMÁN, MOMBER, *et al.*, 2010).

Figure 12 provides a schematic representation of private owned stations with public access.

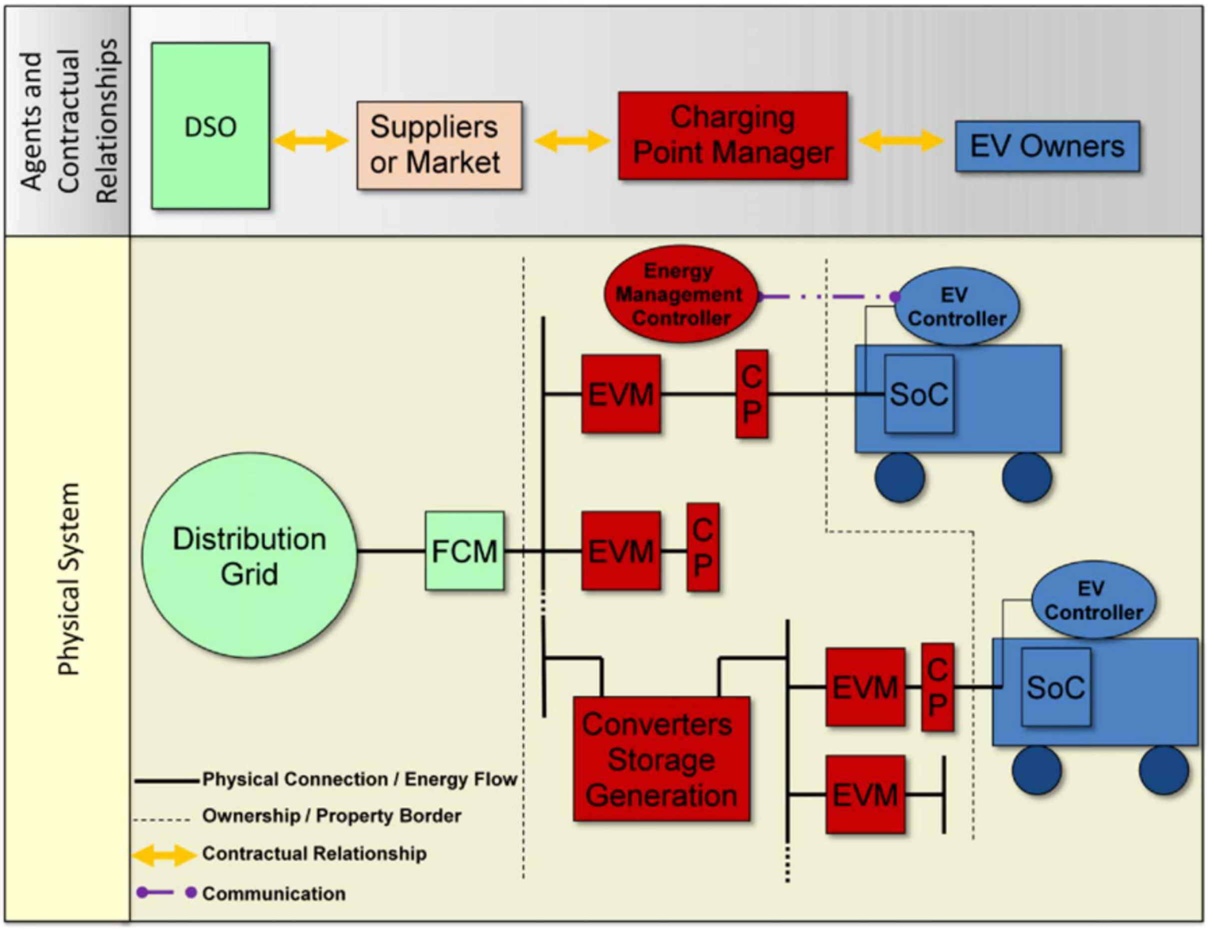

Figure 12 - Privately owned charging station offering special services (ROMÁN, MOMBER, et al.*, 2010)*

2.7.3. Alternative charging modes

In this section, two important alternative EV charging modes are going to be briefly explained: EV charging at home under EVSA management and commercial or office building with EV parking and integrated management of energy. They are variations of the three main cases already explored (ROMÁN, MOMBER, *et al.*, 2010).

The EV charging at home under EVSA management defines the case in which an aggregator buys the energy from a supplier or participates in the market and resells this energy for the EV owners, who are under a charging contract. It makes It possible an integration of public and residential charging points, optimizing the energy consumption, reducing costs and simplifying the contractual relationships. Besides, it makes it easy to implement specific taxes and special rates for EV charging in households, once it is made separately from the basic electrical appliances (ROMÁN, MOMBER, *et al.*, 2010). Figure 13 provides a schematic representation of this model.

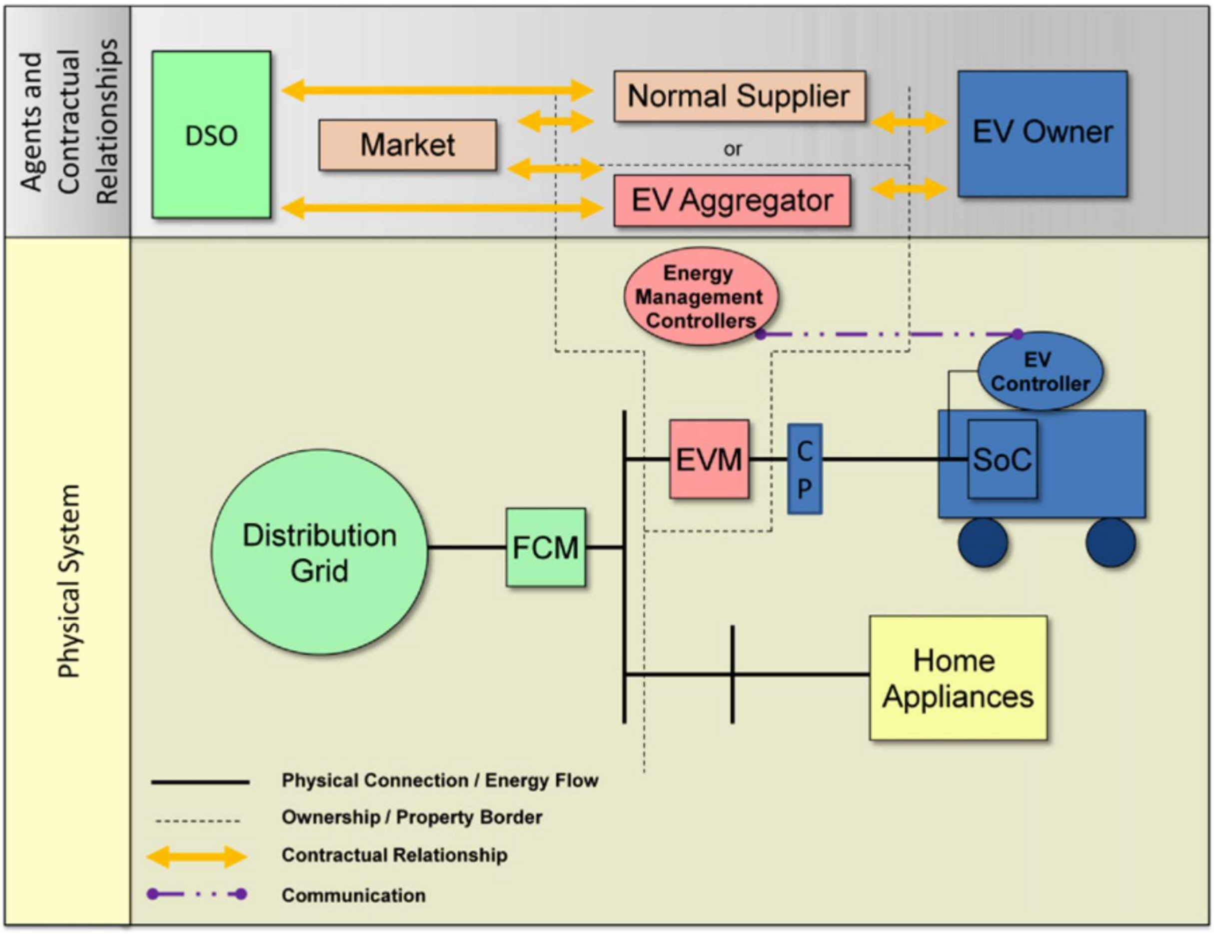

Figure 13 - EV home charge under EVSA management (ROMÁN, MOMBER, et al.*, 2010)*

The second alternative charging mode is the commercial or office building with EV parking and integrated management of energy. This scenario works very similarly to the stations on private property with public access: the commercial or office building acts are the charging point manager (CPM), installing the infrastructure and buying energy to resell. The main difference is that, instead of public access, in this example the EV owners utilizing the service are employees and/or customers of the CPM. (ROMÁN, MOMBER, *et al.*, 2010). Figure 14 provides a schematic representation of this model.

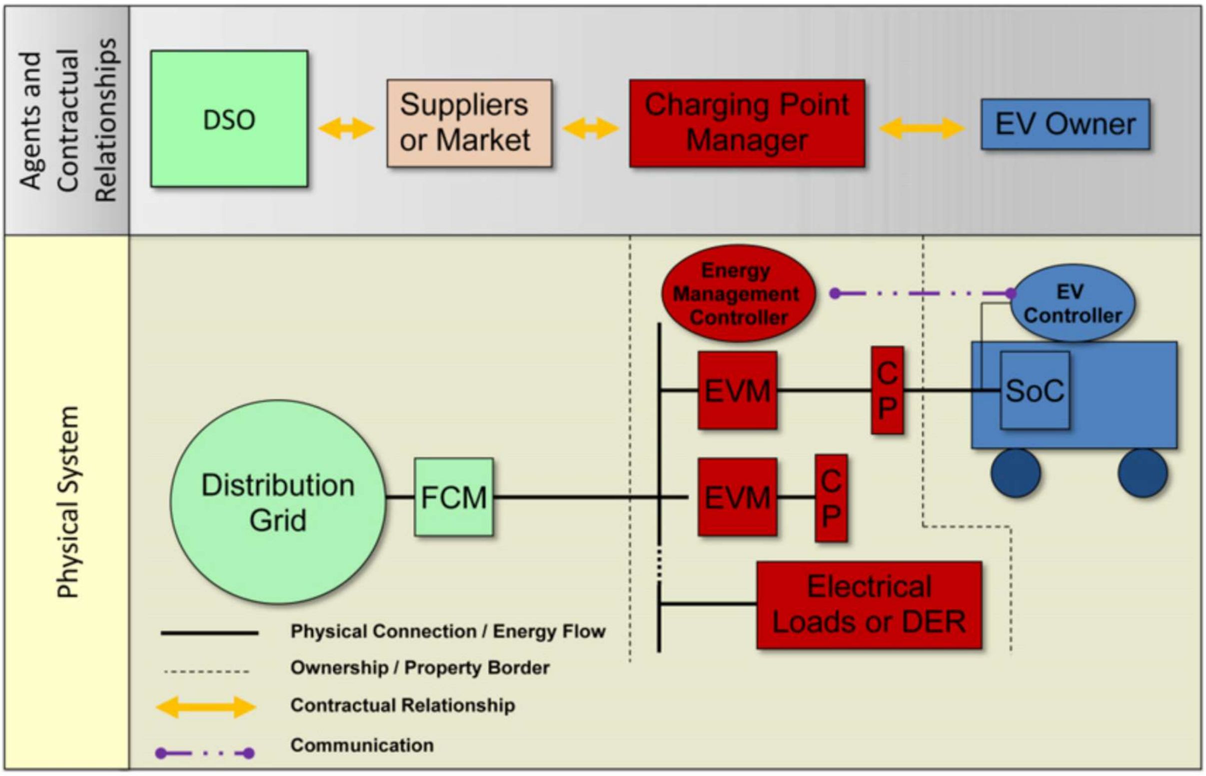

Figure 14 - Office building with integrated energy management (ROMÁN, MOMBER, et al.*, 2010)*

It is also possible an intersection between these two alternative charging modes, in which the office or commercial building delegates the control and management of EV charging to an EVSA (ROMÁN, MOMBER, *et al.*, 2010).

2.7.4. EV charging modes variations with V2G services

The precious models considered only the EV owner's necessities of charging their cars. The vehicle-to-grid technologies, in other hand, provide the possibility of injecting power from the car battery to the grid, optimizing power operations and minimizing costs. These modes need specific and well defined regulatory mechanisms to work. Three scenarios will be explained taking into account the V2G possibility in some of the charging modes presented: EV managed at home as storage resource to minimize electricity payments; EV connected at home providing V2G managed by an EV aggregator and EVs connected at public parking sites, office or commercial buildings providing V2G managed by an EV aggregator (ROMÁN, MOMBER, *et al.*, 2010).

2.7.4.1. EV managed at home as storage resource to minimize electricity payments

This model is a variation of the EV home charging (2.7.2.1) in which the electric vehicle works as an electrical energy storage unit for minimizing payments. It is suitable for charging contracts with peak and off-peak different prices or hourly charges differentiation. The electric vehicle is programmed to store energy on times when the prices are lower and serves as a generator on times when prices are higher. The efficiency of this mode depends on factors like the times when the car is parked ate home, the battery degradation with discharging and hourly electricity time spreads (ROMÁN, MOMBER, *et al.*, 2010). Figure 15 provides a schematic representation of this scenario.

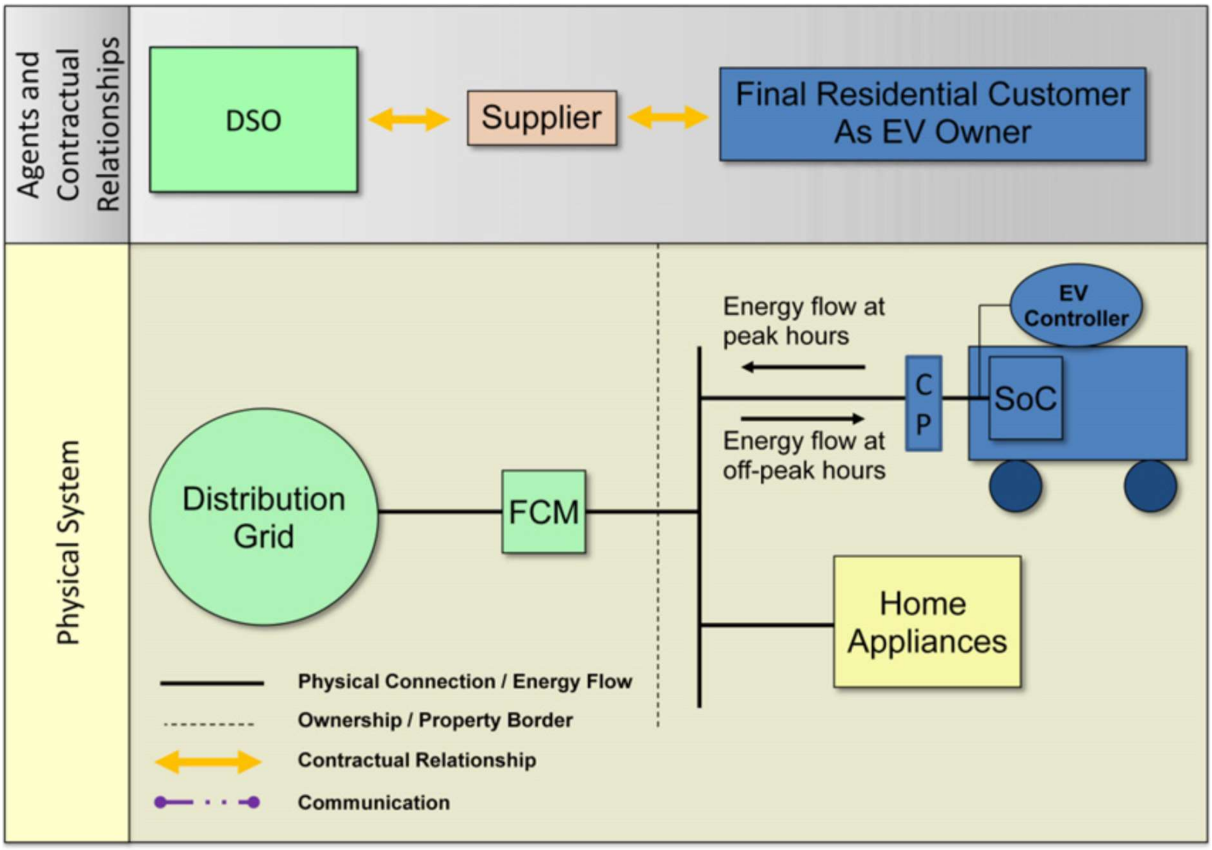

Figure 15 - EV providing V2G to minimize home electricity payments (ROMÁN, MOMBER, et al.*, 2010)*

2.7.4.2. *EV connected at home providing V2G managed by an EV aggregator*

This model is an intersection between EV charging at home under EVSA management (2.7.3) and EV managed at home as storage resource to minimize electricity payments (2.7.4.1), in which the aggregator manages the EVs with V2G capability buying and selling energy according to its hourly variant prices. The EVSA takes advantage of arbitrage opportunities creating an energy real-time market and providing regulation reserves, beneficiating both the EV owner and the EV aggregator. These transactions have to be under a higher organ supervision and rely on a bi-directional measuring equipment to control energy flows in both ways (ROMÁN, MOMBER, *et al.*, 2010). Figure 16 provides a schematic representation of this model.

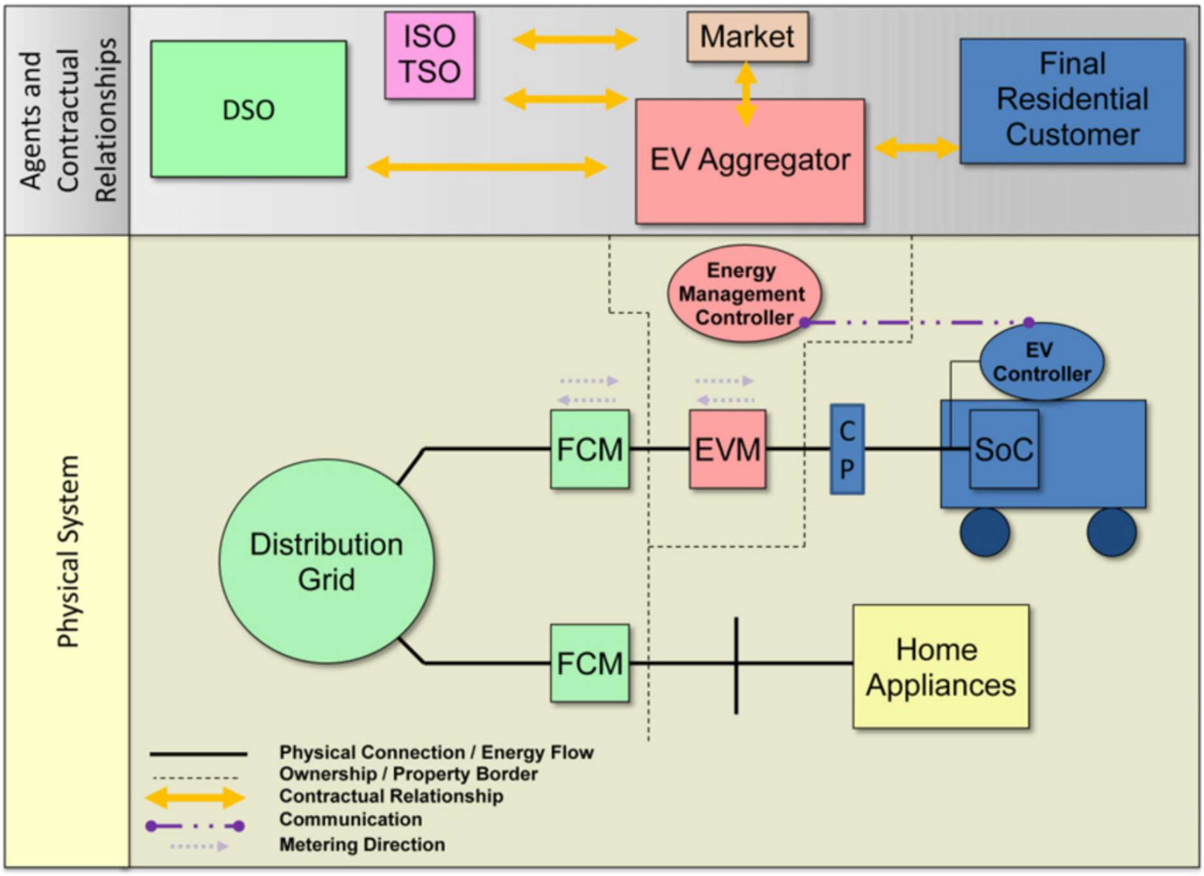

Figure 16 - Aggregator providing V2G services at home (ROMÁN, MOMBER, et al.*, 2010)*

2.7.4.3. EVs connected at public parking sites, office or commercial buildings providing V2G managed by an EV aggregator

This model is very similar to the previous one (EV connected at home providing V2G managed by an EV aggregator) with the difference that, instead of working on the EV owner house, it takes place in any public or private charging point. The aggregator intermediates the energy distribution and controls electricity flows both ways, making use of the prices differentiations to reduce costs and create revenues (ROMÁN, MOMBER, *et al.*, 2010).

2.8. CHARGING STATIONS GOVERNANCE MODELS

In this section, the governance models and players relationships of some of the charging modes presented will be deeply assessed and discussed using real examples and recent news on the field. The Public street charging (2.7.2.2) and the Stations on private property with public access (2.7.2.3) are the two charging modes that fit better in the objectives of this document and will be the main base for further discussion. One key factor for deploying the charging infrastructure system is understanding who is going to make it and how is it going to be made. There are different existing approaches that need to be considered for comparison and decision making.

Today, there are some ways the charging stations are built that appear in the huge majority of existing cases. The four agents responsible for biggest participation in the building and paying for these charging points are: auto manufacturers, big utilities - an electric utility company is a Distribution System Operator (DSO) and/or a Transmission System Operator (TSO) -, third-party charging networks and traditional fueling services companies (HOIUM, 2017).

2.8.1. Auto manufacturers

Some of the biggest car manufacturers have united in Europe for a joint venture including Volkswagen, BMW, Daimler and Ford. The Munich-based “Ionity” is aiming to regain some of the market share lost to Tesla and its proprietary Supercharger network. It inaugurated its first station on April 2018, in Germany, and has a goal of 400 ultra-fast charging stations with renewable sources power until 2020. Its advantages over the Tesla Motors network are the use of the standardized CCS plug, backed by the European Union, and its ultra-fast charging technology with 350 kW capacity, against Tesla's Supercharger 120 kW. Nowadays there is no vehicle on the market that can make full use of that capacity, but it is expected that by 2019 it exists a car with 350 kW capacity on sale (MCHUGH, 2018).

The €7 million worth Rapid Charge Network (RCN) project took place in 2014 and 2015 in Great Britain, Ireland and North Ireland. It was funded by a consortium between Nissan, BMW, Renault and Volkswagen, along with Irish ESB e-cars business. The European Union's TEN-T program co-financed the project (ZERO CARBON FUTURES, 2018). It installed 74 electric vehicle public charging stations with rapid chargers on the main highways of the region that are now operated by Ecotricity's Electric Highway network in Great Britain and ESB's e-cars network in Ireland (SERRADILLA, WARDLE, *et al.*, 2017).

In Italy and Austria, EVA+ (Electric Vehicles Arteries) project installed its first charging point in October 2017. The program is a partnership between Renault, Nissan, BMW and Volkswagen Group Italy, and is under the coordination of Enel (main electricity utility in Italy) and Verbund (main electricity utility in Austria). The project is co-financed by the European Commission through the "Connecting Europe Facility" program and intends to install, in three years, 200 fast-charging multi-standard stations in both countries, including the electrification of the rout Milan-Rome with charging points each 60 km (LA STAMPA MOTORI, 2017).

The biggest EV company, Tesla Motors, goes against the stablished standards and uses its proprietary charging technology. That can become an obstacle for the company in the future, when the big competitors gain market share with standardized technologies. The company sells most of its own charging components to customers and created its own charging network, the Tesla's Supercharger network. The network is being built entirely by Tesla and is intended for the users of the company's own customers (HOIUM, 2017). However, Elon Musk (Tesla's co-founder and CEO) announced that Tesla is open to making agreements with other electric manufacturers in which they configure their vehicles to be able to use the Superchargers upon a payment (ZOLFAGHARIFARD, 2018).

The Superchargers can charge 80% of a vehicle's battery in 30 minutes and the company is developing the Megachargers, that are expected to have double the capacity of the current model (ZOLFAGHARIFARD, 2018). By May 2018, the Supercharger network had 1,229 stations with 9,623 fast chargers in Europe alone and it plans to grow exponentially in the next years (MCHUGH, 2018). In Figure 17 the existing Supercharger stations in Europe are shown in red, while the planned for opening in a close future are in grey.

Figure 17 – Existing (red) and planned (grey) charging stations for Tesla's Supercharger network in Europe (TESLA MOTORS, 2018)

The contractual relationships in the auto manufacturers' case is usually similar to the ones in Stations on private property with public access (2.7.2.3). The car manufacturer acts as the charging point manager (CPM). It has a contract with a supplier, in which it buys energy and resells to its clients. The supplier pays to the DSO the regulated network charges and provides to the CPM the required connection capacity. The process is inspected by a regulatory governmental entity (ROMÁN, MOMBER, *et al.*, 2010). In the Tesla situation the charging occurs differently based on the country: it can be charged per minute or per kWh, including taxes and the values vary from country to country (TESLA MOTORS, 2018).

2.8.2. Utilities

In the past few years, the big utilities are facing growth obstacles due to a stagnant demand and an expectation on them to integrate new energy sources. As the electromobility market has been growing exponentially, these utilities have been showing big interest in investing on electric vehicles charging stations (DOURIS, 2017).

In the Unites States of America, the participation of the big utilities in this market has been the center of big discussion in the last year that has not yet come to a conclusion. However, each state took its decisions differently and there are various governance models examples that can be taken in consideration. The existing discussion is on whether the utilities should be allowed to own and manage charging stations (DOURIS, 2017).

One of the main concerns relates to the fact that these huge and stablished companies have a similar to monopolistic participation locally and are usually owned or supported by the government. This would stifle private competition and would force electric customers to contribute to subsidize an infrastructure that would be used only by a minority (DOURIS, 2017). While the utilities' participation in the market provides a low cost of capital and a consequent quicker spread of a charging network, it also hinders more innovative business models from private companies (HOIUM, 2017). Besides that, as a public institution, the utilities have biggest interest in installing infrastructure on disadvantaged communities commonly forgotten by the private industry because of its lower financial returns (FEHRENBACHER, 2018).

Some states like Missouri, Michigan and Kansas have denied utilities permissions for building charging points. On the other hand, Texas guarantees to the utilities exclusivity in owning and operating charging stations. Once private companies are not able to own and operate the stations, some of them made partnerships with municipally owned electric companies to provide charging services (DOURIS, 2017). The state of New York recently approved a $250 million program with the New York Power Authority (NYPA) to build charging infrastructure through the entire state. (FEHRENBACHER, 2018).

In the state of Massachusetts, a different policy is in place. It consists in an arrangement called “make ready”, in which the utility is allowed to build the underground infrastructure for charging stations and the above-ground installation is left to private companies. That would avoid the fear of private companies of being excluded from this market. The utility National Grid proposed preparing 140 “make ready” sites for $24 million (DOURIS, 2017).

California, one of the world leaders in the electromobility industry, banned the utilities from participating in the charging stations market until 2015, when it decided that the development and spread of this market is of public interest and gave the utilities the opportunity of owning and managing charging points (DOURIS, 2017). The state of California aims, with this decision, to achieve its goal of deploying 1.5 million EVs by 2025, educating the customers of the benefits of driving on electricity and challenging the monopoly of the oil industry (BAUMHEFNER, 2016).

Southern California Edison planned to raise $570 million for 50 ports with fast-charging technology, development of electric buses and trucks charging technology and implementation of rate incentives for off-peak charging. Besides that, the company is implementing 1500 level 2 chargers at workplaces and multifamily houses. San Diego Gas & Electric was approved for the installation of 3500 utility-owned charging stations for $45 million (DOURIS, 2017).

Pacific Gas & Electric was approved by the California Public Utilities Commission for the largest deployment of charging stations in the USA: $130 million for 7500 charging points. The agreement works on a hybrid model (public-private partnership) in which the utility company owns and operates the chargers installed by third-party vendors in underserved markets. In the non-underserved markets, the company will support electrical infrastructure to the charging stations. PG&E will build at least 15% of the charging units in disadvantaged communities (BAUMHEFNER, 2016).

More recently, the California Public Utility Commission (CPUC) approved a $738 million portfolio of charging projects for Pacific Gas & Electric, San Diego Gas & Electric and Southern California Edison. This represents one of the largest public funding for electromobility infrastructure in the history (FEHRENBACHER, 2018).

The state of Kentucky presented a creative solution for the debate on utilities participation in the market. Louisville Gas and Electric and Kentucky Utilities are allowed to build and operate charging stations, but they should charge customers an extra hourly fee when charging their cars. That revenue is intended to recoup the investment and costs of the infrastructure so that those who do not use the service are not paying for it (DOURIS, 2017).

The contractual relationships in the utilities' case is usually similar to the ones in Public street charging (2.7.2.2) but may vary on each example given. In the cases in which the charging point management is exclusively public owned, the utility company works as aggregator, providing power at regulated fees and eventually charging for extra costs (the Kentucky case). When the utility company provides only the site infrastructure it works as supplier, and the private company acts as CPM, becoming similar to the Stations on private property with public access (2.7.2.3) (ROMÁN, MOMBER, *et al.*, 2010).

2.8.3. Third-party

The third-party companies are usually whether existing technology groups or new companies focused on electromobility charging. In the charging stations market, they aggregate two big advantages over the other options: differently from the utilities, it has a national scope and the advantage over the auto manufacturers is the possibility to provide different charging technologies to achieve every EV on the road. As a disadvantage, there is the tendency of these companies to concentrate in EV high density centers and their non-existence in regions where EV volumes are lower, caused by the low financial attractiveness of these zones (HOIUM, 2017).

In some countries, the governments create partnerships with these companies for giving incentive to the industry. That is made by public funding the charging network and is the case of Estonia, Ireland, Norway and Germany. There are, also, examples of third-party companies that started their networks with private funding, which is the case of UK Ecotricity (SERRADILLA, WARDLE, *et al.*, 2017).

With agreements with Volvo, Nissan, Ford and others, the technology company AeroVironment has a leading position in the Californian charger market, building a network on the West Coast with level 2 (19-42 km per hour of charge) and fast charging (~64 km per hour of charge) (HOIUM, 2017).

As other example, there is EVgo, created by NRG Energy but sold to an investment firm, that has the advantage of being an early mover and having partnerships with BMW, Ford and Nissan. Blink also represents a considerably large network in the American market, with about 4000 stations (HOIUM, 2017).

The third-party cases are simple Stations on private property with public access (2.7.2.3), in which the third-party company acts as CPM, buying energy and reselling to the final customer. The fees must be regulated by a responsible authority (ROMÁN, MOMBER, *et al.*, 2010).

2.8.4. Traditional fueling services companies

The global oil demand is expected to reach its peak in the next few years and, later, start a big decline and one of the main reasons for that is the development and growth of the electromobility industry. As a response to that, traditional fueling services companies are trying to get a position in that market. Recently, in order to achieve that, oil majors have been making big investments in companies of the electromobility sector (WARD e HOOK, 2018).

It is the case of the giant British Petroleum (BP) that recently invested $20 million in StoreDot, an ultra-fast charging batteries developer from Israel. The company also partnered with the Chinese private equity group, NIO Capital, to invest in “advanced mobility” technology in China, and bought a stake in FreeWire, a rapid-charging infrastructure American company (WARD e HOOK, 2018).

The Royal Dutch Shell bought an entire company that operates one of the largest EV charging networks called NewMotion. And Total S.A. acquired the Saft battery business and started developing next-generation EV technology (WARD e HOOK, 2018).

Many traditional fueling services companies are making agreements with charging station companies to diversify its offer and enter the market with lower investments. The Ionity joint venture has, among its 300 sites for charging points installation, many fueling stations (MCHUGH, 2018). ChargePoint, the largest charging network in the world, owns no charging stations of its own, it supplies charging hardware and software used to connect outlets and is owned by, among others, BMW, Daimler and Siemens. It has recently set an agreement with the Technical Services Group (TSG), a private-owned petrol station service group. TSG provides maintenance to about 32 thousand petrol stations in Europe and Africa, besides actively participating in their construction. ChargePoint aims to conquer even more European presence with this cooperation, by covering site construction, installation and maintenance of EV charging stations. The partnership is initially covering France, Germany, Ireland, Netherlands and Britain (STEITZ, 2017).

The participation of the traditional services fueling companies in the charging stations market falls into the third-party companies’ case and the contractual relationships are the ones in the Stations on private property with public access case (2.7.2.3) (ROMÁN, MOMBER, *et al.*, 2010).

3. DATA COLLECTION AND ASSUMPTIONS

In this section, the data necessary for the realization of the case study will be assessed by benchmarking and research. The main data wanted are costs and revenues information, including capital expenditure, operation and management, utilities costs and the usage fees.

Here, the use of benchmarking will help the estimation of costs. One important example used is the Rapid Charge Network (RCN) project built in the United Kingdom in 2014 and 2015 because of the big quantity of information available about it.

3.1. PARAMETERS USED

In this section some of the parameters used in the case study will be assessed mainly by benchmarking and making assumptions based on known information.

The useful life of the charging equipment is going to be considered of 10 years, the same as the declared by DBT in the Rapid Charge Network project. And at the end of the operational life, the charger will have a salvage value of 5% of its purchase price. The usability of the charger points is of 16h per day if there is enough demand (BLYTHE, NEAIME, *et al.*, 2015).

For the financial factors, the rates are assumed based on acceptable values found in literature. The annual discount rate is of 5% and the inflation rate for operating costs is 2% (SERRADILLA, WARDLE, *et al.*, 2017).

3.2. CAPITAL EXPENDITURE (CAPEX)

Among the capital expenditure expected for a network of charging stations, the most important factors are chargers purchase and delivery, installation project management, Distribution System Operator power connections, site preparation works and commissioning (SERRADILLA, WARDLE, *et al.*, 2017).

3.2.1. Chargers purchase and delivery

Chargers purchase and delivery include the actual charger costs and its warranties, their delivery to local storage facilities and their testing and updating (SERRADILLA, WARDLE, *et al.*, 2017).

For the accelerated charging stations, a benchmarking research was done with chargers between 7kWh and 22kWh of power. The prices in Italy for chargers from SCAME, obtained from the company by email are expressed on Table 4. The "*colonnine*" models shown are those similar to totems, that are probably going to be most used in public areas.

Table 4 - Prices from SCAME

Model	Price
Colonnine in lamiera verniciata - 7kWh	€3.784,96 - €7.221,78
Colonnine in lamiera verniciata - 22kWh	€4.731,68 - €6.773,08
Colonnine in acciaio INOX - 7kWh	€6.175,45 - €6.225,74
Colonnine in corten - 7kWh	€13.745,37 - €13.795,65
Colonnine light - 7kWh	€ 7.122,18
Colonnine light - 22kWh	€ 8.067,93

(SCAME, 2018)

The average price for a charging station obtained from the SCAME data is €7.764,38.

For fast charging stations, the RCN project is used as estimation base. In the project, the chargers had a power of 44kWh and the average charger purchase and delivery cost was approximately €25.737,41. That represents, in this project, 54,7% of the total CAPEX for an average charger unit, 49,9% for a charger unit with need for new power connections and 57,2% for a charger unit without in which a new power connection was not necessary. This represents the largest investment needed in the project (SERRADILLA, WARDLE, *et al.*, 2017).

3.2.2. Installation project management

Installation project management includes all on-site works management activities, like surveys, permissions and warrants. In the RCN project, the average charger installation project management cost was approximately €3.623,00. This represents 7,7% of the total CAPEX for an average unit in the project (SERRADILLA, WARDLE, *et al.*, 2017). This cost is considered to be the same for both fast charging stations and accelerated charging stations because of the equal need for an installation project management regardless of the power of the chargers.

3.2.3. Distribution System Operator power connections

DSO power connections are the costs related to the installation of new power connections between the charger and the local electricity distribution grid when necessary. It is a cost that depends on location and is affected by factors like power requirement, length of cable run and transformer requirements and may not be necessary if the charger is placed in a prepared location. In the RCN project, DSO new power connections were required in 26% of the charging sites and its costs varied from €1.240,49 to over €24.809,88, consisting of 14,2% of the total CAPEX for the average unit with new power connections. In the average charger that is a cost of €6.822,72. That represents 4,3% of the total CAPEX for an average unit (SERRADILLA, WARDLE, *et al.*, 2017). That cost is expected to be much lower for accelerated chargers than for fast chargers because of the necessity of specific high-power cables setting in the last ones. For that reason, the assumption made is that it is going to represent the same percentage of total CAPEX in both cases.

3.2.4. Site preparation works

Site preparation works involve all civil and electrical engineering works necessary for the installation of the charging station. In the RCN project, site preparation works represented the second largest investment needed. In the average charger unit, it consisted of 30,4% of the total CAPEX. Its approximate value is of €14.303,79 (SERRADILLA, WARDLE, *et al.*, 2017). This factor is also going to be considered proportional to the total CAPEX for accelerated charging stations because, due to their slower charging characteristic, they are mostly intended to be placed in places like public parking lots, that already have most of the site preparation needed, representing a smaller value for this type of charger.

3.2.5. Commissioning

Commissioning are the costs related to taking the equipment from local storage facilities to site, connecting to power and testing communication, functions and safety. In the RCN project, commissioning represented an average cost of €1.364,51 per charger unit. That is 2,9% of the average total CAPEX (SERRADILLA, WARDLE, *et al.*, 2017). This cost is expected to be the same for both fast and accelerated charging stations because it is not dependent on power.

3.2.6. Total CAPEX

The average total CAPEX estimated per unit for the accelerated charging stations is €17.677,37. And the average total CAPEX per unit for the fast charging stations from the RCN project was €47.051,94.

As a comparison and additional information, the average total CAPEX per unit for the fast charging stations in the EVA+ project developed in Italy and Austria is €42.500,00. This cost was found by dividing the total budget of the project (8.5 million euros) by the total number of charging stations (200) (BRIGATTI, 2017).

3.3. OPERATIONAL EXPENDITURE (OPEX)

Among the operational annual expenditure expected for a network of charging stations, the most important are electricity cost, site rent, back office running costs, maintenance insurance and unplanned maintenance (SERRADILLA, WARDLE, *et al.*, 2017).

3.3.1. Electricity cost

Electricity cost is the cost of the energy used and delivered to the clients' electric vehicles. Italian energy market has some obstacles when considering competitiveness. Its prices are among the highest in Europe, mainly due to the energy mix for electricity that is based on gas (differently from the European average that is focused on nuclear and coal energy) and the country's dependency on importation of electricity (DELOITTE, 2015).

The cost of electricity for non-domestic use in Italy can vary depending on the volume of consumption. The data below was taken from a United Kingdom Department of Business, Energy & Industrial report. Table 5 and Figure 18 - Annual electricity price for non-domestic consumers in Italy including taxes (€/kWh) show the average annual electricity price in Italy for non-domestic consumers in the last 10 years including taxes (UNITED KINGDOM DEPARTMENT FOR BUSINESS, ENERGY & INDUSTRIAL STRATEGY, 2018).

Table 5 - Annual electricity price for non-domestic consumers in Italy including taxes (€/kWh)

	Small Consumers	**Medium Consumers**	**Large Consumers**	**Extra Large Consumers**
2008	0,1582	0,1340	0,1201	0,1085
2009	0,1587	0,1278	0,1109	0,0934
2010	0,1539	0,1253	0,1106	0,1007
2011	0,1797	0,1344	0,1231	0,1008
2012	0,1922	0,1653	0,1328	0,1176
2013	0,1967	0,1565	0,1351	0,1149
2014	0,1974	0,1557	0,1362	0,1100
2015	0,1878	0,1487	0,1266	0,1055

2016	0,1812	0,1426	0,1247	0,0937
2017	0,1725	0,1335	0,1190	0,0871

(UNITED KINGDOM DEPARTMENT FOR BUSINESS, ENERGY & INDUSTRIAL STRATEGY, 2018)

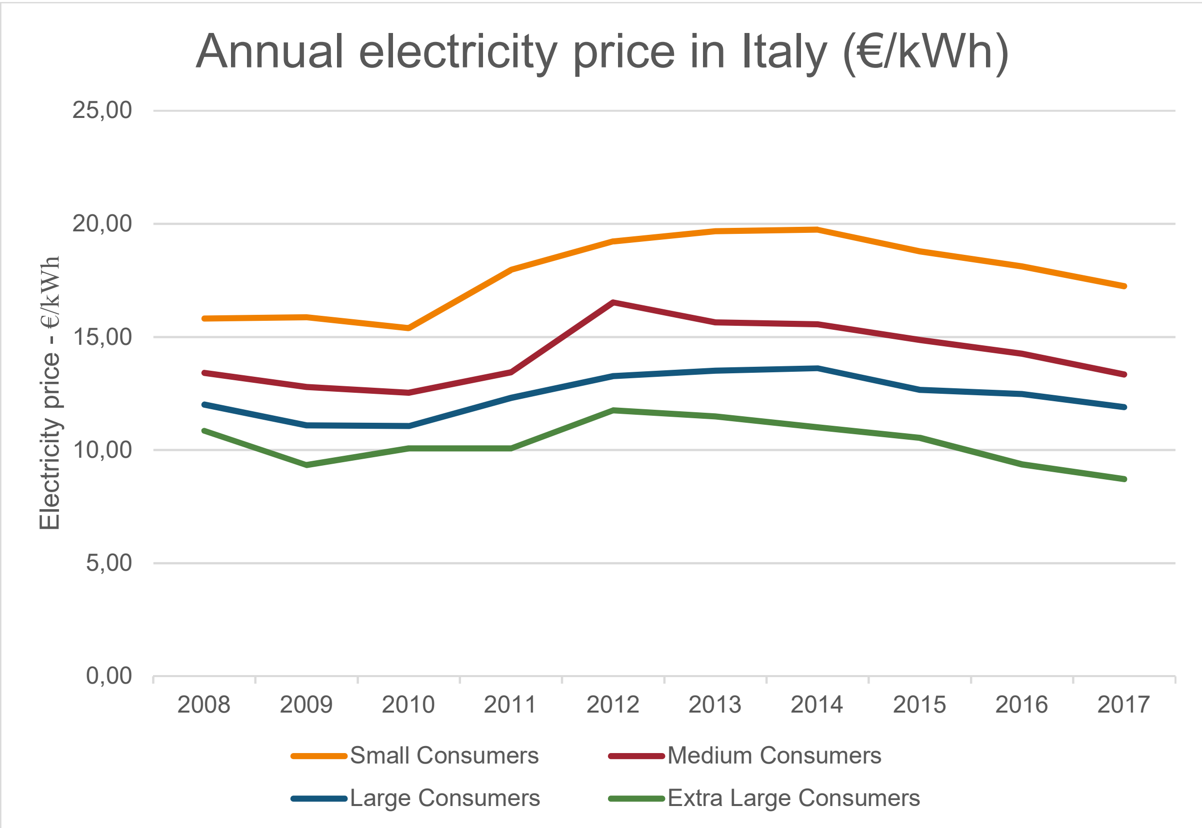

Figure 18 - Annual electricity price for non-domestic consumers in Italy including taxes (€/kWh) (UNITED KINGDOM DEPARTMENT FOR BUSINESS, ENERGY & INDUSTRIAL STRATEGY, 2018)

The consumers categories used in the data shown above are related to the size bands defined in Table 6.

Table 6 - Consumers categories size bands

Consumer categories	Annual consumption (MWh)
Small	20 - 499
Medium	2,000 - 19,999

Large	20,000 - 69,999
Very Large	70,000 – 150,000

(UNITED KINGDOM DEPARTMENT FOR BUSINESS, ENERGY & INDUSTRIAL STRATEGY, 2018)

Starting in 2013 the energy prices stabilized and even dropped. That is mainly due to the Italian National Energy Strategy (*Strategia Energetica Nazionale* – SEN) that was approved by the Economic Development Ministry (*Ministero dello Sviluppo Economico* - MISE) in that year. The strategy was made to improve competitiveness and sustainability of the Italian energy sector by 2020. Its objectives included reducing energy costs to align with the European average prices, once in 2012 they were 34% higher in the country than the average in the continent for residential customers (DELOITTE, 2015).

Among the objectives of the Italian National Energy Strategy for 2030, there is narrowing the gap in costs and prices for electricity. In 2015 the electricity in the country costed 25% above than the average in Europe for companies (MINISTERO DELLO SVILUPPO ECONOMICO; MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE, 2017). In the last years, electricity prices in Europe have risen mainly due to taxes, network charges and levies needed to finance investments and policy related to the development of renewable energies and a decarbonization of the industry (EUROPEAN COMMISSION, 2016).

With those information, an assumption taken is that the electricity price in Italy will be lower or equal to the average annual growth of electricity prices in Europe since 2008, that was, according to the European Commission (2016), 3% per year.

3.3.2. Planned maintenance costs

The planned maintenance costs include site rent, back office running costs and maintenance insurance. Site rent is the rental fee payed to the site operator and is only considered in the cases where the site where the charging station is placed is not purchased (in this case it would be put with the CAPEX). Back office running costs include those related to management of chargers, user-related costs (user registration and customer support services etc.) and fees for software provision, upgrades and development. Maintenance insurance are the routine checking costs and expected maintenance activities like call-out arrangements and stock of spare parts (SERRADILLA, WARDLE, *et al.*, 2017).

The most common issues that would require some kind of repair in existing charging points include: wear on the connector pins due to constant use that causes bad connection and need for replacement; damage from being hit by vehicles; and weather-related issues like charging cords damaged because of snow. The basic monthly care needed by a charging station include cleaning (once or twice a month depending on use) and cords inspection (at least once a month) (ENERGETICS INCORPORATED, CLEAN COMMUNITIES OF CENTRAL NEW YORK & THE ITHACA-TOMPKINS COUNTY TRANSPORTATION COUNCIL, 2017).

The practical experience of the Rapid Charge Network in the United Kingdom had an average annual planned maintenance cost of 3% of the charger purchase and delivery costs (SERRADILLA, WARDLE, *et al.*, 2017). This percentage is assumed to be the same for both fast and accelerated charging stations.

3.3.3. Unplanned maintenance costs

Unplanned maintenance costs are those for unexpected contingencies like vandalism and non-warranty part failure. A practical experience with 200 fast-charging stations in the UK for 3 years provided an approximation of unplanned maintenance costs to 4% of the charger purchase and delivery costs (SERRADILLA, WARDLE, *et al.*, 2017). This percentage is assumed to be the same for both fast and accelerated charging stations.

3.4. REVENUES

The expected revenue of a charging station comes primarily only from electricity sales. It is possible, taken the time needed to recharge an electric vehicle, to offer services that consist in additional sources of income like snack bars or amenities stores (SERRADILLA, WARDLE, *et al.*, 2017). Figure 19 shows the distribution of values spent in pounds in additional services in amenities adjacent to the charging stations. The average consumer spent £8,50 (BLYTHE, NEAIME, *et al.*, 2015). However, those additional services would add also new investments and costs to the operation, with high uncertainty and variability. Because of that, those additional activities are out of the scope of this study, that will take in consideration only the charging service selling as source of revenue.

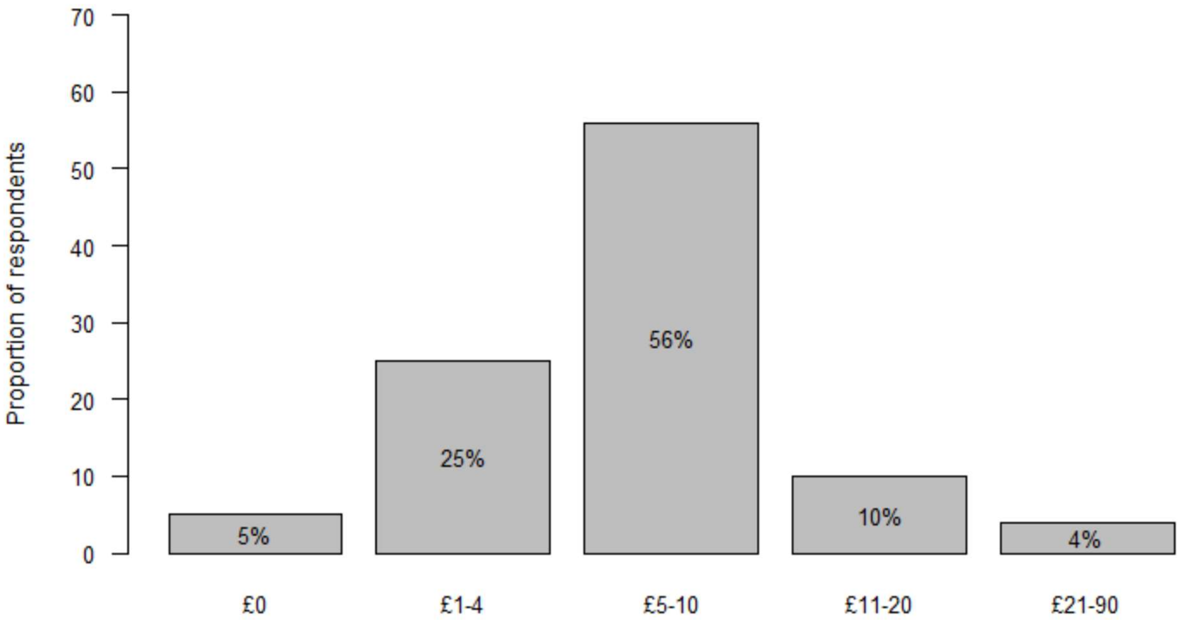

Figure 19 - Additional driver expenditure at adjacent retailing facilities (BLYTHE, NEAIME, et al.*, 2015)*

The AFI Directive let the operators to freely decide on the prices for electric vehicles charging, stating only that it should be reasonable, easily and clearly comparable, transparent and no-discriminatory (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2014). Because of that, the actual prices for electric vehicle charging have to be estimated based on benchmarking. Most authors affirm that there is a maximum that EV owners are willing to pay for charging. This limit value is assumed to be the equal to the running cost of internal combustion engine vehicles (SERRADILLA, WARDLE, *et al.*, 2017).

3.5. ADDITIONAL DATA

According to a Newcastle University study based on the Rapid Charge Network data, 71,1% of the energy used for electric vehicles recharging comes from home charging. Electric vehicles owners tend to program themselves to charge the vehicles at night at home or at work and the use of public rapid chargers is usually only for specific situations like longer trips, that require more electricity than the maximum range of the vehicle. Figure 20 and Figure 21 illustrate the relationship between the number of charge events and the travelled distance daily and weekly, respectively. Because of that, public chargers with slow-charging technologies are the least used source of energy: 3,5% of the total. The energy from rapid charger public locations represents 15,9% of the total used by electric cars. The remaining 9,5% comes from other locations like the work place (BLYTHE, NEAIME, *et al.*, 2015).

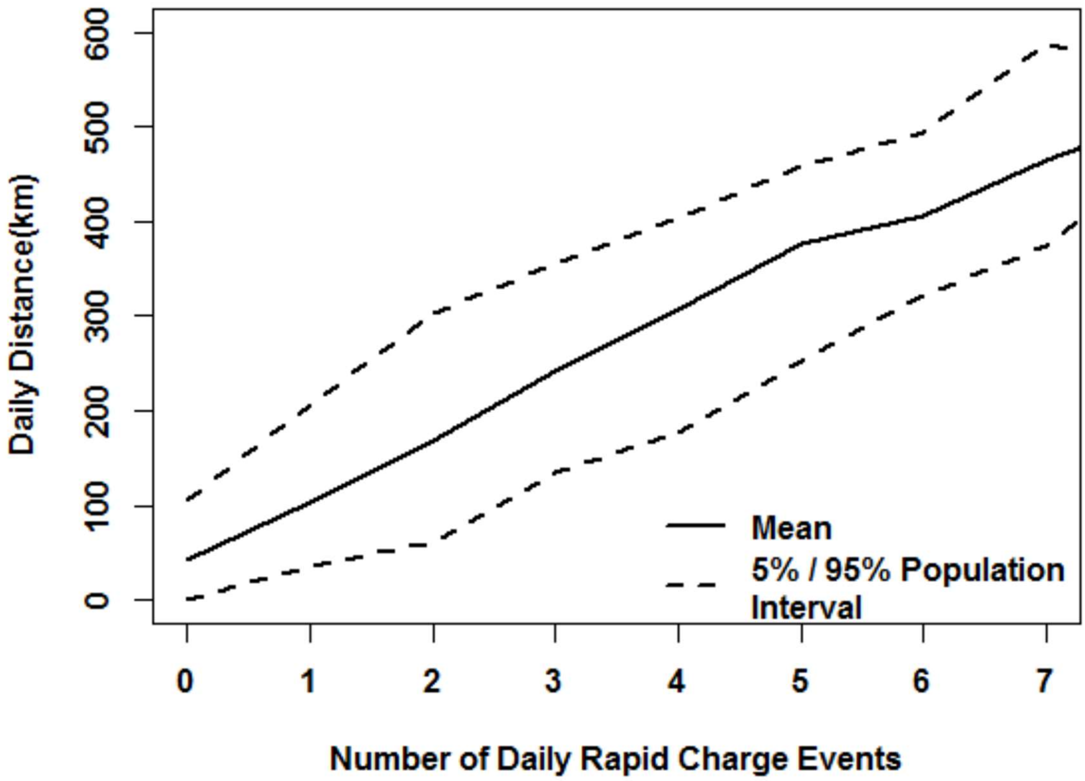

Figure 20 - Relationship between rapid charge events and daily distance travelled (BLYTHE, NEAIME, et al.*, 2015)*

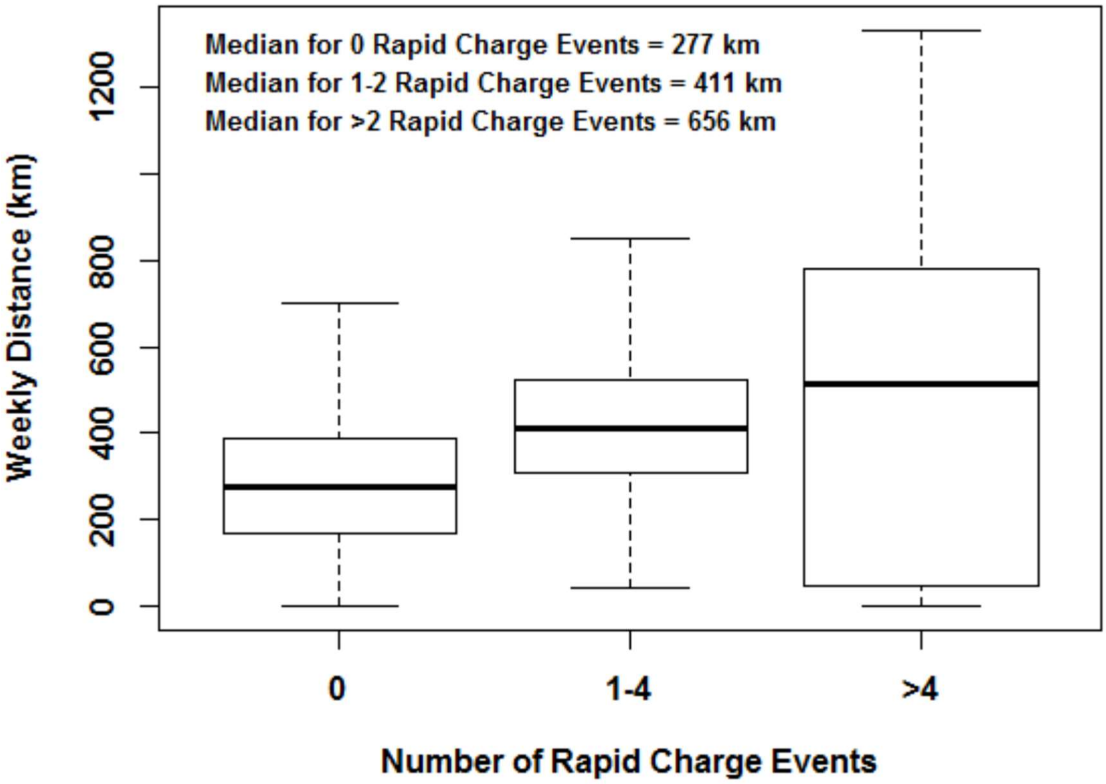

Figure 21 - Boxplots showing weekly driving distance and charging events (BLYTHE, NEAIME, et al.*, 2015)*

The National Infrastructure Plan for Charging Vehicles Powered by Electricity (*PNire - Piano Nazionale Infrastrutturale per la Ricarica dei veicoli alimentati ad energia Elettrica*) established for Italy some imported parameters and objectives that should be considered. First, it divided the charging stations by power: slow charging (*ricarica lenta*) stations are those with power inferior or equal to 7kWh, that can charge 1 or 2 vehicles a day; those with power between 7kWh and 22kWh are the accelerated charging (*ricarica accelerata*) stations, that can charge 2 to 6 vehicles a day; and those with power superior to 22kWh are considered fast charging (*ricarica veloce*) stations, that can charge up to 24 vehicles a day. The slow charging stations are considered mostly private possession for private use, while the fast charging and accelerated charging are of public interest (MINISTERO DELLE INFRASTRUTTURE E DEI TRASPORTI, 2016).

The PNire also stablishes that the proportion of charging stations for electric vehicles must be of 1:10 and that the ideal proportion of accelerated charging stations and fast charging stations is between 2:1 and 4:1 (MINISTERO DELLE INFRASTRUTTURE E DEI TRASPORTI, 2016).

The plan also includes the estimations that by 2020, 1-3% of the vehicles sales in the country are going to be electric ones and that the life cycle of an average car is of 7 years (MINISTERO DELLE INFRASTRUTTURE E DEI TRASPORTI, 2016). According to the Italian Car Dealers Federation (*Federazione Italiana Concessionari Auto – Federauto*), the electric vehicles fleet in Italy is of 0,1% of the total in 2018 (GIA e JADELUCA, 2018) and according to the International Energy Agency (IEA)'s EV30@30, the target for 2030 is of 30% sales share for electric vehicles (CLEAN ENERGY MINISTERIAL & ELECTRIC VEHICLES INITIATIVE, 2017). The IEA also stated that the market share of electric vehicles in Europe tend to be of 23% by 2030 (DICHRISTOPHER, 2018). The annual average mileage per car in Italy in 2015 was of 9.596 kilometers (ODYSSEE-MURE, 2015).

4. CASE STUDY – THE BIELLA PROJECT

The Province of Biella is located in the Piedmont, in Italy. It has an area of 913 square kilometers divided in 82 *comuni*, and a population of 178.551 people. The aim of this section is to assess a business plan for the installation of a complete infrastructure for electric vehicles charging in the province. The assessment will be made based on the information found in the literature and exposed previously in this work.

The electromobility market in Biella is gaining interest and in 2018 the government set partnerships and goals to develop its infrastructure for electric vehicles charging. The city intends to install chargers in points of interest for the general population like public parking lots and parking spaces for commercial centers. The province has already 4 stations in its territory. The business plan here developed has the objective to assess a financial analysis for a horizon up to 2030.

4.1. GOVERNANCE

The most suitable governance models for the Biella case are the public street charging and the stations on private property with public access. And two main players are the most important: the utility companies and private companies. There are basically two possible models:

The first model (Governance Model I) is divided into two very similar contractual relationships. They are the ones in which the private companies or the utilities companies act both as Charging Point Manager (CPM) and EV supplier-aggregator. When talking about private companies, they would be responsible for managing and operating the stations and would buy and re-sell energy from a DSO to the EV owners. In the utility case, the company operates and manages the station selling the energy directly to the drivers with an extra fee to cover costs from the station.

The other model (Governance Model II) consists in the outsourcing of the charging points by the utilities companies to private companies. That means the utility company would act as EV supplier-aggregator providing the energy through stations built and managed by the private companies that act as CPM. The private companies, here, acts as only an infrastructure provider.

The main differences between these models is in the costs and revenues structure. In the case in which a company acts as both CPM and EV supplier-aggregator, the electricity cost is included in the calculation and the revenues are variable depending on the amount of energy sold (or re-sold). In the case in which the utility company acts as EV supplier-aggregator and a private company acts as CPM, the cost of electricity is not included in the CPM's account and the revenues come as a fee or regular payment from the utility company based on the excess charged on the energy sold. In the first model the CPM is liable for a higher risk, while in the second one the risk remain on the aggregator and the CPM has a more comfortable and stable position.

In further analysis, both models are going to be considered and assessed in order to cover the main possibilities and even providing a judgement on each one is more favorable.

4.2. THE EV MARKET GROWTH IN BIELLA

The first important aspect to be considered is the number of electric vehicles that are going to be circulating in the province in the next years. It is important to emphasize that, as this market is exponentially growing, a dynamic analysis through the years must be made for a correct meeting of the demand.

The total number of cars in the province of Biella in 2015 was 126.497. As the population in the country has been nearly constant and tends to decrease in the next years (ISTAT – ITALIAN NATIONAL INSTITUTE OF STATISTICS, 2018) it is expected that the number of vehicles circulating do not have a significant growth. Thus, for the sake of simplifying the analysis, it is going to be assumed constant until 2030.

As stated before, the Italian electric vehicle fleet represents 0,1% of the total number of cars by 2018 (GIA e JADELUCA, 2018). So, using the 126.497 cars as base, it is expected the electric fleet in Biella to be of approximately 127. By 2030, that market share is expected to grow to 23% (DICHRISTOPHER, 2018), what will represent approximately 29,094 cars.

In order to estimate the annual growth of the electric vehicles fleet, some approximations were needed. Based on the data that, by 2020, 1-3% of car sales in

Italy are going to be of electric vehicles and that the life cycle of an average car is of approximately 7 years (MINISTERO DELLE INFRASTRUTTURE E DEI TRASPORTI, 2016), it was made the approximation that both in 2019 and 2020 the percentage of electric vehicles in total sales is going to be of 2%. The only reason this estimation was made is to find a trend curve that fits better in the future growth than a linear one.

Using these previous assumptions, in 2020 the total EV fleet in Biella is going to be of approximately 849. The calculus made was that one seventh of the total quantity of cars is exchanged by new models every year (because of the 7 years life cycle) and that 2% of that is going to be electric. No exchange from an electric car for a new electric car was considered due to the novelty of this market and, hence, the novelty of the existing cars circulating. Figure 22 represents the estimated curve for the total number of electric vehicles in Biella obtained.

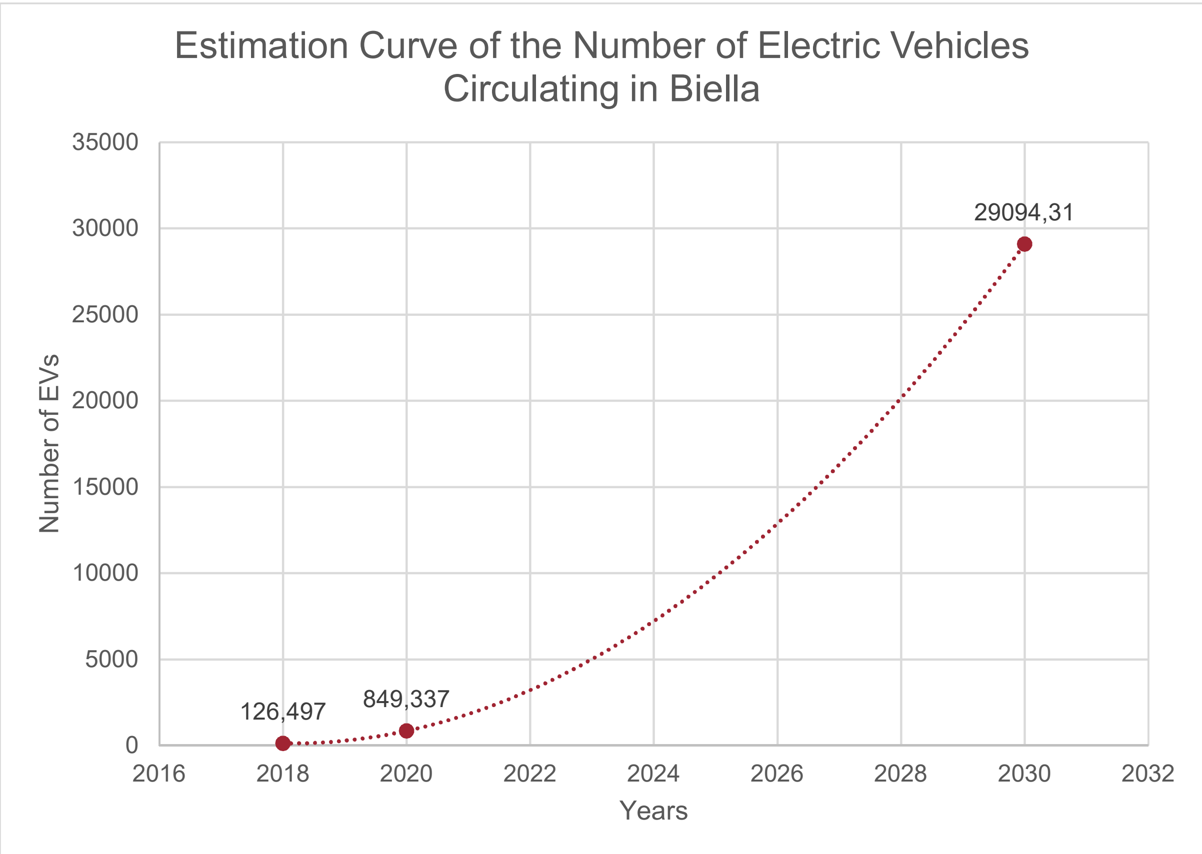

Figure 22 - Estimation Curve of the Number of Electric Vehicles Circulating in Biella

By linear interpolation, the numbers represented in Table 7 are going to be considered for further analysis.

Table 7 - Linear interpolation approximation of the number of EVs in Biella

Year	Number of EVs in Biella
2018	128
2019	284
2020	851
2021	1828
2022	3216
2023	5015
2024	7224
2025	9843
2026	12873
2027	16313
2028	20164
2029	24426
2030	29098

4.3. THE CHARGING STATIONS

The second step is estimating the quantity of charging stations needed throughout the years. Using the previous presented estimation of 1 charging point for each 10 electric vehicles circulating (MINISTERO DELLE INFRASTRUTTURE E DEI TRASPORTI, 2016) and the estimation of the number of electric vehicles yearly in Biella, Table 8 shows the estimated number of charging stations needed yearly and the number of new charging stations that must be installed yearly in order to correctly meeting the demand. The already existing 4 charging points in the province were taking in consideration. It was also considered that the project would begin only in 2019 due to the short time window left in 2018 for its implementation. Also, it was decided that the installation of new charging points would be made distributed throughout the entire time horizon studied (until 2030). The exponential growth of the market makes it impracticable to install all the projected stations at the beginning of the time window. It would be a too big initial investment and would cause most of the stations not to be much used because of the still small number of electric vehicles in the region.

Table 8 - Estimated number of charging stations needed yearly in Biella

Year	Number of charging stations needed	Number of NEW charging stations needed
2018	13	
2019	28	24
2020	85	57
2021	183	98
2022	322	139
2023	501	179
2024	722	221
2025	984	262
2026	1287	303
2027	1631	344
2028	2016	385
2029	2443	427
2030	2910	467

It is also important to consider the proportion of accelerated charging points and fast charging points considered ideal when between 2:1 and 4:1 (MINISTERO DELLE INFRASTRUTTURE E DEI TRASPORTI, 2016). Table 9 and Figure 23 show the estimations of yearly new stations needed for both types of charging stations for both the maximum and minimum proportions.

Table 9 - Number of new accelerated and fast charging stations needed yearly

	New accelerated charging stations in 2:1 proportion	New accelerated charging stations in 4:1 proportion	New fast charging stations in 2:1 proportion	New fast charging stations in 4:1 proportion
2019	16	20	8	5
2020	38	45	19	11
2021	65	78	33	20
2022	93	111	46	28
2023	120	144	60	36
2024	147	177	74	44
2025	175	210	87	52
2026	202	242	101	61
2027	229	275	115	69
2028	257	308	128	77
2029	284	341	142	85
2030	311	374	156	93

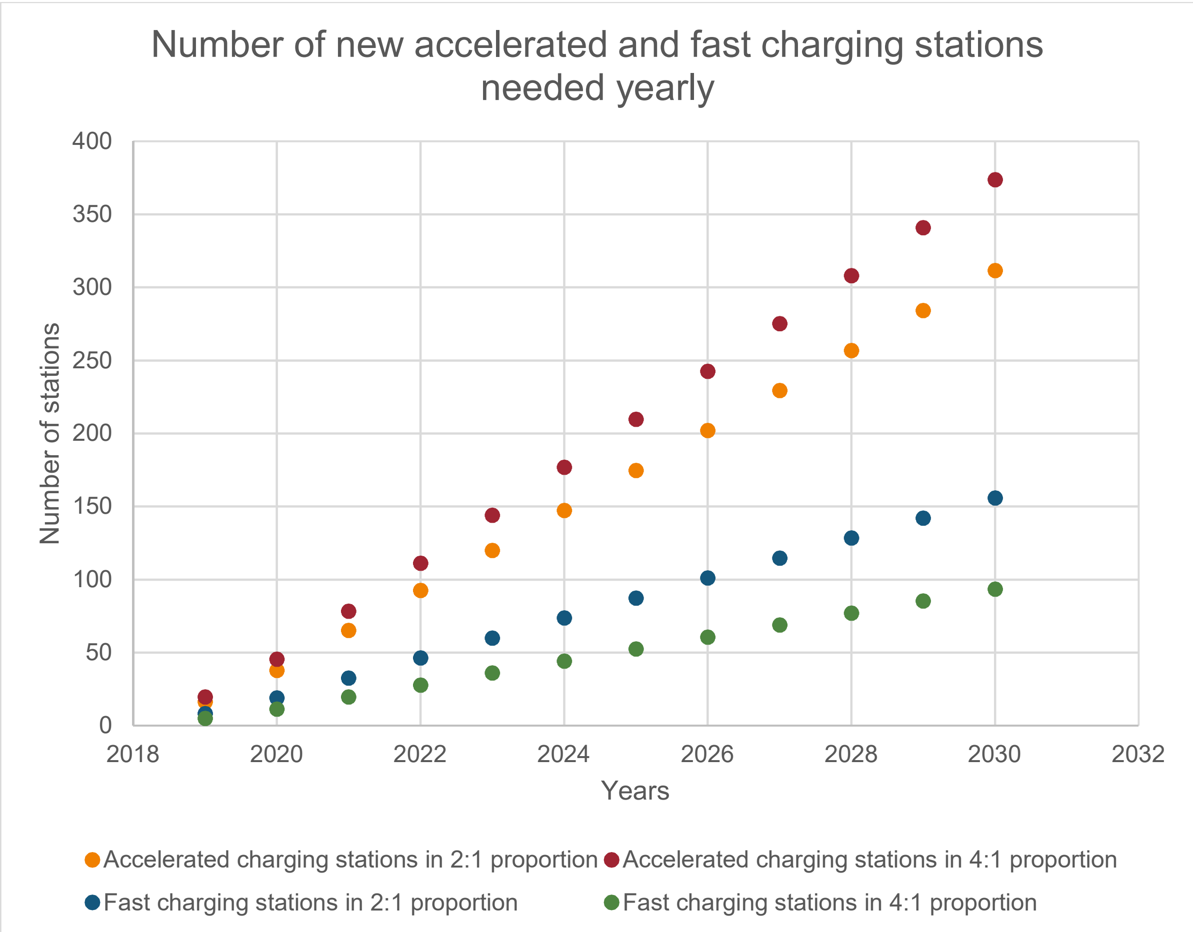

Figure 23 - Number of new accelerated and fast charging stations needed yearly

4.4. CAPEX FOR THE BIELLA PROJECT

With the estimations of the quantity of new stations needed for each type in the horizon studied and the estimations for the capital expenditures previously presented it is possible to assess the total investment needed yearly.

The average total CAPEX estimated per unit for the accelerated charging stations is €17.677,37. For the sake of simplifying further calculus, the value used is going to be of €17.700,00. It is expected that the difference of €22,63 is going to be insignificant for the final result obtained.

The average total CAPEX per unit for the fast charging stations from the RCN project was €47.051,94 and for the EVA+ project was €42.500,00. The EVA+ project is expected to have a more similar cost structure to the one found in Biella because of its geographical location (Italy and Austria) and because it is a more recent information.

These values are used as initial values for 2019 and an annual inflation rate of 2% is applied from 2020 on. With that in mind, the CAPEX value for both the maximum and minimum proportions of accelerated to fast charging stations were calculated, assessing, for every year, a range of values for the capital expenditure needed. Table 10 and Figure 24 show the results of those calculations.

Table 10 - Annual CAPEX for Biella Project

	CAPEX in proportion 2:1		CAPEX in proportion 4:1	
2019	€	634.002,13	€	553.266,56
2020	€	1.501.332,42	€	1.310.148,63
2021	€	2.640.408,41	€	2.304.171,55
2022	€	3.824.446,90	€	3.337.431,33
2023	€	5.054.790,77	€	4.411.099,83
2024	€	6.332.818,62	€	5.526.380,10
2025	€	7.659.945,66	€	6.684.507,14
2026	€	9.037.624,65	€	7.886.748,70
2027	€	10.467.346,83	€	9.134.406,13

2028	€	11.950.642,85	€	10.428.815,16
2029	€	13.489.083,76	€	11.771.346,78
2030	€	15.084.282,06	€	13.163.408,15

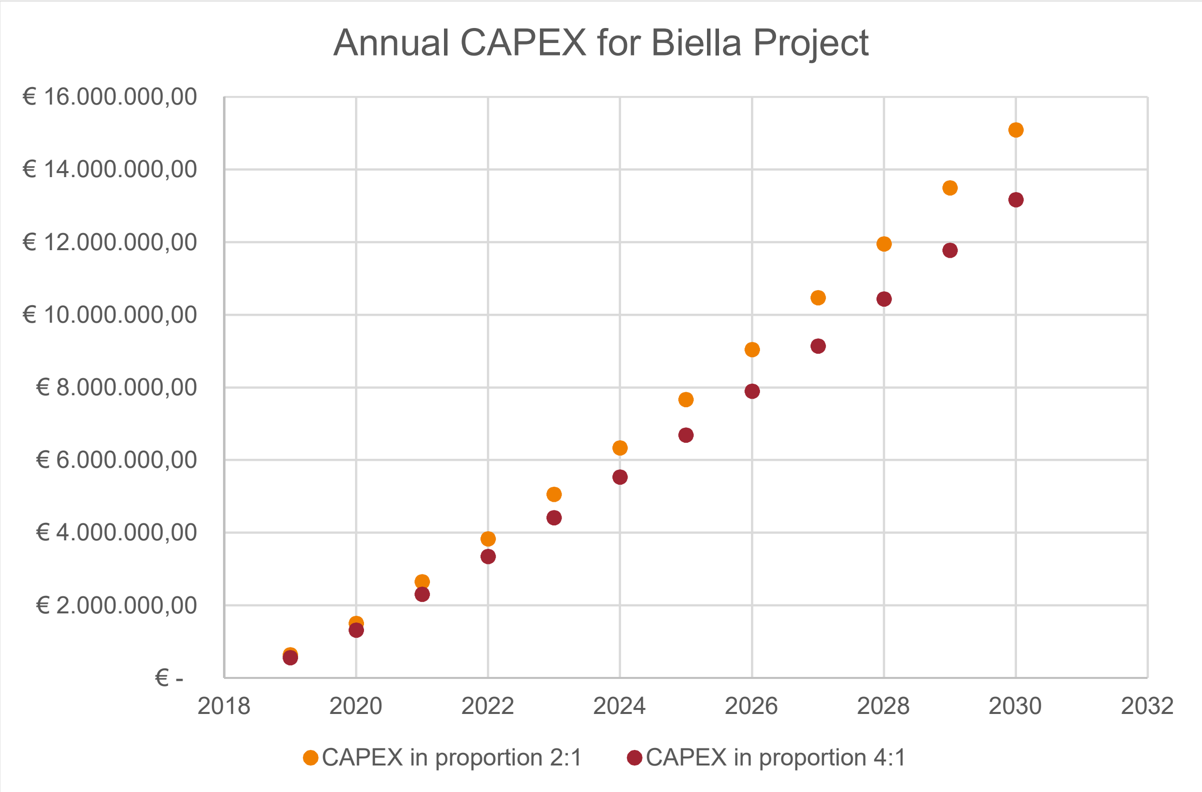

Figure 24 - Annual CAPEX for Biella Project

Considering an annual discount rate of 5%, the present value of the investment in both cases is calculated with Equation 1, where *PV* is Present Value, FV_n is the Future Value in the n^{th} year, *i* is the annual discount rate and *n* is the number of years passed.

Equation 1 - Present Value

$$PV = \sum_{n} \frac{FV_n}{(1+i)^n}$$

With that, the present value expected for the total capital expenditure needed is in the range from € 50.622.953,78 to € 58.010.122,09.

4.5. OPEX FOR THE BIELLA PROJECT

In this section, as previously explained, two main approaches for governance are going to be taken in consideration: the “Company acting as both CPM and aggregator” case and the “Company acting as outsourced infrastructure provider” case. The planned and unplanned maintenance costs do not have a differentiation in both cases, so are going to be treated earlier.

The annual planned maintenance costs are expected to be 3% of the charger purchase and delivery costs. The average price obtained for an accelerated charging station is €7.764,38. Thus, the annual planned maintenance cost for accelerated charging stations is considered to be € 232,93. For fast charging stations, the charger purchase and delivery costs are expected to be 54,7% of the total €42.500,00, that is € 23.247,50 and the annual planned maintenance cost (3% of that) is € 697,43.

The unplanned maintenance costs are expected to be 4% of the charger purchase and delivery costs. That means, for an accelerated charging station, an annual cost of € 310,58 and for a fast charging station, an annual cost of € 929,90.

Considering an inflation rate of 2% yearly, the annual costs for planned and unplanned maintenance for both the maximum and minimum proportion of accelerated and fast charging stations are expressed in Table 11.

Table 11 - Planned and unplanned maintenance costs in €

	Annual planned maintenance cost (2:1)	Annual planned maintenance cost (4:1)	Annual unplanned maintenance cost (2:1)	Annual unplanned maintenance cost (4:1)
2019	9.467,63	7.955,47	12.623,56	10.607,38
2020	22.419,58	18.838,73	29.892,90	25.118,54
2021	39.429,53	33.131,87	52.572,94	44.176,24

2022	57.110,92	47.989,20	76.148,22	63.986,19
2023	75.483,79	63.427,57	100.645,49	84.570,87
2024	94.568,74	79.464,27	126.092,19	105.953,34
2025	114.386,88	96.117,08	152.516,50	128.157,28
2026	134.959,93	113.404,21	179.947,34	151.207,00
2027	156.310,14	131.344,38	208.414,42	175.127,45
2028	178.460,38	149.956,79	237.948,19	199.944,23
2029	201.434,10	169.261,16	268.579,95	225.683,63
2030	225.255,38	189.277,73	300.341,80	252.372,63

4.5.1. OPEX for Governance Model I

In this case, the electricity cost is considered as a CPM's cost and must be estimated. For that, the amount of energy sold (or re-sold) yearly must be estimated.

Using the supply approach, the usability of the charger points is considered of 16h per day if there is enough demand. As the accelerated charging station is liable to charge up to 6 cars a day, in a 16h usable window, it can charge up to 4 vehicles. For the fast charging station working full day, the number of cars charged is up to 24, so, in the 16h interval, it is expected that up to 16 cars are serviced. That represents an annual supply for 1.460 vehicles per accelerated charging station and 5.840 vehicles for fast charging ones.

As previously explored in the literature review, the accelerated charging stations represent a charging level 2 destination AC charging, that have a maximum electricity consumption per charge of 32kWh. And the fast charging stations represent a charging level 3 fast DC charging, having a maximum electricity consumption per charge of 90kWh. That represents an annual supply of 46.720kWh per accelerated charging station (1.460 vehicles times 32kWh) and 525.600kWh per fast charging station (5.840 vehicles times 90kWh). Using the number or accelerated and fast charging stations planned for both the maximum and minimum proportions, Table 12 represents the total annual energy supplied.

Table 12 - Annual energy supply

Year	Total annual energy supply in kWh in 2:1 proportion	Total annual energy supply in kWh in 4:1 proportion
2019	5.038.160,21	3.479.182,34
2020	11.696.554,45	8.077.243,26
2021	20.167.497,81	13.926.989,06
2022	28.638.441,17	19.776.734,85
2023	37.109.384,53	25.626.480,64
2024	45.580.327,89	31.476.226,43
2025	54.051.271,25	37.325.972,22
2026	62.522.214,61	43.175.718,02
2027	70.993.157,97	49.025.463,81
2028	79.464.101,33	54.875.209,60
2029	87.935.044,69	60.724.955,39
2030	96.405.988,05	66.574.701,18

Using the demand approach, the annual average mileage per car in Italy in 2015 was of 9.596 kilometers. Assuming it will remain constant for the years studied, we have the total annual average mileage for all the electric cars in Biella distributed as show in Table 13.

Table 13 - Total annual mileage for EVs in Biella

Year	Number of EVs in Biella	Annual mileage (km)
2019	284	2.726.799,36
2020	851	8.166.196
2021	1828	17.544.942,56
2022	3216	30.863.039,04
2023	5015	48.120.485,44
2024	7224	69.317.281,76
2025	9843	94.453.428
2026	12873	123.528.924,2
2027	16313	156.543.770,2
2028	20164	193.497.966,2
2029	24426	234.391.512,2

2030	29098	279.224.408

An acceptable approximation is that the electricity consumption for an average EV is of 13,7kWh/100km and knowing that 71,1% of the energy used for electric vehicles recharging comes from home charging, it is possible to assess the total demand for energy in the years studied. The information obtained from that are shown in Table 14.

Table 14 - Total and non-domestic annual energy demand

Year	Total annual energy demand in kWh (13,7kWh/100km)	Non-domestic annual energy demand in kWh (28,9%)
2019	373.571,51	107.962,17
2020	1.118.768,85	323.324,20
2021	2.403.657,13	694.656,91
2022	4.228.236,35	1.221.960,30
2023	6.592.506,51	1.905.234,38
2024	9.496.467,60	2.744.479,14
2025	12.940.119,64	3.739.694,57
2026	16.923.462,61	4.890.880,69
2027	21.446.496,52	6.198.037,50
2028	26.509.221,37	7.661.164,98
2029	32.111.637,17	9.280.263,14
2030	38.253.743,90	11.055.331,99

Comparing Table 12 and Table 14 it is evident that the demand is inferior and, thus, Table 14 is going to be used as base for further calculations. Considering the consumers categories size bands in Table 6, this distribution would be considered as a small consumer until 2023 and a medium consumer from 2024 on. Assuming the energy price growth in Italy is going to be inferior or equal to the average in Europe, it is expected that it does not exceeds 3% yearly. The prices of electricity for the years studied and the total annual electricity cost expected are, therefore, the expressed in Table 15.

Table 15 - Expected energy price and total annual electricity cost

	Expected energy price (€/kWh)	Total annual electricity cost
2019	0,1830	€ 19.757,64
2020	0,1885	€ 60.945,13
2021	0,1942	€ 134.867,83
2022	0,2000	€ 244.361,24
2023	0,2060	€ 392.428,79
2024	0,1642	€ 450.610,98
2025	0,1691	€ 632.433,98
2026	0,1742	€ 851.928,91
2027	0,1794	€ 1.112.007,49
2028	0,1848	€ 1.415.746,68
2029	0,1903	€ 1.766.396,73
2030	0,1960	€ 2.167.389,55

Uniting the values for Table 11 and Table 15 it is possible to achieve the maximum and minimum total annual operational costs for this model, as shown in Table 16.

Table 16 - Total annual operational costs (Governance Model II)

	Total annual operational cost (2:1)	Total annual operational cost (4:1)
2019	€ 41.848,83	€ 38.320,49
2020	€ 113.257,60	€ 104.902,41
2021	€ 226.870,30	€ 212.175,93
2022	€ 377.620,39	€ 356.336,63
2023	€ 568.558,07	€ 540.427,22
2024	€ 671.271,91	€ 636.028,60
2025	€ 899.337,36	€ 856.708,34
2026	€ 1.166.836,18	€ 1.116.540,12
2027	€ 1.476.732,04	€ 1.418.479,31
2028	€ 1.832.155,25	€ 1.765.647,70
2029	€ 2.236.410,78	€ 2.161.341,52

2030	€ 2.692.986,74	€ 2.609.039,90

Considering the annual discount rate of 5%, the present value of the operational costs in the time horizon considered, calculated as shown in Equation 1 is in the range from € 7.585.529,58 to € 7.908.366,71.

4.5.2. OPEX for Governance Model II

In this model, the electricity cost is not considered as an operational cost. Therefore, the total annual operational cost is only the sum of the planned and the unplanned maintenance costs, as shown in Table 17.

Table 17 - Total annual operational costs (Governance Model II)

	Total annual operational cost (2:1)	Total annual operational cost (4:1)
2019	€ 22.091,19	€ 18.562,85
2020	€ 52.312,47	€ 43.957,28
2021	€ 92.002,47	€ 77.308,11
2022	€ 133.259,15	€ 111.975,39
2023	€ 176.129,29	€ 147.998,43
2024	€ 220.660,93	€ 185.417,61
2025	€ 266.903,38	€ 224.274,36
2026	€ 314.907,27	€ 264.611,21
2027	€ 364.724,56	€ 306.471,82
2028	€ 416.408,57	€ 349.901,02
2029	€ 470.014,05	€ 394.944,79
2030	€ 525.597,19	€ 441.650,35

Considering the annual discount rate of 5%, the present value of the operational costs in the time horizon considered, calculated as shown in Equation 1 is in the range from € 1.698.469,35 to € 2.021.306,48.

4.6. REVENUE FOR THE BIELLA PROJECT

Just like the operational costs, the revenues considered are dependent on the governance model considered. As the revenue is dependent on choices made by the charging point manager, the aim of this part is to provide different possible scenarios, that are going to be later studied in a sensibility analysis that involves the net present value and payback times.

4.6.1. Revenue for Governance Model I

In this first model, the revenues are only the amount of money received for the selling (or re-selling) of the electricity. Seven different scenarios with variation of the fee charged per kWh were assessed. Table 18 shows the seven scenarios studied. The values presented represent the initial price per kWh charged in 2019. It is considered that these prices are following the growth in the general electricity pricing, having a maximum growth of 3% per year.

Table 18 - Scenarios for electricity selling pricing

	Starting price per kWh in 2019	
Scenario 1	€	0,20
Scenario 2	€	0,25
Scenario 3	€	0,30
Scenario 4	€	0,35
Scenario 5	€	0,40
Scenario 6	€	0,45
Scenario 7	€	0,50

With that and the annual expected demand from Table 14, Table 19 and Table 20 show the expected annual revenues in each scenario studied.

Table 19 - Revenue scenarios (1 to 4)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
2019	€ 21.592,43	€ 26.990,54	€ 32.388,65	€ 37.786,76
2020	€ 66.604,78	€ 83.255,98	€ 99.907,18	€ 116.558,37
2021	€ 147.392,30	€ 184.240,38	€ 221.088,45	€ 257.936,53
2022	€ 267.053,80	€ 333.817,25	€ 400.580,71	€ 467.344,16
2023	€ 428.871,62	€ 536.089,52	€ 643.307,42	€ 750.525,33
2024	€ 636.320,70	€ 795.400,88	€ 954.481,05	€ 1.113.561,23
2025	€ 893.078,18	€ 1.116.347,72	€ 1.339.617,27	€ 1.562.886,81
2026	€ 1.203.033,27	€ 1.503.791,59	€ 1.804.549,90	€ 2.105.308,22
2027	€ 1.570.297,69	€ 1.962.872,12	€ 2.355.446,54	€ 2.748.020,96
2028	€ 1.999.216,52	€ 2.499.020,65	€ 2.998.824,79	€ 3.498.628,92
2029	€ 2.494.379,53	€ 3.117.974,41	€ 3.741.569,29	€ 4.365.164,17
2030	€ 3.060.633,00	€ 3.825.791,25	€ 4.590.949,50	€ 5.356.107,75

Table 20 - Revenue scenarios (5 to 7)

	Scenario 5	Scenario 6	Scenario 7
2019	€ 43.184,87	€ 48.582,98	€ 53.981,08
2020	€ 133.209,57	€ 149.860,77	€ 166.511,96
2021	€ 294.784,61	€ 331.632,68	€ 368.480,76
2022	€ 534.107,61	€ 600.871,06	€ 667.634,51
2023	€ 857.743,23	€ 964.961,14	€ 1.072.179,04
2024	€ 1.272.641,40	€ 1.431.721,58	€ 1.590.801,76
2025	€ 1.786.156,36	€ 2.009.425,90	€ 2.232.695,45
2026	€ 2.406.066,54	€ 2.706.824,86	€ 3.007.583,17
2027	€ 3.140.595,38	€ 3.533.169,81	€ 3.925.744,23
2028	€ 3.998.433,05	€ 4.498.237,18	€ 4.998.041,31
2029	€ 4.988.759,06	€ 5.612.353,94	€ 6.235.948,82
2030	€ 6.121.265,99	€ 6.886.424,24	€ 7.651.582,49

With that, the Equation 1 and the annual discount rate of 5% were used to calculate the present value for the time horizon studied (until 2030) for the revenue in each scenario (Table 21).

Table 21 - Revenue Present Value (scenarios 1 to 7)

	Revenue Present Value	
Scenario 1	€	8.090.084,70
Scenario 2	€	10.112.605,88
Scenario 3	€	12.135.127,05
Scenario 4	€	14.157.648,23
Scenario 5	€	16.180.169,40
Scenario 6	€	18.202.690,58
Scenario 7	€	20.225.211,75

4.6.2. Revenue for Governance Model II

In this model, the revenue comes from a regular fee payed from the utility company for the infrastructure service provided. This reduces considerably the risk from the charging point manager. For this study, 20 scenarios with annual fee varying from €500.000,00 to €10.000.000,00 were studied. In these scenarios, the annual revenue expected is constant and expressed for each case in Table 22.

Table 22 - Revenue scenarios (A to T)

	Annual revenue			Annual revenue	
Scenario A	€	500.000,00	**Scenario K**	€	5.500.000,00
Scenario B	€	1.000.000,00	**Scenario L**	€	6.000.000,00
Scenario C	€	1.500.000,00	**Scenario M**	€	6.500.000,00
Scenario D	€	2.000.000,00	**Scenario N**	€	7.000.000,00
Scenario E	€	2.500.000,00	**Scenario O**	€	7.500.000,00
Scenario F	€	3.000.000,00	**Scenario P**	€	8.000.000,00
Scenario G	€	3.500.000,00	**Scenario Q**	€	8.500.000,00
Scenario H	€	4.000.000,00	**Scenario R**	€	9.000.000,00
Scenario I	€	4.500.000,00	**Scenario S**	€	9.500.000,00
Scenario J	€	5.000.000,00	**Scenario T**	€	10.000.000,00

With that, the Equation 1 and the annual discount rate of 5% were used to calculate the present value for the time horizon studied (until 2030) for the revenue in each scenario (Table 23).

Table 23 - Revenue Present Value (scenarios A to T)

	Revenue Present Value		Revenue Present Value
Scenario A	€ 4.431.625,82	**Scenario K**	€ 48.747.884,00
Scenario B	€ 8.863.251,64	**Scenario L**	€ 53.179.509,82
Scenario C	€ 13.294.877,45	**Scenario M**	€ 57.611.135,64
Scenario D	€ 17.726.503,27	**Scenario N**	€ 62.042.761,46
Scenario E	€ 22.158.129,09	**Scenario O**	€ 66.474.387,27
Scenario F	€ 26.589.754,91	**Scenario P**	€ 70.906.013,09
Scenario G	€ 31.021.380,73	**Scenario Q**	€ 75.337.638,91
Scenario H	€ 35.453.006,55	**Scenario R**	€ 79.769.264,73
Scenario I	€ 39.884.632,36	**Scenario S**	€ 84.200.890,55
Scenario J	€ 44.316.258,18	**Scenario T**	€ 88.632.516,36

4.7. NET PRESENT VALUE FOR BIELLA PROJECT

For each of the scenarios studied, the net present value (NPV) was calculated by subtracting the present value of the OPEX and the CAPEX from the present value for the revenues. As both the CAPEX and OPEX were assessed for two extreme situations (proportions of accelerated and fast charging stations 2:1 and 4:1), the obtained results represent the maximum and minimum values for the net present value of the project.

The project counts with big capital expenditure in all of its time horizon and, thus, it is expected its net present value to be negative. Further, a study of the payback times and possible co-financing options are going to be made.

4.7.1. NPV for Governance Model I

For the seven scenarios studied for this model, the maximum and the minimum net present value were assessed and disclosed in Table 24 and Figure 25Figure 25 - Net Present Value (scenarios 1 to 7). As expected, they all have negative values and growing values as the initial price per kWh grows. The minimum values represent the proportion 4:1 as the number of the cheaper type of stations is bigger and the number of the most expensive one is smaller.

Table 24 - Net Present Value (scenarios 1 to 7)

	Net Present Value		
Scenario 1	**Max.**	-€	50.118.398,67
	Min.	-€	57.828.404,10
Scenario 2	**Max.**	-€	48.095.877,49
	Min.	-€	55.805.882,93
Scenario 3	**Max.**	-€	46.073.356,32
	Min.	-€	53.783.361,75
Scenario 4	**Max.**	-€	44.050.835,14
	Min.	-€	51.760.840,58
Scenario 5	**Max.**	-€	42.028.313,97
	Min.	-€	49.738.319,40
Scenario 6	**Max.**	-€	40.005.792,79
	Min.	-€	47.715.798,22
Scenario 7	**Max.**	-€	37.983.271,62
	Min.	-€	45.693.277,05

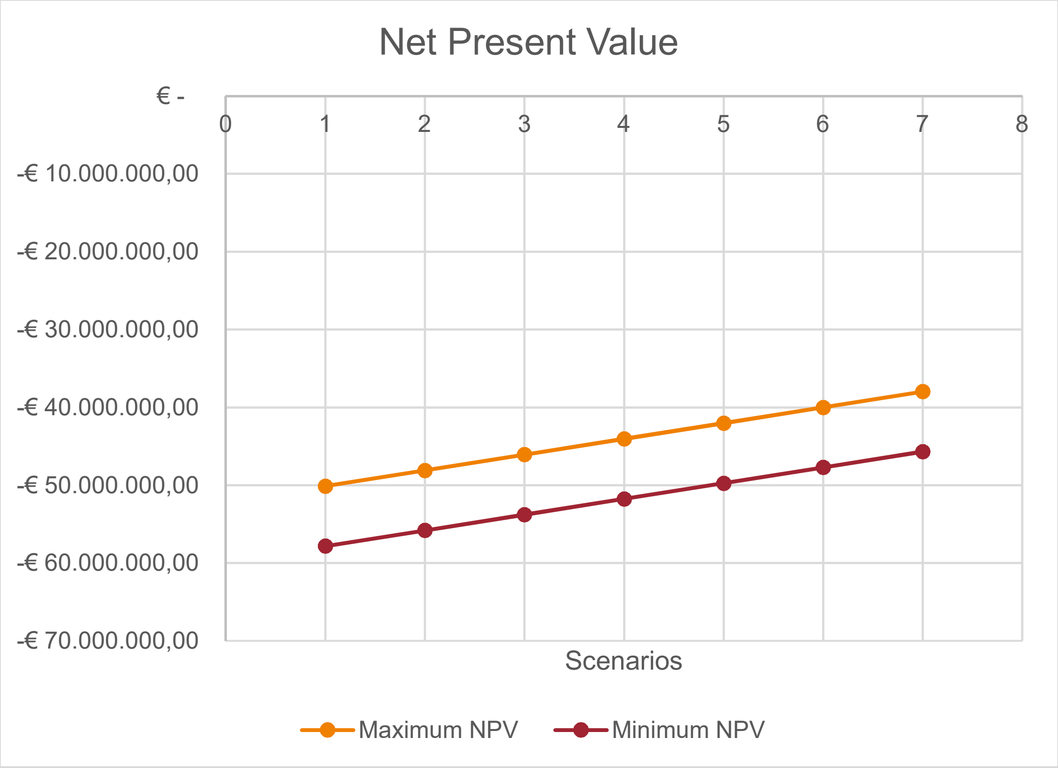

Figure 25 - Net Present Value (scenarios 1 to 7)

4.7.2. NPV for Governance Model II

Also, for the 20 scenarios studied in this model, the net present value was assessed for both the extreme proportions between accelerated and fast charging stations, obtaining a minimum and a maximum value for each case. Table 25, Table 26 and Figure 26 show de windows for net present values obtained for each case.

Table 25 - Net Present Values (scenarios A to J)

		Net Present Value
Scenario A	**Max.**	-€ 47.889.797,32
	Min.	-€ 55.599.802,75
Scenario B	**Max.**	-€ 43.458.171,50
	Min.	-€ 51.168.176,94
Scenario C	**Max.**	-€ 39.026.545,68
	Min.	-€ 46.736.551,12
Scenario D	**Max.**	-€ 34.594.919,86
	Min.	-€ 42.304.925,30
Scenario E	**Max.**	-€ 30.163.294,05
	Min.	-€ 37.873.299,48
Scenario F	**Max.**	-€ 25.731.668,23
	Min.	-€ 33.441.673,66
Scenario G	**Max.**	-€ 21.300.042,41
	Min.	-€ 29.010.047,84
Scenario H	**Max.**	-€ 16.868.416,59
	Min.	-€ 24.578.422,03
Scenario I	**Max.**	-€ 12.436.790,77
	Min.	-€ 20.146.796,21
Scenario J	**Max.**	-€ 8.005.164,96
	Min.	-€ 15.715.170,39

Table 26 - Net Present Values (scenarios K to T)

		Net Present Value
Scenario K	**Max.**	-€ 3.573.539,14
	Min.	-€ 11.283.544,57
Scenario L	**Max.**	€ 858.086,68

	Min.	-€	6.851.918,75
Scenario M	Max.	€	5.289.712,50
	Min.	-€	2.420.292,94
Scenario N	Max.	€	9.721.338,32
	Min.	€	2.011.332,88
Scenario O	Max.	€	14.152.964,14
	Min.	€	6.442.958,70
Scenario P	Max.	€	18.584.589,95
	Min.	€	10.874.584,52
Scenario Q	Max.	€	23.016.215,77
	Min.	€	15.306.210,34
Scenario R	Max.	€	27.447.841,59
	Min.	€	19.737.836,16
Scenario S	Max.	€	31.879.467,41
	Min.	€	24.169.461,97
Scenario T	Max.	€	36.311.093,23
	Min.	€	28.601.087,79

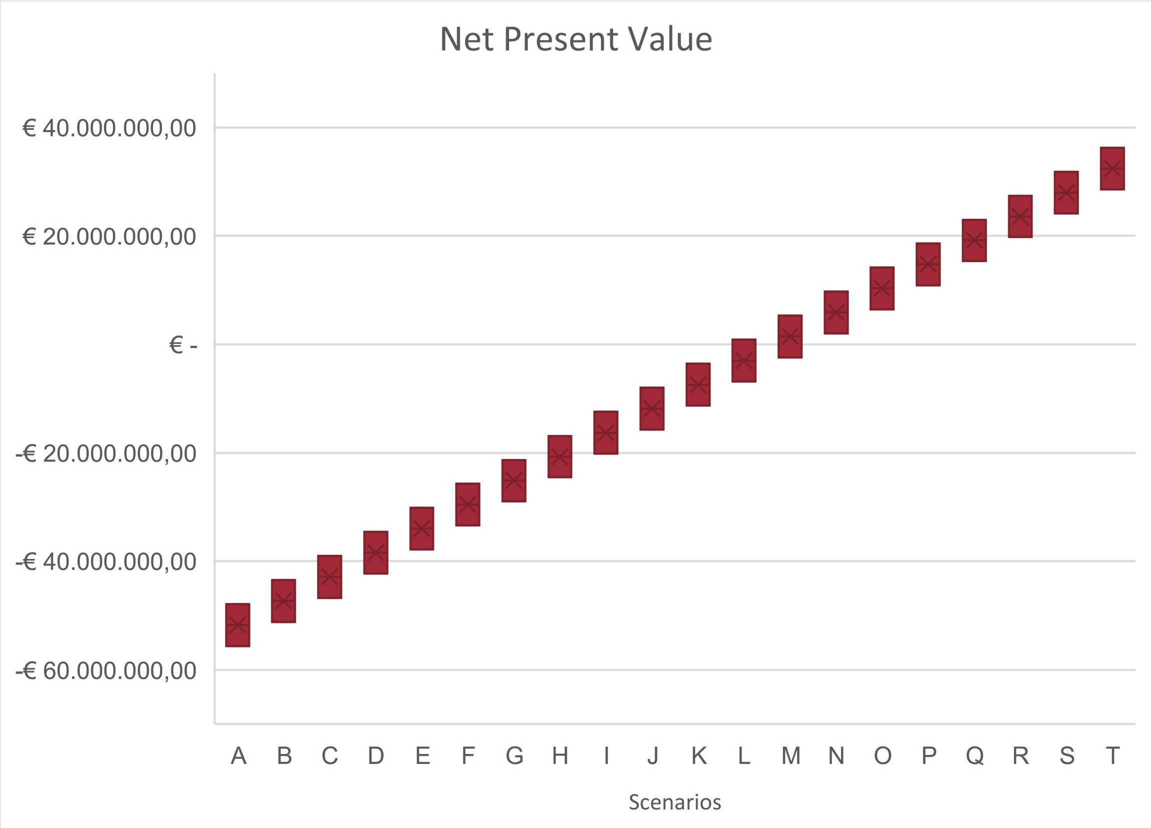

Figure 26 - Net Present Values (scenarios A to T)

As expected, most of the values obtained here were negative. On both scenarios L and M (annual revenue of €6.000.000,00 and €6.500.000,00), there are maximum values positive, what means that depending on the proportion chosen, it is possible to have a positive net present value for the project within the time horizon until 2030 for these scenarios. All the possibilities from scenario O to T (annual revenue of €7.000.000,00 to €10.000.000,00) have a positive net present value.

4.8. PAYBACK TIMES FOR BIELLA PROJECT

It was seen that most of the scenarios studied had negative net present values in the horizon studied (until 2030). That was expected due to the necessity of big investments in every year of the project. Because of that, a study of the payback times for every scenario was made. The payback times were obtained calculating when the net present value of the project would reach zero (breakeven).

4.8.1. Payback times for Governance Model I

Some assumptions were made for calculating the payback time for the Governance Model I. The calculation was made considering only the installment of the stations previewed for meeting the demand until 2030, that is, capital expenditure used after 2030 is not taken in consideration. The CAPEX, thus, is the same as the previously assessed for the project. For the operational costs, the planned and unplanned maintenance costs are considered the same of the expected for 2030 with only the variation of the inflation (2%).

For the electricity cost a series of conclusions were made. The demand for the years following 2030 were obtained by the equation obtained from the linear approximation for the non-domestic annual energy demand in Table 14, that provided a tendency for the future values. That energy demand was limited by the maximum energy supplied (Table 12) that is considered constant from 2030 on. The maximum was reached in 2054 for 2:1 proportion case and in 2048 for the 4:1 cases. That was combined with the expected cost per kWh (growth of 3% yearly) to obtain the total electricity cost, that was added to the planned and unplanned maintenance costs providing the OPEX.

It is important to highlight that in 2035 the consumer category for both cases (2:1 and 4:1 proportions) was changed for “Large Consumer” because the consumption exceeded 20.000MWh (Table 6). Again in 2049, the consumer category was changed for “Very large consumer” but, this time, only for the 2:1 proportion because the upper limit for energy supply for 4:1 proportion (66.575MWh) was inferior to the limit rate of 70.000MWh expressed in Table 6. Those consumer category size band upgrades resulted in inferior costs of energy.

With all the CAPEX and OPEX ready, the revenue was calculated starting with the initial value for each scenario (Table 18) with a 3% annual growth. The net present value was, then, calculated for these three factors according to Equation 1 and with the annual discount rate of 5%. The OPEX and CAPEX NPV were subtracted from the Revenue NPV for each year until the breakeven was found. The breakeven was achieved in the future year in which the NPV was equal or superior to zero. The payback time is the difference between the breakeven year and the beginning of the project (2019). Table 27 shows the results obtained for each scenario.

Table 27 – Breakeven year and payback time for Governance Model I

		Breakeven	Payback time
Scenario 1	**(2:1)**	2055	36
	(4:1)	2059	40
Scenario 2	**(2:1)**	2050	31
	(4:1)	2049	30
Scenario 3	**(2:1)**	2046	27
	(4:1)	2045	26
Scenario 4	**(2:1)**	2044	25
	(4:1)	2042	23
Scenario 5	**(2:1)**	2042	23
	(4:1)	2040	21
Scenario 6	**(2:1)**	2040	21
	(4:1)	2039	20
Scenario 7	**(2:1)**	2039	20
	(4:1)	2038	19

An interesting situation happened in this study. Usually (for scenarios 2 to 7), the best-case scenario is usually the one with proportion 4:1 and the worst-case in proportion 2:1. However, in scenario 1 that characteristic is inverted. That happens because of the combination of some factors like the different maximum amount of energy supplied and the extra change in consumer category for 2:1 proportion case. Figure 27 shows how the total annual energy supply stabilized in 2048 for 4:1 proportion and in 2054 for 2:1 proportion. Simultaneously, the electricity costs fell for the 2:1 proportion due to the upgrade in its customer category.

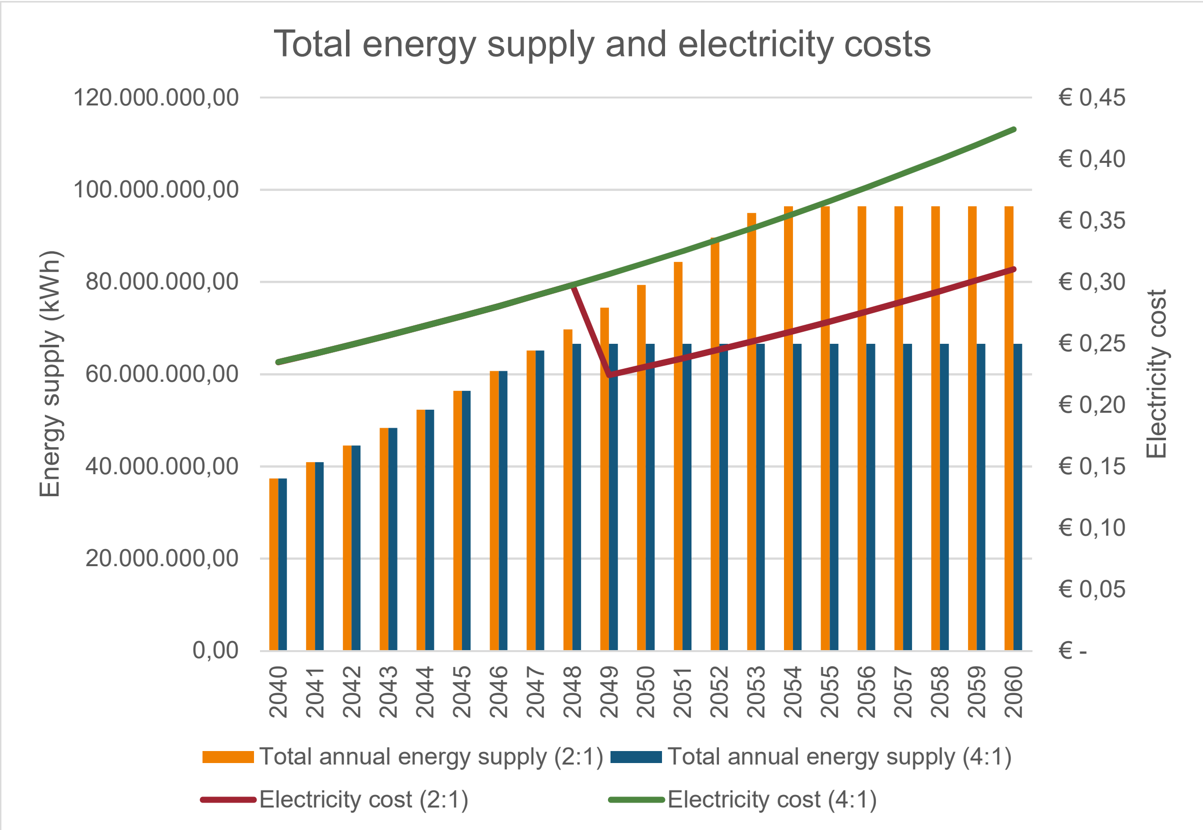

Figure 27 – Total energy supply and electricity costs (2040-2060)

Figure 28 shows how the characteristics of Figure 27 affect the total revenue and the energy cost (and consequently the total operational cost). While until 2048 the total revenue is the same for both the proportions, from that year on it is higher for the 2:1 case because of its higher energy supply. At the same time, in 2049 the total energy cost (and consequently total operational cost) for the 2:1 case falls under those from 4:1 proportion, and, even when it gets higher than the one for the 4:1 case, the difference between them is much smaller than the difference between the total revenues in both cases.

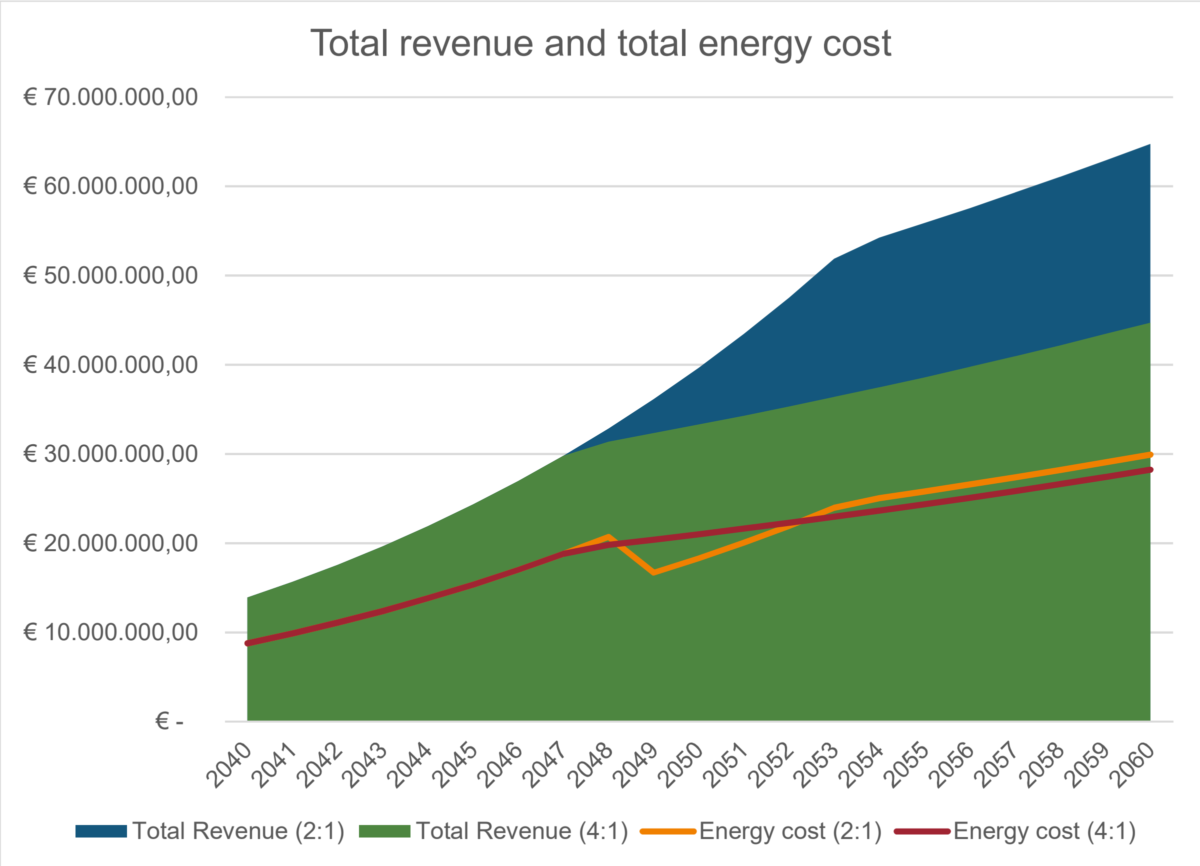

Figure 28 – Total revenue and total energy cost (2040-2060)

With a bigger revenue and lower operational costs, the 2:1 proportion achieves the breakeven before the 4:1 case exceptionally for scenario 1 (the only one in which it is not achieved before those years. Even if scenario 2's breakeven happen in 2049 and 2050 (after those happenings), the smaller amount of time needed for it to achieve the breakeven is not enough for the 2:1 case to have a considerable advantage.

4.8.2. Payback times for Governance Model II

Just like in the Governance Model I, the payback times in this model were found by finding the year in which the net present value for each case was equal or superior to zero. This case was simpler because it did not depend on the electricity cost. The OPEX was, then, considered constant after 2030, varying only in the inflation rate of 2%. The annual revenues were also considered constant and the annual discount rate was of 5%. Figure 29 and Figure 30 show the breakeven breakdown for proportions 2:1 and 4:1 respectively.

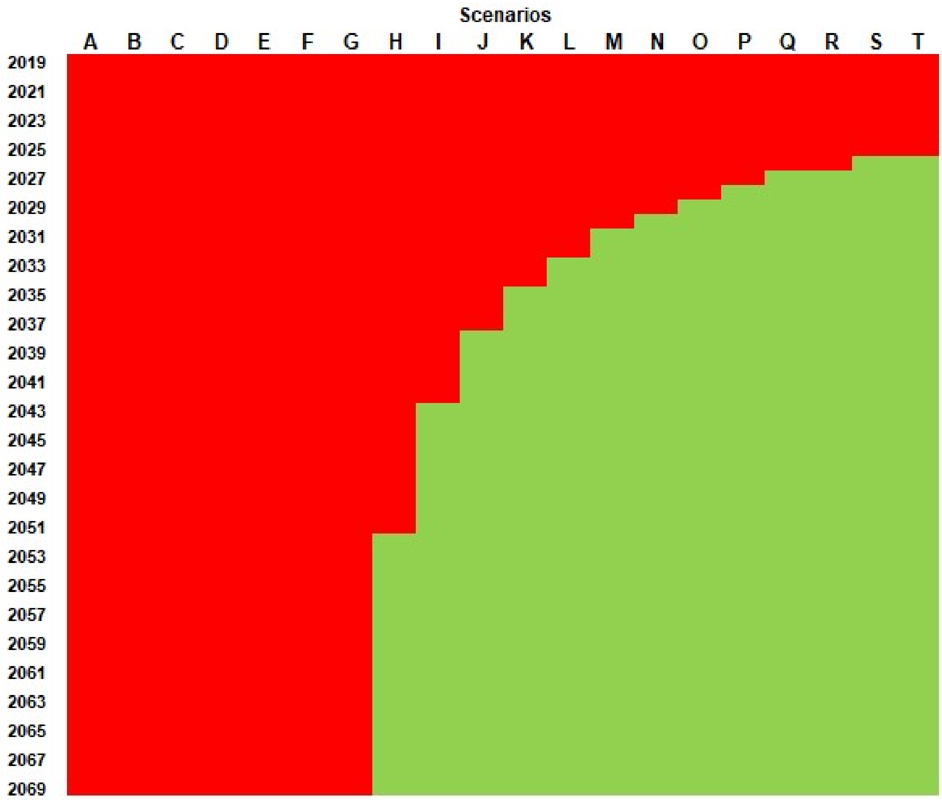

Figure 29 – Breakeven for Governance Model II in proportion 2:1

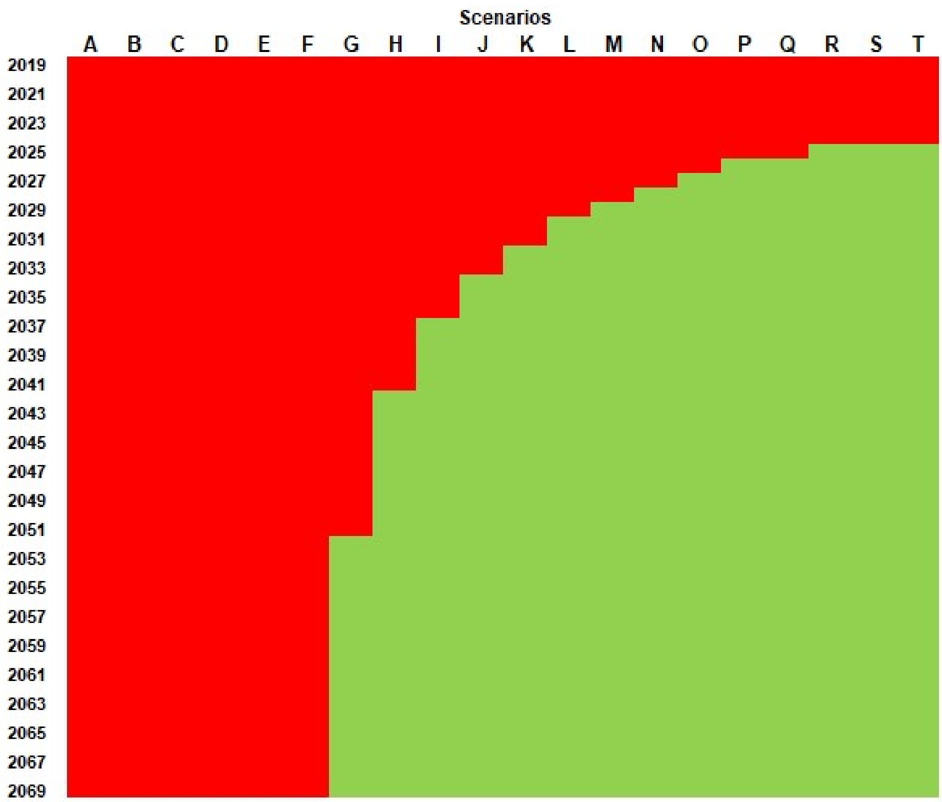

Figure 30 – Breakeven for Governance Model II in proportion 4:1

Table 28 summarizes the information from previous images and shows the payback times calculated. Payback times superior to 50 years were not considered.

Table 28 – Breakeven year and payback time for Governance Model II

		Breakeven	Payback time			Breakeven	Payback time
Scenario A	**(2:1)**	>2069	>50	**Scenario K**	**(2:1)**	2035	16
	(4:1)	>2069	>50		**(4:1)**	2032	13
Scenario B	**(2:1)**	>2069	>50	**Scenario L**	**(2:1)**	2033	14
	(4:1)	>2069	>50		**(4:1)**	2030	11
Scenario C	**(2:1)**	>2069	>50	**Scenario M**	**(2:1)**	2031	12
	(4:1)	>2069	>50		**(4:1)**	2029	10
Scenario D	**(2:1)**	>2069	>50	**Scenario N**	**(2:1)**	2030	11
	(4:1)	>2069	>50		**(4:1)**	2028	9
Scenario E	**(2:1)**	>2069	>50	**Scenario O**	**(2:1)**	2029	10
	(4:1)	>2069	>50		**(4:1)**	2027	8
Scenario F	**(2:1)**	>2069	>50	**Scenario P**	**(2:1)**	2028	9
	(4:1)	>2069	>50		**(4:1)**	2026	7
Scenario G	**(2:1)**	>2069	>50	**Scenario Q**	**(2:1)**	2027	8
	(4:1)	2052	33		**(4:1)**	2026	7
Scenario H	**(2:1)**	2052	33	**Scenario R**	**(2:1)**	2027	8
	(4:1)	2042	23		**(4:1)**	2025	6
Scenario I	**(2:1)**	2043	24	**Scenario S**	**(2:1)**	2026	7
	(4:1)	2037	18		**(4:1)**	2025	6
Scenario J	**(2:1)**	2038	19	**Scenario T**	**(2:1)**	2026	7
	(4:1)	2034	15		**(4:1)**	2025	6

As expected, because of the results of the net present values (Table 25, Table 26 and Figure 26), scenarios from A to K have their breakeven year after 2030, scenarios L and M have it on the year 2030 or before for the best-case situation and after it on the worst-case situation and scenarios from N to T have all breakeven years inside the horizon of the project (2030). An interesting fact is that scenarios from A to F and scenario G on the worst-case situation all have their payback times superior to 50 years. That happens because it was not considered re-evaluations of the annual fee payed by the utility company. Long-term projects are usually subject to periodical re-evaluation of values in order to fix possible discrepancies caused by inflation and by the de-valorization of capital. Figure 31 illustrates how the net present value vary for the proportion 2:1 (it is similar for proportion 4:1). This format happens because while the operational costs are growing due do inflation, the revenue is considered constant and, therefore, as time goes by, the net present value tend to decrease it's growing rate.

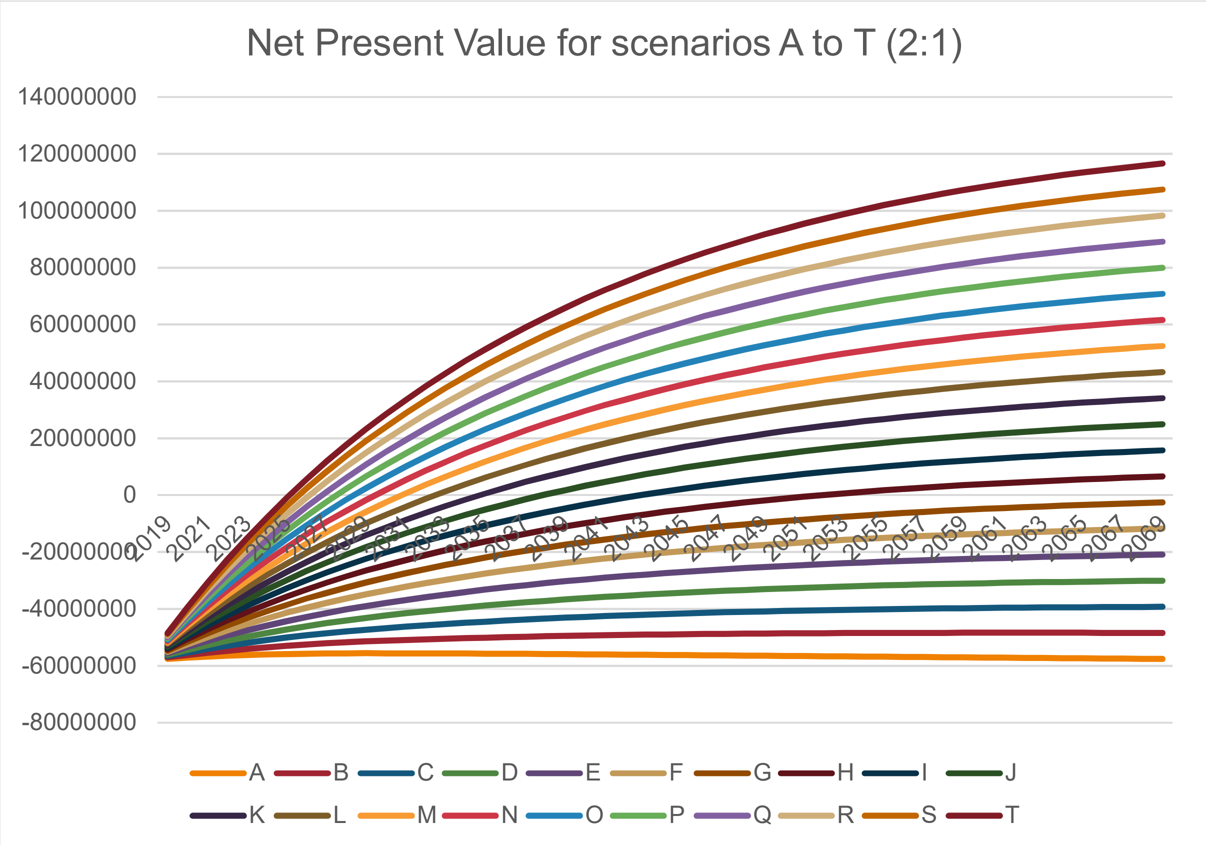

Figure 31 - Net Present Value for scenarios A to T in 2:1 proportion

4.9. CO-FINANCING POSSIBILITIES FOR THE BIELLA PROJECT

The Italian government and the administration of Piedmont offered project co-financing opportunities for electromobility infrastructure related works. With that, public money has been used to make it more attractable for companies to enter in this market. Usually, the co-financing does not exceed 50% of the total project capital expenditure.

Because of the payback high payback times found in most of the scenarios and having in mind that most of the net present values for the scenarios studied were negative due to the high investment requires, a study of co-financing results in it was made.

4.9.1. Co-financing for Governance Model I

Figure 32 shows a sensitivity analysis for different co-financing percentages in scenarios 1 to 7. Red spaces are those with negative net present values and green ones are those with positive. It is known that co-financing high above 50% of the total project investment are not very much feasible and realistic. The results show that, in the case of a 50% co-financing (50% of the CAPEX paid by government), the net present value of the project shows positive results (for the time horizon until 2030) when the price charging for selling (or re-selling) of energy is of €0,45 or above. For the initial price of €0,40 for the selling of energy, a positive net present value is possible depending on the proportion between accelerated and fast charging stations. However, these results prove that the model where company acts as both CPM and aggregator is a very risky one and, in the time horizon studied, is very probably going to present negative net present value.

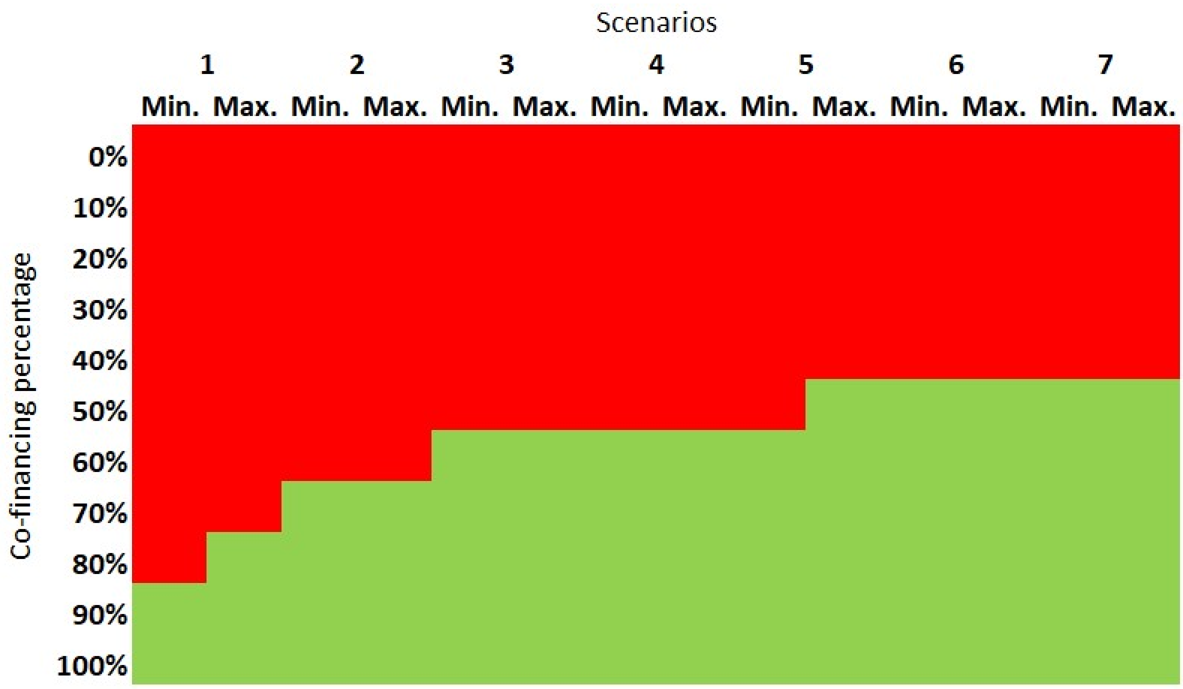

Figure 32 - Co-financing percentage results in NPV (scenarios 1 to 7)

4.9.2. Co-financing for Governance Model II

The same sensitivity analysis was made for scenarios A to T (Figure 33). Once again, the green spaces represent situations in which the net present value for the project within the time horizon until 2030 is positive and the red ones are the negative. As expected, once scenarios O to T represented already a positive NPV value without co-financing, they have a positive result for any percentage of it. Scenario N, that showed a minimum value negative for a 0% co-financing presented, also, for every situation from 10% to 100% a positive value. As stated before, a co-financing percentage high above 50% is not feasible and realistic. Thus, for any scenario from H to M (annual revenue from €4.000.000,00 to €6.500.000,00) there are plausible positive values for the project within 2030. For scenario G (annual revenue of €3.500.000,00), the net present value can assume positive values depending on the proportion for accelerated and fast charging stations chosen. As expected, this governance model presented much more reliable and less risky results for the charging point manager.

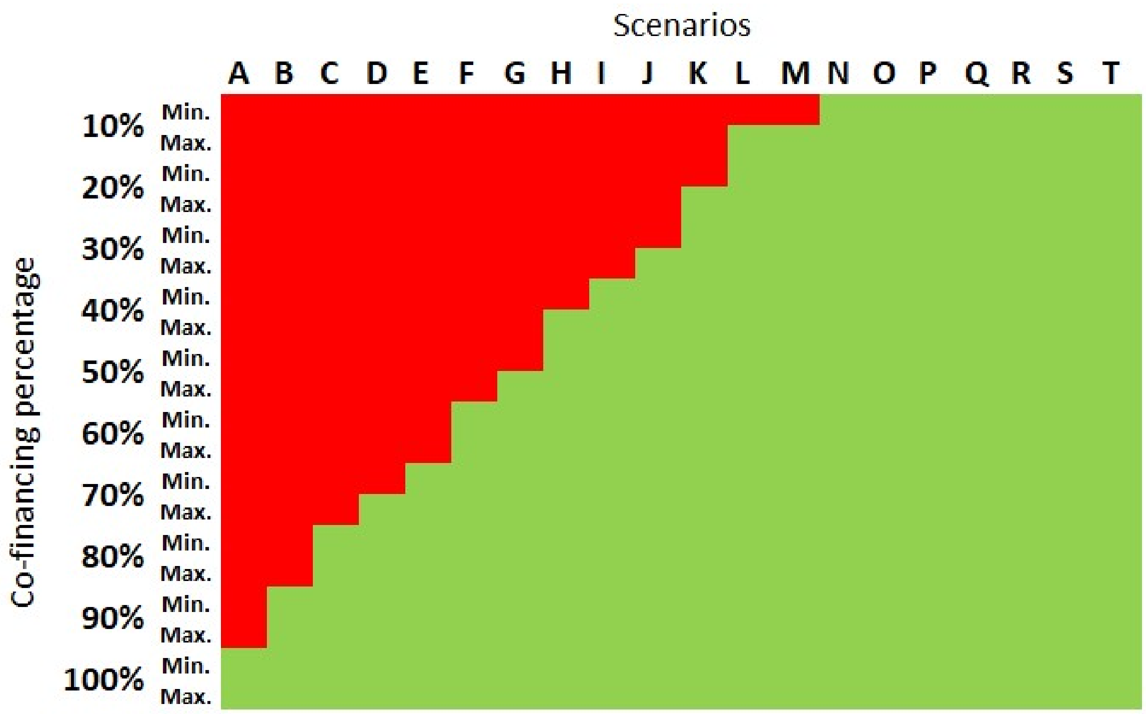

Figure 33 - Co-financing percentage results in NPV (scenarios A to T)

It was seen that, in the first model, the possibility of positive net present values for low percentages of co-financing is low. One explanation for that is that, in that model, the costs vary accompanying the revenues, because they are both linked to the amount of energy sold (or re-sold). In the second model, that linkage does not exists and when the revenue is increased the costs remain constant, making it possible more optimistic scenarios even with lower co-financing percentages.

5. CONCLUSION

After a broad review on the literature and a collection of important data, a case study was developed to assess the governance models and the economies related to the implementation of a complete infrastructure for recharging electric vehicles in the province of Biella. The time horizon chosen was from today until 2030, with the actual installment of the stations starting on 2019 and spread throughout these years keeping a reasonable proportion with the expected number of electric vehicles in the region.

For the governance model, two most probable possibilities were considered, and the calculations and analysis were made for both in order to obtain a base for comparison. The Governance Model I is that in which the company responsible for the station acts as both charging point manager and aggregator and the Governance Model II is the one in which the company responsible is an outsourced infrastructure provider contracted by the utility company, who is the aggregator and sells the energy.

Two bands of charging power were considered: the accelerated charging stations are those with its power between 7kWh and 22kWh, and the fast charging ones present power above 22kWh. The ideal proportion for these two types of chargers is between two extreme values and, thus, every calculation made after this distribution was made with a minimum and a maximum value based on it.

With those initial settings defined, an estimation of the number of electric vehicles in the province of Biella was made for every year until 2030 and the total number of charging stations as well as the number of each type of charger needed were calculated. After that, the analysis started by developing the cost structure of the project. Based on benchmarking obtained data, the capital expenditure and the operational costs for each case studied were obtained.

The capital expenditure factor was equal for both governance models and varied depending on the proportion between the types of stations needed. As this project has planned big investments through the complete time horizon, the capital expenditure values presented high values.

For the operational costs, the main difference was that for, Governance Model I, the electricity cost had to be taken in consideration. That meant a much higher annual operational cost expected for this model when comparing with the Governance Model

II. For estimating the electricity cost, the annual demand and supply of energy (based on the number of vehicles and the number of stations respectively) were used, as well as an estimation of the growing prices of energy in the future.

With the cost structure ready, the revenues were estimated. For Governance Model I, the revenues were considered to coming from the energy selling (or re-selling), while for Governance Model II it was a regular periodical fee payed by the utility company to the outsourced infrastructure provider. Sensitivity analysis were made in both cases, with varying energy selling price and periodical fees respectively. The results obtained were, then, paired with the previously obtained capital and operational expenditures.

Firstly, the net present values expected for the project were calculated in each situation. It was reached by subtracting the present value of the investments and costs from the present value of the revenues within the time horizon considered (until 2030). As the project predicts the constant installment of new points throughout its duration, it was expected its net present values to be negative. That expectations were met for most of the cases, except for cases on the Governance Model II with annual revenues equal or superior to €6.000.000,00. On average, the net present values for the project in the first governance model were much higher than the ones for the second. It is considered much safer and less risky for the charging point manager to receive a periodical fee than to depend on the amount of energy sales to profit.

The next step was to study the breakeven years and payback times for each scenario. For the Governance Model I, the payback times were on average smaller, with the highest one being 40 years from the start of the project. However, while having some really high payback times, the variation on the Governance Model II payback times was much bigger, with its lowest value equal to 6 years (13 years shorter than for the first model). The explanation for that is that no re-evaluation of the contractual payments was considered. In long-term contracts it is usual to re-calculate the payments periodically. So, depending on the value agreed and on the conditions for periodical re-evaluations, the Governance Model II is still preferred, offering less risk to the company.

The last step was the study of co-financing options. The Italian government and the administration from Piedmont offered in the last years the possibility for co-financing projects for the upgrading of the electromobility system in the region. For each scenario, the effect of co-financing in different percentages on the net present value of the project were analyzed. As expected, it had a greater effect on the Governance Model II. That happens because, in the first model, one important cost considered is the energy cost, that is not affected by the co-financing. At the same time, in the second model, the operational costs are much smaller and less variable, leading a co-financing scenario to have a big effect on the net present value of the project.

Analyzing the characteristics studied, it is understood that Governance Model II should be preferred: it presents much smaller risks and, with a coherent periodical contractual re-evaluating clause and the possibility of co-financing, will present much higher net present values and a greater possibility of success and profits for the responsible company.

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