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Prospects for the electrification of light and ultralight vehicles in cities considering an evolutionary scenario of sharing mobility

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Abstract in Italian

L'industria dei veicoli di trasporto è destinata a cambiare radicalmente nei prossimi anni. A causa della presumibile riduzione delle risorse di petrolio e gas a prezzi ampliamente accessibili, dell'inquinamento locale nelle città, della diffusione della sharing economy, dell'aumento della popolazione in alcune parti del mondo e della migrazione verso le città ancora in corso in alcuni continenti, la mobilità deve esprimersi in modo più congruente alle esigenze dei tempi, promuovendo la mobilità elettrica in particolare in città e traendo vantaggio dalla sharing mobility, laddove utile.

Lo scopo di questa tesi è, prima di tutto, quello di offrire una panoramica generale sull'industria dei veicoli elettrici e di presentare le opportunità e le problematiche ad essa associate. In secondo luogo, il documento tratta il concetto di sharing mobility e delle sue varie caratteristiche. Infine, l'obiettivo principale di questo lavoro è quello di valutare le prospettive di elettrificazione dei veicoli stradali in uno scenario evolutivo di sharing mobility. Viene anche utilizzata una metodologia Delphi per prevedere l'evoluzione della mobilità nelle città, basandosi sul raggiungimento del consenso tra esperti.

Un ulteriore obiettivo è quello di analizzare le aree di utilizzo ottimali per i veicoli elettrici in ambito urbano, tenendo conto delle loro caratteristiche in termine di massa, autonomia, costi e tempi di ricarica.

I risultati mostrano un forte consenso verso la mobilità elettrica nelle città. Un certo numero di esperti ritiene che il miglior veicolo elettrico dovrebbe essere un'auto piccola e leggera, o addirittura uno scooter se utilizzato in flotte di servizi di sharing mobility, alimentati da un motore completamente elettrico, con 5 posti e con un’autonomia della batteria superiore ai 300 km, seppure alte autonomie implicano masse consistenti stante la densità energetica delle batterie odierne. Inoltre, secondo esperti, le città offriranno molte stazioni di ricarica elettrica pubbliche e avranno una rete di smart grid perfettamente integrata con i veicoli elettrici. Molte applicazioni potranno essere sostituite da flotte di veicoli elettrici, come la consegna dell'ultimo miglio, i servizi postali, alcuni trasporti pubblici, il car sharing e i servizi di ride sharing.

Condizioni comuni per l’utilizzo di veicoli elettrici sono la possibilità di ricarica la sera, l’utilizzo del veicolo per tragitti brevi caratterizzati da un ritorno ad una base comune nella quale sia possibile ricaricare le batterie.

Abstract in English

The mobility industry is expected to change radically in the next few years. Because of the presumable reduction of oil and gas resources, the pollution in urban contexts, the introduction of the sharing economy, the increase of population in some areas of the world and the migration towards cities, the mobility must adapt, to move towards electric mobility in urban contexts and to take advantage of sharing mobility.

The purpose of this M.Sc. thesis paper is, firstly, to offer a general overview on the electric vehicles industry and to present the opportunities and the issues associated with it. Secondly, it discusses the concept of sharing mobility and all its features. Finally, the main goal of this work is to assess the prospects for the electrification of vehicles in an evolutionary scenario of sharing mobility. In particular, a Delphi methodology has been used in order to forecast the evolution of mobility in cities, by obtaining a consensus among experts.

A further objective is to analyse the optimal areas of use for electric vehicles in urban areas, taking into account their characteristics in terms of mass, autonomy, costs and recharging times.

The results show a strong agreement towards e-mobility in cities. A number of experts consider that the best electric vehicle should be a car, or even a scooter if used in sharing mobility fleets, being powered by a full electric motor, having 5 seats and with a mileage higher than 300 km, though high autonomies imply relevant masses given the present power density of the electric batteries. Moreover, they believe that cities will offer many public charging stations and will have smart grid network perfectly integrated with electric vehicles.

Many applications are supposed to be substituted by full electric fleets, such as last-mile delivery, postal services, some public transports, car sharing and ride sharing services.

Common conditions for the use of electric vehicles are the possibility of charging in the evening, the use of the vehicle for short journeys characterized by a return to a common base in which it is possible to recharge the batteries.

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1. Executive Summary

1.1 Problem definition and objectives

Nowadays, the automotive sector is pushing for Electric Vehicles (EVs) due to an increased sensibility towards the environment, aiming at reducing greenhouse gases (GHG) emissions such as CO2 and pollution in cities, but also due to the fact that fossil fuels will not last forever and new technologies have to be developed to guarantee the future of mobility. It is important to notice that Electric Vehicles have some specific characteristics in term of efficiency, charging time, discharging time and mileage that must be considered to shape the future of mobility. Governments are also implementing policies incentivizing the adoption of EVs in their countries and they are investing in the infrastructure of cities to reach the objective of sustainable mobility.

In addition to that, thanks to the evolution of Internet Technology, to the diffusion of smartphones and to the ability of managing real time data, a new way of moving around cities has appeared and it is called Sharing Mobility. Sharing mobility allows cities to have less vehicles, it helps to solve some problems related to parking, it allows to reduce the number of passengers using public transports that in some cities are always overloaded and it creates diversity in mobility modes in cities.

The goal of this thesis is first to analyse the prospects for EVs in cities, then to assess which application or use of light/ultralight vehicles can benefit from a full electrification and to understand how sharing mobility can together with EVs impact on the shape of future mobility in cites and on the infrastructure. A further analysis assesses the best characteristics required by electric vehicles if used for urban mobility.

1.2 Structure of the work

The thesis is divided into five main parts. The first part is dedicated to a literature review on the recent and past papers discussing about the future of electric mobility and car sharing.
The second part is focused on the description of EVs, from a general overview and a picture of the market, to the analysis of the current technology, followed by a focus on batteries and on charging systems.
The third part is intended to introduce the concept of sharing mobility. Different types of shared mobility modes are analysed together with the impact it has on the future infrastructure of cities.
The following part shows the Delphi methodology that has been used to assess the prospects for electric vehicles in an evolutionary scenario of sharing mobility. A brief introduction of the methodology is made before discussing in detail the study, showing the assumptions, the questionnaires that have been used and the results that have been obtained.
The last part analyses the best features required by electric vehicles to be used in cities, by taking into account current technology and real data on distance travelled.

1.3 Main Results

The goal of this thesis was to assess the prospects for the electrification of vehicles in an evolutionary scenario of sharing mobility. Thanks to a Delphi methodology approach, the future of mobility has been assessed by obtaining the consensus among experts. Then, with the creation of a model, the best electric vehicle for urban mobility has been found.

First, focusing on the issues affecting the adoption of electric vehicles, experts believe that high prices, the lack of charging infrastructure, the issues related to batteries such as mileage and safety and some cultural barriers (i.e. the lack of knowledge about electric vehicles technology, the tendency to prefer traditional engines, etc.) have a strong impact on the diffusion of electric vehicles.

Secondly, experts believe that the ideal electric vehicle should be a 5 seats car, having a full electric motor, with at least 300 km mileage. On the other hand, if the electric vehicle is expected to be used in sharing mobility fleets, then it should be rather a car or a scooter, with a mileage between 100 km and 300 km and powered by a full electric vehicle.

Moreover, according to experts, there are many fleets that will be substituted by full electric vehicles in cities. As a matter of fact, they agreed that last-mile delivery, postal services, car sharing and ride sharing services, public transports, police fleet and electricians, plumbers and painters' vehicles can be substituted by full electric vehicles, since they have some common characteristics that are perfectly suitable for the use of battery electric vehicles.

In addition to that, experts consider that in the next 10 years, public parking and roads will offer many charging stations for electric vehicles, roads will be adapted for the transit of autonomous cars and electric public transports. There will be more space in cities thanks to a diffusion of sharing mobility and this will allow to create more parks and public spaces in cities. Smart grid is expected to be fully integrated with electric vehicles and with renewable energy sources. Very few experts believe that there will not be major changes in the infrastructure of cities. Cities will offer new recharging spots in places such as sport centres, supermarkets, parking, old gas stations, private houses and close to offices.

Finally, the results showed that the lightest electric vehicle to be used in cities should be an ultralight electric vehicle, weighting between 85 kg and 395 kg, with an average battery energy of 6.5 kWh and having batteries that can be fully recharged in around 5 hours.
Moreover, ultralight vehicles represent the cheapest solution available on the market to satisfy the urban mobility.
These results offer also the opportunity to think about modular vehicles and the mechanism of battery swap to improve the range of the vehicle and to satisfy any mobility requirement of citizens.

2. Literature Review

The prospects for the electrification of vehicles in an evolutionary scenario of sharing mobility have been discussed in late 2012 by (Luè A., 2012). They proposed a business model for Electric Vehicles Car Sharing (EVCS) systems that highlighted the opportunity that this network offers to increase sustainability in cities. In fact, (Vervaeke M., 2015) confirmed the importance of EVs in Car Sharing services that have experienced a positive evolution in the past years, especially due to the fact that users were ready to use EVs. (Parzinger G., 2016) carried out a study on the use of s in the fleet of car sharing companies in Germany, pointing out that only one quarter of providers doesn't have EVs in their offer. Another research from (Lemme R., 2019) shows that the electric vehicle technology will certainly play a major role in the fleet composition of station-based car sharing systems, helping the society moving towards sustainable mobility. In effect, many authors believe that car sharing can benefit from the use of EVs. (Fairley, 2013) presented a report showing the added value generated by EVs from the users' point of view, considering also the shape of these systems in cities. At the same time, (Kim, 2015) demonstrated the positive reactions from customers that, according to a survey, were willing to use these systems. According to (Plötz, 2015) the use of EVCS systems is particularly influenced by Government policies that must propose some subsidies and they have to work on electricity prices to make EVs attractive both for companies and citizens. (Hao, 2017) believe that to increase the appeal of EVs, tax exemptions, free parking in city centres and other incentives have to be offered by Governments. To support the decision makers, (González Palencia, 2017) advise to develop consistent research to be also able to evaluate the future penetration of EVs in fleets.

The goal of the thesis is not to model sharing mobility systems using EVs, since a lot of studies have been made on this topic. (Illgen S., 2018) carried out an analysis on this type of network by proposing a simulation model that indicated different success factors linked to the competitive advantage offered by the electrification of vehicles in car sharing systems. In addition to that, many authors such as (He, 2017) and (Li, 2016) focused on the issues related to these systems, specifically related to battery issues and on performance, as it is investigated by (Zhang, 2017). Then, (Helmers, 2017) make a life-cycle assessment for electric mobility, aiming at helping to shape the future of sharing EVs.

The aim of the thesis is to assess the prospects for the electrification of vehicles considering also the evolution of sharing mobility in cities. (Vasconcelos, 2017) discusses about how EVs impact all the three dimensions of sustainability - environmental, social and economic – considering the point of view of both sharing mobility operators and any other stakeholders.

Another important topic that has been discussed widely in literature is the infrastructure of cities that have to be adapted to this new type of vehicles requiring charging stations for example (Brandstätter, 2017) state that car sharing companies need to push towards the implementation of charger infrastructure to be able to switch their fleet to 100% electric. Moreover, (Lee, 2017) developed a model to assess how to allocate public charging stations. Another interesting article was published by (Levinson, 2017) in which they proposed different scenarios made of several fleet compositions and power-trains technologies in order to understand what the impact on the future infrastructure would be.

3. Electric Vehicles (EVs)

3.1 General overview and market

3.1.1 History

The history of EVs begins in the first half of the 19^{th} Century when Ányos Jedlik, a Hungarian engineer, inventor and priest created the first electric motor powering a small car (Guarnieri, 2012). Few years later, in 1834 Sibrandus Stratingh, a professor of Chemistry and Technology at the University of Groningen, built another small electric car with non-rechargeable batteries. One of the main issues at that time was represented by the fact that batteries used for electric car models were not rechargeable. Only in the second half of 1800 an engineer and inventor, Thomas Parker invented in London the first electric car using batteries that could be recharged (The Daily Telegraph, 2009).

At the beginning of the 20^{th} Century, many companies, such as the Electric Vehicle Company, operating in cities like London, Paris or New York decided to develop fleets of taxis made of EVs. The development in cities was due to the exclusive features of these engines that allowed to travel short distances and they reduced pollution that was already a major problem at that time. Even if that period is reminded as the Golden Age of EVs, in which more than one third of vehicles were powered by an electrical engine in the United States of America, some major issues for the further development of EVs were related to the lack of infrastructure outside cities, to the deficiency of recharging structures, to the high costs that enabled only the high-class to travel using these vehicles and to the intrinsic characteristics of low driving range and slow speed. (Kirsch, 2000)

The abovementioned factors, together with the progression in technology for traditional engines, to the cost reduction in gasoline and in gas-powered vehicles related to the beginning of mass production, lead to a progressive decline in the success of electric vehicles in the middle of the 20^{th} Century.

In the 60s, new efforts were made to develop the research and the prototyping of new battery EVs and plug-in EVs but without relevant success. Only at the beginning of the last decade of the 20^{th} Century, the increase in interest towards the environment created a new wave of attention for electric vehicles, thanks to the new trend of creating zero-emission vehicles. Again, the diffusion was not so relevant due to the low speed and short mileage. In fact, around the World, the main type of EVs was the Neighbourhood Electric Vehicle (NEV), a small battery EV able to reach low speeds, the maximum speed was around 40 kilometres per hour, fully electric, not producing GHG emissions and recharged in specific chargers spread all over the cities.

In late 2000s, thanks to the mass production of the first full electric sports car made of Lithium-Ion batteries, the Tesla Roadster, having a mileage of around 320 kilometres (Shahan Z. , 2015), many car automakers begun to propose new electric models both Battery Electric Vehicles (BEVs) and Plug-in EVs (PEVs) all over the World, from China to USA passing from Europe.

From 2010 until now, thanks to the rapid increase of customers demand, all major manufacturers are offering EVs models to mass market. In 2014, Nissan Leaf was the best electric car in terms of sales with more than 60,000 vehicles sold, twice the sales of the second player, Tesla Model S. (Cobb, 2015)

At the end of 2015, the target of one million electric cars sold was reached and in late 2016 cumulative full-electric cars sold overpassed the milestone of 1,000,000. (Shahan Z. , 2016)

Finally, in 2018 the proportion between BEVs and Plug-in Electric Vehicles (PHEVs) has increased, passing from around 50/50 in 2013 to 69/31. (Hertzke, Müller, Schenk, & Wu, 2018)

3.1.2 Market

Nowadays, the global market of EVs in the World is around $120 billion[8] and it is expected to go beyond $500 billion in 2025 (Allied Market Research). In 2018, more than 2 million electric cars have been sold with China playing a leading role covering more than a half of the total market share. Considering only Europe, Norway is the market leader but Germany, and the United Kingdoms are quite close to it. In 2018, Tesla Model 3 was the best seller among all electric car, followed by BAIC EC-Series and the old leader Nissan Leaf.

Existing car producers playing on the EVs market are Tesla, Ford, Toyota, Nissan, BMW, Audi, Daimler, Volkswagen, General Motor, Kia Motors, Hyundai and BYD but many other players are expected to enter the market in the next years, such as Volvo, Porsche and Aston Martin.

While analysing the EVs market in Europe, it is important to use a methodological approach such as a SWOT analysis to understand which Strengths, Weaknesses are of an electric car

[8] Worldwide revenues market size - Electric Vehicles Worldwide, STATISTA

and which Opportunities and Threats have to be considered in that industry due to the macro-environment factors.

Beginning with strengths, EVs offer to car manufacturers the opportunity to sell in new markets and to explore new segments that are extremely important to diversify revenues. Moreover, since the market is quite young, it is possible to obtain a leadership position in the market in short time. On the other hand, car makers can innovate and to propose their new solutions to customers and they have the chance to be disruptive and to become trend setter in that market, as it was for Tesla, Nissan and other brands. As far as it concerns the car itself, EVs offer silent eco-friendly car, characterised by low costs of ownership, a simple engine and with a lot of synergies with autonomous driving systems.

On the contrary, some weaknesses exist. For the moment, gross margins are quite low, even if cars are sold with high prices. That is due to the fact that batteries are still expensive, but prices are now declining as it will be discussed later. Another faintness is represented by low investments in EVs customer-oriented services that need to be improved otherwise it will be impossible to reach mass adoption of these vehicles. One more issue concerns the declining trend of per unit revenue for EVs that is generated by high competition in a small market.

Another weakness is due to the low loyalty between suppliers.

Considering the electric cars themselves, they have long charging times, there is a lack of charging infrastructure and people are not yet ready to move to full electric due to the low mileage offered by actual technologies.

Moving to opportunities, low inflation rates brings stability to the market, allowing credit to be granted at low interest rates to potential buyers and this could increase the purchases and the development of EVs. Secondly, bonding global car manufacturers having methods, processes and implementation knowledge with local players that have the expertise of local requirements and characteristics of customers, it can provide growth opportunities for EVs in international markets. In addition to that, a huge opportunity comes from the fact that customers, thanks to the easy access to information, to the trend of rapid adoption of new technologies, to the interest in innovative products and to the increase in incomes, are ready to try new models, new technologies and are willing to switch to EVs to follow the current trend towards sustainability. Moreover, governments are offering subsidies for the ownership of EVs and they are pushing towards full electric transportation, both for personal and for public transports. Fuel costs are also increasing, and it is evident that fossil fuels are not sustainable in the future so EVs have the chance to grow even faster than expected.

Finally, major treats are linked to government and institutions in the case they slow down their programs aiming at improving e-mobility and at offering tax savings and other incentives to EVs purchasers. Then, competition in form of alternative fuels, hydrogen-powered cars can represent a threat for the expansion of EVs, together with the increase in the cost of electricity, mainly due to the use of renewable power sources that have higher production costs and probably they will lead to an increase of electricity prices in the following years.

3.1.3 Market drivers

Focusing on market drivers for the future of e-mobility, three main drivers exists: low battery cost, governments policies to promote EVs and what is considered as the Tesla effect.
First, since governments need to reach some emission goals in the next few years, they are pushed to incentivise the use of EVs in their countries. In fact, according to the Massachusetts Institute of Technology, by replacing most of the Internal Combustion Engine (ICE) vehicles, it is possible to reduce by one third the total amount of emissions from transport, by considering the emissions generated by the energy produced from power plants too.
Governments can use different forms of incentive schemes, spacing from the tax exemption, grants and various subsidies. Some advanced countries such as China, have introduced some energy credit rating systems that will assess the car manufacturers in their ability to meet emission targets.
Secondly, the Tesla effect has had a relevant influence on the evolution of EV market. Since in the old days EVs were considered environmentally friendly but they lacked efficiency, performance and aesthetics, with the advent of Tesla the perception from the public became totally different thanks to the renewed aesthetics and the great performance offered by these full electric cars. Due to the huge interests from the customers towards Tesla, many other manufacturers have begun to develop some electric car models in their portfolio. Moreover, thanks to the huge investments in the road infrastructure carried out by Tesla all over the World, aiming at creating an ecosystem in which EVs were able to recharge everywhere, many players have seen this as an opportunity to develop their EVs due to the fact that a basic infrastructure was already in place in many countries, even if a lot of investments have to be made, especially in cities.
Finally, to make EVs more affordable, it is necessary to decrease battery costs that represents a big issue for the market. Large scale adoption of EVs is influenced by battery costs that

historically have been extremely high but in recent years are dropping. The average price for battery packs in dollar per kWh passed from 1,000 USD/kWh in 2010 to less than 200 USD/kWh in 2017 and it is expected to fall even more in 2030 plummeting to less than 100 USD/kWh. (McKinsey, 2017) According to the Nature Climate Change journal, EVs will be competitive with ICE cars if battery costs fall below 150 USD/kWh but with the future technology, even higher costs will be suitable to the mass adoption of EVs among customers.

3.1.4 Market Challenges

One more topic that must be addressed when presenting the EVs market concerns the challenges for the widespread adoption of EVs.

Many private investments are required to develop the infrastructure, specifically to progress in the construction of charging stations that are not enough in 2019. There is a lack of public charging infrastructure that is necessary to improve customer confidence in EVs. That is the reason why, as mentioned before, some companies, such as Tesla, are investing to create a widespread charging network with standardized systems. Governments have invested a lot to create the basic infrastructure for EVs but now it is time to private companies to invest and develop the actual infrastructure with new sustainable business and financing models to help the market growing. The problem is that private companies have to face high installation costs and they know that most EVs are charged at home or at the office.

In addition, due to the high cost of electric batteries, EVs suffers high up-front costs. Since EVs are not a mass product, car manufacturers need to face high costs that are reducing enormously their profits. Half of the price of an electric car is accountable to the battery costs. On the other hand, it is worth to say that operating costs are very low in comparison with standard cars. Due to the high costs that generates a high price for EVs, customers still consider them as premium cars, not affordable. That is a big obstacle for the mass adoption and it doesn’t allow car manufacturers to take the advantages from economy of scale that would eventually lower costs.

Another issue is represented by the lack of information related to EVs and to the scarce confidence towards the adoption of electric vehicles from customers. According to a study made by Accenture, 70% of people need to understand more the technology of EVs before making a choice between ICE and electric car. Furthermore, customers are worried by the short mileage and by the safety of these vehicles since sometimes in the news they see EVs on fire due to battery issues. Actually, the battery range is now wide enough to satisfy consumer's average use of car and nowadays safety has improved a lot.

One last barrier to the mass adoption of EVs is represented by lobbies. The fast progress in the electric mobility represent a key issue for oil companies and O&M lobbies. If EVs gain market share it means that the demand of gasoline will drop. That is the reason why lobbies are trying to create strong relationships with governments in order to slow down the adoption of electric vehicles.

3.2 Technology

With Electric Vehicle (EV), we consider a vehicle characterized by an electric drive propulsion system that can also be plugged in to recharge batteries that provides at least some energy storage to the vehicle. The most diffused EVs are Battery Electric Vehicles (BEVs) that use batteries in order to store energy and they have to be plugged in to be recharged, and Plug-In Hybrid Electric Vehicles (PHEVs) that have both liquid fuel energy storage systems and batteries, they have also an Internal Combustion Engine (ICE) and they can be plugged in to recharge or they can be refilled with liquid fuel. There are also Hybrid Electric Vehicles (HEVs) that don't have the possibility to plug in and recharge batteries, but the liquid fuel can recharge directly batteries on board, together with the regenerative brakes systems.

Normally, BEVs have bigger battery packs respect to PHEVs since they don't have the internal combustion engine working with the liquid fuel. The latter have smaller driving range with batteries but thanks to the ICE, their actual driving range is the same as a normal ICE powered vehicle, reaching more than 700 km. On the other side, BEVs have smaller ranges overall, covering only 200 km mileage, even if some recent models such a Tesla Model S can reach also 300 km, but it is still far away from a traditional ICE vehicle.

The following graph shows the difference between BEVs and PHEVs in terms of mileage of batteries and battery capacity. It is possible to notice that, as mentioned before, BEVs have higher battery capacity and higher mileage but only if the battery driving range is considered, since in truth PHEVs have a higher mileage thanks to the ICE using liquid fuel. The graph is quite old since it refers to 2015 but the main difference in terms of batteries between BEVS and PHEVs are always the same, what is different is the current mileage of BEVs that is sometimes reaching even 400 km, it is no more below 100 km as presented in the figure.

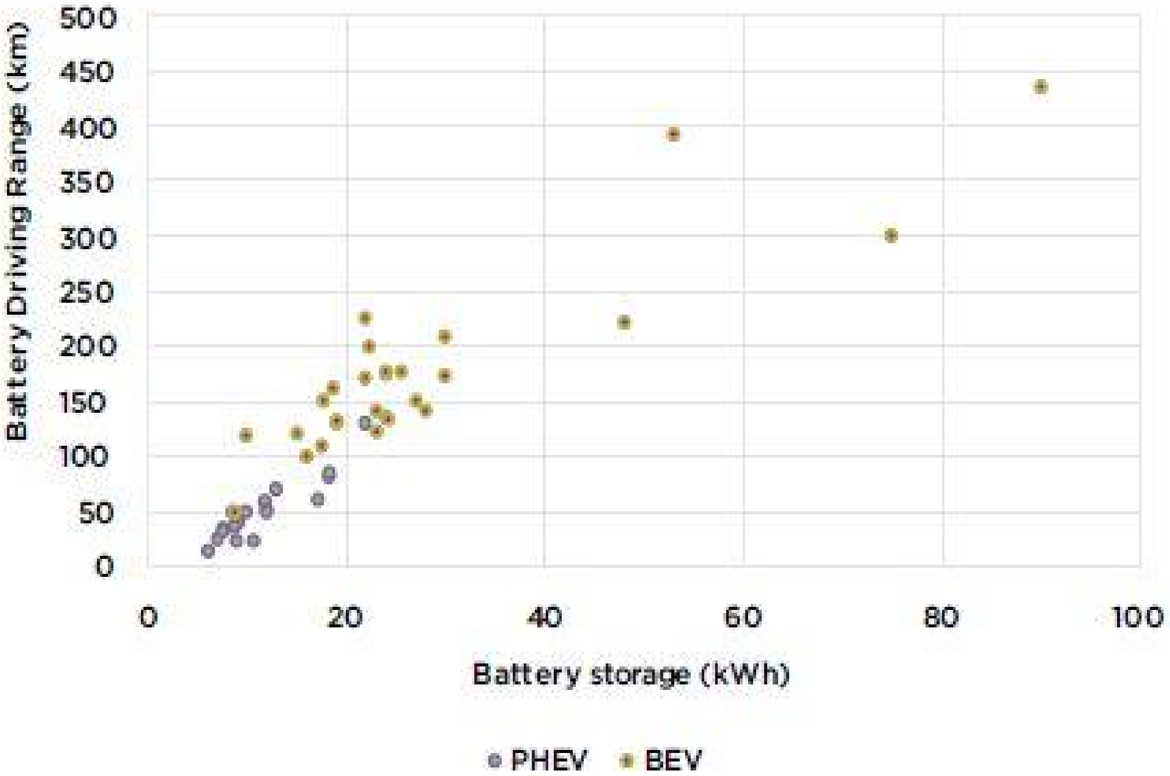

Figure 1- Differences between BEVs and PHEVs in terms of mileage and battery capacity (IRENA)

In general, liquid fuels, in particular gasoline and diesel, have high energy density that allows to travel long distances on these vehicles and refuelling lasts few minutes in petrol stations, so they offer a huge mileage to the owner. The problem is that most of the energy contained in the fuel is wasted in the combustion process, in form of heat losses. In fact, the conversion efficiency of an ICE is between 20% and 30%.

On the other hand, electric engines are more efficient, with conversion efficiencies of around 95%. The issue is that it is quite complex to store enough energy in batteries to offer a normal mileage, without plugging in every 200 km. In fact, a lot of efforts are being made in R&D to develop batteries with higher energy density. Nowadays, EVs use Lithium-Ion Batteries that have high energy density, long life cycle and high specific energy. Batteries will be analysed in a dedicated section of this thesis.

Since this work in focused on light and ultra-light EVs, the following sections will analyse more in depth these different types of vehicles.

3.2.1 Light EV

Light EVs are basically constituted of all electric cars, from the one powered by a full electric engine (BEVs), to the ones powered by both electric and a fossil fuel engine (PHEVs and HEVs).
It is important to notice that Fuel Cell Vehicles (FCEVs) have not to be taken into account even if they usually have an electric motor onboard. In particular, several challenges have to be overcome before these vehicles are cost-competitive with conventional vehicles even if the potential benefits of this technology are substantial and comparable to those listed for electric vehicles.

Battery Electric Vehicles (BEVs)

BEVs are propelled only by an electric motor. The motor is powered by rechargeable battery packs. The car, from the outside, is the same as a normal ICE car but the main difference is that there isn't the typical sound of a gasoline engine, it is very silent.
In a BEV, the Direct Current (DC) electric motor is powered from a DC controller that is absorbing the power from rechargeable batteries. The power sent to the DC motor is then used to rotate the transmission line that turns wheels.
In the following figure, the mechanism of a BEV is shown.

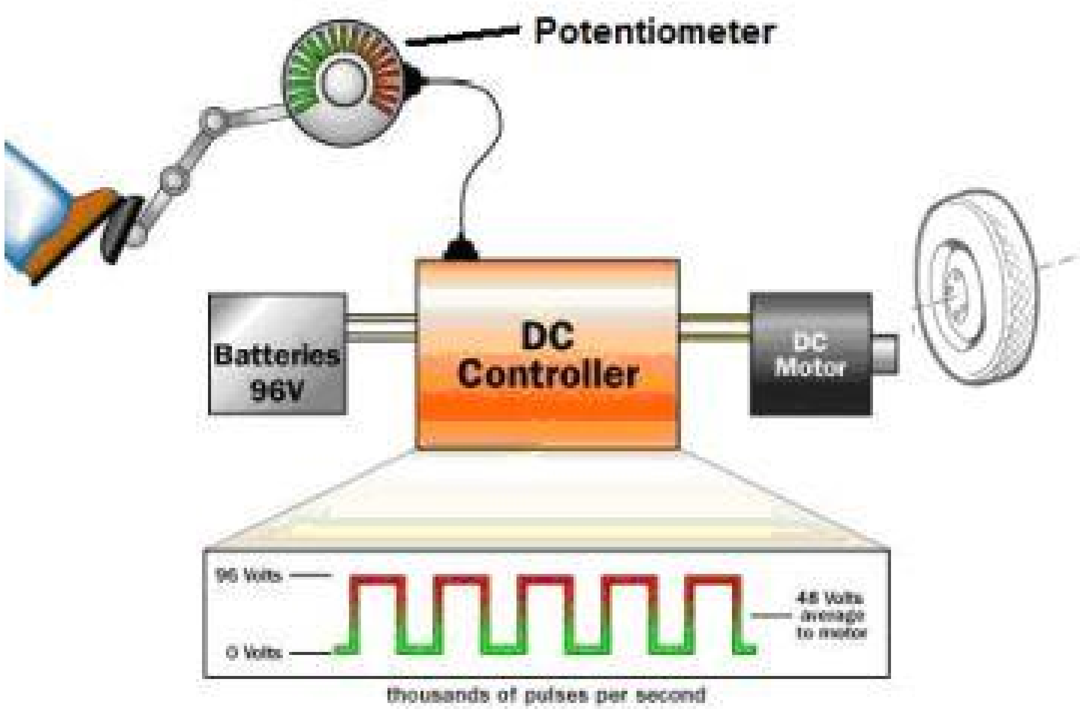

Figure 2 - Parts of a Battery Electric Vehicle (BEV)

The potentiometer is circular and is hooked to the accelerator. It is a variable resistor that according to how much the accelerator is pushed, it sends a signal to the DC controller on how much power must be sent to the DC motor from battery packs.
The batteries are necessary to provide the power to the motor. There are different types of batteries that can be used, each type with different characteristics in term of voltage, power, energy density, battery cycle, charge and discharge time, etc. The most used is Lithium-Ion battery, but also Lead-Acid and Nickel-Metal hybrid batteries exist.
The DC controller, as mentioned before, has to send the power from the battery to the motor. When the car is not moving the controller delivers no power and when the accelerator is pushed down to the floor it provides the maximum electric power. The DC controller, according to the inputs from potentiometers, can deliver any power level between the minimum and the maximum discussed before. The motor turns the transmission that eventually turns the wheels.
These vehicles have a lot of benefits, such as energy efficiency, thanks to the high rate of conversion of chemical energy stocked in batteries used to power the electric motor, it is the most environmentally friendly way of moving since they have zero emission of toxic substances such as carbon dioxide or other GHG gases. Finally, thanks to the evolution of electricity networks and to the development in technologies, in the future these car can represent a huge advantage for the net since they can be used as an energy storage when they are connected with the plug to the grid, being able to subtract power from the grid in charging phase and distribution power to the grid when more power is requested by consumers. That is one of the main principles of what we call Smart Grid.
Among the challenges these vehicles must face, there is the low mileage, since most of them have to be recharged after less than 100 kilometres and in addition to that charging times are too long now, even if technology is improving a lot in this direction.
Finally, they have large battery packs, that are heavy, they occupy a lot of space, they are very expensive, and they have small life cycles. That is the reason why they are the predominant technology in the EVs market, and they are expected to gain more and more market share in the next years. Nowadays they own more than 50% of the total EVs market and according to the estimates made by JP Morgan, they will pass from 3% of the global vehicle market share in 2020 to more than 18% in 2030. (J.P. Morgan, 2018)

Hybrid Electric Vehicle (HEV)

Hybrid Electric Vehicles (HEVs) are powered both by a traditional gasoline engine and an electric motor. Normally, most of the power necessary to rotate the transmission comes from the gasoline engine, while the electric motor provides additional power when needed, for example when there is the necessity to accelerate fast and pass other cars.

There is a traditional small fuel-efficient gasoline engine coupled with the electric motor that offers power in acceleration. The electric motor is powered by a battery pack that is recharged automatically when driving the car, differently from Plug-In Hybrid Electric Vehicles (PHEVs) that have a plug-in recharging system, but this will be discussed later.

The following figure shows the components of an HEV.

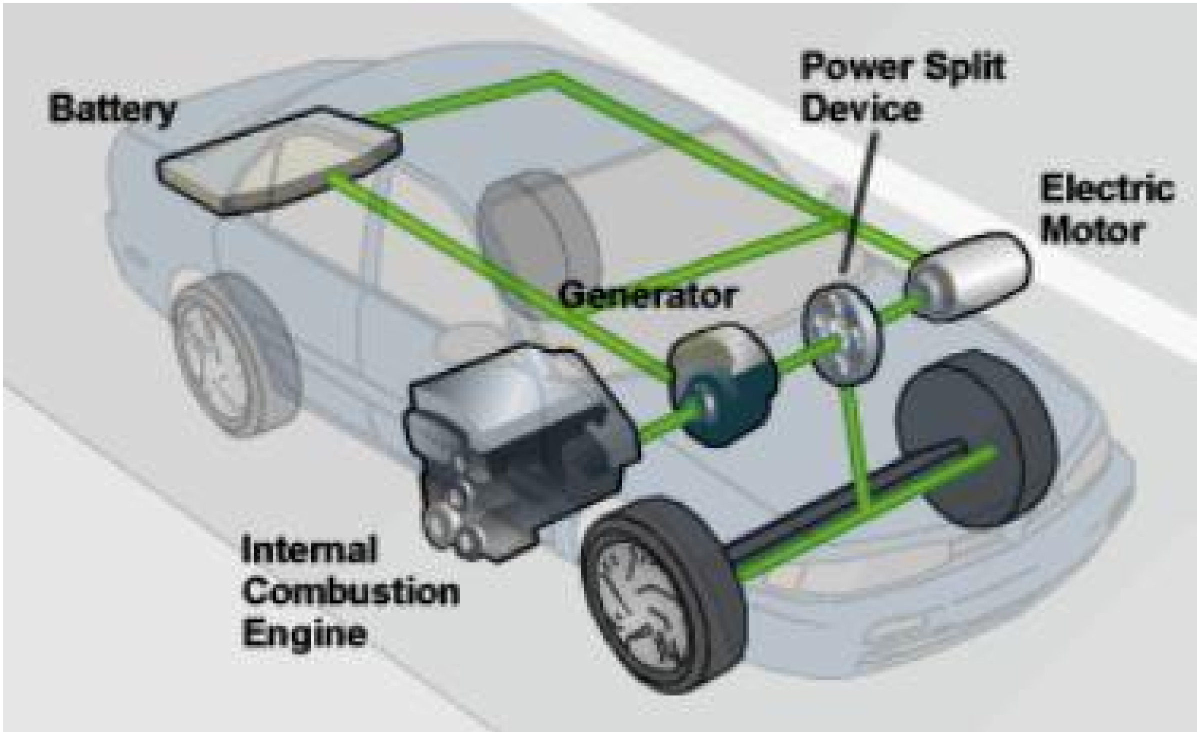

Figure 3 - Parts of a Hybrid Electric vehicle (HEV)

In HEVs, batteries are storing energy for the electric motor. In particular, batteries can receive power from the electric motor, when the driver is using the ICE and they can distribute power to the electric motor when accelerating or when additional power is required to help the gasoline engine. In fact, the energy used when braking is converted in electricity and sent to the batteries. When braking, the electric motor is reversed and since wheels are rotating with the transmission, this rotation is used by the motor to create electric energy. This is a main

difference between the functioning of a BEV and a HEV. This system in called Regenerative Braking and it allows to recover part of the kinetic energy from car's momentum when the driver is braking.
When batteries are not used, they help providing power to the auxiliary systems such as air conditioning, and the infotainment system.
The engine is an ICE and usually it uses gasoline as liquid fuel. Differently from traditional cars, the gasoline engine is smaller, and it uses various technologies to decrease emissions and to improve the conversion efficiency. Fuel is contained in a tank that has to be refilled as any car at petrol stations.
In HEVs, there is a generator. It is very similar to the electric motor, but it uses the power generated from the ICE to recharge batteries. In addition, between the generator and the electric motor there is a power split device that must create a continuously variable power to be transferred to the transmission that will turns the wheels. The power received by this device is generated by both motors, since the ICE and the electric motor works simultaneously, providing both power to the power split device.
Moreover, two types of HEVs exists:

- Series Hybrid EVs: ICE and electric motor are in series. They are all-electric drive-train decoupling the ICE from the drive shaft, so that he can only drive the generator
- Parallel Hybrid EVs: The combustion engine operates in parallel to the electric motor. It can run full electric or only with the gasoline engine or in a combination of both.

As mentioned before, the electric motor provides additional power to assist the engine in accelerating, passing, or climbing hills, permitting to have a smaller, more efficient engine to be used. Sometimes, the motor alone provides power for low-speed driving conditions, where ICE is less efficient.
Another interesting feature of these vehicles is the Start and Stop technology that automatically shuts off the engine when the vehicle is stopping and restarts it when the accelerator is pushed, preventing a waste of energy from idling.

Plug-In Hybrid Electric Vehicles (PHEVs)

Plug-In Electric vehicles are HEVs having the possibility to recharge batteries that are powering the electric motor from an off-board power source, by plugging- in to a charger connected with the grid. These vehicles can use both the internal combustion engine or the electric motor, they offer then a choice between using traditional fuels such as gasoline or electricity directly transferred to batteries by the plug. Thanks to the opportunity to choose which engine to use, they represent a good trade-off.

Differently from BEVs, they have no issues regarding mileage since in the case of long trips, the combination of the two engines guarantees as many kilometres as normal cars. Moreover, for normal use, i.e. to go to work and to come back home, they can satisfy the whole power demand using only the electric motor. That is a major advantage since the owner can have the full benefits of an electric car but without the range anxiety, referred as the fear of finishing the power after a certain number of kilometres, that is a major issue for BEVs.

On the other hand, issues related to such EVs are due to the huge space occupied by the battery and to the increase in weight that lowers performances of the ICE and the electric motor in terms of power conversion.

The following figure shows the main components of a PHEV, in green are presented the parts linked to the electric motor and on green components necessaries for the conventional engine.

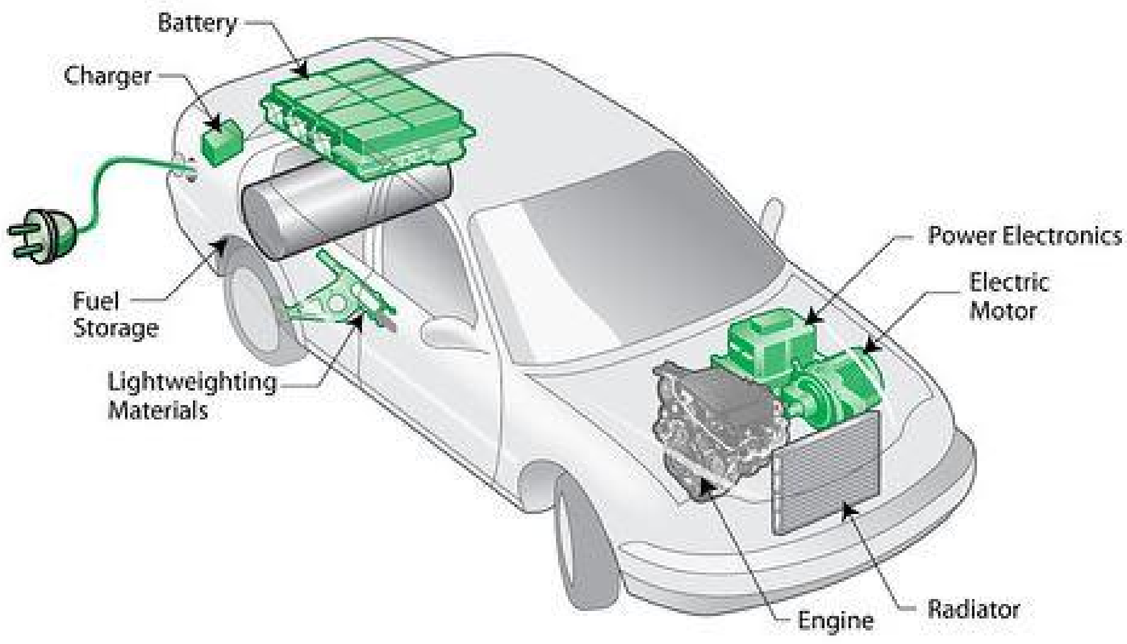

Figure 4 - Plug-In Hybrid Electric Vehicle components

PHEVs can offer all the advantages of BEVs and they partly hedge some of their weaknesses, such as the mileage issue. On the other hand, the goal of reaching zero emissions in transports can’t be reached by using PHEVs, that is the reason why even if now they are second in term of market share in the EVs market, in the future they will be loose share since BEVs are more environmentally friendly and governments and car manufacturers will put a lot of effort in developing these vehicles trying to push customers towards the full electrification of vehicles.

3.2.2 Ultralight EV

Ultralight Electric Vehicles (ULEVs) are small, one, two or even three-person vehicles, usually powered by a full electric motor, but also some hybrid models exist, that are generally characterised by high efficiencies, low maximum speed of around 70-80 km/h and designed to solve the short distance transportation in cities and in suburban areas.
Most of these ULEVs have three wheels, they use lightweight materials such as carbon fibre or fibre reinforced plastic (FRP), they have a quite small mileage between 50 and 100 kilometres since they have small batteries and they can be charged with standard electrical outlets. In the pictures below, two examples of ULEVs are shown.

Figure 5 - Two examples of Ultralight Electric vehicles (ULEVs)

On the left there is SAM, a two seat, three-wheeled full electric urban vehicle that combines technology and design.
It has an intelligent charging system allowing to recharge almost half of the battery in just one hour and it takes maximum 5 hour to fully charge the batteries. It can be charged by using normal plugs, and on average the autonomy is around 100 kilometres. The maximum speed is around 100 kilometres per hour and the consumption is 8 kilowatt-hours per 100 kilometres. The price starts from 9,975 dollars. (Sam of USA, 2019)
On the right, there is another three-wheeled full electric motorcycle called Zbee. It can transport up to three people and it is possible to carry small goods. It is tiny and three Zbee can fit in a normal parking slot, so it is perfect to be used in city centres. It has a good

acceleration, it weighs only 280 kilograms, being a perfect combination of lightness and safety thanks to the material used. It has a top speed of 45 kilometres per hour and a mileage of almost 80 kilometres. It is extremely efficient, in fact it uses only 4 kilowatt-hours per 100 kilometres and the electric motor doesn't require any maintenance. The charging time is around 5 hours. Currently this vehicle has been launched in India, where there is a big market potential for these three-wheeled full electric vehicles. (Zbee, 2019)

ULEVs allows consumers to obtain a full electric vehicle at low costs, therefore they can exploit all the advantages of an EV without the need of a high initial investment. In particular, they represent an ecologic way of transportation that is way faster than a bike, offering the same protection of a car (such as protecting against the rain, against cold weather, etc.) and almost the same safety of a traditional car in cities.

This type of EV is not so developed in cities, even if it can have huge applications in some countries such as India or China where the pollution in cities is a main issue and since they usually have small cars or tricycles they can be easily converted to environmentally friendly ultralight EVs.

Among ultralight EVs, also scooters should be considered. In most cities, such as Paris, New York and Singapore, the short-term transportation is satisfied with electric scooters, usually spread around the city in a sharing system. Together with e-bikes, these vehicles offer to citizens the opportunity to travel small distances without using public transport systems and enjoying the city. In addition to that, they represent the fastest way to move in a city since scooters can reach almost 70 km/h as maximum speed and they can be used in bicycle lanes too. They are the best solution to avoid traffic jams and they solve the problem of finding parking spots in city centres.

Focusing on technology of ULEVs, the same electric motors discussed before for light EVs are used. In addition to that, in ULEVs there is the opportunity to have BEVs, HEVs or PHEVS, but normally they are BEVs. Since they are so small, and they require a lower power, they can exploit all the advantages of the full electric motor and batteries have not to be extremely big to satisfy the daily usage of these vehicles.

3.3 Batteries

Batteries are the most important component in EVs, that is the reason why researchers are putting a lot of efforts in innovating and in analysing new types of batteries that will enable to cut costs of EVs and to make them more appealing to the public thanks to an improved efficiency, time of charge and discharge and especially autonomy. According to BNEF, batteries are responsible for 50% of the cost of an EV and they believe that this cost can be reduced to 18% by 2030.

Currently, batteries used in electric cars are made of Lithium-ion (Li-ion) technologies. In recent years, thanks to the advancements in research and development pushed by the electronic devices industry, batteries have improved their performances and now they can be designed specifically for EVs, being able to match the performances of traditional ICE cars.

Main characteristics for EVs batteries concern the autonomy, in particular the mileage they can offer, the battery life and the capacity of retaining its initial capacity.

Typical Li-ion batteries can support more than 1,000 cycles (Warner, 2015)This measure indicates that a battery can satisfy the average lifetime of a car that is around 170,000 kilometres. As a matter of fact, if the battery capacity is of 35 kWh, according to market average, and if the car consumption is of 0.2 kWh/km, it means that one single battery can be used for at least 175,000 km, that is more than the average car lifetime. Then there is no need to change batteries.

Focusing on Li-ion batteries, three performance drivers can be detected, from battery chemistry and size capacity to charging speed.

First of all, talking about batteries chemistry, batteries are made of two poles: one positive, known as cathode and one negative, called anode. Normally, cathodes are made of lithium nickel manganese cobalt (LNMC), lithium nickel cobalt aluminium oxide (LNCA), lithium manganese oxide (LMO) or lithium iron phosphate (LIP). On the other hand, anodes are made of graphite. The two poles are immersed in an electrolyte that usually is liquid, even if researchers are studying polymeric electrolytes that can be more stables.

The first two above-mentioned cathode technologies provide higher energy density and that is the reason why most batteries are made of these technologies, as far as it concerns the electric vehicles industry. Specifically, LNMC have an energy density that varies proportionally with the quantity of nickel contained in the cathode (HJ Noh, 2013). The higher the quantity of nickel, the higher the energy density, the lower the amount of material to be used, the lower the weight and finally the lower the cost of the battery. The issue is that a higher amount of

nickel leads to a lower thermal stability that can be dangerous since it can lead to the burning of the battery itself. Some companies such as Aminox are working on new technologies that shut down default cells in batteries before they can catch fire, improving the safety of batteries and of electric vehicles.
Secondly, EVs have very variable battery sizes, the range is between 20 and 100 kWh for BEVs. Small cars require only 20 kWh batteries size while bigger vehicles such as SUVs require 100 kWh batteries. On average, medium electric cars need a battery capacity of 40 kWh. Usually small batteries tend to have higher cost per energy stored, due to the fact that they have a smaller cell to pack ratio.
Thirdly, another important feature of batteries, especially for BEVs, concerns the charging speed. Currently, most of BEVs are quite fast in recharging batteries since they can charge more than ¾ of the battery in less than one hour when fast chargers are used. Anyways, there is a need to improve the charging time in order to close the gap with Ice cars that can refill their thermal fluid storage in less than 5 minutes at petrol stations. That is the reason why battery producers are designing ultra-fast charging batteries that will solve this issue, but it will decrease battery life, energy density and it will increase costs.
An important issue to be solved by battery manufacturers is the lack of Lithium and Cobalt, in fact reserves are quite limited all over the World and they are spread geographically between Congo, Australia, Cuba, Philippines, Zambia, Russia, Canada and few other locations. Most of these reserves are in Congo where there is political instability and so the extraction can be very unpredictable.

Moving to costs, the model used by the IEA to assess the cost of batteries shows that the range for battery used for light-duty BEVs is between 155 \$/kWh and 360 \$/kWh. In the lower range there are large batteries produced in large volumes while smaller batteries are generally more expensive, especially if they have lower volumes. For PHEVs, battery cost per energy unit is usually 20% higher.
The next generation of batteries that will appear on the market in late 2030 will create a cost reduction due to (i) an increase in battery capacity, (ii) higher energy density and (iii) a lower use of Cobalt. The new cost range is expected to be between 100 \$/kWh and 122 \$/kWh that is in line with the European Union (EU) targets of 93 \$/kWh to be reached in 2030.
Moreover, a cost driver is the increase in mass production that will generate an increase in the manufactory production scale that automatically decreases costs. This scale, according to

some expert, can be reached when costs will reach around 5 $/kWh and when the mileage will be between 600 and 800 km.

As far as it concerns technology developments, according to the International Energy Agency (IEA), Li-ion batteries will still lead the market in the next 10 years (International Energy Agency (IEA), 2018)That is the reason why researchers are now focusing on reducing cobalt in cathodes to reduce costs and to increase energy density in Li-ion batteries (Chung, 2017). Together with that, they are improving the graphene structures at anode to obtain a faster charging speed and they are trying new gel electrolytes to reach higher voltage in the electrolyte that will improve batteries performance. New electrolytes will enable cars to travel even 400 km with one charge and they will double the energy density. Other companies are creating a titanium niobium oxide anode that increases the battery autonomy up to 300 km after a 6 minutes of ultra-fast charging time. Finally, other researchers are developing a cubic crystal layer between the electrodes to improve their connection.

After 2025, Li-ion batteries will be replaced by Lithium Air or lithium sulphur batteries, even if they still must be tested. Lithium Air batteries have the potential of having higher energy per unity of mass and of volume, but they have also a lower energy efficiency and they degrade faster. Some companies are also creating batteries based on organic nanomaterials that can recharge the entire battery in just half an hour. In addition to that, some researchers think that ultracapacitors, stocking energy trough an electric field, can be added in EVs to offer an additional power supply to the electric motor, improving a lot its performance and permitting to supply a huge amount of power in less time. Ultracapacitors have also a longer lifecycle but normally they are more expensive and have lower energy density respect to traditional chemical batteries. When these new technologies will be ready to be used in EVs, the market will be already saturated by the mass production of Li-ion batteries, so they will be marketable only in 2030, according to IEA.

Some car manufacturers, such as Volkswagen, are now experimenting solid state batteries, using solid electrolyte rather than a liquid one. The main advantage is to decrease losses, avoid catching fires and improve battery life. By using these batteries, it is possible to decrease costs since cheaper materials can be used.

Another type of batteries they are experimenting is based on Aluminium-ion technology. The main goal is to improve safety, shorten charging time and increase life cycle. The only issue is the low energy density in the batteries that makes them unfit with the EVs requirements.

One more technology that is entering the EVs market is based on Lithium-Sulphur mixtures. These batteries can have up to 5 times the energy density of normal Li-ion batteries and they offer a higher mileage, more than 400 km will be achieved. In addition to that, they are made of Sulphur that is safe, environmentally friendly and quite cheap.

The only problem is that they have a very short battery life and the efficiency decrease too rapidly.

Since Li-ion batteries tend to lose their charge even when they are not used, researchers are creating plastic membranes that by controlling the charge flows in the battery, they avoid the discharge of batteries when the vehicle is switched off and they enable the ultra-fast batteries charging.

One last technology that is being assessed by researchers is the graphene-based supercapacitor. There is a one atom thick film made of graphene that can be placed everywhere in an EV, saving s lot of space and decreasing the weight, differently from classical batteries. Then, it enables ultra-fast recharging, it offers long life cycles and it is efficient also at low temperatures. The main problem is the low capacity of storing energy. In fact, less than 10% of the energy of a normal Li-ion battery can be stored in this supercapacitor.

The following figure, taken from a report on EVs published by Statista, shows a comparison between different battery technologies in terms of mileage, price and specific energy.

It is possible to notice that current players are offering batteries with costs lower that 150 $/kWh. The mileage is quite low for cheaper car such as Nissan Leaf that offers only 200 km, that anyway it is more than what a normal car user travel every day, especially in cities, but it is not enough to go to work and come back home in certain areas, such as in the USA where the territory is wider and people travel more to go to work. Other companies such as Tesla are offering a great autonomy in terms of kilometres since the Model S can travel more than 400 km without the need to be charged, thanks to the Lithium Sulphur batteries.

Figure 6 - Comparison between battery technologies in terms of mileage, price and specific energy (Statista, 2017)

3.4 Charging Systems

The adoption of EVs is growing and the charging infrastructure needs to grow at the same pace to catch up. The most developed Country in terms of infrastructure is China where the next year there will be 4 million news charging spots and more than 10,000 charging stations, thanks to huge investments from the State. European oil and gas companies are investing in charging infrastructure, especially French multinational such as Shell and Engie.
Charging points can be divided in 4 classes:

- AC Level 1 are cheap, and they are quite slow in recharging batteries, that is the reason why they are normally used for domestic applications, to recharge cars during the night.
  An AC charger uses an in-car inverter converting Alternate Current (AC) in Direct Current (DC) that charges the battery at the typical household outlet level of 120 Volts (V)

- AC Level 2 are faster, they can charge a medium sized car in around 5 hours. They are used both for domestic applications and for public charging points. They charge batteries at 240 V. A Level 2 charger costs between $1,000 for home applications and $5,000 for public purposes

- DC Level 3 are called rapid chargers, they can charge more than ¾ of the medium sized car battery in half an hour. They are more expensive and few public charging points used this technology so far.
  This system directly converts AC from the grid in DC and charges directly the battery without needing an in-car inverter. It can also operate at power in the range of 350 kW. The higher the power supported, the faster it can charge batteries. This type of charger costs between $25,000 and $200,000 according to the power capacity supported

- Wireless charging points uses electromagnetic waves to recharge batteries. A plate is attached to the car and a wall socket is connected to a sort of charging pad.

There are more than 1,300 Tesla Superchargers around the World but Tesla don’t allow other car manufacturers to recharge at their charging points and this represents a competitive advantage for Tesla since only its customers can profit from a proper network of chargers all over the world. For that reason, other manufacturers such as Volkswagen, are planning to install new charging stations across Europe.

One major issue related to charging stations is that customers are obliged to sign up for multiples companies that provides and manage charging stations. Each company has his own card or apps, so it becomes a mess for EV owners.

A study from McKinsey & Company[9] expects that between 2020 and 2030 the worldwide electricity demand from EVs will rocket, passing from 20 billion kWh to more than 280 billion kWh (McKinsey, 2018). The whole energy market should adapt to this dramatic change in consumption and renewable energy sources will play a major role in designing the future of electricity supply, especially thanks to smart grid applications.

Luckily, EVs can be charged both at home, at work and on the street. Generally, individual cars are parked at home from 8 to 12 hours every night. That is the reason why most people can charge their car directly at home. Of course, not everybody has a garage or a charging station at home so many users need to charge on streets, especially in the future when the mass adoption of EVs will be reached. Anyways, 70% of the EVs owners are expected to be able to charge their car at home during the night. According to McKinsey, home charging will be able to satisfy at least 75% of the power requirements of all EVs in the USA and the rest of the power will be supplied at work or at charging stations. In Europe the scenario is quite different since public options are expected to be more attractive for EVs owners. Home charging will drop to 40% by 2030, since the middle to low class will buy electric cars thanks to the drop of prices but they will not have the possibility to charge at home. That is the reason why it will be very important that authorities invest in the infrastructure to satisfy the demand of charging stations.

[9] Considering annual mileage of 18,095 km in USA, 14,989 km in EU and 11,000 km in China. Battery efficiency is 20 kWh per 100 km

4. Sharing Mobility

4.1 General overview and trends

Historically, public transport has been the preferred way to move, especially in cities. Since many people want to have a personal car to be independent, also private cars are a major mean of transportation.

Researchers showed that private car owners use their car only one hour per day on average and more than 60 days per year the car is not used, resulting in a car usage of around 4% of the total time available in one year (Yakovlev, 2018). This research shows that most of the time cars are parked and since in cities car parking are less and less and they cannot satisfy the entire demand, it is evident that car sharing can be the best solution to improve the mobility in cities.

Thanks to digitalisation, the widespread use of smartphones and the new-born concept of sharing economy, nowadays other services exist, such as free-floating car sharing (e.g. Car2Go, Enjoy), peer-to-peer car sharing (e.g. BlaBlaCar, OuiCar), carpooling (e.g. Karzoo) and ride sharing (e.g. Uber, Lyft). These services can represent the future of mobility, especially in cities where they can even replace both current public transports, taxis and personal vehicles.

The following graph shows all the different types of sharing mobility services.

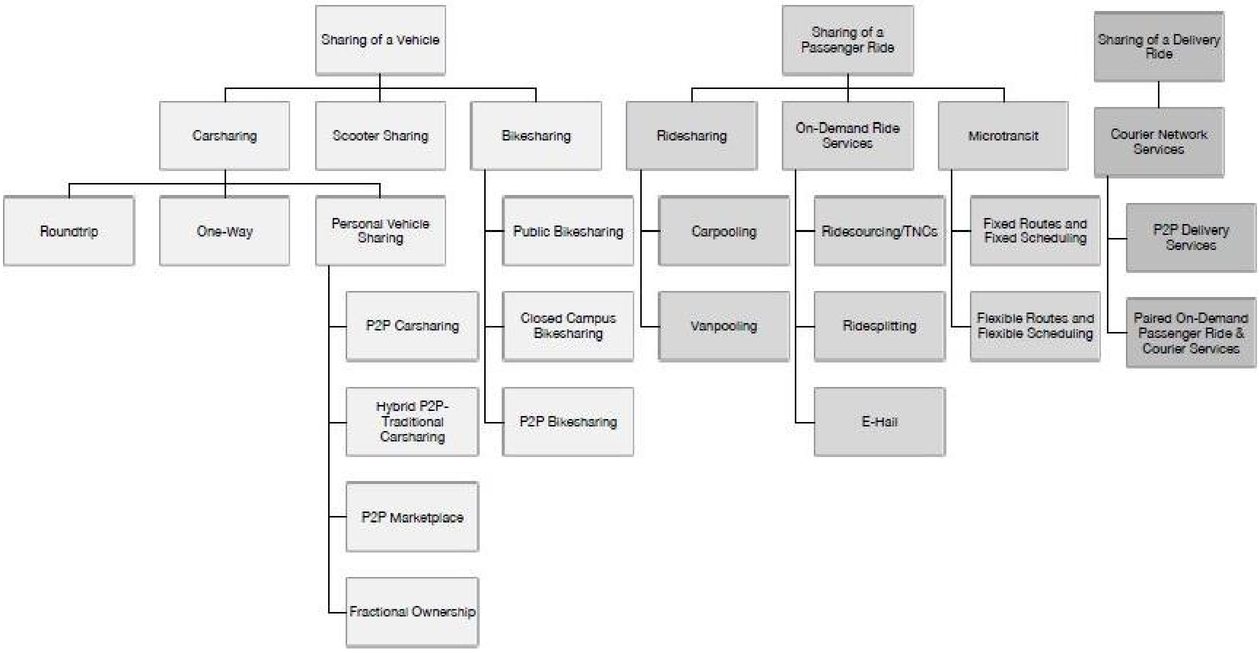

Figure 7 - Sharing mobility services

Car Sharing

Car sharing is quite like classic car rental but with some differences. First, for most types of car sharing, it is not required to return the vehicle in a specific place once it has been used, it is possible to park it in any public parking around the city. Secondly, the cost is based on a minute-based tariff, it means that the customer pays according to the minutes the car has been used, there is not an hourly tariff or a fixed tariff that has to be paid, as it is in normal rental offers. Thirdly, car sharing offers a different service to clients, it enables them to do short trips, even in city centres but for example if a customer must visit a country, will probably choose a car to rent rather than using a mix of car sharing services and public transports. That is the reason why car sharing is more willing to replace personal cars, taxis and public transports.

Car sharing services can be considered as platforms offering the access to vehicles for short time periods characterised by per minute payments or payments based on the distance travelled and with vehicles widely distributed around the city. An important characteristic is the fact that customers drive themselves the car, otherwise it would be a ride sharing service. Car sharing operators can rather own the fleet or just connect individuals with their own car. Moreover, there are various forms of car sharing, from free-float services, where the car can be picked up everywhere and van be parked all around the city, to point to point services where the car has to be picked in specific locations and parked in specific spots and finally peer-to-peer that allows private car owners to offer their car to be used by customers.

A recent study made by ING economics department, considers that in Europe, in 2035, there will be around 7.5 million vehicles used in car sharing fleet, while today only 370,000 cars are employed in car sharing (ING Economics Department, 2018). It is interesting to notice that the most common car sharing service is the peer-to-peer scheme, where car owners offer their car to other people. Then, the rest of cars is mostly used for professional fleets and for free float services.

Thanks to the rapid growth of car sharing services, many car manufacturers are entering the business, such as BMW with DriveNow, Mercedes Benz with Car2Go. In fact, car sharing can have a huge impact on their business models since they are currently making profits by selling a huge number of cars, exploiting economy of scale and mass production together with the maintenance of cars. If car sharing will cover a big part of the mobility market in the next years, then car manufacturers will have to manage car sharing fleets. Rather than only

produce cars to obtain profit, they will also need to create peer-to-peer platforms to make profit from the operation of the fleet of vehicles. That represents a huge revolution in the automotive industry.
Nevertheless, currently the car sharing market is smaller than what was predicted 5 years ago, the main countries in which car sharing is attractive to customers are Italy and Japan, followed by Spain and France.
This scarce adoption of car sharing services is due to the fact that a lot of barriers exist. First, car sharing services are not enough clear in the mind of people around the world. Secondly, there are a lot of concerns related to the availability of cars when needed and specifically the specific car required in that moment, about the maintenance of these vehicles, their cleanliness and about the responsibilities between the time you park the vehicle and the time another user opens the vehicle.
Reliability is an important aspect to be improved, together with the user experience by offering more cars and a faster booking system for customers. One last barrier is due to the high cost per minute that is way higher than the cost of public services that if well developed, they represent a better solution.
On the other hand, a lot of benefits exist. There is no need to take care of the car nor to use always the same model or type of vehicle since you can choose the vehicle that best suits in that occasion and it is also possible to access vehicles that normally would be too expensive. Other advantages are linked to the cost reductions since there are no ownership costs such as insurance and maintenance, there is no need to have a parking spot or a garage, it is cheaper than taxis and last but not least, there is no need to purchase a vehicle.

Scooter Sharing

Scooters have always been used widely in cities, thanks to the easiness of moving around, to the higher chance of finding parking and to the lower cost respect to other vehicles such as cars. Scooter sharing was born in the United States of America in 2012 and now is booming in most cities in USA, in Europe and in Asia.
The scooter sharing market considers both electric and combustion scooters and kick scooter, widely spread in cities like Paris and Madrid, covering more than one third of the total scooter sharing fleet. Kick scooter seems to be the best alternative to public transport for short trips in cities, that is why a lot of companies are offering this service. For example, in Paris 2 years ago there was only one scooter sharing provider, considering kick scooters, while now there

are 8 providers offering the same service. Of course, most people travel using public transports, especially subway, but roads are full of scooters and people are getting more and more used to this new way of travelling.
In 2017, there were more than 25,000 scooter sharing vehicles available in the world in or than 60 cities, most of them in Europe, with almost two million people registered to these services.
Free floating services are dominating this market, since they offer the opportunity to park the kick scooter anywhere in the city, from sidewalks to streets. Moreover, all of them are full electric, except for some traditional scooters that can be powered by hybrid engines, even if the current trend is towards the full electrification of fleets.
According to experts, users are mostly young people, and they tend to use also car sharing and ride sharing systems to get around the city, together with the traditional public transports. (Degele, 2018)
The average distance travelled by customers is around 4,5 kilometres per ride and the average time is 20 minutes. Each scooter is used more than six times per day and the peaked in demand for scooters is during the evening while a smaller peak appears also in the morning. In working days rentals are higher, reflecting the fact that scooters are widely used for commuting during the week and a bit less for leisure during weekends. (Howe, 2018)
Previous data are valid for scooters, kick scooters are characterised by smaller distances travelled per ride, but they have a higher usage of the vehicle, since each vehicle is used more than 10 times per day. The average time travelled per ride is quite similar.

Bike Sharing

Bike sharing is one of the oldest sharing mobility services offered for the first time in Amsterdam in 1965, where the city authorities decided to offer fifty white bikes to its citizens so that anybody could use it. Already at that time, many of them were damaged or stolen, practice that represents a major issue even nowadays. After this year, many other systems have been invented and proposed to citizens all around the world, but only in 2013 they begun a fast-growing phase thanks to what we call dock-based bike sharing systems. These systems permitted to use bikes, usually placed in specific stations all around the town, from one point to another, thanks to a rechargeable car that allowed customers to unlock their bikes. A per minute tariff was paid by customers and this allowed many people to pass from cars or

traditional public transports to an environmentally friendly and healthier vehicle, bicycles. Nowadays, this system is still available in most cities in Europe, Asia and USA.
Actually, the new bike sharing systems allows people to find bikes in a free-float fleet, permitting them to park bicycles anywhere in the city. Of course, this represents an issue both for the bike sharing operators and for the governments. In fact, shared bikes are affected by vandalism, littering and thefts. Many operators went bankrupt or they decided to leave some cities due to the fact that people tend to destroy bikes, to throw them in rivers and in landfills without reasons.
For governments, free float bike sharing systems create a problem of regulation and of restrictions. As a matter of fact, city authorities need to regulate the parking of bikes since sometimes they are left in places where they create an obstacle for walking or driving. Authorities need to preserve the order of cityscape. Moreover, since bicycles can ride in the streets, safety issues exist, and infrastructure investments have to be made, such as building new cycle lanes, to match with the growth in the use of bikes.
In the market there are 3 models: free floating, hybrid and dock based.
As mentioned before, free floating bike sharing has no fixed pick-up points, are managed directly towards an app for mobile phones and bikes are spread all around the area of operations. Hybrid bike sharing consists in picking up a bike in a fixed point and then the customer can drop it off anywhere inside the operating area. Finally, dock-based systems permit to rent a bike from one station to another station, bikes are locked in pick-up points.
Currently, electric bikes are booming, especially if coupled with sharing mobility services. Many companies, such as Uber with his new e-bike sharing system called JUMP, are entering the sharing mobility market with electric bikes that are a valid alternative to the traditional bikes, to public transports and to scooters or motorbikes. They allow to reach 25 km/h, permitting to move faster in traffic and they offer a lower price than scooters (excluding kick scooters that can have similar tariffs). They can have fixed battery charging stations or they can have portable batteries so that the operator can replace batteries without transporting the bike to a charging point and allowing riders to drop off the bike anywhere around the town.

Ride Sharing

Ride sharing, also called ride hailing, is another sharing mobility service that allows the connection between drivers and riders. Riders are passengers that thanks to an app they can join a driver. It is like a normal taxi service and that is the reason why in many countries, such as Italy, most of these services are not authorized by the government after the complaints from taxi drivers. Usually, drivers are the owner of their cars and this enables ride sharing companies to provide only a sort of platform linking driver with their own car and riders looking for a drive, without the necessity to have a car fleet, a parking and without incurring in maintenance costs for vehicles.

Normally, ride sharing is more widespread than car sharing, in fact, one quarter of people living in cities have used ride sharing and half of these are using it more than twice every month.

Some barriers exist. There is a high volatility in prices since tariff can vary a lot according to the demand and to the time in which you are willing to take a ride, sometimes there are not vehicles available, it is not always easy to trust the driver and you don't know if the car will be clean or not.

Together with these potential issues, a lot of benefits exist. First, they offer the same service of normal taxis, but it is cheaper, and you are aware of the price you are going to pay before the ride, so that you can't be fooled by the driver. Another advantage is the short waiting time and the satisfying availability of vehicles all around the city. Since they are app-based services, it is easy to ask for a ride and it is immediate. Finally, thanks to the evaluation score that is usually used to evaluate both drivers and riders, cars are cleaner and drivers but also riders have to be politer.

5. Prospects for Electric Vehicles

5.1 Delphi Method

To assess the prospects for EVs in an evolutionary scenario of sharing mobility, a Delphi methodology has been chosen. This chapter will describe the background of this study methodology, presenting hypothetical issues that can be found together with its strengths.

The Delphi methodology has been used for the first time by the American Government in the '50s to improve decision making when the Rand Corporation, a think tank company created with the support of the Department of Defence (DoD) of the United States of America, had to find a method to forecast hypothetical scenarios in different areas such as the outcomes of a nuclear war. (Vázquez-Ramos, 2007)

At that time, Delphi methodology has been introduced since, as said by one of the developers of the method, it permits to efficiently make decisions regarding one topic, such as the outcomes of the war, building on the opinion of experts that generate a consensus.

The Delphi methodology allows experts to express their thoughts anonymously, permitting to expand the horizons of the topic to be analysed and to introduce specific insights that enables decision makers to take the right choices, being aware of the different scenarios that their decisions will generate. The goal of the methodology is to create consensus around the topic securing the understanding of experts.

It is still not clear if the Delphi methodology is a qualitative method, a quantitative method or a mix of both. In fact, it collects anonymous opinions – a qualitative feature - by following a well-structured process made of different steps and it analyses results also using some statistics – a quantitative characteristic. (Sekayi, 2017)

Dalkey, the father of this methodology together with Helmer, expressed the concept of opinion as a judgement or something in-between knowledge and speculation. Knowledge is the information that is based on evidence, that can be demonstrated, while speculation is on the opposite side of information since it doesn't provide any evidence, it is just a matter of hypothesis, beliefs. Dalkey considers the opinion of experts fundamental to be properly informed on one topic and he considers information as a mix between knowledge, opinion and speculation. (Dalkely, 1972)

Three main different forms of Delphi studies exist. The first one is the policy Delphi study that allows researchers to find different points of view taken from experts on a topic and to check if there is a consensus or if there are different opinions. The second one is the numeric Delphi study, used to obtain predictions on a topic based on statistics results. The last one is the historic Delphi study, a method that is used to analyse the past issues that have had an impact on the decisions made in the past.

Before using a Delphi methodology, it is important that the researcher understands why he should use this method rather than others, if he can reach out some experts and how, and which kind of results he is aiming for.

As a matter of fact, the Delphi methodology is particularly suitable for four main research objectives. First, when there is the need to find some insights enabling to find a consensus on a specific issue within a group of people. Secondly, to allow a group of people to discover the different points of view on an argument so that they can get a better knowledge in this field. Thirdly, Delphi method can be used to determine the issues related to a specific topic that generated diverse interpretations. Finally, this methodology can be used to simply compare experts' different perceptions on many disciplines. (Hasson, 2000)

A Delphi study is not suitable for analysis in which there is the requirement of analytical tools, but it is useful when the group's opinion and the different rounds of feedback can support the research. (Linstone, 1975)

The Delphi methodology has many advantages.

First, thanks to the anonymity offered to the experts involved in the study, they feel free to express their ideas without running the risk of being judged and they can be totally sincere when expressing their opinions. Together with that, the anonymity permits to avoid the all the group dynamics that can influence the results, typical of a focus group, such as dominance of one though and conflicts. (Boberg, 1992).

Secondly, thanks to the fact that the study is based on various rounds, as it will be discussed later, experts have the chance to perfect and to modify their answers, being also aware of the opinions expressed by other experts.

Moreover, Delphi method is considered to be superior respect to other practises since it allows to mix a group of people together with the opinion of experts and a statistics investigation.

In addition to that, the advantage of this method is that experts can express their reasoning in a written form, the solution can be reached quite rapidly if experts are available and thanks to the fact that participants are exposed to a feedback process, there is the possibility to modify the opinion obtaining a deeper analysis of the topic.

On the other hand, some concerns exist regarding the Delphi methodology.
According to some researchers, such as Sackman, a former colleague of Dalkey, this method is not reliable nor scientific since there is not a solid literature review in place to assess whether the assumptions are correct or not.
Another issue is related to the possibility to influence the results. In fact, since during the various rounds of feedback experts can see the answers of other group members, they can be influenced by these different views and this can lead to a common consensus only determined by a group influence grown in the various feedback rounds.
Moreover, a major problem in this method is that sometimes some experts don't participate to all rounds and this is out of the control of the researcher. In addition to that, since the questionnaire and the following feedback rounds are sent online to experts, there is not the chance to have a real conversation between them, they cannot directly debate around the topic, going more in depth and expressing more in detail their opinions. (Hasson, 2000)
Together with that, the topics discussed can be oversimplified and this can lead to an uncomplete vision of the topic that leads poor results.

A Delphi study is composed of various rounds in which the researcher collects data.
During the first round, called exploration, the researcher presents to the experts a list of open-ended questions related to the topic that has to be discussed. These questions are necessary to offer the base to the following steps. In fact, these questions should provide to the researcher a set of statements, ideas and opinions that will be used in the next steps.
The following rounds are called controlled feedback or evaluation (Adler, 1996). As a matter of fact, the researcher classifies the statements obtained in the first round using a content analysis technique, in which statements are ranked according to the number of times they have been proposed by experts in the first round (Stemler, 2001). Then, the facilitator asks experts to rank these statements according to their beliefs and preferences. If possible, experts should also justify their choices so that the analysis can be carried more in depth. Once all the participants complete this step, the facilitator must sum up the results obtained from this step, showing which percentage of participants agree or disagree with each question, and send results to all participants. This can be done in an iterative way; the researcher can decide how many rounds he needs, until the consensus is reached. Generally, two or three rounds are enough to obtain a reliable result (Hasson, 2000). At each round, experts will have to rank

some statements and the result will be a general consensus on some statements rather than others. (Meijering, 2016)

Usually, the researcher must define what is the level of agreement from panellists that will consider as a consensus. For example, it can be when more than three quarters of experts agree on the statements. It is also possible that consensus is not reached. In that case, if after some rounds, experts are not modifying their answers, but they stick on their ideas, a stability point is reached.

The result is a quantitative collection of individual opinions that will form a group opinion on the topic being analysed. That is the reason why it is difficult to assess whether it is a qualitative or a quantitative study methodology. At the end, it is probably a mix of both.

5.2 Study Methodology

The literature confirms that there is a need to know what the prospects for electric vehicles are. Governments have to get a full picture on the possible scenarios that can be forecasted in order to take the right decisions, to provide the correct incentives and to develop policies in line with market expectations and that will enable all countries to meet their energy and environmental requirements in the coming years. That is the reason why a Delphi methodology has been chosen to assess the prospects of electric vehicles. In particular, a policy Delphi methodology has been selected since it was necessary to find various opinions taken from experts working in the EVs industry and to check if there was a consensus about the future of e-mobility, considering also the improvement of sharing mobility.

Moreover, since the subject is quite technical, the opinion of expert was considered to be more relevant than the opinion of a wide sample of people.

Then, a Delphi methodology was more appropriate than a focus group or a group discussion since it allowed to gain the perspectives of different countries since it has been possible to contact people all around Europe and in the United States of America. That was a major advantage for using Delphi method, in fact it was quite difficult to contact experts and since there wasn't the possibility to have a meeting with them, it was necessary to choose a method that allowed to get their opinions via an online questionnaire.

Finally, experts involved in this study were free to express their ideas since the questionnaire was anonymous and they were able to comprehend what other experts believed. Together with that, Delphi methodology allowed to avoid the noise effect typical of group discussions and permitted to build a general group consensus based on the individual opinions of experts.

Expert selection

One of the most important phases in a Delphi study is the selection of experts that will participate to the discussion. In fact, the selection of experts should be purposive, experts must be chosen according to their experience in the field that has to be analysed, in this case the electric vehicles field. Of course, literature points out that is quite complex to give a proper definition of an expert and that is the reason why some researchers consider it as a method that is not scientifically effective. (Sackman, 1975) Normally, experts have to be familiar with the topic to be discussed, they need to be available for the completion of the questionnaire and the next steps and they finally must be able to prioritize the statements to be discussed after the first round. (Adler, 1996)

For this project, experts were required to have the following characteristics: (i) at least 5 years of experience in the EVs sector or in mobility, (ii) currently working in this industry, or even in another industry but dealing with these 2 sectors, (iii) English speakers.
According to the literature, the number of experts selected is never going to be statistically significant since the goal is to look for the opinions of experts only. That is the season why 10 to 15 can be a proper number of experts to obtain reliable results (Adler, 1996).
In this study, more than 40 experts have been targeted, but at the end only 19 decided to participate and only 18 were meeting all the three requirements to be defined as an expert. This value is higher than expectations since it exceeds the range of 10 to 15 participants found in literature.

To contact these experts, different strategies have been used.
The first tool that has been used was LinkedIn. Thanks to the possibility to reach a huge network of people, specialized in different fields, it was a perfect platform to get in touch with experts in the electric vehicles industry and in the mobility sector. In order to select experts, specific filters have been used. For example, people working in companies such as Tesla, Nissan and other market leaders in electric cars industry were reached, together with people working in banks or consultancy firms but that were specialised in the transport, mobility or energy sector.

Moreover, on LinkedIn a lot of groups exist, some of them are closed groups while others are opened to every account. By searching for e-mobility related groups, a huge panel of experts was available and many of them have been contacted via LinkedIn to participate to the study. It was quite hard to find experts interested in participating to the project but at the end, a clear majority of people included in the study have been found on LinkedIn.

A second strategy that has been used to find experts was the use of personal contacts and the direct invitation to the study through emails, phone calls or messages. Thanks to my energy engineering background, I knew some people working in the electric vehicle sector and I asked them to participate to the discussion. Furthermore, thanks to my experience in investment banking, a huge network of people working in banks and consultancy firm, specialised in the energy and mobility sectors, were contacted.

Finally, the last method used to find experts was by participating to specific events related to e-mobility, such as the Formula-E Gran Prix in Paris and other events proposed by the school or found directly online.

Demographics of participants

The 19 participants that decided to take part to the study were mainly males, only 21.1% of them were female. Only 18 participants were considered experts according to the characteristics of (i) experience in the EVs sector or in mobility, (ii) status of current worker in the EVs industry, in the car industry or even in another industry but dealing with these 2 sectors and (iii) English speaker. As it is shown in the pie chart below, most of them were between 35 and 44 years old and their experience in the electric vehicle field was on average between 5 to 10 years. These data depend on the fact that main experts have been found on LinkedIn, where more than 50% of users are between 25 and 44 years old. (Statista, 2019)

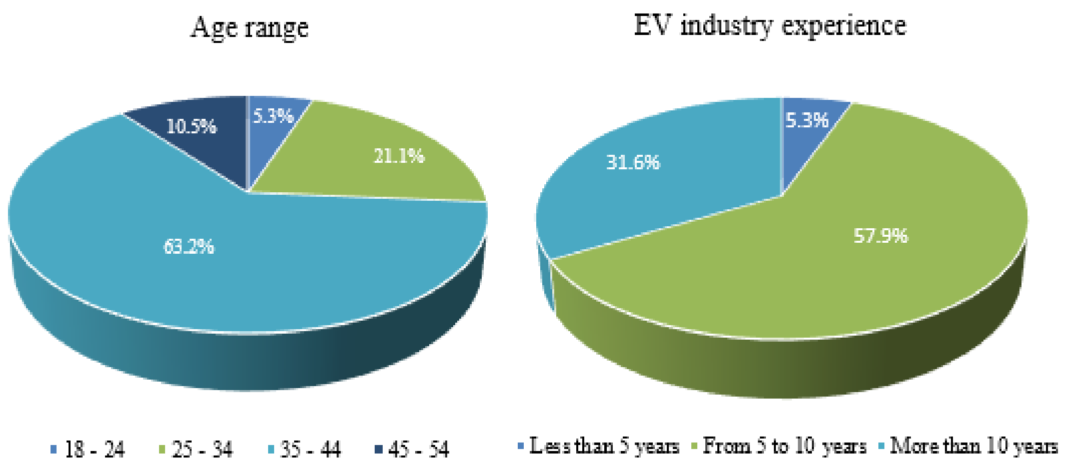

Figure 8 - Experts age range and industry experience

The Delphi study

First Round

In the first round, experts were given an introduction of the topic to be discussed, together with an explanation of the methodology to be used. Then, after few demographic questions concerning the age and experience in the electric mobility field, five open-ended questions were provided. Questions were based on the general topics about electric vehicles and sharing mobility found in the current literature review, in particular related to the typical issues and possible prospects for the electrification of vehicles, aiming at obtaining the point of view of experts on these issues and their opinion of the future of mobility.

For each open-ended question, at least 5 responses were asked to be answered per question, aiming at creating a solid base of statements for the following round.

The round one was conducted online by sending the Google Docs link and experts had 10 days to respond to the questions contained in the first round.

The questions found in in the first round were the following:

1. What issues do you think affect the large-scale adoption of Electric Vehicles (EVs)?
2. Focusing on cities, in what applications the current fleet can be substituted by full electric vehicles, considering their characteristics in terms of time of charge and discharge, autonomy, etc? (e.g. Police fleet, postal services, food delivery, road/networks maintenance or any other use of cars from one point to another in a restricted area)
3. Considering Sharing Mobility and focusing on cities, what should be the ideal Electric Vehicle in terms of: (a) type (car, ultralight vehicle, motorbike or scooter); (b) Engine: Full electric or Hybrid; (c) number of seats; (d) mileage (it is the autonomy in terms of kilometres)
4. What are the characteristics of the ideal Electric Vehicle without considering Sharing Mobility? What is the level of autonomy in terms of kilometres that it should have to satisfy the average daily distance travelled (e.g. 100 km)?
5. How will be shaped the infrastructure of cities in 10 years, considering a full electrification of vehicles and sharing mobility (think about parking, charging infrastructure, smart grid, public transports)?

Please find in Annex A the complete questionnaire from the first round.

Second Round

In the second round, the answers obtained in the first round have been analysed and all the statements have been categorized in a Likert-scaled questions to be sent to the experts to understand which opinions are more likely to be agreed by experts on the future of mobility in cities. It has been used a seven-point Likert scale, as suggested in the work of Lori Anne Magnuson (Magnuson, 2012).

In fact, to understand how experts agreed on topics proposed in the first round, each statement was provided with seven points, where:

- 1 meant not important or completely disagree;
- 2 meant slightly important or disagree;
- 3 meant somewhat important or slightly disagree;
- 4 meant moderately important or neutral;
- 5 meant important or slightly agree;
- 6 meant very important or agree;
- 7 meant extremely important or completely agree;

When all responses were collected, the mean, the median and the standard deviation were evaluated for each answer, in order to prepare the third and final round of the study.

In Annex B is presented the questionnaire used in the second round.

Third Round

In the third round, experts were asked to provide a rating to the same statements that they found in the second round. These statements had been created for each of the 5 questions according to the frequently mentioned topics from the first round. In this case, an additional information was given to the participants. In fact, for each statement they were provided with the average answer of the group from the second round. Since the goal of the entire study was to identify which topics generated a global consensus, thanks to the awareness of the mean rating from the group, experts were influenced by that and they had the opportunity to align or not to the group belief. In the case of alignment, the consensus could be reached.

In the literature, there is not an agreement on the ideal statistical measure to be used to justify Delphi rounds and to assess consensus. According to Hasson, agreement levels can be considered between 51% and 80% of agreement on the topics discussed in the study. This is the range in which the last round of a Delphi study is reached since the consensus is obtained. (Hasson, 2000)

In this study, standard deviation measures have been used. In fact, for each statement, the standard deviation has been computed to assess if there was an agreement between experts on the rating. The hypothesis that has been made is that on a 7-point rating Likert scale, a standard deviation lower than 1.000 would have implied that the participants agreed on the rating given to that statement.

Since the goal was to obtain a consensus among experts, once more than 51% of the statements were considered to be agreed among participants, the Delphi study was completed, and the consensus was reached.

In Annex C, the copy of the questionnaire used in the third round is shown.

5.3 Results

The purpose of this study was to acquire perspectives from experts on the future of mobility, particularly focusing on electric vehicles and sharing mobility. That is the reason why the Delphi methodology has been chosen. In fact, thanks to a three-round questionnaire, it has been possible to reach a consensus among experts concerning the future of mobility in cities.

First round

In the first round, experts were given some guidelines on the topic to be discussed and on the methodology to be used, before being asked to provide some statements by answering to 5 questions. They had to provide at least 5 answers per question, for a total of 25 possible statements per person. The questions asked in the first round were:

1. What issues do you think affect the large-scale adoption of Electric Vehicles (EVs)?
2. Focusing on cities, in what applications the current fleet can be substituted by full electric vehicles, considering their characteristics in terms of time of charge and discharge, autonomy, etc?
3. Considering Sharing Mobility and focusing on cities, what should be the ideal Electric Vehicle in terms of: (a) type (car, ultralight vehicle, motorbike or scooter); (b) Engine: Full electric or Hybrid; (c) number of seats; (d) mileage (it is the autonomy in terms of kilometres)
4. What are the characteristics of the ideal Electric Vehicle without considering Sharing Mobility? What is the level of autonomy in terms of kilometres that it should have to satisfy the average daily distance travelled?
5. How will be shaped the infrastructure of cities in 10 years, considering a full electrification of vehicles and sharing mobility?

All the answers have then been grouped and analysed using a qualitative method. In fact, for each question, all the answers have been grouped according to the topic they were addressing and for each topic the number of answers linked to that theme was evaluated to understand which statements were more common than others.

In Annex D are presented the first-round results.

Question 1

In the first question, experts were asked to propose some issues to be considered as responsible for a slow adoption of electric vehicles across the World. Most of experts, almost 80%, considered high prices of vehicles a strong barrier, together with a poor charging infrastructure that doesn't allow customers to be attracted by the e-mobility. Other important issues were represented by the fears related to batteries, from their low mileage to their safety, since sometimes batteries can catch fire. In addition to that, around 50% of experts considered cultural barriers an important obstacle, coupled with the fact that people are not aware of the technology and the advantages offered by EVs. As a matter of fact, people are still preferring traditional engines rather than electric motors and the environmentally friendly culture is not well developed everywhere. Another problem was considered by many experts to be the low model range offered by electric vehicles together with a low marketing effort made from car manufacturers. Finally, two more issues that were addressed were the lack of incentives from governments and the unreadiness of the electric power grid to accept the mass adoption of electric vehicles.
At the end, all these answers were grouped in 9 main issues, ready to be discussed in the second part of the study.

Question 2

In the second question, experts had to propose some applications or fleets that could be substituted by hybrid or full electric vehicles in cities. More than 70% of respondents proposed postal services and food delivery as suitable for the use of full electric vehicles. Then, many experts proposed also road and networks maintenance services. Moreover, many of them considered also ride sharing and car sharing fleets, together with taxi fleets as great opportunities for the switch to e-mobility. Other experts added also public services and municipal vehicles, together with police fleet. Finally, other answers proposed garbage trucks, company cars and vehicles used by plumbers, electricians, carpenters and painters.
Many suggestions were given in these answers that have been classified in 11 elements to be discussed in the following rounds.

Question 3

In the third question, experts had to give their opinion about the best characteristics of an electric vehicle if used in a sharing mobility fleet. They had to discuss about what type of vehicle is best suited and how many seats should it has. They had also to assess if the motor should be hybrid or full electric and what is the best level of autonomy in terms of kilometres. More than a half of the participants answered that the best vehicle should be a car, while one third expressed a favourable opinion towards scooters and few respondents considered ultralight vehicles a good choice. The experts were quite misaligned on the optimal number of seats, in fact both 2 seats and 4 seats were considered the best solutions and fewer respondents proposed more than 4 seats too. Focusing on engine, 60% of experts preferred the full electric motor. Finally, most participants considered a mileage between 100 and 300 km the perfect autonomy for an electric vehicle used for car sharing purposes.

Question 4

In the fourth question, experts were asked to discuss about the characteristics that an electric vehicle should have in the case of personal ownership, not to be used for sharing mobility purposes. In that case, nobody considered ultralight vehicles as a good solution and most experts considered car as the ideal type of vehicle. Moreover, these vehicles should have more than 4 seats, according to more than 70% of experts. Finally, almost all the participants answered that mileage should be between 100 and 300 km or even higher.

Question 5

In the fifth and last question, the participants had to discuss about the future of the infrastructure in cities in 10 years, considering an evolutionary scenario of sharing mobility and of electric mobility. Many experts introduced the theme of the diffusion of charging stations. In fact, according to them, future cities will offer charging stations for electric vehicles, considering also inductive charging plates, both in parking areas and on the roads, permitting a widespread use of EVs. Moreover, some experts considered that the public infrastructure would be all electricity based and roads will be adapted to the transit of EVs and autonomous cars. In addition to that, another important theme was the integration of EVs with the smart grid that will impact the shape of the infrastructure of cities. Finally, some

experts also considered that in 10 years there will be no radical changes in the infrastructure of cities.
All the themes introduced in these answers have been grouped in 4 main areas: smart grid, public charging stations, road adapted to the transit of new vehicles and no changes in infrastructure.

Second round

In the second round, experts were asked to rate the importance or the agreement with 44 statements, built for each question from their answers in the previous round. Once all the answers were collected, the mean, the median and the standard deviation have been evaluated for each statement to see what the level of agreement between participants was.
Since the main goal was to assess the consensus towards some topics, the hypothesis that has been made is that all the statements with a standard deviation lower than 1.000 were considered to generate agreement among participants.
At the end of the second round, 15 out of 44 statements reached already an agreement between participants, representing a 34.1% agreement. Since the agreement between experts was lower than 51%, the consensus was not reached in the second round.
In Annex E, the summary of the results from the second round are shown.

Question 1

In question one, the participants had to rate the importance of some issues affecting the use of electric vehicles. The agreement has been reached on 3 issues out of 9.
High prices, the lack of charging infrastructure, the fear related to batteries and the unawareness of people on the advantages of EVs were considered very important issues from experts. On the other hand, issues related to the power grid were not considered important. Low model range, low marketing efforts from car manufacturers, low incentives from governments and cultural barriers were considered as important.

Question 2

In the second question, experts had to rate the level of agreement with 11 applications or fleets that could be substituted by electric vehicles in cities. The agreement was reached on almost 50% of the applications proposed in the first round.
Experts fully agreed on food delivery services and they agreed on postal services, car sharing fleets, public transports, taxi and ridesharing fleets, last-mile delivery, road and network maintenance, police fleet and garbage vehicles. Moreover, they expressed a neutral position towards company cars, where the standard deviation was anyways higher than for the other applications, with a value of 1.317.

Question 3

In the third question, the participants had to rate their level of agreement on the best features of an electric vehicle used in car sharing fleets. The group agreement was reached only on 3 out of 10 features. In particular, it was met for the fact that the ideal EV in cities should be a scooter, it should be powered by a full electric motor and the mileage should be between 100 km and 300 km. Experts disagreed on the fact that the engine should be hybrid and that a mileage below 100 km was enough. On the other hand, they agreed on the fact that the ideal car can be a car or a scooter and that it should have 1 or 2 seats. They also slightly agreed on the fact that seats should be 3 to 5 and that the mileage can be higher than 300 km.
High standard deviations were found in this question, in fact a value of 1.961 was calculated for the statement that the engine should be hybrid, showing a huge misalignment between experts on that and the same for the mileage higher of 300 km.

Question 4

In the fourth question, experts were asked to rate their level of agreement on the best features for an electric vehicle to be used for personal ownership. In this case, only 2 features out of 10 had a standard deviation lower than 1.000 and they were the agreement respect to the fact that the motor should be full electric and that vehicles should have from 3 to 5 seats.
Experts were misaligned in rating the agreement towards the hybrid motor and the mileage between 100 km and 300 km, in fact the standard deviation was higher than 2.000.
They expressed a complete disagreement towards the mileage below 100 km and they slightly disagreed on the fact that the ideal vehicle should be an ultralight vehicle, that it should have

1 or 2 seats and that mileage should be between 100 km and 300 km. Moreover, they were quite neutral in the rating of the hybrid engine and the scooter as an optimal vehicle.
They agreed in considering the car an ideal EV, in preferring a full electric motor with a mileage higher than 300 km, having from 3 or 5 seats.

Question 5

In the fifth question, they had to express their agreement or disagreement with the 4 topics proposed in the first round concerning the future of city's infrastructure. Only 2 of them obtained a group consensus. The experts agreed in considering that smart grid will be well integrated with renewable energy sources and with electric vehicles. They also believed that public parking and roads will offer many charging stations, including inductive plates and that roads will be adapted for the passage of autonomous cars and scooters and other shared vehicles. On the contrary, they disagreed on the fact that there won't be any change respect to the current infrastructure.

Third round

The third round was the same as the second round but in this case, for each statement of all the 5 questions, the average rating given from the group in the second round was given. This additional information has had a huge influence on the results of the third round, in fact the number of statements that reached the agreement of the whole group of experts passed from 15 of the second round to 25. Thanks to this increase in the agreement, the third round has been the last round. As a matter of fact, 61.4% of the statements were agreed by most of the participants and this was above the threshold of 51%, so that, according to the literature, the consensus was reached.
In Annex F, the summary of the results obtained in the last round are shown.

Question 1

In question one, the participants had to rate the importance of some issues affecting the use of electric vehicles. The agreement has been reached on 5 issues out of 9.
Again, as in the second round, high prices, the lack of charging infrastructure, the fear related to batteries and the unawareness of people on the advantages of EVs were considered very

important issues from experts. In addition to that, all of these obtained a standard deviation lower than 1.000. Even cultural barriers obtained a low standard deviation of 0.600 and it was considered important by the experts, such as low incentives, low marketing efforts and low model ranges. Once again, issues related to the power grid were considered not important.

Question 2

In the second question, experts had to rate the level of agreement with 11 applications or fleets that could be substituted by electric vehicles in cities. The agreement was reached on more than 80% of the applications proposed.
Unlike the previous round, experts fully agreed on food delivery services, postal services, car sharing, taxi and ride sharing and last-mile delivery. Moreover, they agreed on public transports, road and network maintenance, police fleet, garbage vehicles and electricians, plumbers, carpenters' vehicles. Finally, again they expressed a neutral position towards company cars.

Question 3

In the third question, the participants had to rate their level of agreement on the best features of an electric vehicle used in car sharing fleets. The group agreement was reached on 50% of the features. In particular, they were aligned in saying that the ideal EV in cities should be both a car or a scooter, it should be powered by a full electric motor and the mileage should be between 100 km and 300 km. Experts slightly disagreed on the fact that the engine should be hybrid while they disagreed in offering a mileage lower than 100 km. Then, they agreed on the fact that the ideal car can be both a car or a scooter and that it should have a mileage between 100 km and 300 km. Once again, they slightly agreed that seats should be 3 to 5 and the mileage can be higher than 300 km. High standard deviations were persisting for the hybrid engines and the mileage higher that 300 km.

Question 4

In the fourth question, experts were asked to rate their level of agreement on the best features for an electric vehicle to be used for personal ownership. In this case, 4 features out of 10 had a standard deviation below 1.000 and they were the complete disagreement in having a

mileage below 100 km and the agreement that the motor should be full electric, that vehicles should have from 3 to 5 seats and they should be cars.
Experts were misaligned in the rating of the agreement towards the hybrid motor and the mileage between 100 km and 300 km, where standard deviations were high.
They also slightly disagreed on the fact that the ideal vehicle should be an ultralight vehicle, and that it should have 1 or 2 seats.

Question 5

In the fifth question, they had to express their agreement or disagreement with the 4 topics proposed in the first round concerning the future of city's infrastructure. In this round, all of them obtained a group consensus. The experts agreed in considering that smart grid will be well integrated with renewable energy sources and with electric vehicles and that roads will be adapted for autonomous cars and scooters. They strongly believed that public parking and roads will offer many charging stations, including inductive plates. Finally, they disagreed on the fact that there won't be any change respect to the current infrastructure.

6. The lightest and cheapest electric vehicle for urban mobility

The aim of this chapter is to assess what would be the best electric vehicle if used only for urban applications. In particular, in order to answer this question, a focus is made on the characteristics of batteries. As a matter of fact, batteries play a fundamental role in the analysis of the performance of electric vehicles. Their features will influence the weight of the vehicle, the mileage, the charging time and the possibility of having a battery swap.

The whole analysis begins with a comparison between different features of electric vehicles, in order to have a general overview on the main differences. Mass, range, cost, battery energy and charging time will be considered as the main features describing an electric vehicle.

Then, by taking into account the average distance travelled by car in cities, together with the current technology available for batteries and for electric vehicles, the optimal electric vehicle will be found.

6.1 Key features for electric vehicles

In the first step of the analysis, different categories of electric vehicles are considered. A database has been created including cars, ultralight vehicles, mopeds, scooters and bicycles. The rationale is that all these vehicles are used in cities to commute to work and to move around. Data were found on specialized magazines such as Quattroruote and on specialized online websites.

The parameters that have been taken into account are the following:

- Vehicle's mass (kg)
- Range or mileage (km)
- Battery energy (kWh)
- Motor power (kW)
- Number of passengers (#)
- Charging time (h)
- Price (€)

The database is shown in Figure 9.

Type	Company	Model	Mass (kg)	Range (km)	Battery (kWh)	Motor Power (kW)	Passengers (#)	Charging time - 1-Phase 32A(7.4kW) (h)	Charging time - Wall plug (2.3kW) (h)	Price (EUR)
Cars	Audi	e-tron 55 quattro	2.565	400	95	300,00	5	14	43	85.100
	BMW	i3 120 Ah	1.320	359	38	125,00	4	6	20	40.600
	Citroen	C-Zero Full electric airdream Seduction	1.195	150	14	49,00	4	5	8	30.891
	DS	DS 3 Crossback E-Tense	1.600	430	50	100,00	5	8	25	39.600
	Hyundai I	Ioniq Electric EV 28kWh	1.495	280	28	88,00	5	6	20	40.300
	Hyundai K	Kona Electric EV 64 kWh Xprime	1.760	482	64	150,00	5	10	32	43.300
	Jaguar	I-Pace EV kWh 400 CV Auto AWD S	2.244	470	90	294,00	5	14	44	82.460
	Mercedes	EQC 400 4Matic Sport	2.495	445	80	300,00	5	13	41	76.838
	Nissan	Leaf Acenta 40kWh	1.995	270	40	110,00	5	12	19	37.000
	Nissan	Leaf e+ Tekna	2.140	385	72	160,00	5	10	29	44.775
	Opel	Corsa-e 5p Selection	1.530	435	50	100,00	5	8	25	29.900
	Peugeot	e-208 100kWh 5p Active	1.530	450	50	100,00	5	8	25	33.400
	Renault	Zoe Life R90 Flex	1.543	403	41	65,00	5	9	27	26.100
	Smart 2	fortwo EQ Coupé Youngster	1.085	160	18	60,00	2	5	9	24.368
	Smart 2c	fortwo EQ Cabrio Youngster	1.115	155	18	60,00	2	5	9	27.718
	Smart 4	forfour EQ Youngster	1.200	155	18	60,00	4	5	9	24.918
	Tesla 3	Model 3 Stadard Range Plus	1.931	409	75	258,00	5	8	26	49.480
	Tesla S	Model S Long Range AWD	2.290	610	100	310,00	5	15	49	89.880
	Tesla X	Model X Long Range AWD	2.533	505	100	310,00	5	15	49	95.380
	Volkswagen	e-Golf 136 CV	1.540	300	36	100,00	5	5	17	40.750
Ultralights	Zbee	RS	280	80	4	4,00	3	5	5	10.000
	SAM	USA	500	100	7	19,60	2	5	5	9.000
	Tazzari EV	Zero city	450	200	15	15,00	2	8	8	15.000
Mopeds	Askoll 1	ES1	72	100	-	1,50	2	3	3	2.290
	Askoll 3	ES3	87	80	-	2,70	2	6	6	3.590
	BMW	C Evolution	265	100	-	35,00	2	3	3	15.650
	Etropolis R	Retro	140	70	-	2,00	2	5	5	2.916
	Etropolis V	VX	107	90	-	4,00	2	5	5	3.990
	Niu	N Sport	45	95	-	2,40	2	6	6	2.899
	Rieju	Nuuk	140	110	-	10,50	2	3	3	6.990
	Vespa	L1	130	100	-	4,00	2	4	4	6.390
Scooters	Xiaomi	MI	13	30	-	0,25	1	5	5	400
	Megawheels	S1	8	10	-	0,25	1	3	3	210
	i-Bike	Mono Air 8.5	13	20	-	0,35	1	4	4	390
	Ninebot	Segway ES2	13	25	-	0,30	1	4	4	500
	E-Twow	Booster s2	11	32	-	0,50	1	2	2	1.000
Bicycles	Nilox	E-Bike X5	23	55	-	0,25	1	3	3	690
	Momodesign	Florence	29	70	-	0,25	1	4	4	1.200
	Coppi	REPZL20206	20	30	-	0,25	1	4	4	600
	Nilox	Doc X1 Plus	20	25	-	0,25	1	3	3	600
	Moma	Bikes	20	80	-	0,25	1	4	4	1.000
	Electra	Townie Go! 8i	26	120	-	0,40	1	4	4	2.700

Figure 9 - Electric vehicles database

The first step of the analysis consisted in drawing a graph representing the relationship between the mass of the vehicle and the range. As a matter of fact, vehicle's mass is a crucial liability for electric vehicles since the higher the mass, the lower the mileage, due to the fact that the batteries discharge faster.

The results are presented in Figure 10.

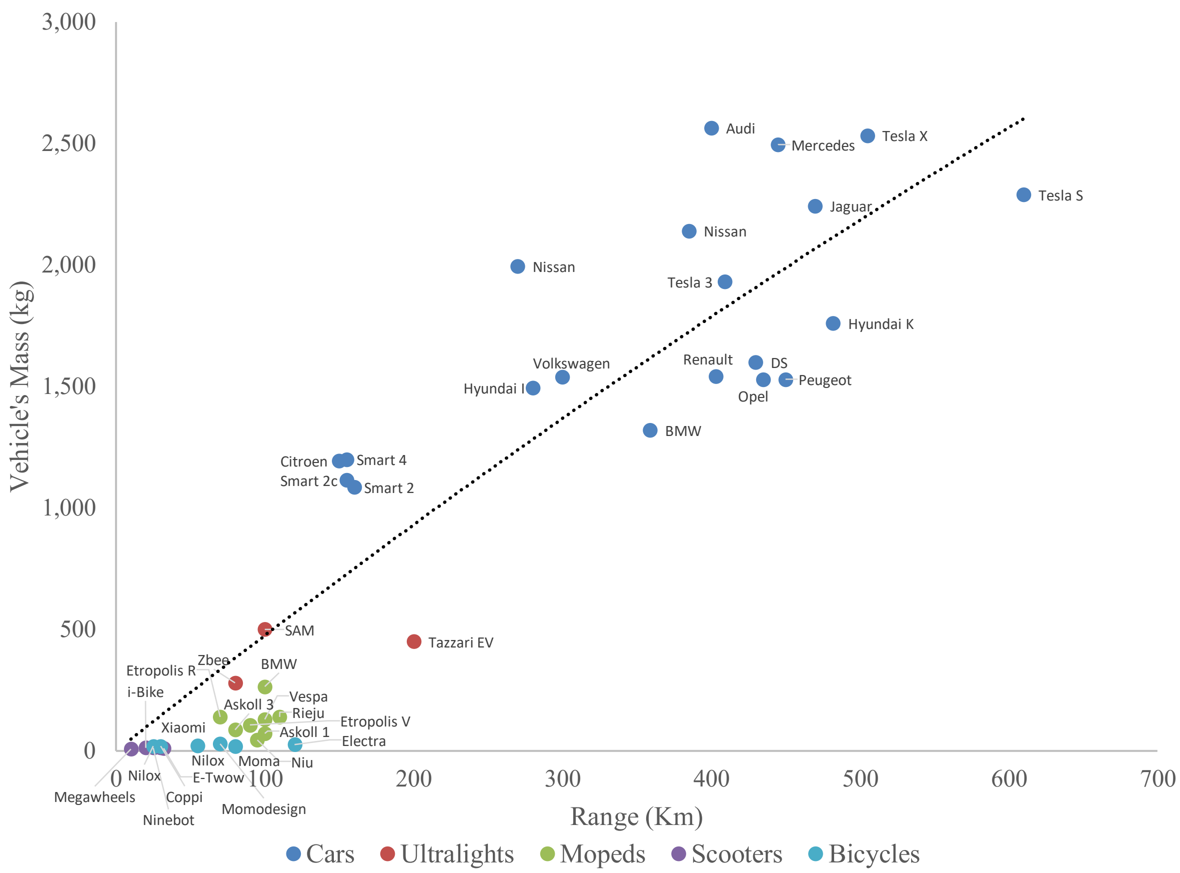

Figure 10 - Vehicle's mass vs Range

The graph shows a positive relationship between mass and range and it is in line with expectations. A higher mass allows to use a bigger battery that will improve the mileage. The issue is that bigger batteries requires long hours to be fully recharged, creating many issues to customers. In addition to that, the efficiency would decrease, and costs will be higher since battery costs represents almost 50% of total costs.

It is important to notice how ultralight electric vehicles can reach a good mileage by keeping a low mass. In fact, the ultralight vehicle Tazzari Ev Zero City can reach a range of 200 km by keeping the mass below 500 kg. A similar consideration can be made for bicycles, offering up to 110 km of autonomy and maintaining a small mass of the vehicle.

A further graph has been created to show the relationship between charging time and range.

It has not been considered the fast charging option, all data reflect a standard, slow, charging system, the home plug.

The minimum time required to charge completely the batteries is around 2 hours for the E-Twow Booster s2 scooter while the maximum charging time is 49 hours for the Tesla Model S Long Range AWD. The results are shown in Figure 11.

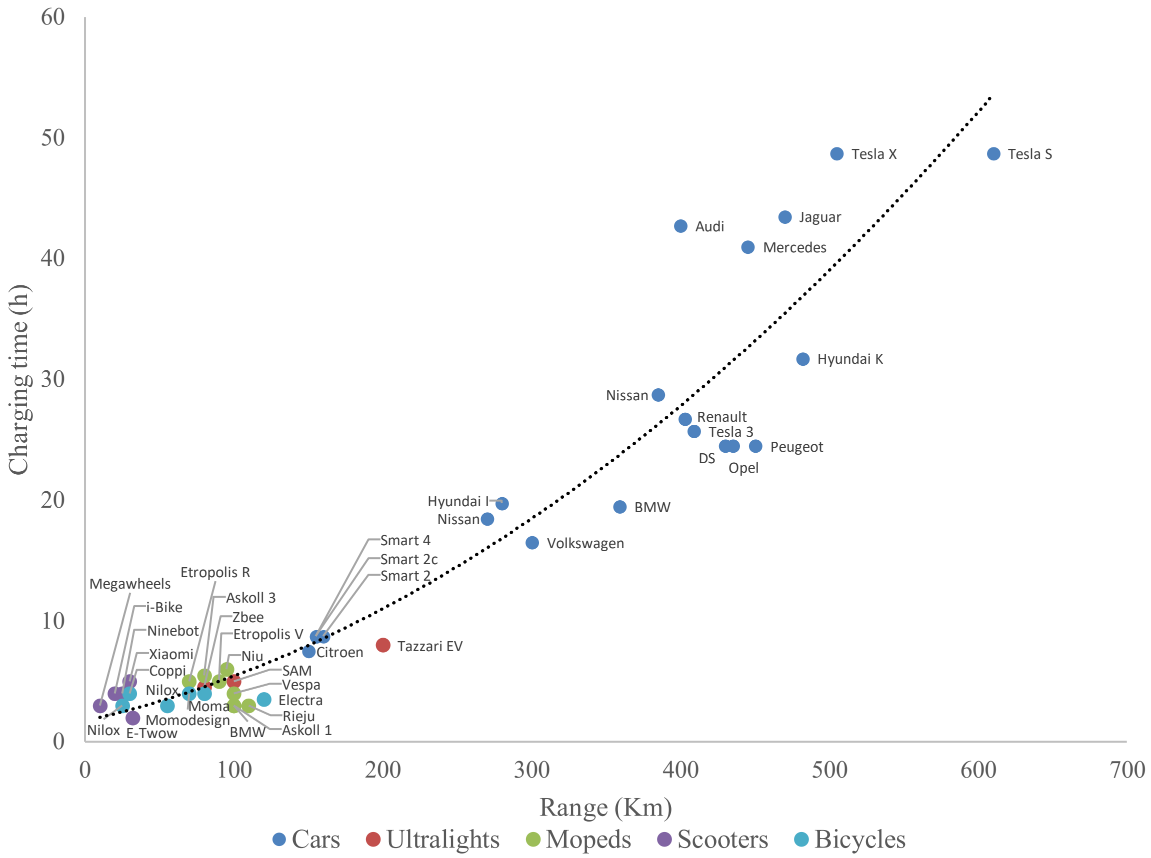

Figure 11 - Charging time vs Range if charged by using home plug

From this graph, it is possible to see that the charging time is not directly proportional to the mileage, in fact, as mileage increases, the charging time increases more, especially above 300 km of range. This is a big issue for electric cars, since they require a lot of charging time to satisfy their autonomy, if charged with a home plug.

Among all vehicles, the best in term of charging time and associated range is the moped Rieju Nuuk, allowing to reach 110 km with only 3 hours of charging time.

Among cars, the Citroen C-Zero full electric airdream Seduction show good results since it can offer 150 km of autonomy by recharging batteries in less than 8 hours by using a house plug.

On the other hand, results are quite different when using for example a 1-Phase 32A (7.4kW), in this case the charging time for cars is shorter, and it comes closer to the rest of vehicles, allowing to recharge the car on a daily base. In the following graph a 1-Phase 32A (7.4kW) charger is considered for cars.

At this charging speed, the vehicle allowing a higher range per hour of charging time is the Peugeot e-208 100kWh 5p Active, that requires less than 8 hours to fully recharge batteries and to offer an autonomy of 450 km.

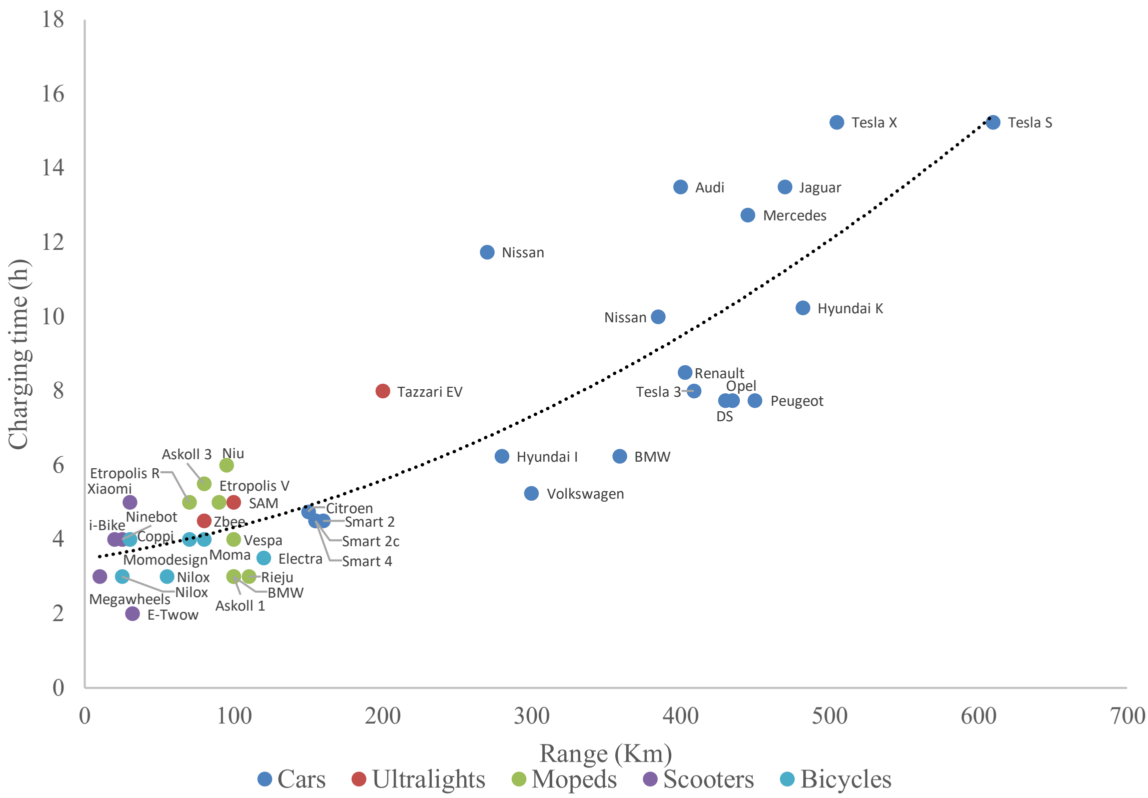

Figure 12 - Charging time vs Range if charged by using a 1-Phase 32A (7.4kW) charger

The next graph shows the relationship between the price of the vehicle and his mileage.

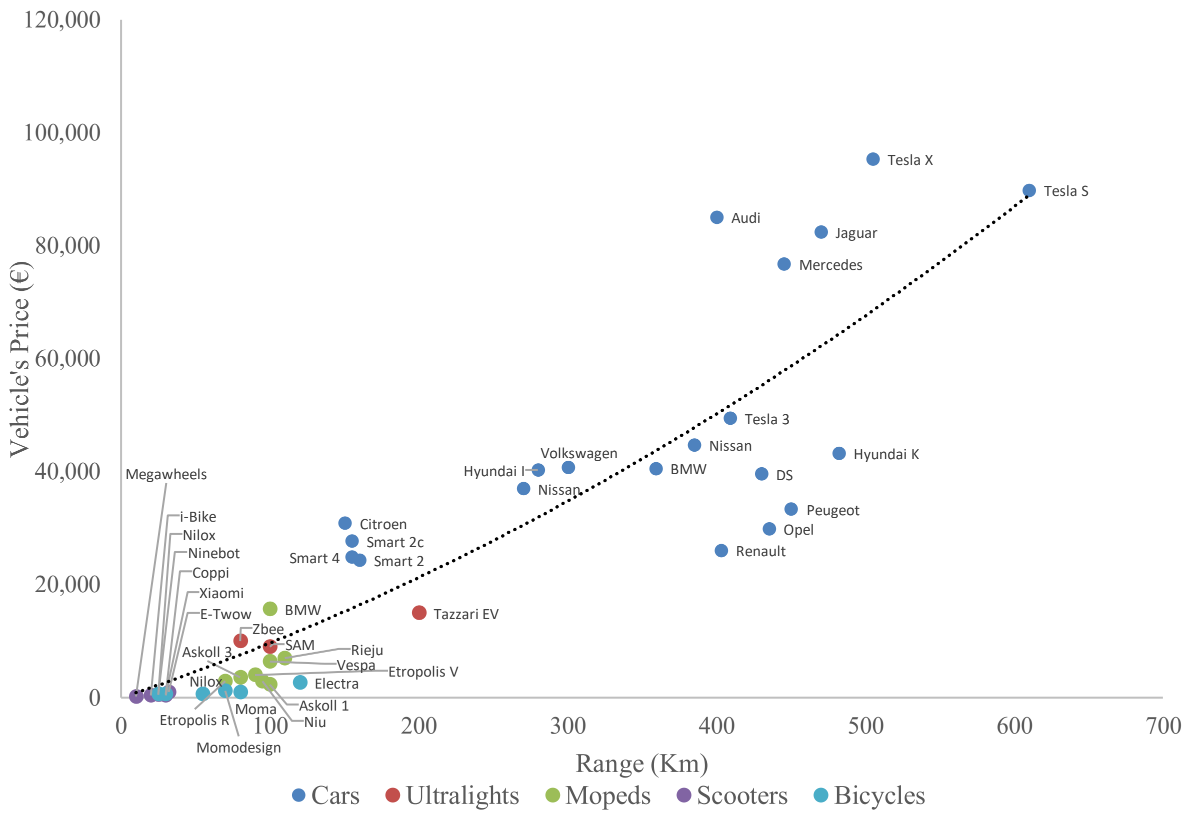

Figure 13 - Vehicle's price vs range

As mentioned before, a higher mileage is usually due to a bigger battery and it means a higher price for the vehicle. In fact, as it is presented in Figure 13, on average, the higher the mileage, the higher the price. The cheapest vehicle per unit of range is the bicycle Moma Bike, having a mileage of 80 km at a competitive price of €1,000. Focusing on cars, the vehicle that has the lowest price per range is the Renault Zoe Life R90 Flex, €26,000 and more than 400 km of autonomy.

Another parameter to be considered is the number of passengers for each vehicle. In fact, if cars can have up to 5 passengers per vehicle, scooters and bicycles will be good only for one person. This set the basis for a discussion about the possibility to compare these different vehicles' categories.

First of all, cars and ultralight vehicles are suitable for all the weather conditions, from cold winters to hot summers and rainy days, while scooters and bicycles are good in fewer conditions and that can generate discrepancies while analysing the optimal electric vehicle to be used in urban areas.

Then, their costs are very different, scooters and bicycles can be bought for less than €1,000 while ultralight electric vehicles are sold at €10,000 at least and cars starts from €30,000. Once again, this results in a difficult comparability between these categories.

These are the reasons why in the following sections, a focus will be made only on the following categories of vehicles: cars and ultralight vehicles.

6.2 Urban mobility

The goal of this paragraph is to identify the average distance travelled in cities and in urban areas. In literature, many studies exist about this topic, that is the reason why to assess the average daily distance travelled in urban areas, different sources are considered, and the average value will be considered for the following analysis.

Focusing on European data, the average daily distance travelled in Germany is 40 km (Franke, 2013). On the other hand, the average distance travelled in Norway is around 15 km, but a further analysis showed that it increases to 26 km for electric vehicle owners (Figenbaum E., 2014).

In France, the average trip length is up to 7 km in cities, so that the daily distance travelled could be considered around 28 km, considering 4 trips per day (Martouzet D., 2012).

Similar values can be found in Italy, where the daily average distance travelled is between 32-39 km while the average trip length is around 5 km per trip in urban areas (Dalla Chiara, Deflorio, Pellicelli, Castello, & Eid, 2019).

The table below summarize all the average daily distance travelled in these countries and shows the value we will consider as a good proxy for the following analysis about the best electric vehicle for urban mobility.

Country	Average daily distance travelled
	28 km
	40 km
	32-39 km
	26 km
	≈ 35 km

Figure 14 - Average distance travelled

The average daily distance travelled results to be around 35 km in Europe. The value obtained is in line with another study made by Dalla Chiara et al., in partnership with FCA, in which they analysed a huge dataset provided by FCA and they showed that more than 99% of daily distances travelled are lower than 35 km. (Dalla Chiara, Deflorio, & Eid, 2019)

6.3 The model

The goal of this analysis is to understand what the lightest electric vehicle would be to satisfy the urban mobility needs. To answer this question, an equation has been created in order to take into account all the different factors influencing the performance of electric vehicles.
As a matter of fact, the equation considers various parameters such as range, vehicle's mass, battery mass, battery's specific energy and vehicle's energy consumption. In addition to that, a further analysis includes the charging time of batteries to assess if it is possible to recharge the vehicle during the day or the night to grant a longer range.

Assumptions

The first assumption that has been made refers to the percentage of mass covered by batteries. According to a study run by the Boston Consulting Group, the battery's weight is between 20-25% of the total weight of the car (BCG, 2019). This result is in line with electric car manufacturers expectations, setting the limit to the battery weight to 20%. For our analysis, it is assumed that the battery weight corresponds to 25% of the vehicle's weight.
A further assumption is about the specific energy of batteries available on the market.
The specific energy is the capacity of a battery to store energy per kilogram of battery's weight. The current battery technology offers a specific energy between 0.08 kWh/kg and 0.12 kWh/kg (BCG, 2019). The maximum value that seems to be achievable in the next 10 years would be around 0.20 kWh/kg, still below 2% of the specific energy of gasoline, about 13 kWh/kg. For the following analysis, as a proxy of the current technology will be considered that specific energy is 0,12 kWh/kg.
Moving to energy consumption, to assess how much energy is discharged per kilometre, a database has been used where the battery's energy of each vehicle has been divided by its range. The average of this ratio has been calculated for cars and for ultralight vehicles. The results show that the energy consumption in cars is more than twice the consumption of ultralight vehicles. In fact, the average energy consumptions for electric cars is 0,142 kWh/km while it is only 0,065 kWh/km for ultralight vehicles.
These results are coherent since official data from electric car manufacturers show similar energy consumption values, considering both cold and mild weather conditions in cities.
Moving to the average daily distance travelled, a further assumption is made. According to literature, the value should be around 35 km. Batteries of electric vehicles should have a minimum state of charge (SOC), usually between 15% and 25% of the battery. Than, in order

to satisfy a range of 35 km, the battery should be designed by taking into account this factor. Thus, to consider this effect, the model will assume a higher daily distance travelled, up to 50 km.

The following table shows a recap of the main assumptions made for the model.

Parameter	Value
Average battery % of vehicle's weight	25%
Batteries' average specific energy	0.12 kWh/kg
Batteries' average energy consumption	
Cars	*0.142 kWh/km*
Ultralights	*0.065 kWh/km*
Daily distance travelled	50 km

Figure 15 - List of assumptions

The equation

To predict what would be the best characteristics for an urban electric vehicle, the following model is used. The equation is taking into account all the features influencing the performance of the vehicle and takes into account all the aforementioned assumptions.

The model is the following.

$$Range = \frac{Weight_{Vehicle} \times Percentage_{Battery} \times \ Specific\ Energy_{Battery}}{Energy\ Consumption}$$

Where:

- Range: it is the mileage of the vehicle, expressed in km;
- $Weight_{Vehicle}$: is the vehicle's weight, in kg;
- $Percentage_{Battery}$: is the percentage of the vehicle's weight due to the battery;
- Specific $Energy_{Battery}$: is the battery's energy per kilogram unit, in kWh/kg;
- Energy Consumption: is the energy consumed by the battery per kilometre, in kWh/km;

There are three variables, the range, the vehicle's weight and the energy consumption. In fact, since all the other parameters are fixed or dependent on current technology, the goal of this analysis is to understand what the lightest vehicle would be satisfying urban mobility needs.

6.4 Results

In the first step, the abovementioned equation has been used to evaluate the range offered by the electric vehicles contained in the database under the previous assumptions and in function of (i) their real mass and (ii) their real energy consumption.

The results have been compared with the real data to understand how much real data differ from the model.

The results are shown in Figure 16.

Figure 16 - Mass vs Range for cars and ultralight vehicles

The graph shows that, according to the model, the maximum range that can be reached is 455 km, obtained by the Renault Zoe Life R90 Flex. It is important to make a comparison between electric cars and ultralight vehicles. First of all, there is a clear distinction between their range.

According to the results from the model, ultralight vehicles can be used below 250 km of range while cars offer at least 300 km of autonomy. The vehicle with the lowest vehicle's mass to range ratio is, thanks to a low energy consumption, the ultralight Zbee RS, offering 168 km of autonomy weighting only 280 kg. On the other hand, the car with the lowest ratio of 3.11 is the Citroen C-Zero Full electric airdream Seduction. This car allows to reach 384 km of range with a battery weighting 299 kg.

A further comparison should be made between real data and model results.

There is a variance between the real range offered by vehicles and the range obtained by using the model. Part of the difference is due to the fact that real cars don't always have a battery weight of 25% of the vehicle's weight, they can have a bigger battery that allows them to cover longer distances even if the weight increases. For example, Tesla Model S has a real range of 610 km while according to the model the range should be lower, 419 km. This difference is also due to the specific energy of batteries. In fact, an average specific energy has been considered, taken from literature, but some car manufacturers, such as Tesla, are improving their batteries offering a higher specific energy that allows the car to improve a lot the range.

In the second step, the goal was to determine the minimum dimension of the car allowing to satisfy the urban range. According to the assumptions, the distance travelled was 50 km. All the specific characteristics of the vehicles were known from the assumptions and the only unknown was the weight of the car. The equation solving the problem was the following:

$$Weight_{Vehicle,min} = \frac{Range_{min} \times Energy\ Consumption}{Percentage_{Battery} \times\ Specific\ Energy_{Battery}}$$

The results show that the minimum weight of the vehicle should be between 85 kg and 395 kg, depending on the energy consumption specific of each vehicle in the database. This means that the battery should weigh between 21–99 kg and it would have an energy of 2.5–12 kWh. Ultralight vehicles require a lower weight to travel the same distance thanks to their lower energy consumption, around 0.065 kWh/kg.

Focusing on charging time, according to the literature, the charging time per battery energy is 0.67 h/kWh (BCG, 2019). This value is confirmed by the data available in the database, under the assumption of recharging the car by using a home plug. Once this factor is known, it is possible to see that the time required to fully charge the batteries of an electric vehicle

designed in order to satisfy the daily distance travelled is between 2–8 hours, depending on specific energy consumption of the vehicle.
The Figure 17 summarize these results.

Parameter	Value
Vehicle's weight	85-395 kg
Batteries' weight	21-99 kg
Batteries' energy	2.5-11 kWh
Charging time	2-8 h

Figure 17 - Results

According to the main features required by the electric vehicle suitable for urban mobility, the one available on the market that best fits is the ultralight Zbee RS. As a matter of fact, its weight is 280 kg, the battery has an energy of 4 kWh and it offers up to 80 km of electric range with less than 5 hours of charging time.

Finally, a further analysis investigates the maximum range available for each vehicle if charged during the night using a home plug. An interval of 7 hours has been considered as a good proxy for the time available to charge the batteries in one night.
This has been compared to the price of the vehicles, to understand what the cheapest car would be, allowing to cover enough range. The results are shown in Figure 18.
Considering a mileage of 50 km, all the vehicles satisfy the range but there are huge differences in term of prices. In fact, the best choice in this case would be the ultralight vehicle SAM Usa that costs only € 9,000.
In terms of price to range ratio, the best solution would be SAM Usa, with the lowest ratio of 64 €/km. As a matter of fact, there is a huge difference between cars and ultralight vehicles. Cars have ratios ranging between 315 €/km and 1315 €/km, while ultralights have lower ratios, between 64 €/km and 85 €/km.
It is possible to conclude that for urban mobility, ultralight vehicles are the cheapest choice that allows to satisfy most of mobility requirements in cities.

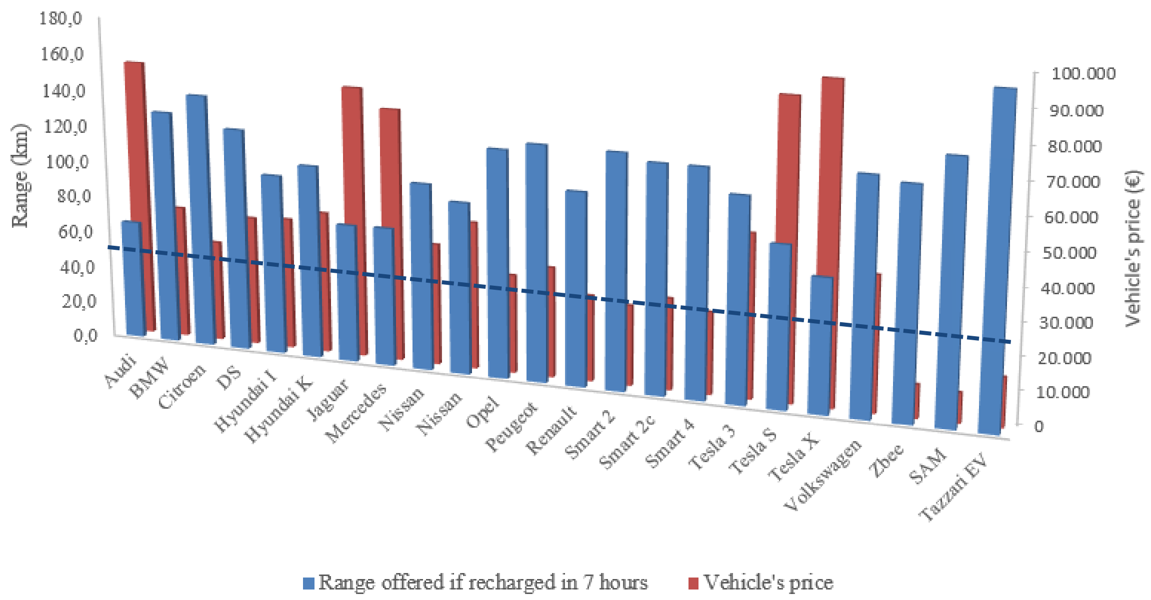

Figure 18 - Range available in 7h of charging time and vehicle's price

Further considerations

Since the cheapest vehicle is a small ultralight one, there can be an issue regarding the lack of space to carry people and objects. In order to solve the problem, the opportunity would be to create modular vehicles, enabling the owner to add more parts, such as more seats, a trailer or even an additional source of energy to the car.

These solutions have already been designed by some start-ups, such as Ep-Tender. This French company already provides a battery tender that allows to extend the electric vehicles range by providing additional energy. The service offers the electric vehicles owners the opportunity to rent online the tender and to use it from point A to point B by leaving the tender in point B. The tender can have a battery, a fuel cell or even an ICE engine, both offering an additional mileage to the car. It is a good solution for ultralight vehicles owners since it allows to increase the range of the vehicle to cover longer distances. For example, it can be used during holidays or for long trips.

Figure 19 shows the product that has just been described.

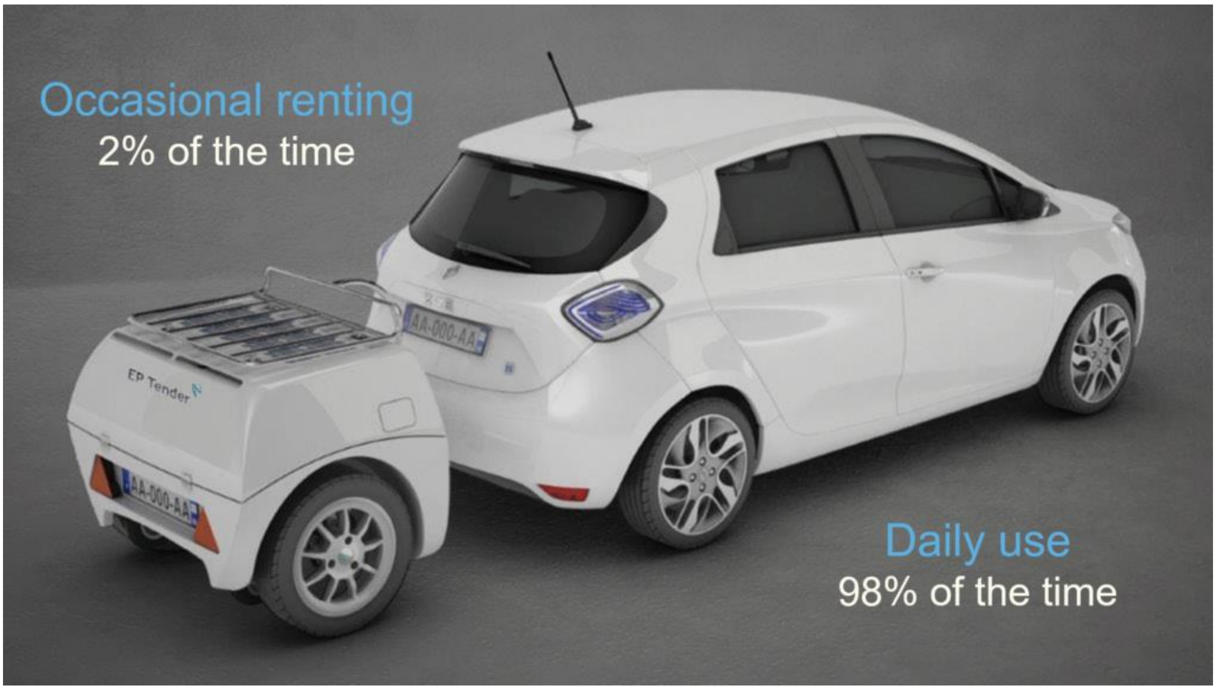

Figure 19 - Ep-Tender system

Finally, since ultralight electric vehicles in cities will have batteries weighting around 50 kg, it is possible to think to a battery swap mechanism, allowing the owners to change a low battery with a charged one, by offering twice the electric range that otherwise it would have had. This can be incentivized if the battery on the vehicles are modular, meaning that rather than having one battery of 50 kg, there are maybe two or three smaller batteries weighting in total 50 kg.

In this scenario, the range offered by the vehicles would be three or four times bigger than the basic scenario since when batteries are swapped, the old ones are charged and ready to be used when the new ones are low.

7. Conclusions

The scope of this study was to assess the future of mobility, specifically of electric mobility, and to consider also a scenario of sharing mobility. To predict the challenges and the opportunities for the development of electric vehicles in cities, a Delphi study methodology was chosen since it allowed a group of experts to express their opinions on the subject without personal meetings but just expressing their ideas towards different rounds of questionnaire, until a general consensus was reached.
As a matter of fact, after the first round in which experts were asked to answer to five open ended questions, it took two more rounds to obtain a consensus among experts.

At the end of the third and last round, the experts agreed that the major issues influencing the mass adoption of electric vehicles are the current high purchase prices of vehicles, the lack of charging infrastructure both in major and minor cities, the unawareness of the advantages and the characteristics of electric vehicles, together with the fears related to batteries in term of autonomy, technologies, number of battery cycles and even safety.
Then, since experts were asked to discuss the best characteristics of electric vehicles, the results showed that for personal ownership, the best electric vehicle should be a 5-seater car, with a full electric motor and having a battery with an autonomy higher than 300 km. In addition to that, experts believed that ultralight electric vehicles are not the best choice while scooters can be a good alternative, especially in cities.
On the other hand, experts have also expressed their opinion on the current fleets that can be converted in full electric fleet in the next years. They all agreed that last-mile delivery services, postal services, car sharing, ride sharing, road maintenance, public transports, police fleet, garbage vehicles and electricians, plumbers, painters and carpenter vehicles can be substituted by vehicles powered by full electric motors.
Moreover, according to the results, the best electric vehicle to be used in car sharing fleets in cities should be a car or a scooter, characterised by a mileage between 100 km and 300 km, with a full electric propulsion and offering from 2 to 5 seats. In general, a mileage lower than 100 km was considered too low to satisfy any usage of electric vehicles.
Moving to the future of the infrastructure of cities, there was a total disagreement with the idea that there will be no evolution in the infrastructure. In fact, most of the participants agreed that cities will offer many public charging stations, they will have more free spaces thanks to a reduction in the number of cars circulating, because of sharing mobility and ride

sharing fleets. In addition to that, they all expect roads to be slightly reshaped to facilitate the transit of autonomous vehicles and of electric public transports.

This study has shown that there will be a lot of changes in the mobility of the future. The major trends are expected to be the booming of electric vehicles, the growth of sharing mobility services and the rise of autonomous cars. That is the reason why most of the major car manufacturers are investing a lot in the research and development of new vehicles with the abovementioned characteristics. Moreover, many companies are growing fast thanks to the fact that they provide new services that are aligned with the needs of the future of mobility.
In fact, the goal of this thesis was also to give the reader the opportunity to reflect on the opportunities that this evolving market is going to offer.

Finally, the further analysis that has been made on the characteristics of electric vehicles showed that the lightest vehicle for city applications will be an ultralight, having a weight below 400 kg, along with a 5kWh battery energy and being completely charged in less than 6.5 hours. In addition to that, it has been demonstrated that ultralight vehicles are the cheapest solution available to satisfy the maximum range required for urban mobility.
Furthermore, there will be also the chance to design modular vehicles and to introduce and optimize a system of battery swap that will improve the mileage by covering all the mobility requirements.

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9. Appendix

Appendix A – First round questionnaire

Prospects for the electrification of vehicles

According to the New Climate Institute, all Internal Combustion Engines (ICEs) must be replaced by 2035 if the global temperature rise target of 1.5 degree Celsius, agreed at the 2015 UN Framework Convention on Climate Change (UNFCCC), is to be met.

That is the reason why, nowadays, the market of Electric Vehicles (EVs) is booming, all car manufacturers are switching to electric motors or at least they are proposing new models of full electric or hybrid cars.
The goal of this survey is to understand the prospects for the electrification of light and ultralight Electric Vehicles (EVs) in an evolutionary scenario of Sharing Mobility (SM).

A Delphi survey technique is used. The procedure used for this study is designed to convene a group of experts to share their perspectives based on their experience on the topic. Rather than meeting in person, the Delphi methodology permits to participate to the survey at geographical distance and since it is totally anonymous, it allows experts to express their ideas in complete freedom.
The methodology is composed on 2 steps. In the Round One, experts are asked to answer 5 open-ended questions, designed to elicit some insights about the topic. The Round Two will give the experts the chance to select how much they agree or disagree on certain topics highlighted in the first round, aiming at obtaining a common view on the prospects for the electrification of vehicles.

1. **What is your gender?** *

   Contrassegna solo un ovale.

   - Male
   - Female
   - Prefer not to say

2. **What is your age range?** *

   Contrassegna solo un ovale.

   - 18 - 24
   - 25 - 34
   - 35 - 44
   - 45 - 54
   - 55 - 64
   - 65+

3. **How many years have you been working in the Electric Vehicles sector (or in something correlated)?** *

   Contrassegna solo un ovale.

   - less than 5 years
   - from 5 to 10 years
   - more than 10 years

Thank you for agreeing participate in this study about the prospects of Electric Vehicles.

Please find below the questions related to the Round One of this survey.

1. **What issues do you think affect the large-scale adoption of Electric Vehicles (EVs)?** *
   Please describe at least 5 issues.

2. **Focusing on cities, in what applications the current fleet can be substituted by full electric vehicles, considering their characteristics in terms of time of charge and discharge, autonomy, etc? (e.g. Police fleet, postal services, food delivery, road/networks maintenance or any other use of cars from one point to another in a restricted area)** *
   Please describe at least 5 possible applications.

3. **Considering Sharing Mobility and focusing on cities, what should be the ideal Electric Vehicle in terms of: (a) type (car, ultralight vehicle, motorbike or scooter); (b) Engine: Full electric or Hybrid; (c) number of seats; (d) mileage (it is the autonomy in terms of kilometres)** *
   Please explain why you make these choices.

4. **What are the characteristics of the ideal Electric Vehicle without considering Sharing Mobility? What is the level of autonomy in terms of kilometers that it should have to satisfy the average daily distance traveled (e.g. 100 km)?** *
   Please answer the first part of the question analyzing topics considered in the previous question.

5. **How will be shaped the infrastructure of cities in 10 years, considering a full electrification of vehicles and sharing mobility (think about parking, charging infrastructure, smart grid, public transports)?** *
Please describe at least 5 topics related to the future of infrastructure.

Thank you for your help!

Have a nice day.

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Appendix B - Second round questionnaire

Prospects for the electrification of vehicles in cities - Second Round

Welcome to the second round of the survey exploring the prospects for the electrification for light and ultralight electric vehicles (EVs) in cities. The comments you provided in the first round were insightful and very interesting. Thank you for your previous answers that allowed to enhance this study.

In this second round, you are asked to provide a rating to the statements that you introduced by answering the questions in the first round. These statement have been created for each of the 5 questions according to the frequently mentioned topics from the first round.
The rating scale is from 1 to 7, where 1 means that that you totally disagree with the topic or that you consider the statement not important while 7 means that you completely agree or you consider it extremely important.

Open-ended spaces are provided at the end of each question so that you can address any comment, add new topics, present new issues etc.

Once all the responses have been compiled and statistically analyzed, you will receive the third and final round. In round three, you will receive the same set of questions but with the information about the average rating given at each topic from the group.

Once again, I remind you that your answers are completely anonymous.

Thank you for your participation.

Question 1

In the first round, you answered the following question:

What issues do you think affect the large-scale adoption of Electric Vehicles (EVs)?

1. **Please rate the importance of the following issues according to how much do you think they affect the use of EVs.** *
Contrassegna solo un ovale per riga.

	Not important	Slightly important	Somewhat important	Moderately important	Important	Very important	Extremely important
High prices and high ownership costs							
Lack of charging infrastructure							
Fears related to batteries (i.e. mileage and safety)							
Cultural barriers (i.e. old habits, still preferring ICE vehicles, not environmentally friendly)							
Low models range							
People are not aware of the advantages and the technology of EVs							
Car manufacturers are not pushing EVs' sales through marketing							
Not enough incentives from governments							
Electric power grid is not ready to support many EVs connected to the grid							

2. **Optional additional comments - here you can identify new issues that have not been discussed before and you can add any other comment**

Question 2

In the first round, you answered the following question:

Focusing on cities, in what applications the current fleet can be substituted by full electric vehicles, considering their characteristics in terms of time of charge and discharge, autonomy, etc? (e.g. Police fleet, postal services, food delivery, road/networks maintenance or any other use of cars from one point to another in a restricted area)

1. **Please rate your level of agreement with the following applications/fleets according to how much do you think they can be switched with full electric vehicles** *
Contrassegna solo un ovale per riga.

	Completely disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Completely agree
Food delivery							
Postal services							
Car sharing							
Public transports							
Taxi and ride sharing (e.g. Uber) fleet							
Last-mile delivery							
Roads/Networks maintenance							
Police fleet							
Company cars							
Electricians, plumbers, carpenters and painters' vehicles							
Garbage vehicles							

2. **Optional additional comments - here you can identify new applications that have not been discussed before and you can add any other comment**

Question 3

In the first round, you answered the following question:

Considering Sharing Mobility and focusing on cities, what should be the ideal Electric Vehicle in terms of: (a) type (car, ultralight vehicle, motorbike or scooter); (b) Engine: Full electric or Hybrid; (c) number of seats; (d) mileage (it is the autonomy in terms of kilometers)?

5. **Please rate your level of agreement with the following statements according to the best features of an electric vehicle used for car sharing** *

Contrassegna solo un ovale per riga.

	Completely disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Completely agree
The ideal EV is a car							
The ideal EV is a scooter							
The ideal EV is a ultralight vehicle							
The motor should be full electric							
The engine should be hybrid							
It should have 1 or 2 seats							
It should have 3 to 5 seats							
Mileage can be less than 100 km							
Mileage should be between 100 and 300 km							
Mileage should be higher than 300 km							

6. **Optional additional comments - here you can add new featured that have not been discussed before and you can add any other comment**

Question 4

In the first round, you answered the following question:

What are the characteristics of the ideal Electric Vehicle without considering Sharing Mobility? What is the level of autonomy in terms of kilometers that it should have to satisfy the average daily distance traveled (e.g. 100 km)?

7. **Please rate your level of agreement with the following statements according to the best features of a personal electric vehicle** *
Contrassegna solo un ovale per riga.

	Completely disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Completely agree
The ideal EV is a car							
The ideal EV is a scooter							
The ideal EV is an ultralight vehicle							
The motor should be full electric							
The engine should be hybrid							
It should have 1 or 2 seats							
It should have 3 to 5 seats							
Mileage can be less than 100 km							
Mileage should be between 100 and 300 km							
Mileage should be higher than 300 km							

8. **Optional additional comments - here you can add new featured that have not been discussed before and you can add any other comment**

Question 5

In the first round, you answered the following question:

How will be shaped the infrastructure of cities in 10 years, considering a full electrification of vehicles and sharing mobility (think about parking, charging infrastructure, smart grid, public transports)?

8. Please rate your level of agreement with the following statements related to the future of the infrastructure in cities *

Contrassegna solo un ovale per riga.

	Completely disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Completely agree
Smart grid perfectly integrated with renewable energy sources and with electric vehicles							
Public parking and roads offering many charging stations, including inductive plates							
Not many changes, the infrastructure will be similar to the actual one							
Roads adapted to the transit of EVs and autonomous cars							

9. Optional additional comments - here you can add new topics that have not been discussed before and you can add any other comment

Thank you for your help, the second step is finished !

Appendix C – Third round questionnaire

Prospects for the electrification of vehicles in cities - Third Round

Welcome to the third and last round of the survey exploring the prospects for the electrification for light and ultralight electric vehicles (EVs) in cities. The comments you provided in the previous rounds were insightful and very interesting. Thank you for your previous answers that allowed to enhance this study.

In this third round, you are asked to provide a rating to the same statements that you found in the second round. These statements have been created for each of the 5 questions according to the frequently mentioned topics from the first round.
The rating scale is from 1 to 7, where 1 means that that you totally disagree with the topic or that you consider the statement not important while 7 means that you completely agree or you consider it extremely important.
Now, you will be provided with the average answer given by all the experts for each statement.

Again, open-ended spaces are provided at the end of each question so that you can address any comment, add new topics, present new issues etc.

Once all the responses have been compiled, the results will be statistically analyzed, in order to assess in which topics a consensus has been reached.

Once again, I remind you that your answers are completely anonymous.

Thank you for your participation.

Question 1

In the first round, you answered the following question:

What issues do you think affect the large-scale adoption of Electric Vehicles (EVs)?

1. **Please rate the importance of the following issues according to how much do you think they affect the use of EVs.** *
Contrassegna solo un ovale per riga.

	Not important	Slightly important	Somewhat important	Moderately important	Important	Very important	Extremely important
High prices and high ownership costs [Avg = 6.18]							
Lack of charging infrastructure [Avg = 6.53]							
Fears related to batteries (i.e. mileage and safety) [Avg = 6.18]							
Cultural barriers (i.e. old habits, still preferring ICE vehicles, not environmentally friendly) [Avg = 4.94]							
Low models range [Avg = 4.76]							
People are not aware of the advantages and the technology of EVs [Avg = 6.18]							
Car manufacturers are not pushing EVs' sales through marketing [Avg = 4.82]							
Not enough incentives from governments [Avg = 4.88]							
Electric power grid is not ready to support many EVs connected to the grid [Avg = 2.18]							

2. **Optional additional comments - here you can identify new issues that have not been discussed before and you can add any other comment**

Question 2

In the first round, you answered the following question:

Focusing on cities, in what applications the current fleet can be substituted by full electric vehicles, considering their characteristics in terms of time of charge and discharge, autonomy, etc? (e.g. Police fleet, postal services, food delivery, road/networks maintenance or any other use of cars from one point to another in a restricted area)

1. **Please rate your level of agreement with the following applications/fleets according to how much do you think they can be switched with full electric vehicles** *
Contrassegna solo un ovale per riga.

	Completely disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Completely agree
Food delivery [Avg = 6.65]							
Postal services [Avg = 6.47]							
Car sharing [Avg = 6.47]							
Public transports [Avg = 5.94]							
Taxi and ride sharing (e.g. Uber) fleet [Avg = 6.41]							
Last-mile delivery [Avg = 6.41]							
Roads/Networks maintenance [Avg = 5.82]							
Police fleet [Avg = 5.88]							
Company cars [Avg = 4.12]							
Electricians, plumbers, carpenters and painters' vehicles [Avg = 5.94]							
Garbage vehicles [Avg = 5.76]							

2. **Optional additional comments - here you can identify new applications that have not been discussed before and you can add any other comment**

Question 3

In the first round, you answered the following question:

Considering Sharing Mobility and focusing on cities, what should be the ideal Electric Vehicle in terms of: (a) type (car, ultralight vehicle, motorbike or scooter); (b) Engine: Full electric or Hybrid; (c) number of seats; (d) mileage (it is the autonomy in terms of kilometers)?

5. **Please rate your level of agreement with the following statements according to the best features of an electric vehicle used for car sharing** *
Contrassegna solo un ovale per riga.

	Completely disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Completely agree
The ideal EV is a car [Avg = 5.94]							
The ideal EV is a scooter [Avg = 5.76]							
The ideal EV is a ultralight vehicle [Avg = 4.24]							
The motor should be full electric [Avg = 6.71]							
The engine should be hybrid [Avg = 2.71]							
It should have 1 or 2 seats [Avg = 5.71]							
It should have 3 to 5 seats [Avg = 4.88]							
Mileage can be less than 100 km [Avg = 1.94]							
Mileage should be between 100 and 300 km [Avg = 6.06]							
Mileage should be higher than 300 km [Avg = 4.94]							

6. **Optional additional comments - here you can add new featured that have not been discussed before and you can add any other comment**

Question 4

In the first round, you answered the following question:

What are the characteristics of the ideal Electric Vehicle without considering Sharing Mobility? What is the level of autonomy in terms of kilometers that it should have to satisfy the average daily distance traveled (e.g. 100 km)?

7. **Please rate your level of agreement with the following statements according to the best features of a personal electric vehicle** *

Contrassegna solo un ovale per riga.

	Completely disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Completely agree
The ideal EV is a car [Avg = 6.41]							
The ideal EV is a scooter [Avg = 3.82]							
The ideal EV is an ultralight vehicle [Avg = 3.12]							
The motor should be full electric [Avg = 6.24]							
The engine should be hybrid [Avg = 4.41]							
It should have 1 or 2 seats [Avg = 2.53]							
It should have 3 to 5 seats [Avg = 6.59]							
Mileage can be less than 100 km [Avg = 1.35]							
Mileage should be between 100 and 300 km [Avg = 3.39]							
Mileage should be higher than 300 km [Avg = 5.94]							

8. **Optional additional comments - here you can add new featured that have not been discussed before and you can add any other comment**

Question 5

In the first round, you answered the following question:

How will be shaped the infrastructure of cities in 10 years, considering a full electrification of vehicles and sharing mobility (think about parking, charging infrastructure, smart grid, public transports)?

8. Please rate your level of agreement with the following statements related to the future of the infrastructure in cities *

Contrassegna solo un ovale per riga.

	Completely disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Completely agree
Smart grid perfectly integrated with renewable energy sources and with electric vehicles [Avg = 6.00]	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Public parking and roads offering many charging stations, including inductive plates [Avg = 6.50]	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Not many changes, the infrastructure will be similar to the actual one [Avg = 2.13]	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Roads adapted to the transit of EVs and autonomous cars [Avg = 5.69]	⬭	⬭	⬭	⬭	⬭	⬭	⬭

9. Optional additional comments - here you can add new topics that have not been discussed before and you can add any other comment

Thank you for your help, the third and last step is finished !

Appendix D – First round results

First round

Gender	Age range	Years working in the Electric Vehicles sector (or correlated)	1.What issues do you think affect the large-scale adoption of Electric Vehicles (EVs)?	2.Focusing on cities, in what applications the current fleet can be substituted by full electric vehicles, considering their characteristics in terms of time of charge and discharge, autonomy, etc?	3.Considering Sharing Mobility and focusing on cities, what should be the ideal Electric Vehicle in terms of: (a) type (car, ultralight vehicle, motorbike or scooter); (b) Engine: Full electric or Hybrid; (c) number of seats; (d) mileage (it is the autonomy in terms of kilometres)	4.What are the characteristics of the ideal Electric Vehicle without considering Sharing Mobility? What is the level of autonomy in terms of kilometers that it should have to satisfy the average daily distance traveled (e.g. 100 km)?	5.How will be shaped the infrastructure of cities in 10 years, considering a full electrification of vehicles and sharing mobility (think about parking, charging infrastructure, smart grid, public transports)?
Male	35 - 44	more than 10 years	price, culture, marketing, usability, spread	postal services, food delivery, road/networks maintenance	car hybrid, 4/5,	200km	presence of smart grid (well spread), higher % of public transport
Male	35 - 44	from 5 to 10 years	Cost	Delivery	City car, 5 seats, full electric	250km	Parking places with charging terminals; more supply of energy is needed
Male	35 - 44	more than 10 years	Number of charging stations and consequent distance between them, initial investment, lack of information on the total cost of ownership, non-homogeneous incentives, small diversity of models, international pressure of the lobby of oil producers.	Postal service, food delivery, police fleet, public transportation, garbage trucks and city cleaning vehicles.	Ultralight vehicle, 2 seats (in case there are more people more cars can be rent, but on average only 1 or 2 seats are used), full electric with 30-50 km of autonomy (the average urban trip is shorter but in case the car is not left at the station for enough time to charge, it can last for a few trips).	The difference would be in the size of the car and autonomy. In this case I would say 4 seats car with at least 200km autonomy. In this case it can be used to reach vacation houses where sometimes there is not enough electricity to charge the vehicle. In this way you can avoid installing	The parking will be all converted to charging stations. Ideally, inductive charging will be used on larger scale allowing on the road charging. All public infrastructure will be electric and thanks to shared mobility, the reduction of vehicles will allow smaller and and emptier roads, that could be converted to "park avanues" and public spaces. They will also be 100% bike friendly.
Male	45 - 54	more than 10 years	Price, awareness, usability, economies of scale	Food delivery, postal services	Ultralight, hybrid	150km	Same
Male	18 - 24	less than 5 years	Charge stations infrastructure	Car sharing, postal services, public transportation	A) car B) full electric C) 4/5 D) 100km (and charging overnight)	300 km	Parking lots with charging infrastructure in the main public and work places. Smart grid perfectly integrated with RES. Buildings electrification. Different energy price billing.
Male	35 - 44	from 5 to 10 years	Competition of classic diesel cars, environmental issues, price of such vehicles, customers awareness	Food delivery, police fleet	Car, hybrid, 4/5 seats, 120 km	1,5 liters/ 50 km	People will use only EV
Male	35 - 44	more than 10 years	Battery, cost, recharge, maintenance, choice	Postal service, food delivery, last mile delivery, private security, car sharing	Car, hybrid, 4seats, 200km	No sound, very comfortable and good performances, 200 km	More charging columns, less polluted cities, possibility to interact with the grid, possibility to recharge while using the vehicle, connected cars
Female	45 - 54	more than 10 years	Recharge infrastructures Buying cost Environmental protection sensibilation Habits Vehical choices	Urban Police fleet Postal services Urban bus services Taxi fleet Product delivery services	Scooter for their usefulness in city and easyness in be driven (everyone could do it) and the recharge speed , full electric, 2 (better 2 than 1 because it is more practical) , 150km because I think it is a good autonomy for a multiple shared use in a city.	Car because it is the most widely used, hybrid to ensure autonomy in case of extraordinary longer uses without recharge possibility, 5, 250/300km to give autonomy to the ones working in a city different to the city where they live	Only public electric cars, free parking with charging infrastructure each parking. Electrified public transports traveling the most traveled streets to lower traffic jams
Male	25 - 34	from 5 to 10 years	Grid balancing, electric energy market operation, energy production sources, batteries	Taxi, food delivery, road maintenance, public transport	Ultralight vehicle, full electric, 300 km. So that emissions are avoided and consumption reduced with lightweight vehicles + large battery allows to commute and to accumulate energy in the car when it is cheap	Cheap and easy to manufacture and of compact size to be able to find parking spaces	Car sharing will be probably more present and less people will need to own a car. For vehicle built for the city, small cars and bikes will require less parking space, but charging infrastructure might be difficult to implement all over the city
Male	35 - 44	more than 10 years	- expensive - lack of charging stations - habits - the biggest industrial players have not implemented yet a method for large scale production	- Postal services - Public transports - Private transports - Car sharing	- Small cars, full electric, 4 seats with 150 km of autonomy	Medium size cars with 250 km of autonomy	Most of public parkings will be connected to inductive charging plates. Ideally, most of the energy consumed should be produced by renewable sources. Public transportation will be totally electric and their batteries should be used to balance the electric production consumption based on the time of the day (like a storage).
Male	25 - 34	from 5 to 10 years	Electric engine efficiency; electricity availability on the roads; sourcing of lithium for batteries; technology support and autonomy	Postal services, garbage trucks, couriers	(B) since Hybrid engines ensure more autnomy and performance	450 km	Parking places with charging terminals; more supply of energy is needed
Male	35 - 44	from 5 to 10 years	Charge station, economic aspects	Delivery good car sharing	Scooter	120	Chargig infrastructures
Male	25 - 34	from 5 to 10 years	The autonomy of the batteries, the price of the EVs, the lack of mass-produced vehicles (ie important volume of vehicles), the absence in some areas of recharging terminals and the relative new introduction of these types of vehicles that people take time to adopt	Taxis or Uber, public transportation such as buses, food delivery, commercial vehicles and municipal vehicles	A full electric car with 4 seats and an autonomy of 200km is ideal for me: it will be easier to pick up people in this type of car for an Uber for example, and an all electrical car incitate people to buy EVs	I think the ideal vehicle would be a scooter or a car, since they are the most used vehicles nowadays: it is important to show they are the same type of vehicles. I think an autonomy of 100km should be enough	A lot of charging points will be very important if EVs have a future, parking will be an issue for sure but not only for EVs: for all types of vehicles so cities should deal with this problem anyway, public transportation should become in the future years all electric: the cities and regions have a role of example in the society, so if they use EVs it will incitate citizens to do the same; cities and countries would implement taxes if other vehicles are used
Male	35 - 44	more than 10 years	Battery recycling - Price - Autonomy - Lack out charging stations - Models available	Public transports - Postal services - Taxis - Company vehicles - Buses	Autonomous car with 6 seats, hybrid with an autonomy of 500 km - It could come to take passengers and leading each of them to its destination while optimizing the journey, it should have the autonomy to complete a full day in town and never stopping to optimize its use	It should be a small electric vehicle, one or two seats for daily travels, able to complete 100 km at least	Vehicles should be all autonomous, able to park themselves in smart car parks, and the roads should have induction spots in order to charge the vehicles while moving

Female	25 - 34	more than 10 years	High prices Lack of charging infrastructure Low mileage People's lack of knowledge about EVs High pressure from car manufacturer willing to sell traditional Internal Combustion Engine vehicles	Car sharing Taxi Postal services Food delivery Public transports	Car, full electric, 2 to 4 seats, 300km of autonomy	Car, hybrid, 4 seats, 400km mileage	Smart grid will be set place, traditional car parkings will be substituted by parkings with charging systems (to be helpful for smart grids), a lot of vehicles around the city being part of car sharing fleets, transport systems will be all electric, a lot of cycle lanes fot electric bikes and scooters, both offered also in sharing
Female	35 - 44	more than 10 years	Few models Not enough access to charging systems High costs Safety issues (autonomy, fire)	Postal services Sharing vehicles Electricians Plumbers Food delivery	Car / motorbike / scooter Full electric 1 to 4 300km if car, less if the others	Car Full electric 5 400km	Chargers all around the town Cars used as energy storage for smart grid Less cars thanks to car sharing leading to a decrease in parkings Creation of specific spaces for sharing e-bikes and e-scooters so that they are not left randomly around the city Less traditional public transports and more diffusion of ride sharing services, based on EVs
Male	35 - 44	from 5 to 10 years	Recharging towers in cities Recharging towers outside big cities (so suburbs and countryside) Autonomy for travelling Expertise needed to repair them (excluding car manufacturer) Expensive and high cost of maintenance	Airports transportations could be completely renewed Company cars, can be shared among colleagues to go to work or anything Postal services Food delivery Ride sharing (Uber)	a. Car b. Full electric c. 5 d. 600km	An ideal electric vehicle should have a good assistance, an easy recharging mode in order to be as flexible as possible, 60/70 km for daily commutes would be ideal.	All parking would have a charging stations All houses would have charging stations Development of public transportations in order to minimize the quantity of vehicles Change the way parking are used, only electric vehicles can park but for free as long as they pay for their charge.
Female	35 - 44	more than 10 years	- Performances should improve - Infrastructure is not ready to support the mass adoption of EV - few models - Scarse awareness among people - Governments proposes incentives that are too weak	- Ride-sharing services - Food delivery - Postal services - Car sharing and Scooter fleets	Scooter Full electric 1/2 places At least 100 km	Car, 5 seats, full electric with a mileage of at least 400 km	Well developed charging stations network Less parking thanks to the use of sharing mobility services Roads adapted to create a safe environment for electric bikes and scooters
Male	35 - 44	more than 10 years	Few models available for customers Weak incentives from governments High costs People are scared by the mileage (even if it is quite high) Scarse infrastructure (charging stations)	Postal services Food delivery Any kind of delivery service not requiring a van nor a truck Road maintenance fleet Taxi fleet	Scooter - full electric - 2 seats - around 300km	Car - 5 seats- full electric - 400 to 500 km	Electric public transports Electric sharing mobility in city centres with dedicated parkings Most of parkings adapted for electric vehicles Roads adapted to autonomous cars Few parkings dedicated to traditional vehicles

Appendix E – Second round results

The following table shows the meaning of the rating given to each statement in the second and the third round.

Extremely important	7	Completely agree
Very important	6	Agree
Important	5	Slightly agree
Moderately important	4	Neutral
Somewhat important	3	Slightly disagree
Slightly important	2	Disagree
Not important	1	Completely disagree

Second Round

QUESTION 1

Please rate the importance of the following issues according to how much do you think they affect the use of EVs.

High prices and high ownership costs	Lack of charging infrastructure	Fears related to batteries (i.e. mileage and safety)	Cultural barriers (i.e. old habits, still preferring ICE vehicles, not environmentally friendly)	Low models range	People are not aware of the advantages and the technology of EVs	Car manufacturers are not pushing EVs' sales through marketing	Not enough incentives from governments	Electric power grid is not ready to support many EVs connected to the grid
6	7	6	5	6	5	5	5	2
6	7	7	5	3	5	5	3	2
6	7	7	5	6	6	3	3	2
6	6	7	5	6	6	6	5	2
7	7	7	5	5	6	3	3	1
7	6	6	4	5	7	2	6	2
6	7	7	7	6	7	7	5	1
6	7	7	2	5	7	6	5	1
7	7	7	6	6	7	6	6	3
7	7	7	6	7	7	6	7	2
5	6	6	5	6	7	4	5	1
7	7	7	5	4	7	6	6	1
7	7	7	4	3	6	4	6	1
5	6	7	4	5	6	4	6	1
7	7	4	4	4	5	7	6	4
4	5	3	5	3	5	4	3	5
6	5	3	7	1	6	4	3	6

Average	6.18	6.53	6.18	4.94	4.76	6.18	4.82	4.88	2.18
Median	6	7	7	5	5	6	5	5	2
Standard Deviation	0.883	0.717	1.425	1.197	1.562	0.809	1.468	1.364	1.510

QUESTION 2

Please rate your level of agreement with the following applications/fleets according to how much do you think they can be switched with full electric vehicles

Food delivery	Postal services	Car sharing	Public transports	Taxi and ride sharing (e.g. Uber) fleet	Last-mile delivery	Roads/Networks maintenance	Police fleet	Company cars	Electricians, plumbers, carpenters and painters'	Garbage vehicles
7	7	6	6	7	7	6	5	4	6	6
7	7	6	6	6	7	6	5	5	6	4
7	7	7	7	7	7	6	6	5	6	5
7	7	7	6	7	7	6	7	3	6	6
6	6	7	5	6	6	5	4	3	6	4
6	6	6	5	6	6	4	6	2	6	4
6	6	5	5	5	6	4	5	5	6	4
7	7	7	6	6	7	7	6	3	7	6
6	7	6	7	7	6	4	5	5	6	5
7	7	7	6	7	7	6	7	4	5	6
7	6	7	6	7	7	5	6	6	7	7
7	6	7	6	7	7	7	6	3	7	7
7	7	7	6	7	7	6	6	5	7	7
7	7	6	7	7	7	7	7	4	6	7
7	7	7	7	7	7	7	7	7	7	7
6	4	5	3	5	4	6	5	3	4	6
6	6	7	7	5	4	7	7	3	3	7

Average	6.65	6.47	6.47	5.94	6.41	6.41	5.82	5.88	4.12	5.94	5.76
Median	7	7	7	6	7	7	6	6	4	6	6
Standard Deviation	0.493	0.800	0.717	1.029	0.795	1.004	1.074	0.928	1.317	1.088	1.200

QUESTION 3

Please rate your level of agreement with the following statements according to the best features of an electric vehicle used for car sharing

	The ideal EV is a car	The ideal EV is a scooter	The ideal EV is a ultralight vehicle	The motor should be full electric	The engine should be hybrid	It should have 1 or 2 seats	It should have 3 to 5 seats	Mileage can be less than 100 km	Mileage should be between 100 and 300 km	Mileage should be higher than 300 km
	6	6	2	7	4	7	5	3	7	6
	7	6	3	7	6	6	6	2	6	3
	6	6	3	7	6	6	6	3	7	3
	6	7	4	7	2	7	5	1	6	1
	6	7	4	7	5	7	5	2	6	7
	3	6	5	7	2	7	2	1	6	5
	6	5	6	6	2	5	6	1	6	7
	7	6	3	7	1	6	6	1	6	7
	6	6	5	7	1	6	6	2	6	6
	7	6	5	7	1	6	3	2	6	6
	6	6	7	7	1	7	2	1	6	3
	6	5	5	7	1	5	6	1	6	7
	6	6	4	7	1	6	5	1	5	6
	6	4	4	7	3	7	3	2	6	6
	7	4	7	7	1	4	4	4	7	5
	4	6	3	5	3	4	6	5	4	3
	6	6	2	5	6	1	7	1	7	3
Average	5.94	5.76	4.24	6.71	2.71	5.71	4.88	1.94	6.06	4.94
Median	6	6	4	7	2	6	5	2	6	6
Standard Deviation	1.029	0.831	1.522	0.686	1.961	1.572	1.536	1.197	0.748	1.886

QUESTION 4

Please rate your level of agreement with the following statements according to the best features of a personal electric vehicle

	The ideal EV is a car	The ideal EV is a scooter	The ideal EV is a ultralight vehicle	The motor should be full electric	The engine should be hybrid	It should have 1 or 2 seats	It should have 3 to 5 seats	Mileage can be less than 100 km	Mileage should be between 100 and 300 km	Mileage should be higher than 300 km
	7	4	1	6	6	2	7	1	7	6
	7	5	2	6	7	3	7	1	7	6
	7	5	2	7	6	3	7	1	6	5
	7	3	2	7	5	1	7	1	6	7
	7	5	4	6	7	3	6	1	2	6
	5	6	5	5	7	5	6	1	1	7
	7	3	3	7	3	2	7	1	1	6
	7	6	3	7	3	4	6	1	2	6
	7	5	5	7	5	3	7	1	2	7
	7	2	2	7	2	1	7	1	1	7
	7	2	3	7	2	2	7	1	2	7
	6	3	3	5	7	1	7	1	1	6
	7	1	2	7	2	1	7	1	1	7
	6	3	4	6	3	2	7	1	2	7
	7	1	1	7	1	1	7	1	7	1
	3	6	6	4	4	4	5	3	3	5
	5	5	5	5	5	5	5	5	5	5
Average	6.41	3.82	3.12	6.24	4.41	2.53	6.59	1.35	3.29	5.94
Median	7	4	3	7	5	2	7	1	2	6
Standard Deviation	1.121	1.704	1.495	0.970	2.063	1.375	0.712	1.057	2.418	1.478

QUESTION 5

Please rate your level of agreement with the following statements related to the future of the infrastructure in cities				
	Smart grid perfectly integrated with renewable energy sources and with electric vehicles	Public parking and roads offering many charging stations, including inductive plates	Not many changes, the infrastructure will be similar to the actual one	Roads adapted to the transit of EVs and autonomous cars
	6	7	3	7
	6	7	2	6
	6	7	2	5
	6	7	2	5
	7	7	2	6
	5	6	3	5
	6	7	1	5
	6	7	4	5
	6	6	2	6
	6	7	1	6
	7	7	2	6
	6	7	2	7
	6	6	1	6
	7	7	1	6
	6	6	1	6
	4	3	5	4
	6	7	3	7
Average	6.00	6.50	2.13	5.69
Median	6	7	2	6
Standard Deviation	0.730	1.033	1.147	0.793

Appendix F – Third round results

Third Round

QUESTION 1

Please rate the importance of the following issues according to how much do you think they affect the use of EVs.									
	High prices and high ownership costs	Lack of charging infrastructure	Fears related to batteries (i.e. mileage and safety)	Cultural barriers (i.e. old habits, still preferring ICE vehicles, not environmentally friendly)	Low models range	People are not aware of the advantages and the technology of EVs	Car manufacturers are not pushing EVs' sales through marketing	Not enough incentives from governments	Electric power grid is not ready to support many EVs connected to the grid
	7	7	6	5	6	6	6	5	1
	6	7	7	5	3	5	5	5	2
	6	6	7	5	5	6	3	6	2
	6	6	7	5	6	6	6	5	2
	7	7	7	5	5	6	3	3	1
	6	6	6	4	5	7	3	6	2
	6	6	7	5	6	7	7	5	1
	6	7	7	5	5	7	6	5	2
	7	6	5	6	6	6	5	6	3
	7	7	7	6	7	7	5	7	2
	5	6	6	5	6	7	4	5	1
	7	7	7	5	4	7	6	6	3
	7	7	6	4	3	6	4	3	1
	5	6	7	4	5	6	4	6	1
	7	7	5	4	4	5	7	6	4
	5	6	6	5	3	6	4	3	3
	6	6	5	5	2	6	4	5	4
Average	6.24	6.47	6.35	4.88	4.76	6.24	4.82	5.12	2.06
Median	6	6	7	5	5	6	5	5	2
Standard Deviation	0.752	0.514	0.786	0.600	1.393	0.664	1.334	1.166	1.029

QUESTION 2

Please rate your level of agreement with the following applications/fleets according to how much do you think they can be switched with full electric vehicles

	Food delivery	Postal services	Car sharing	Public transports	Taxi and ride sharing (e.g. Uber) fleet	Last-mile delivery	Roads/Networks maintenance	Police fleet	Company cars	Electricians, plumbers, carpenters and painters' vehicles	Garbage vehicles
	7	6	6	6	7	7	6	6	3	6	6
	7	7	6	6	6	7	7	5	5	6	4
	7	7	7	6	7	6	6	6	5	5	5
	7	7	7	6	7	7	6	7	3	6	6
	6	6	7	6	6	6	5	5	3	6	4
	7	7	6	5	6	6	5	6	2	7	7
	6	6	6	5	7	6	5	5	5	6	5
	7	7	7	6	6	7	7	6	3	7	6
	6	7	6	7	7	6	4	5	5	6	5
	7	7	7	6	7	7	6	6	2	5	6
	7	6	6	6	7	7	5	6	6	7	7
	7	6	7	5	7	6	7	6	3	7	7
	7	7	7	6	7	7	6	6	5	6	6
	7	7	6	7	7	7	7	7	4	6	7
	7	7	7	7	7	7	7	7	6	7	7
	7	6	6	6	5	6	6	5	3	4	6
	7	7	7	7	6	6	7	7	3	5	7
Average	6.82	6.65	6.53	6.06	6.59	6.53	6.00	5.94	3.88	6.00	5.94
Median	7	7	7	6	7	7	6	6	3	6	6
Standard Deviation	0.393	0.493	0.514	0.659	0.618	0.514	0.935	0.748	1.317	0.866	1.029

QUESTION 3

Please rate your level of agreement with the following statements according to the best features of an electric vehicle used for car sharing

	The ideal EV is a car	The ideal EV is a scooter	The ideal EV is a ultralight vehicle	The motor should be full electric	The engine should be hybrid	It should have 1 or 2 seats	It should have 3 to 5 seats	Mileage can be less than 100 km	Mileage should be between 100 and 300 km	Mileage should be higher than 300 km
	6	6	2	7	5	7	4	3	7	6
	7	6	5	7	6	6	6	2	6	3
	6	4	3	6	6	6	6	3	7	
	6	7	4	7	2	7	5	1	5	2
	6	7	4	7	5	7	5	2	6	7
	5	6	5	7	2	7	3	1	7	5
	6	5	6	6	2	2	6	1	6	5
	7	6	1	7	1	6	6	1	6	7
	6	6	5	7	2	6	6	2	5	6
	7	6	5	7	1	6	6	2	6	6
	6	6	7	6	3	7	3	1	6	3
	6	5	5	7	1	5	6	1	6	7
	6	6	4	7	1	6	5	1	5	6
	6	7	4	7	3	7	3	2	6	6
	7	4	7	7	1	3	4	3	7	5
	4	6	3	5	3	5	6	4	4	6
	6	6	3	6	6	2	7	1	7	
Average	6.06	5.82	4.29	6.65	2.94	5.59	5.12	1.82	6.00	5.33
Median	6	6	4	7	2	6	6	2	6	6
Standard Deviation	0.748	0.883	1.611	0.606	1.919	1.698	1.269	0.951	0.866	1.543

QUESTION 4

Please rate your level of agreement with the following statements according to the best features of a personal electric vehicle

	The ideal EV is a car	The ideal EV is a scooter	The ideal EV is a ultralight vehicle	The motor should be full electric	The engine should be hybrid	It should have 1 or 2 seats	It should have 3 to 5 seats	Mileage can be less than 100 km	Mileage should be between 100 and 300 km	Mileage should be higher than 300 km
	7	4	2	6	6	2	7	2	7	6
	7	5	2	6	7	3	7	1	6	6
	6	5	3	7	6	3	6	1	6	6
	7	4	2	7	5	1	7		6	7
	7	5	4	6	7	3	6	1	2	6
	6	6	5	5	6	5	6	1	1	7
	7	3	6	7	5	2	7	1	3	6
	7	6	3	7	3	4	6	1	2	6
	6	5	5	5	6	3	7		2	7
	7	2	2	7	3	1	7	1	2	7
	7	2	3	7	2	2	7	1	2	7
	6	4	3	5	7	3	6	2	1	6
	7	1	2	7	2	1	7	1	1	7
	6	3	5	6	3	2	7	1	2	6
	7	2	1	7	2	1	7	1	7	1
	4	6	3	4	4	4	5	3	5	5
	5	5	5	5	5	5	5	4	5	6
Average	6.41	4.00	3.29	6.12	4.65	2.65	6.47	1.47	3.53	6.00
Median	7	4	3	6	5	3	7	1	2	6
Standard Deviation	0.870	1.581	1.448	0.993	1.835	1.320	0.717	0.915	2.239	1.414

QUESTION 5

Please rate your level of agreement with the following statements related to the future of the infrastructure in cities			
Smart grid perfectly integrated with renewable energy sources and with electric vehicles	Public parking and roads offering many charging stations, including inductive plates	Not many changes, the infrastructure will be similar to the actual one	Roads adapted to the transit of EVs and autonomous cars
6	7	3	7
6	7	2	6
6	6	2	5
6	6	3	4
7	7	2	6
6	6	3	5
6	7	1	7
4	7	4	5
6	6	2	6
6	7	1	6
6	7	2	6
4	7	2	7
6	6	1	6
6	7	2	6
6	6	1	6
7	7	4	5
6	7	3	6

Average	5.88	6.63	2.19	5.75
Median	6	7	2	6
Standard Deviation	0.806	0.500	0.981	0.775