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FIAT CHRYSLER AUTOMOBILES

Master degree thesis

- Analysis of the LCV electrification market through in-depth segmentation: trends, enablers and field data -

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1 Introduction

This thesis is based on the activities and the results obtained during the period spent at *FCA Italy*, in particular on the experience matured within Fiat professional, the FCA Brand dedicated to Light Commercial Vehicles (LCV). All the studies focused on the characteristics, features and factors that influence the market of the electric Light commercial vehicles (eLCV). The intention is to report an overview of the parameters that guide the world of these new vehicles and to understand how much the market is ready to receive them. A particular attention has been given to the final user of the vehicles because, depending on his needs and usage characteristics, it is possible to define the most fitting xEV[1].

The world of vehicles used to transport people and goods is changing continuously. New technologies make EVs everyday more reliable and more attractive to customers. The new CO_2 regulations and the ICE banned zones (especially for diesel) push, and have already convinced, many OEMs to invest on EVs. There are still many drawbacks that do not allow the world of electric vehicles to take off: costs and lack of charging infrastructure are two examples of them. In this complex and developing scenario, the EVs are anyway taking a good slice of the market and this portion will surely increase in the near future.

To better understand where these kind of vehicles can fulfill the customer's request, it is worthwhile to analyze the trends and the next challenge that both EVs and LCVs have to face. In addition it is very important to divide the users of commercial vehicles in categories to understand better which customer could substitute his vehicle with an electric one with the right and present technology.

In the near future, the revolution of EVs, which is already growing in the world of passenger cars, will explode and even change the Commercial Vehicle approach. For this reason it is fundamental to make the right decisions at the right moment in order

[1] all vehicles with an electric technology to support or substitute the ICE

to be competitive against the others OEMs. Surely is not simple and immediate to change the soul of a company that have founded its core business and success on conventional cars and vehicles but, this will be necessary. The technological turning point is already underway and who is able to take advantages from this discontinuity will have a solid base to start a future success in the EVs world. In the next pages, there will be a more detailed explanation of the aim of this thesis and of the methodology used.

2 Target and Methodology

FCA with the related brands, (Abarth, Alfa Romeo, Chrysler, Dodge, Fiat, Fiat Professional, Jeep, Lancia e Ram) designs, projects, releases and sells very different kind of vehicles. In this wide and international world, the field in which I have been effectively operating is the Electrification program in the Product Developing by Fiat Professional, the FCA Brand dedicated to Light Commercial Vehicles.

The main scope of the thesis was to understand better the dynamics of the eLCVs market. A deep analysis on the future trends and challenges of these vehicles was necessary to have an overall view of what is changing in this world, with also particular attention to the markets approach of Fiat Professionals competitors. As main core of the thesis, I have analyzed the final user of LCVs by means of real usage data. Thanks to this it has been possible to select specific clusters of customers that could fit the EVs characteristics. All the results obtained will be useful, even if in a smaller part, to make the right decisions while facing the new challenges of the future mobility. Obviously, all the analysis done should give also an idea of how it is possible to maintain sustainable costs and where it is better to invest in order to give benefits and improvements to the product.

To change radically the production approach in all company is necessary to have solid data and information in order the right decision during the process. Having a basement of reliable data, the evolution of the company will be simpler and will follow a specific direction. In a period with so many changes, there is more than one decision that could be adopted but it is very important to take each one knowing the strategy selected and the path that the company wants to follow.

With this approach it is simpler to direct the production in a specific direction, according to the needs and the request of the customers. Obviously, the users side is just one of the many aspects that should be analyze when studying these kind of vehicles, for example the evolution of electric vehicles infrastructures, which will be addressed in this thesis, is an important one. Operating in the Brand Fiat professional, I focused on the requests and needs extrapolated from the market, to support the decisions about eLCVs strategy for the near future. Indeed, there are different ways to achieve this information. One is to look for the challenges that the market of LCV and EV will face in the future. At the end, the final aim is to direct the production and the selling phases in the right direction by knowing which clients will be interested in buying an electric vehicle and then have an idea of the penetration in the EVs market.

The thesis follows a precise path: to have a better knowledge and to simplify the reading of the text, the next section will report the definition of the main terms used in this report. Then there is a section dedicated to the history of LCV and of the electric vehicles. In the following chapter some of the future challenges that the world of transportation of goods will face are analysed with the relative solutions. Thanks to this introduction, it will be possible to read the chapter on the market analysis of the last years with a better knowledge; an overview of the forecast expectation will be also reported. This part will continue with the analysis of the parameters that encourage people to buy an EV, as incentives and charging infrastructure. A very important aspect that pushes OEMs to invest in electric vehicles is the CO_2 emission target that they must achieve for each kind of fleets vehicle otherwise, there will be fine for each single vehicles sold. This very relevant aspect will be analyzed in chapter **9**.

As already mentioned, the main scope of my experience was to concentrate on the user usage of the vehicles; in particular all the analysis that I have done on a set of data belonging to vehicles monitored for a period of six month in Italy.

In the end, the *conclusion* chapter reports which results and considerations have been extract from this thesis experience.

3 Definition

All the terms useful to better understand the thesis are shortly explained in this section.

3.1 Segment

The vehicles can be divided by different classification. One is the division for dimension and intended use, called *Segment*.

Passenger Car

- A - city cars (for example Fiat 500);
- B - slightly bigger than A segment (Alfa Romeo Mito);
  (a) I0 - SUV or Crossover of small dimension (500X)
  (b) L0 - MPV of small dimension (500L)
- C - compact with two o three volumes (Alfa Romeo Giulietta);
  (a) I1 - SUV of medium dimension (Volkswagen Tiguan)
  (b) L1 - MPV of medium dimension (BMW Serie 2 Active Tourer)
- D - sedan of medium dimension (Audi A4);
  (a) I2 - SUV of large dimension (Audi Q5)
  (b) L2 - MPV of large dimension (Ford S-Max)
- E - sedan of large dimension (Mercedes Classe E);
  (a) I3 - luxury SUV of large dimension (BMW X6)
- G - luxury sedan of large dimension, typically flagship models of OEMs (BMW series 7);

- H - hypercar, cars with sport performance (Porsche 911)

Commercial vehicles

Of greater importance for the arguments of this thesis is the classification adopted for commercial vehicles. The world of LCV has very different types of vehicles that have to cover all the needs of all the different clients. They are divided by type of vehicles (car, van, pick up) and by dimensions.

- 1A - car derived van, commercial car derived from city car (Fiat Panda Van);
- 1B - small size van, dimensions similar to segment B (Fiat Doblo');
- 2P - mid size van, commercial vehicles with medium dimensions (Fiat Talento);
- 2G - large size van, commercial vehicles with large dimensions (Fiat Ducato);
- PU - pickup, commercial vehicles with enclosed cab and an open cargo area (Fiat Fullback);

Figure (1) shows the classification by segment and some example of commercial vehicles.

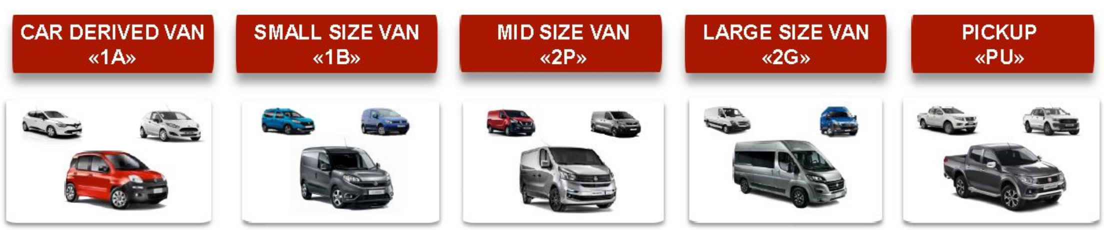


Figure 1: Fiat Professional LCV classification

The most important characteristics, that influence also the classification in segment of LCVs, are volume, payload and internal length of loading area. This three parameters guide also the user's choice.

3.2 Mission

For what concern commercial vehicles, by knowing which is the final purpose of usage it is possible also to make a classification by *Mission*

- General Haul - Transport of goods and/or tools as a non-core activity of individual or small enterprises;
- Delivery - Professional freight logistics;
- Construction - Constructions materials and equipment logistics to/from a job site;
- Special Equipment - Emergency vehicle/maintenance and special public;
- Collective Transport - City/intercity, public/private people transport service;
- Recreational - Leisure application such as vacation and camping;

Figure (2) shows the classification by missions for vehicles of the 2G segment but the same classification is used for all LCVs.

Figure 2: Mission classification

This kind of classification is the most indicated to better understand which kind of user could change their conventional vehicle with an electric one.

3.3 Propulsion Technology

Nowadays, there is a lot of misunderstanding about the different kind of propulsion available, specially with electric vehicles. The next definitions and abbreviation will be used in the report to give another vehicle classification.

- **ICE** - Internal Combustion Engine, most of the vehicles are provided of this propulsion system;
- **xEV** - acronym of all the vehicles with an electrified power-train, are included in this category:

  A) **HEV** - Hybrid Electric Vehicle, an electric motor support the ICE to improve the efficiency of the system. The battery are usually charged thanks to the regenerative braking technology. Depending on the degree of electrification could be defined:

     i) **Micro-hybrid**: uses the Start&Stop system that helps to stop the combustion engine when the vehicle pulls to a stop and restarts when the driver accelerates.

     ii) **Mild-hybrid**: ICE with an electric motor allowing the engine to be turned off while it is coasting, braking or stopped. Very quickly restart. There is not an exclusive electric mode of propulsion.

     iii) **Full-hybrid**: can propel the vehicle solely on its electric motor, without running the conventional engine. Usually just for very light cruising and light acceleration. Not rechargeable by external source.

  B) **PHEV**: Plug-in Hybrid Electric Vehicle, similar to Full-hybrid but the batteries of this vehicle have a larger capacity and can be recharged by external source (charging station).

  C) **REEV**: Range Extender Electric Vehicle, is a vehicle with electric propulsion in which is present an ICE that feeds an electric generator to charge the battery needed for the propulsion.

D) **BEV**: Battery Electric Vehicle, is a completely electric vehicle with one or more motor. The energy is stored in the batteries.

Very often, the combination of PHEV and BEV is called PEV to indicate all the vehicle rechargeable by a plug.
In figure (3) there is a scheme of the technologies available in function of the degree of electrification.

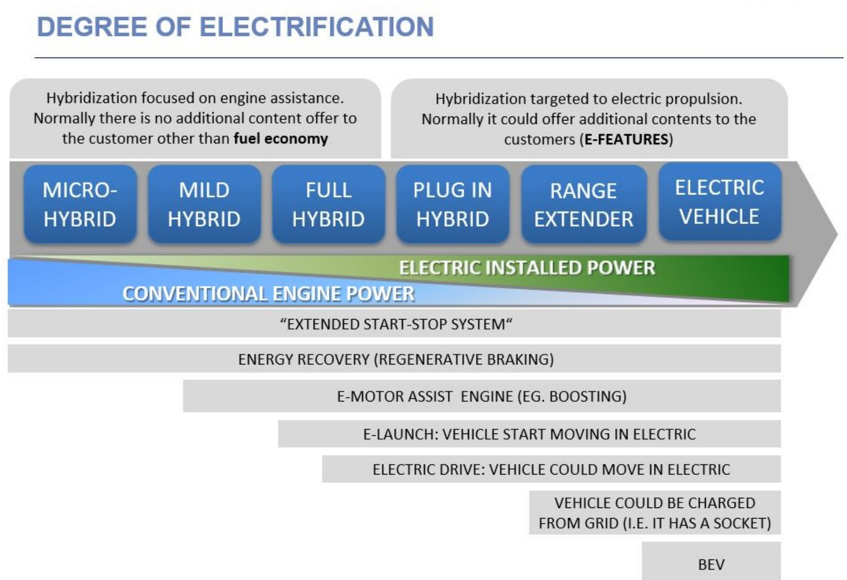


Figure 3: Degree of Electrification

3.4 Fuel

The last definitions that could be useful regard the different fuel mostly used today for passenger car and commercial vehicles:

- Diesel, largely used specially in commercial vehicles;
- Gasoline/Petrol;
- CNG: compressed natural gas, methane;
- GPL o LPG: liquefied petroleum gas.

4 History of LCV and EV

4.1 Fiat Professional LCV

Transport of goods and people has always been one of the most important things to connect cities. Together with the improvement of technology, the possibility to move every kind of object or instrument in a simple way helped the connection between different cities and areas of the same city. With the evolution of urban city centers and the specialization of jobs, the light commercial vehicles changed over the years to be adaptable for all the users. In the following pages there is an overview of the evolution of Fiat Professional LCV.

The newly-created *Fabbrica Italiana Automobili Torino* presented two omnibuses and a revolutionary firemen's trailer at the Milan exhibition. This paved the way for the introduction of the first real Fiat truck, the 24HP, figure 4. Production of light commercial vehicles began with this vehicle, which took its name from its engine power, measured in steam horsepower at the time. Small in size, about the same size as present-day vehicles, the 24HP offered the same uses and the same carrying capacity as a true truck, with a flatbed made of seasoned wood that could carry up to 4000 kg of goods. Given the revolutionary nature of the 24 HP, it became necessary to build three experimental prototypes.

Various test were carried out and the 24 HP breezed through them all. Even the Armed Forces showed an interest in the new vehicle. The 24HP was produced on a small scale, but its successor, the 18-24HP "self-propelled carriage", enjoyed great success and was produced in large numbers.

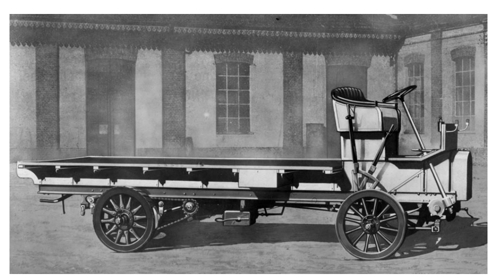


Figure 4: 24 HP, 1903, source [1]

During the period of the first world war, production of the first 'true commercial vehicles' began. The impetus for production came first and foremost from the necessities of World War I. During that period, exports accounted for a very significant proportion of the Turin-based Company's turnover. Armies became Fiat's best customers, and Fiat was soon keeping the War Ministries of France, Russia, Greece and Great Britain supplied with light commercial vehicles.

The 1F was introduced (F stood for 'furgone', i.e. van), the first vehicle with a proper van body, figure 5. With a displacement of 1846 cc and a carrying capacity of 500 kg, this agile vehicle, based on the frame of the TIPO 1 car, was ideal for short range services. For this reason, the British Post Office bought several of them.

Figure 5: F1, 1911, source [1]

The same year also witnessed the appearance of the more robust 2F. Derived from the TIPO 2 of 1910, it had a displacement of 2813 cc, a power rating of approximately 20 HP and a carrying capacity of 1000 kg.

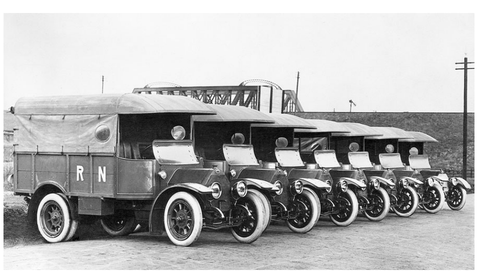
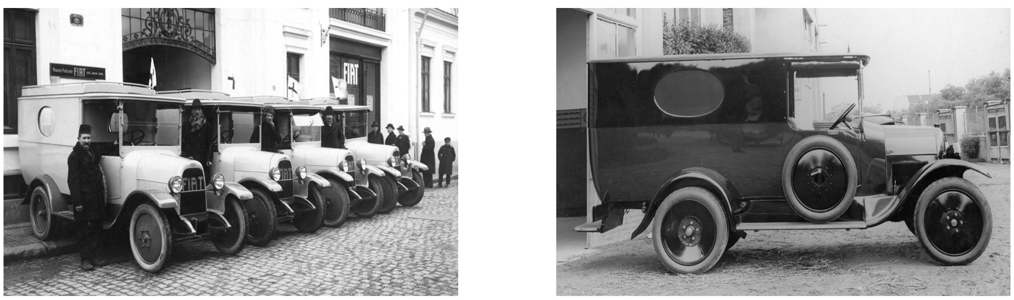


Figure 6: F2, 1911, source [1]

Its truck version, figure 6, with a canvas covered body, was offered for use as a military truck, and was widely used to transport men and materials. In this configuration it was also supplied to the British Royal Navy.

After the economic crisis of 1921, various elements began to indicate recovery. Traffic law was reformed (road tax was abolished and province-based licence plates) and in March 1923, work started on the main road between Milan and the Lakes, the first road with a special lane for commercial vehicles. In light of the ongoing changes, Fiat decided to invest more heavily in the production of commercial vehicles, widening its range and differentiating its offering in terms of payload, size and engine capacity. During this period, the definition of 'light commercial vehicle' began to come into its own. Various light trucks including the 502F, the 503F, the 505F, the 507F and the 509F were produced in response to a growing demand for vehicles to satisfy specific work and transport requirements (including special purposes vehicles such as ambulances, fire brigade vehicles, post office vehicles, etc.).



(a) 505F van (b) 502F van

Figure 7: Different models depending on payload and dimension, 1925, source [1]

Fiat worked hard to accelerate the growth of road haulage, supporting the planning of the route between Turin and Milan, the main road joining Italy's two most important centers of production.

Thanks to the ongoing wellness of the nation, the increase amount of products and goods requested, the LCV production had a boost during this period.

The Balilla Van appeared on the base of the small 508 truck. Light, manoeuvrable and easy to drive, "the pygmy", as the new vehicle was nicknamed, represented commercial version of the famous Balilla car. It boasted comfort, low fuel consumption, a top speed of 75 km/h and a carrying capacity of between 320 and 380 kg.

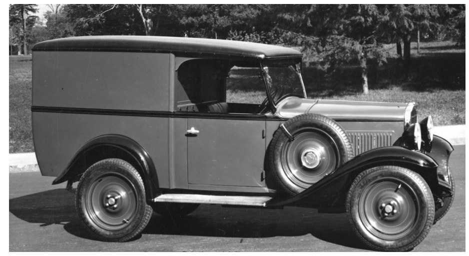


Figure 8: Fiat 508, 1932, source [1]

It was a great success: in 5 years, 113,000 Balillas were produced, including many truck versions.

Another vehicle that dates back to this period in history was the first Fiat truck with a diesel engine, specifically designed for freight transport. This was the 621, with a load capacity of 2250 kg, a closed cab with two doors, wind-down windows, a swivel-opening windscreen, a load bed with fold-down sides and tailgate, and the option of fitting metal arches to support a waterproof canvas roof.

Figure 9: Fiat 621, 1930, source [1]

Figure 10: Fiat 621E, 1938, source [1]

A 4-cylinder 55 HP diesel engine was added to the range, as an alternative to the 45 HP petrol engine. And that's not all. The successful 621 series offered not only diesel and petrol engines, but was even available in an electric drive version with the battery pack under the passenger compartment, figure 10.

Due to the second world war, the production of vehicles dropped drastically. Fiat understood that economic development concerned not only large industries, but small, independent enterprises too. Shopkeepers and tradesmen needed transport that was suitable for their requirements and allowed them to transport small quantities of freight, samples or equipment A new vehicle deriving from the passenger car was produced to satisfy these needs. The Fiat 1100 ALR, figure 11, was one of the first commercial models produced immediately after the war. Along with its outstanding and unique qualities, this meant that the 1100 ALR soon became one of the symbols of the Italian revival. Equipped with a reliable engine, extremely sturdy transmission and a resilient and versatile chassis, which could be adapted to a wide range of uses (farming, industry, passenger and goods transport), the Fiat 1100 ALR is considered the forerunner of later commercial models.

(a) 1100 ALR Truck

(b) 1100 ELR

Figure 11: Different models of Fiat 1100 ALR, 1947, source [1]

Following the success of the multipla 600, Fiat also renewed its range of commercial vehicles, introducing the Fiat 238, a large van based on the mechanics of the Primula (Autobianchi), with a 1.2 44HP engine for giving a top speed of 105 km/h.

Produced between 1967 and 1983, the Fiat 238 was available in different versions from its launch: van, truck, chassis cab, passenger transport and ambulance, figure 12. This philosophy strongly influenced and shaped the later Fiat 242 and Fiat Ducato.

Figure 12: Fiat 238, 1967, source [1]

In the mid '70s, Fiat re-organised to specialise in various sectors. The production of industrial vehicles was separated from that of cars. IVECO was created in 1975 (an important date in the history of road haulage), and the Fiat Light Commercial Vehicles brand was born, bringing onto the market the models 242, 850T, 900T and the Fiorino 127 (made in Brazil and still in production today).

Produced until 1987, the Fiat 242 dominated the market throughout the '70s. Robust and reliable, with a low loading threshold and a flat load bed, it was also sold in special versions, such as public and mixed transport, as well as the innovative and best-selling leisure version, with its motorhome conversion.

Figure 13: Fiat 242, 1974, source [1]

Both in Italy and in Europe, these years saw a growing demand for small vans for town deliveries and intercity links. Fiat's response was the 127 Fiorino, the first small van produced in Italy.

Figure 14: Fiat 127 Fiorino, 1977, source [1]

The Fiorino maintained the mechanical qualities and creature comforts of the 127 passenger car, while offering a load capacity of 360 kg plus driver. A series of plus points set it apart from its competitors: a spoiler, cabin partition (removable in sections), and lockable back doors that opened to 90°.

Among the new products produced in 1978 we cannot fail to mention the Panorama version of the 238E range, a 9-seater designed to respond to the new market for group transport. Built to carry 9 people to work or on holiday, and offering major savings on fuel consumption, it quickly became the ideal vehicle for various sectors,

including hotels, car rental companies, organizations and sports teams.
The first years of the '80s were marked by the introduction of a revolutionary van, the Ducato x2/12. Developed from a 1978 design, the new model aimed to offer a light commercial vehicle that would have become successful throughout Europe. The Ducato x2/12 was followed by the Ducato x2/30. Not only was the objective achieved, but the results exceeded all expectations. Proof of this is the fact that the model is still being produced after more than 30 years later.

(a) 1981

(b) 1990

Figure 15: Different models of Fiat Ducato, source [1]

In the '90s, the Ducato was followed by other successful models like the: Scudo, Doblo' and the van versions derived from various car models. The Scudo, figure 16a, was introduced to offer a new commercial vehicle to professionals in search of a compact van, with a good load capacity and a car-like driving style. The Doblo', produced in Turkey, was launched on the Italian market in 2000 and on other international markets in 2001, figure 16b. It immediately proved to be remarkably successful. Also in 2000, the concept of the pick-up truck, first embodied by the Fiorino in 1981, evolved with the introduction of the Strada, figure 16c, the pick-up version of the Palio family.

(a) Scudo, 1995

(b) Doblo', 2000

(c) Strada, 2000

Figure 16: Three of the most successful models following after Ducato, source [1]

The last models showed are still today one of the best variety to cover all the costumers needs. Obviously they had many facelift and improvement over the years. The different versions available give the possibility to change length, volume and payload. There is also the possibility to make special changing to the structure of the vehicles in case of particular necessity, like thermo-controlled or refrigerated transport. The different solution permits to achieve all the kind of purpose of transport. The world of LCVs will surely change a lot in the next future, due to the introduction of severe CO_2 targets and the city center restricted zone for ICE that will obligate the OEMs to direct their production towards more eco friendly vehicles. The challenge will be to satisfy the needs of all the user with new kind of vehicle but not changing the soul of the present LCV.

4.2 Evolution of Electric Vehicles

It is hard to pinpoint the invention of the electric car to one inventor or country. Instead, it was a series of breakthroughs, from the battery to the electric motor, in the 18^{th} Century that led to the first electric vehicle on the road. In the early part of the century, innovators in Hungary, the Netherlands and in the States began toying with the concept of a battery-powered vehicle and created some of the first small-scale electric cars.

While Robert Anderson, a British inventor, developed the first crude electric carriage around that same time, it was not until the second half of the 19^{th} century that French and English inventors built some of the first practical electric cars.

Figure 17: First EV, 1832

In the U.S., the first successful electric car made its debut around 1890 thanks to William Morrison, a chemist who lived in Des Moines, Iowa. His six-passenger vehicle capable of a top speed of 14 miles per hour was less more than an electrified wagon, but it helped spark the interest in electric vehicles. Over the next few years, electric vehicles from different automakers began popping up across the U.S. New York City even had a fleet of more than 60 electric taxis. By 19^{th} Century, electric cars were at their heyday, accounting for around a third of all vehicles on the road. During the next 10 years, they continued to show strong sales.

To understand the popularity of electric vehicles circa 19^{th} Century, it is also important to understand the development of the personal vehicle together with the other options available. At the turn of the 20th century, the horse was still the primary mean of transportation. But as Americans became more prosperous, they turned to the newly invented motor vehicle, available in steam, gasoline or electric versions, to get around.

Steam was a tried and true energy source, having proved reliable for powering factories and trains. Some of the first self-propelled vehicles in the late 1700s relied on steam; yet it took until the 1870s for the technology to take hold in cars. Part of this was because steam wasn't very practical for personal vehicles. Steam vehicles required long startup times, sometimes up to 45 minutes in the cold, and would need to be refilled with water, limiting their range.

As electric vehicles came onto the market, so did a new type of vehicle, the gasoline powered car, thanks to improvements to the internal combustion engine in the 1800s. While gasoline cars had promise, they weren't without their faults. They required a lot of manual effort to drive – changing gears was no easy task and they needed to be started with a hand crank, making them difficult for some to operate. They were also noisy, and their exhaust was unpleasant.

Electric cars didn't have any of the issues associated with steam or gasoline. They were quiet, easy to drive and didn't emit a smelly pollutant like the other cars of the time. Electric cars quickly became popular with urban residents, specially for women. They were perfect for short trips around the city, and poor road conditions outside cities meant few cars of any type could venture farther. As more people gained access to electricity in the 1910s, it became easier to charge electric cars.

Many innovators at the time took note of the electric vehicle's high demand, exploring ways to improve the technology.

For example, Ferdinand Porsche, founder of the sports car company by the same name, developed an electric car called the P1 in 1898. He created the world's first hybrid electric car: a vehicle that was powered by electricity and a gas engine.

Figure 18: Edison and the EV, 1901

Thomas Edison, one of the world's most prolific inventors, thought electric vehicles were the superior technology and worked to build a better electric vehicle battery. Even Henry Ford, who was friends with Edison, collaborated with Edison to explore options for a low-cost electric car in 1914, according to Wired.

Yet, it was Henry Ford's mass-produced Model T that dealt a blow to the electric car. Introduced in 1908, the Model T made gasoline-powered cars widely available and affordable. By 1912, the gasoline car cost only \$650, while an electric roadster sold for \$1,750. That same year, Charles Kettering introduced the electric starter, eliminating the need for the hand crank and giving rise to more gasoline-powered vehicle sales.

Other developments also contributed to the decline of the electric vehicle. With the discovery of Texas crude oil, gas became cheap and readily available for rural Americans, and filling stations started popping up across the country. In comparison, very few Americans outside of cities had electricity at that time. In the end, electric vehicles all but disappeared by 1935.

Over the next 30 years, electric vehicles entered a sort of dark ages with little advancement in the technology.

Soaring oil prices and gasoline shortages, peaking with the 1973 Arab Oil Embargo, created a growing interest in lowering the U.S.'s dependence on foreign oil and finding homegrown sources of fuel. Congress took note and passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, authorizing the Energy Department to support research and development in electric and hybrid vehicles.

Many car manufacturers began exploring options for alternative fuel vehicles, including electric cars. For example, General Motors developed a prototype for an urban electric car that was displayed at the Environmental Protection Agencys First Symposium on Low Pollution Power Systems Development in 1973, and the American Motor Company produced electric delivery jeeps that the United States Postal Service used in a 1975 test program.

Figure 19: Urban EV, 1973

Even NASA helped raise the profile of the electric vehicle when its electric Lunar rover became the first manned vehicle to move on the moon in 1971.

Yet, the vehicles developed and produced in the 1970s still suffered from drawbacks compared to gasoline-powered cars. Electric vehicles during that time had limited performance, usually topping at speeds of 70 km per hour, and their typical range was limited to 65 km before needing to be recharged.

In the 20 years since the long gas lines of the 1970s, interest in electric vehicles had mostly died down. But new federal and state regulations begin to change things. The passage of the 1990 Clean Air Act Amendment and the 1992 Energy Policy Act, plus new transportation emissions regulations issued by the California Air Resources Board, helped create a renewed interest in electric vehicles in the U.S.

During this time, car manufacturers began modifying some of their popular vehicle models into electric ones. This meant that electric vehicles achieved speed and performance much closer to gasoline-powered vehicles, and many of them had a range of 95 km.

One of the most well-known electric cars during this time was GMs EV1, figure 20. Instead of modifying an existing vehicle, GM designed and developed the EV1 from the ground up.

With a range of 130 km and the ability to accelerate from 0 to 80 km per hour in just seven seconds, the EV1 quickly gained a cult following. But because of high production costs, the EV1 was available only in long term rental.

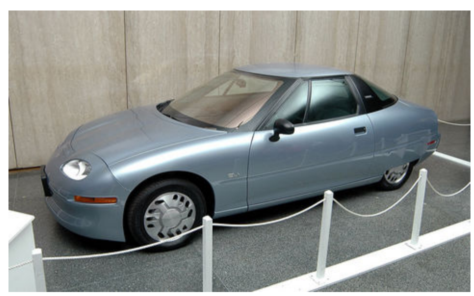


Figure 20: EV1, 1996

While all the starts and stops of the electric vehicle industry in the second half of the 20th century helped show the world the promise of the technology, the true revival of the electric vehicle didn't happen until around the start of the 21st century. Depending on whom you ask, it was one of two events that sparked the interest we see today in electric vehicles.

The first turning point many have suggested was the introduction of the Toyota

Prius. Released in Japan in 1997, the Prius became the world's first mass-produced hybrid electric vehicle. In 2000, the Prius was released worldwide, and it became an instant success with celebrities, helping to raise the profile of the car.

Figure 21: First Mass produced HEV, 1997

To make the Prius a reality, Toyota used a nickel metal hydride battery, a technology that was supported by the Energy Department's research. Since then, rising gasoline prices and growing concern about carbon pollution helped make the Prius the best-selling hybrid worldwide during the past decade.

The other event that helped reshape electric vehicles was the announcement in 2006 that a small Silicon Valley startup, Tesla Motors, would start producing a luxury electric sports car that could go more than 300 km on a single charge, figure 22.

Figure 22: Tesla Roadster, 2008

Tesla's announcement and subsequent success spurred many big car manufacturers to accelerate work on their own electric vehicles. In late 2010, the Chevy Volt and the Nissan LEAF were released in the U.S. market. The first commercially available plug-in hybrid, the Volt has a gasoline engine that supplements its electric drive once the battery is depleted, allowing consumers to drive on electric for most trips and gasoline to extend the vehicle's range (PHEV). In comparison, the LEAF is an all-electric vehicle (BEV), meaning it is only powered by an electric motor.

Over the next few years, other car manufacturers began rolling out electric vehicles. At the same time, new battery technology began hitting the market, helping to improve a plug-in electric vehicle's range (PEV), in particular the lithium-ion battery which are the ones used nowadays.

It is hard to tell where the future will take electric vehicles, but it is clear they hold a lot of potential for creating a more sustainable future. Obviously the progress made for the passenger car help the world of LCVs that, although late, are getting into the world of xEV due to different reasons, see 5.

5 E-LCV future challenges

Cities are home to more than half the world's population. They dominate culture and politics and are the showplace of some of history's greatest achievements. In figure 23 is possible to see how the urbanization process is influencing the mobility of people and goods in urban areas.

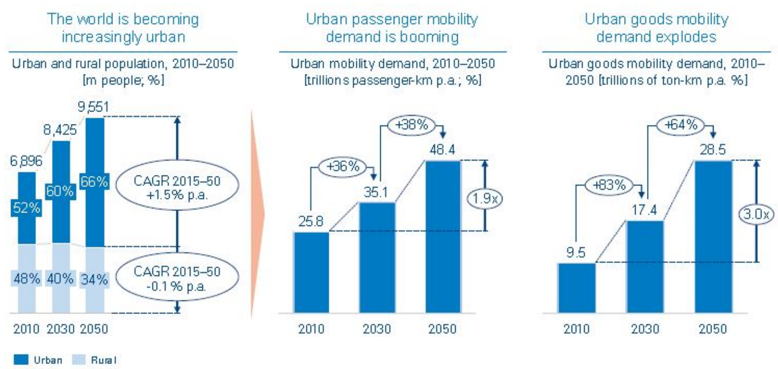


Figure 23: Urbanization trend and goods movement, source [5]

On a day-to-day level, cities are the heart of the global economy. Roads, rails, and other forms of transportation are the arteries that nourish that heart. When these become clogged, businesses, residents, and cities all suffer. Four trends are rapidly changing passenger transport: electrification, autonomy, connectivity, and sharing. The same four trends will, to a large degree, shape the future of commercial urban transport. The movement of goods is an essential part of economic life. Commercial vehicles (LCVs) account for a significant share of traffic; they take up space and stop and start with infuriating inexactitude. With a billion more people projected to be living in cities by 2030, and with online and other commerce growing, freight volumes are projected to grow 40 percent by 2050, figure 24.

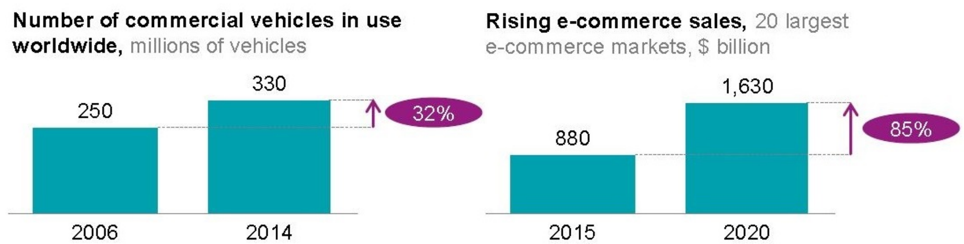


Figure 24: Increase of LCV and e-commerce, source [13]

That means many more CVs on the road. Accommodating them will be essential to ensuring the quality of future urban life. Emerging technologies, such as electric vehicles (EVs), droids, and autonomous ground vehicles (AGVs), will lighten the burden of commercial traffic in congested areas. Even better, there are a number of business models and practices, such as parcel lockers and night deliveries, that have already proved themselves. The commercial vehicles that are on the road today typically generate higher nitrogen oxide (NOx) emissions than passenger cars. Also, many of them use diesel engines; compared to gasoline engines, these emit much higher concentrations of particulate matter, a pollutant harmful to health. CVs also contribute to urban traffic woes beyond their numbers. To improve urban commercial transport, there are different options, spread across the delivery value chain from the location of the supplier to the final destination of the receiver.

First, there are urban consolidation centers (UCCs). UCCs are locations, typically on the outskirts of cities, where deliveries are brought, sorted, and then dispatched. Goods from multiple suppliers can be consolidated into fewer shipments, making it possible to optimize loads and truck sizes, thus cutting down on the number of trips and vehicles required. While UCCs have been around for years, success has been spotty. The business case is becoming stronger, however, as new technologies make implementation easier and the expansion of e-commerce makes it more urgent.

Second, while cities never sleep, when it comes to allowing night deliveries, most of them take a nap, restricting the practice largely because of concerns about noise. It is possible to train people to work more quietly and to require shippers to attach noise-canceling equipment to delivery vehicles. The solutions make sense in and of themselves. The most powerful effect, however, is when two or more are used together, multiplying their respective strengths. Using a fleet of EVs to supply businesses from UCCs, at night, optimizes vehicle utilization, speeds up delivery, and minimizes noise and pollution. In a city like New York, this triple play could cut costs per parcel by 35 percent, eliminate vehicle emissions if the whole fleet is electric, and require one-third fewer CVs.

What matters, then, is selecting the right options. Different combinations will work for different kinds of cities, different customers (B2B versus B2C), and different time windows (same-day/instant versus multiday delivery). For cities, labor costs and population density will, to a large extent, determine what solutions will work best and how fast they can be adopted.

Developed, dense cities are likely to be at the forefront of change for freight mobility, because governments and companies in these cities can afford to invest in urban planning and cutting-edge technology. Moreover, high wages favor the business case for technology-intensive solutions. Autonomous vehicles, for example, likely will be expensive initially and thus most worthwhile in places with high labor costs.

Developed, suburban cities, where sprawl is the norm, will need to consider a different set of solutions. Because of the greater distances between points of delivery, UCCs and parcel lockers might not be as effective as they are likely to be in denser cities, where it is possible to site them within walking distance of many people.

But other approaches, including electrification and night delivery, are still promising.

Finally, in developing, dense cities like Beijing, Mexico City, and Mumbai, deliveries require twice the mileage on average and result in up to two and a half times higher emissions than in developed, dense cities. Due to local road conditions and low labor costs, these cities are likely to be slower to adopt technologies such as AGV lockers.

5.1 Best solutions

There are many ways to mitigate the problems associated with urban commercial transport. A possibility is to group them according to their place in the value chain: suppliers; warehouse and sorting facilities; transportation; point of delivery. Transportation accounts for half the total. Other categories show how optimizing commercial transport is not just a matter of what happens on the roads but also what happens before and after the journey. Although all the available solutions, six stand out when assessed in relation to cost effectiveness, customer and environmental value, and technical feasibility:

- **Urban Consolidation Centers (UCCs)**: are cross-docking transshipment centers where items are consolidated for delivery into urban areas.
- **Night delivery**: shifting delivery to evening hours, when traffic is less, can smooth out congestion and reduce the number of trips.
- **Load pooling**: he online matching of demand for capacity with available supply maximizes vehicle load utilization; fewer trucks therefore make a greater number of deliveries.
- **Parcel lockers**: these are sited in a place where customers can pick up packages at any time with an access code sent to their mobile device.
- **Electric vehicles (EVs)**: are quieter and cleaner than traditional commercial vehicles, particularly when charged using renewable-energy sources.
- **Autonomous ground vehicle (AGV) lockers**: these are parcel lockers on wheels that customers open using a personal code.

These six solutions, spread across the delivery value chain, can reduce tailpipe emissions by more than 30 %, eliminate them altogether through electrification, while also cutting costs per parcel by 25% to 50 %.

Urban Consolidation Centers

UCCs work by giving companies a location, typically outside but near the city center, to which suppliers and retailers can ship their orders. With the goods gathered in one place, they can be consolidated into fewer deliveries. Most trucks entering a city today are underutilized, with room for more cargo. The use of UCCs allows trucks to be loaded to their maximum capacity, thereby reducing the number of vehicles that enter the city. Experience has shown that UCCs work best in dense cities, no more than 30 kilometers from the center, and close to highways or other forms of transit. Companies in developed, dense cities that deploy UCCs could save 25 percent on delivery costs per parcel (compared to traditional methods), due to greater capacity utilization, lower labor costs, and fewer miles driven. If both UCCs and EV are adopted the improvement could be greater, figure 25.

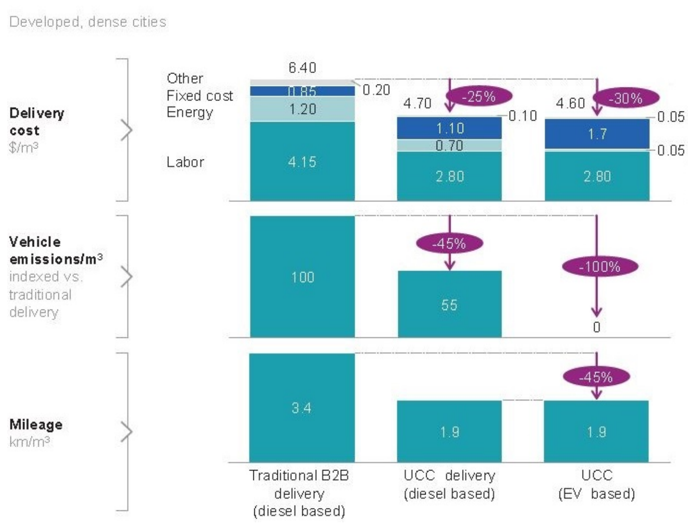


Figure 25: Cost reduction by means of UCCs and EVs, source [13]

Night Delivery

While night delivery is hardly a new or complicated concept, it could nonetheless bring a lot of benefits. The practice is limited at the moment, primarily due to residential noise concerns. Other issues include the higher pay that late-shift workers command and the willingness of consumers, whether individuals or businesses, to receive packages in the off hours. Nonetheless, for specific applications, night deliveries offer significant improvements; in combination with other solutions, such as night delivery to parcel lockers, many of these obstacles can be overcome. For example, using electric trucks could help to reduce noise. EVs are markedly quieter than traditional vehicles; that means bigger EV trucks could be used and still meet noise regulations. At its full potential in a developed, dense city, night delivery could save up to 40 percent in total delivery costs, while also cutting vehicle emissions.

Figure 26: Cost reduction by means of Night Delivery, source [13]

Load Pooling

This practice matches, via an online platform, commercial vehicles with spare capacity with customers who need delivery space. Load pooling can be used for both B2B and B2C deliveries. Drivers advertise available capacity, delivery routes, and any constraints on goods carried (for example, no hazardous material). Customers post the goods to be shipped and the time and destination of delivery; an algorithm optimizes delivery routes and schedules for both carriers and customers and comes up with dynamic pricing.

Shippers benefit from using their fleet more intensively and from higher *drop density* (delivery addresses within a given area); deliveries are picked up directly, no longer going through warehouses. According to our analysis, at full potential, load pooling in urban areas could reduce delivery costs by up to 25 %, figure 27.

Figure 27: Delivery cost reduction

Parcel Lockers

Parcel lockers are on-site drop boxes situated at locations such as apartment buildings, supermarkets, office buildings, and shopping malls, where people can pick up packages using individual access codes sent to their mobile devices. Customers, who can select which location they prefer for each delivery, benefit from convenient 24/7 access; shippers benefit from fewer total delivery locations and fewer failed delivery attempts, saving time and mileage and reducing vehicle emissions. Used to their full potential in developed, dense cities, parcel lockers can decrease labor time per parcel by 60 percent and reduce delivery costs per parcel by 35 percent, figure 28.

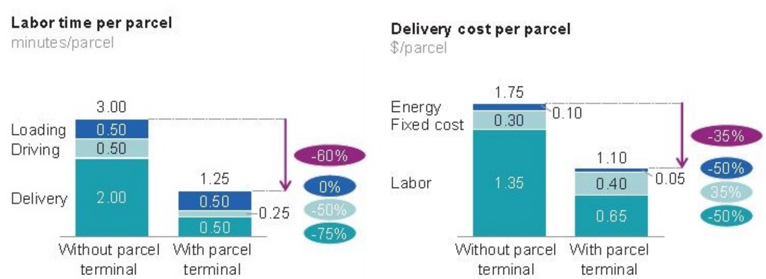


Figure 28: Cost reduction by means of Parcel Locker, source [13]

Parcel lockers, which have been around for at least a decade, have had mixed success. Instituting the system requires a substantial investment and is not suited for all kinds of parcels, such as large appliances or goods that need refrigeration. Many consumers prefer to have their packages delivered straight to their home. To work effectively, parcel lockers need to be convenient, or people won't use them. That means placing terminals in easy to access locations and ensuring they are secure and simple to operate. In order to use the space most efficiently, customers can be rewarded for picking up their goods quickly for example, through loyalty programs and discounts.

Electric Vehicles

Automotive companies are increasing investment in EVs; meanwhile, battery prices are falling, vehicle-emissions standards are tightening, and social cachet is rising. Inevitably, then, EVs are going to become a greater presence on global roadways. The question is not whether electrification is going to happen but how fast.

Urban commercial delivery trucks' route characteristics, infrastructure requirements, utilization, and torque capabilities make CV attractive targets for transitioning to battery power.

- *Route characteristics:* In densely populated regions, delivery vehicles typically travel predictable and relatively short routes. Given such characteristics, battery size can be optimized, minimizing cost.

- *Infrastructure requirements:* Creating a charging network for passenger cars is difficult due to the unpredictability of where and when consumers will need to charge. For medium-range commercial vehicles (CVs), this is less of a problem. They will usually not need to charge during their delivery routes and can return afterward to a local charging hub, see chapter 8.

- *Utilization:* One of the barriers for passenger-vehicle electrification is that private vehicles are typically parked 90 percent of the time or more.14 While operating expenses for EVs are dramatically lower than for traditional vehicles, it is difficult to create a return on their higher capital costs with such a low average utilization. Because CVs are used more intensively, typically for at least a full shift, their higher utilization can overcome the capital-expenditure-versus-operating-expense conundrum.

- *Torque Capabilities:* CVs are often equipped with diesel engines because diesels higher low-end torque performance is superior to that of gasoline engines. Electric motors, however, with their flat torque performance across the full range of motor operation, are even better than diesel engines at low-end torque.

The electrification of the commercial fleet would also provide considerable benefits to city residents. First, many urban areas are struggling with smog and pollution, which CVs exacerbate with their relatively higher emissions and longer running and idling times. There may be debate on the exact well-to-wheels emissions of EVs versus internal combustion engines, especially in places where EVs are charged with carbon-intensive sources of power, but there is no question that electrification of the commercial fleet would significantly reduce the smog-inducing NOx and particulate matter that large diesel engines emit. Regarding this argument it is useful to compare relative emissions across the lifetime of different types of vehicles, from their manufacture to disposal, figure 29.

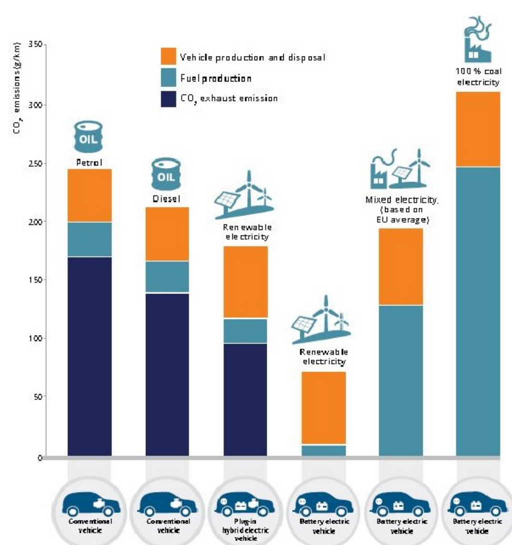


Figure 29: Relative Emission across the lifetime, source [8]

Second, electrified delivery fleets help to abate noise. EVs are much quieter than diesels, especially during idle times. This could prove a significant asset in expanding night deliveries, which are discouraged in large part due to noise concerns.

Autonomous ground vehicle lockers

The concept is simple: self-driving parcel lockers. AGV lockers could make door-to-door deliveries or park in a location advertised to customers so they can collect their parcels. This system does not yet exist, but if it does, it could move goods more efficiently while reducing labor costs.

The process would work as follows: at the warehouse, parcels are loaded into each locker manually; customers are instructed how to open the locker and informed of the estimated arrival time and password. During the journey, the AGV updates customers if there are any delays and notifies them to be ready for pickup.

At the destination, there are two options. In direct delivery, the vehicle sits at the curb, and customers are expected to make their pickup. If they are late, the AGV moves on. In the second, cheaper scenario, the AGV stays in a parking lot and informs customers of when and where they can get their deliveries. The vehicle stays in the parking lot for a defined period.

Because AGV lockers are likely to be smaller than delivery vans, they will need to make more trips to deliver the same volume of goods; electrification is essential for environmental benefits to accrue.

6 Market analysis

During the last years the European market of xEV has had an important growth. The increasing of this sector probably started some years ago after the scandal called *Dieaselgate*. Irregularity were found in some Volkswagen models that were equipped with a software able to understand when the vehicles was subjected to a test, limiting the performance and also the emissions. This moment brought back the interest on the alternative fuel vehicles and in particular on the xEV. From that year, 2014, many countries started to boost the purchasing of electric vehicle by means of incentives, see chapter 7. Most of the money invested is helping to improve also the charging infrastructures, that is one of the most important factors to reduce the distrust of the costumers on electric vehicles, see chapter 8. Obviously the market behaviour of LCVs is different respect to the passenger car that had a larger boost after the *DieselGate*, for those the market share is already over 3%.

6.1 LCV actual market

Anyway even for the light commercial vehicles there is a slight improvement that keeps going on among last years, see 30.

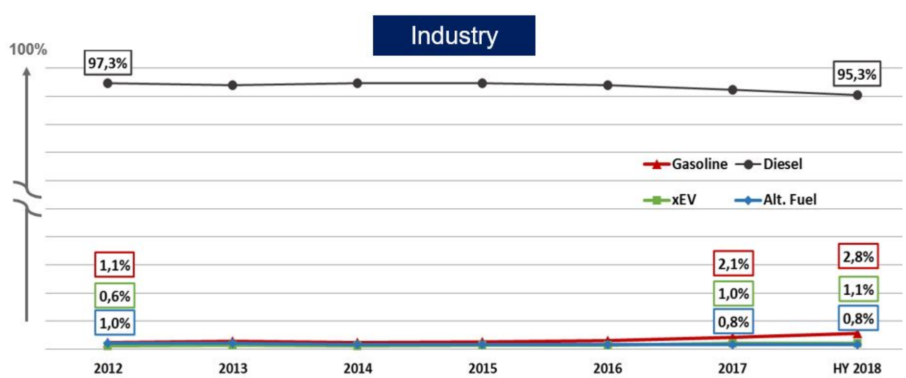


Figure 30: Actual industry share depending on fuel type, source [12]

From the graph above is possible to see that the diesel lost around 2 points from 2012, almost one in the last year. xEV and gasoline keep improve their shares from 2012. Most of the xEV sold belong to the *compact* segment, 1B, indeed the market share is 3%, see figure 31. Among the different possibilities of xEV, the most diffused is the BEV; all the car manufactures are investing a lot on this kind of vehicle because, compared to passenger cars, the user of LCV have a lower usage variability and so could fit better the characteristics of a full electric vehicle.

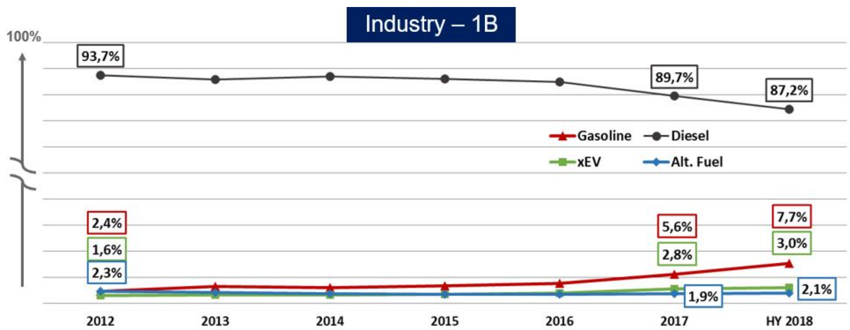


Figure 31: Actual industry share depending on fuel type, segment 1B, source [12]

The others segments show just a trace of xEV even because the range of available vehicles is still poor.

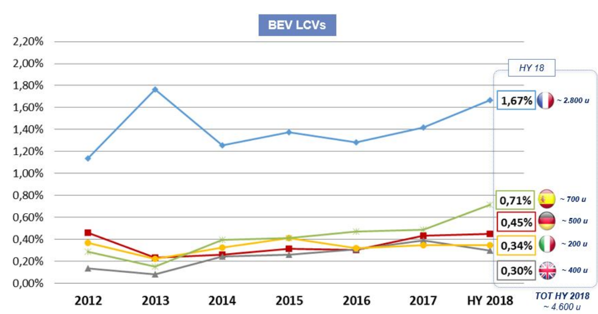


Figure 32: Market share for BEV, source [12]

It is worth to say that each market has a different behaviour, nowadays the selling activity of a countries is highly depending on the incentives, see chapter 7.

Moreover the countries with a higher goods movement have surely a higher weight on the economy of LCV, see figure 32.

An important aspect that has not been considered is the selling channel of LCV. Compared to passenger car, these vehicles are mostly sold to companies that need many vehicles (fleet). The percentage of vehicles bought by a single user is very low. In figure 33 is reported a overview of the sales by selling channel for the most important BEV vehicles now on the market. It is worth to analyse that for electric vehicles the fleet channel is largely more important than the average of the whole segment. Moreover the *Demo* channel is a relevant option for many OEMs to test the behaviour of their vehicles and to have from the costumers the first feedback on the product.

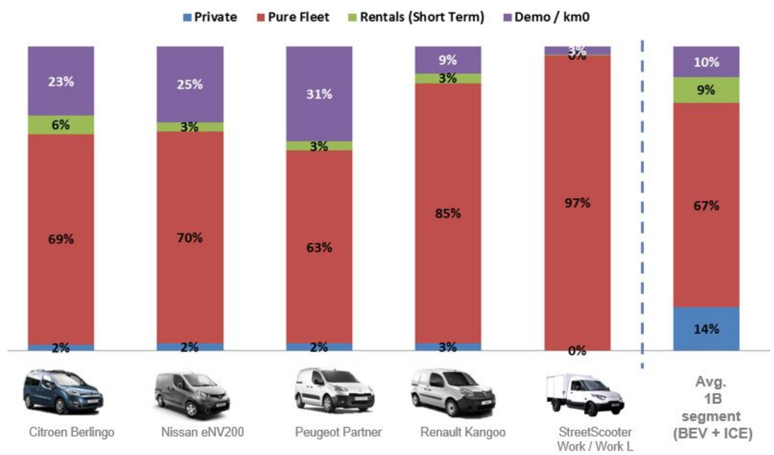


Figure 33: Sales by channel for BEV of 1B segment, source [12]

6.2 Market Forecast

The boost of the of electric light commercial vehicle market is expected to arrive in the following years. The factors that will influence this world are explained partially in chapter 5.

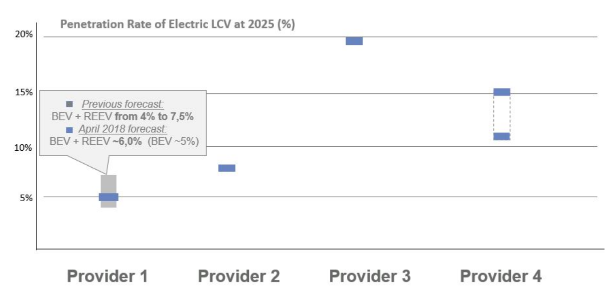


Figure 34: Penetration rate at 2025

In figure 34 it is possible to see how different providers (Ricardo, Frost&Sullivan, IHS, FEV) see the world of e-LCVs in the next future, in particular the percentages report the market share of BEV at 2025.

The industry graph will so evolve from figure 30 to 35, guessing a market share of 6% at 2025 .

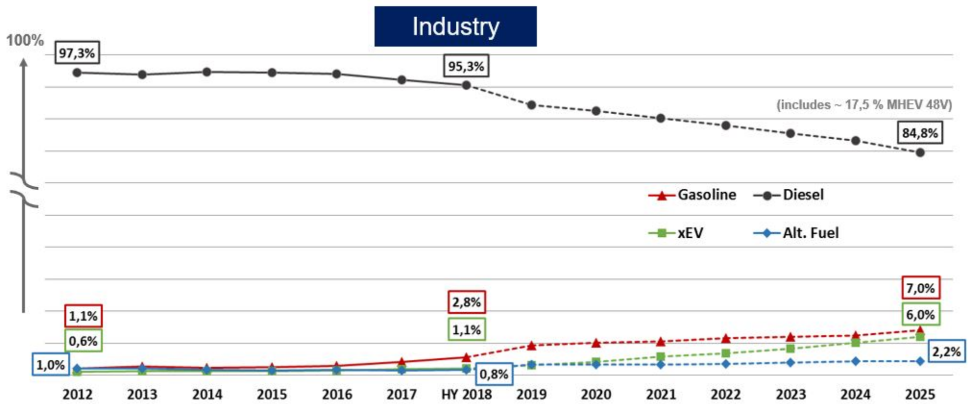
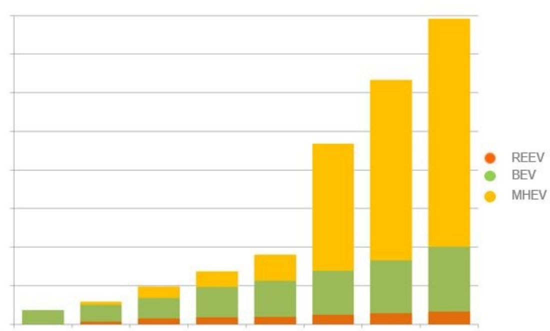


Figure 35: Forecast industry share depending on fuel type, source [12], [7]

Anyway it is important to underline that during the following years some other electric technologies will spread also in the LCVs world. In this way not only BEV will be introduced but many MHEV (mild hybrid) will get into the market. See figure 36 to have a better idea of the evolution of xEV in the following years.



		2018	2019	2020	2021	2022	2023	2024	2025
	BEV	1,1%	1,3%	1,6%	2,4%	2,8%	3,4%	4,1%	5,0%
Market Share	REEV		0,2%	0,5%	0,6%	0,6%	0,7%	0,9%	1,0%
	MHEV		0,2%	0,9%	1,2%	2,0%	9,9%	14,0%	17,7%

Figure 36: Forecast market share depending on xEV, source [7]

According to the forecast all the segments will have an important growth as off 2019, see figure 37. While nowadays only the compact segment has a good range of electric vehicles (mostly BEV), in the future many other models will be available, even in the medium and large segment. The problem that many car manufactures have with BEV for medium and large segment is to still have a high payload of the vehicle. The weight of the battery pack imposes car manufacturers to reduce the available payload that is one of the most important feature for the costumers.

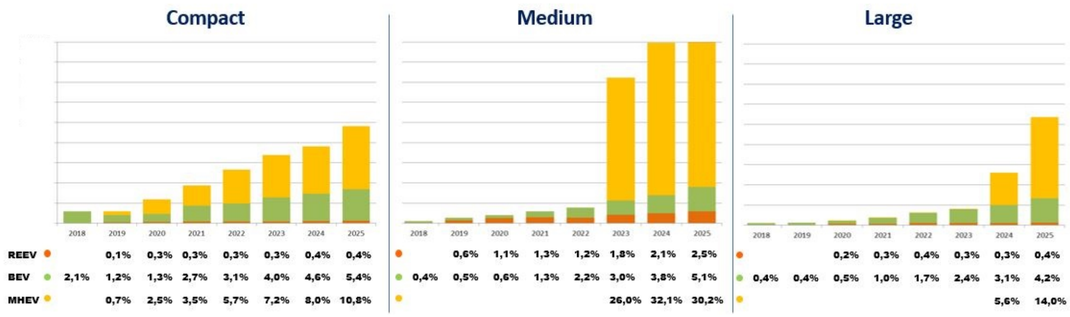


Figure 37: Forecast market share depending on xEV, for segments, source [7]

The increasing in market share for each segment is also confirmed by the speculations and the announcements of the many new models that will be presented in the following years. In the next figures is possible to have an idea of the number of launches for each segment in the near future. For confidential reason the name of the models are not reported unless they have already been announced.

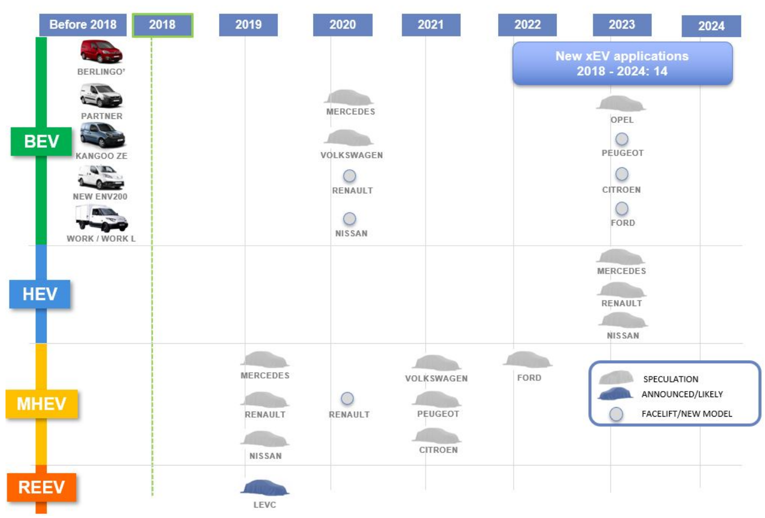


Figure 38: Announcement and speculation on Compact segment

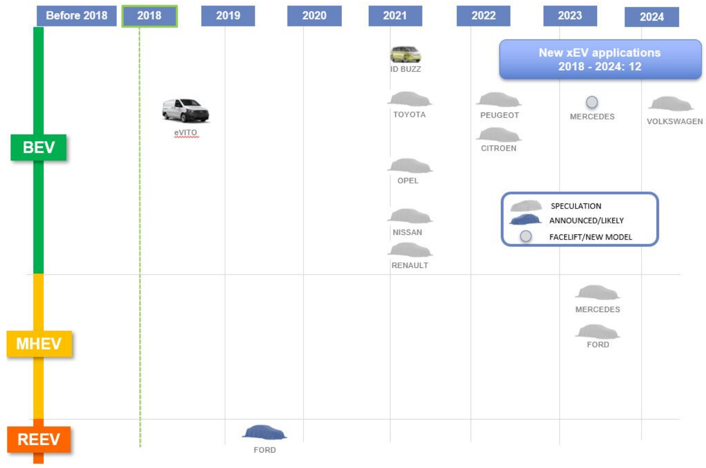


Figure 39: Announcement and speculation on Medium segment

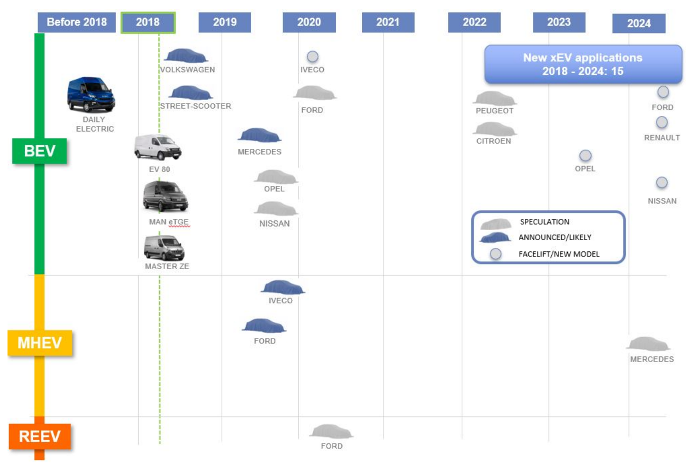


Figure 40: Announcement and speculation on Large segment

It is worth emphasising that during the years the incentives will have a lower value in the purchasing of e-LCV. From 2020/2021 the key factor will be the CO_2 targets and the banned zones for the ICE in the city centers. The CO_2 regulation will force the car manufacturers to push and promote the xEV, chapter 9; while the new laws concerning about the traffic in the urban area will impose more users to change their vehicles, chapter 5. In particular the big fleet of delivery goods and food should be prepared to have in their LCV park a percentage of vehicle without circulation restriction in city center.

7 Incentives

Nowadays and for the following years electric vehicles' sales strongly depend on the different kind of incentives applied in each country. Price of conventional vehicles is still much lower than electric ones. The buyer accepts the drawbacks that EVs have only if the condition of purchase is not too disadvantageous, because he can save money thanks to the lower cost of utilization and to the incentives.
Actually, the price of these kind of vehicles is highly dependent on the battery pack that strongly influences even one of the most important feature: the autonomy. Until the cost of this technology is so high, the EVs market will be influenced by the incentive policy of each country.
A combination of supporting incentives and coordinated policy is the key in accelerating the development of the electric vehicle market. There are many examples of ways in which national governments provide subsidies to consumers who purchase or use new electric vehicles. These include purchase tax exemptions, one-off grants or increasing taxes on fossil fuel use (which makes electricity a more attractive fuel), figure 41.

Countries	Purchase Subsidies	Registration Tax Benefits	Ownership Tax Benefits	Company Tax Benefits	VAT Benefits	Other Financial Benefits	Local Incentives	Infrastructure Incentives
Austria	✔	✔	✔	✔	✔		✔	
Belgium	✔	✔	✔	✔				
Bulgaria								
Croatia		✔						
Cyprus		✔	✔					
Czech Republic		✔	✔					
Denmark	✔	✔		✔			✔	✔
Estonia								
Finland	✔	✔	✔					✔
France	✔	✔	✔	✔			✔	
Germany	✔		✔	✔		✔	✔	
Greece		✔	✔			✔		
Hungary		✔	✔	✔			✔	
Iceland		✔	✔		✔		✔	✔
Ireland	✔	✔	✔	✔			✔	✔
Italy	✔		✔					✔
Latvia		✔	✔				✔	
Liechtenstein	✔							
Lithuania		✔					✔	
Luxembourg	✔		✔	✔				
Malta	✔	✔	✔	✔			✔	✔
Netherlands		✔	✔	✔				
Norway		✔	✔	✔	✔	✔	✔	✔
Poland								
Portugal	✔	✔	✔	✔			✔	
Romania	✔	✔	✔					✔
Slovakia	✔	✔					✔	
Slovenia	✔	✔	✔					
Spain	✔	✔	✔			✔	✔	✔
Sweden	✔		✔	✔				
Switzerland			✔			✔		
Turkey					✔			
United Kingdom	✔	✔	✔	✔			✔	✔

Figure 41: Overview of the incentives in Europe, source [9]

The level at which incentives are implemented and the amount of subsidy paid may differ greatly between countries. Certain ones have used various types of one-off subsidies to encourage the purchase of electric vehicles. Reducing registration tax or exempting new vehicles is common. Reductions can range from 100 % of the normal registration tax, i.e. full exemption (in Belgium/Flanders, Greece, Hungary, Latvia, the Netherlands and Portugal among others), to a more limited reduction (e.g. Denmark, Finland). Some countries reduce the tax by a defined amount (e.g. Ireland). Each country has its own way to push the EVs, in the next pages there is a brief detail for the most important one.

Austria

BEV (up to 2.5 tons): grants up to 4,000 € (private customers) and 3,000 € (businesses & municipalities).

PHEV (up to 2.5 tons): 1,500 € (private customers, businesses & municipalities).

Belgium

Electric vehicles pay the lowest rate of tax under the annual circulation tax in all three regions.

Electric and plugin hybrid (until 31 December 2020) vehicles are exempt from reg tax in Flanders.

Incentives (*Zero Emission Bonus*) for the purchase of battery electric powered cars and vans are granted.

Flemish Region: no annual circulation tax (ACT). Zero Emission Bonus for BEV up to 4,000 €.

BEV, PHEV: deductibility of expenses related to the use of a company car (120% deducibility for BEV, 100% for PHEV $<$ 60g/km).

Denmark

Electric vehicles (BEVs) pay only 40% of the registration tax (in 2017). This percentage will be gradually increased at 65% in 2018, 90% in 2019 and 100% in 2020.

France

Vehicles <20g CO_2/km: bonus on purchase 6,000 €.

Scrapping bonus: 4,000 € to buy BEV and 2,500 € to buy PHEV, if owners send a 11 year old diesel car to the scrapper (vehicles costing more than 40,000 €, excl. tax, are not eligible for the bonus).

Electric vehicles and vehicles emitting less than 60g CO_2/km are not subject to the tax on company cars.

Germany

BEV, PHEV: 10 years of road tax exemption.

Bonus on purchase from July 2016 to December 2020: 4000 € for BEV; 3000 € for PHEV.

The funding is 1.2 billion €, equally shared between the government and automakers.

Vehicles costing more than 60.000 € (excl. tax) are not eligible for the bonus.

Italy

BEV: exempt from road tax for the first 5 years, then road tax is equal to 25% of the road tax of gasoline vehicles.

HEV/PHEV: in some regions (11 out of 20) exempt from road tax for the first 2-5 years.

Incentives for road transport for third parties: 10 000 € for new EV LCVs up to 7t.

Netherlands

BEV: exempt from registration tax (based on CO2 emissions) and road tax until 2020.

PHEV registration tax: 19 per CO_2 g/km if CO_2 is1-30 g/km; 87 per CO_2 g/km if CO_2 is 31-50 g/km, 289 per CO_2 g/km if CO_2 is 51 g/km or more.

BEV 96% discount on Annual Income Tax for private used company cars.

Norway

It is surely the country that has most invested on xEV incentives in the last years. This policy helped the market share of PEV to grow in the last years achieving almost the 50% , figure 42. The incentive program will be revised and adjusted parallel with the market development in coming years. The tax incentives will stay in place till 2018 and then will be revised. Free toll roads will probably be replaced with a new system with differentiated prices depending on CO_2 and NO_x emissions. Anyway, Norway is the confirmation of how nowadays the purchase of xEV is strongly dependent from incentives.

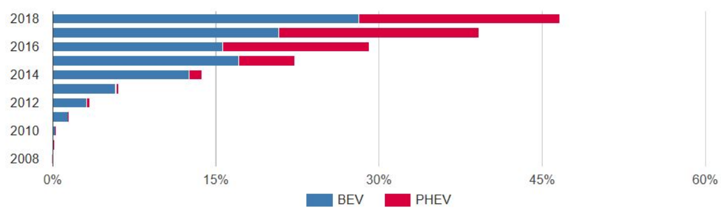


Figure 42: Market share BEV and PHEV vehicles in Norway, source [9]

In particular, nowadays, all-electric cars and vans are exempt from all non recurring vehicle fees, including purchase taxes, and 25% VAT on purchase, making electric car purchase price competitive with conventional cars. Also, a tax reduction for plug-in hybrids went into effect starting in July 2013. Local authorities were granted the right to decide whether electric cars can park for free and use public transport lanes. In 2016, through its National Transport Plan 2018-2029 (NTP), a goal was set for all sales of new cars, urban buses and light commercial vehicles by 2025 to be zero emission vehicles.
Summarizing:

- BEV are exempt from import/purchase tax (based on weight, power, CO_2 and NO_x emissions).
- HEV 5% reduction in weight
- PHEV 26% reduction in weight.
- In addition: Urban toll exemption, Highway toll exemption, Free Parking, Bus lane use.

Spain

Main city councils (eg Madrid, Barcelona, Zaragoza, Valencia etc) are reducing the annual circulation tax (ownership tax) for electric and fuel efficient vehicles by 75%. Reductions are applied on company car taxation for pure electric and plugin hybrid vehicles (30%), and for hybrids, LPG and CNG vehicles (20%).

UK

BEV no annual circulation tax.

BEV no company car tax.

BEV/PHEV (CO_2 under 75 g/km and range at least 10 miles): grants up to 9,500€.

8 Infrastructures

Refueling a conventional vehicle is nowadays a very simple and fast operation. The time spent to fully *recharge* the tank and to be able to restart driving is just little time. Even capillarity of the refuelling stations is spread all over the world so is very difficult to have an empty tank.

The same characteristics are still not present in the recharging system for EVs. First of all the number of charging stations is still not comparable with the conventional one. The users with a garage or a personal area to park the car, may have the possibility to have their personal charging station free in every moment of the day, but for the other EV's owners that must leave their vehicle in public parking, need a wide diffusion of electric infrastructure. Even the improvement of the semi-public areas will be a fundamental factor, if most of the company parking areas will be able to guarantee an efficient system of charging stations, more employees could charge their vehicles during the working hours. Shopping centers, cinemas and highly attended places are included in this category, some hours spent to see a film could be enough to recharge a PHEV or BEV. Semi-public places are specially relevant for eLCVs. Most of the time this vehicles are recharged in the company park during the no working time but, in case of LCVs highly used,it could be necessary a recharge slot during the working activities.

The second problem that should be solved is the charging process time that is not even close to the one of ICE vehicles. With the most simple mode of charging the time spent for a full charge goes from 6 to 12 hours. Obviously there are other method to charge faster but they need a charging station properly installed by specialist.

Before any investments in public infrastructure, it is important to understand which type of device should be installed. Unfortunately, only in the last years the providers of the service and the OEMs are trying to help the standardization and the interoperability of the charging device, in order to guarantee to all vehicles the same possibility of charging. Many providers are trying to increase the diffusion of fast charging station, that have a duration of the process of about 30 minutes. Thanks to this charging mode more EVs could be recharged by the same station during the whole day. Naturally, a system that gives the possibility to substitute a fully charged vehicle with another one must be implemented, to avoid dead time during which the recharging point is not being used.

The world of EVs is anyway trying to solve the different problems and challenges that limit the diffusion of these vehicles.

8.1 Charging modes and Plugs

The fast charging is surely the best solution for all the public infrastructure. This method should be available for all the vehicles that today still have different charging port depending on the OEMs. From a global point of view a standard is still not present but in Europe a specific path have been followed. It is possible to divide the charging mode into *Normal* or *Fast*. In the first case the *Type 2* connector is diffusing as standard; in the second there are two type of options *CHAdeMO and Combo 2*. Going into details the definition given by the International Electro-technical Commission (IEC) for the charging modes are:

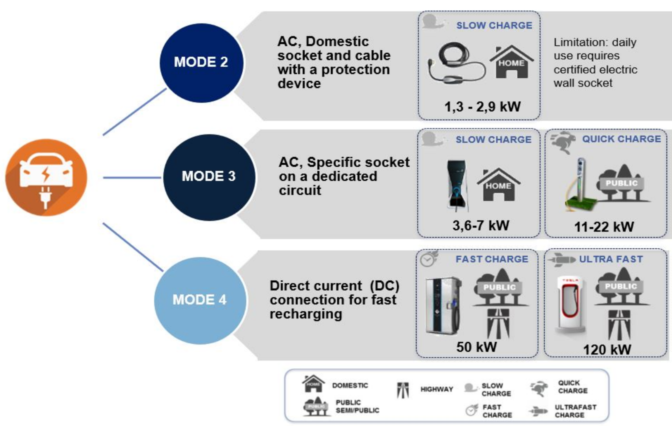
- Mode 1(AC[2]): slow charging from a standard household-type socket-outlet, because there is no protection device to avoid current overload, this system is not allowed in Europe. Charging time from 6 to 12 hours depends on the battery's capacity.
- Mode 2(AC): slow charging from a standard household-type socket-outlet with an in-cable protection device that avoid overload. Even in this case the charging time is over 6 hours.

[2] Alternative Current

- Mode 3(AC): slow or fast charging using a specific EV socket-outlet and plug with control and protection function permanently installed. This is surely the most safe charging mode and can be installed even in a garage or a private area (Wallbox, figure 43b). Charging time could be reduced to 30 minutes with the maximum power of $43kW$ ($400V$ and $63A$)

- Mode 4(DC[3]): fast charging using an external charger. Direct current up to $200A$ that gives the possibility to recharge in less than 30 minutes. Due to the high power, this system cannot be implemented in a domestic electric system but can be used only in dedicated charging station.

A recap of the used mode in Europe in figure 43a.



(a) Charging Mode

(b) Wallbox BMW

Figure 43: Charging mode options and Wallbox

8.1.1 Mode 2

Not considering the mode 1, the first possibility to charge an EV is mode 2. The Mode 2 charging cable is available in different versions. Often the Mode 2 charging cable for connection to an ordinary domestic socket is supplied by the car manufacturer. So if necessary drivers can charge electric cars from a domestic socket in an emergency.

[3]Direct Current

Communication between vehicle and charging port is provided by a box connected between the vehicle plug and connector plug (ICCB In-Cable Control Box). An example is reported in figure 44a.

(a) Cable mode 2

(b) Type 2 plug

Figure 44: Mode 2 devices

The plug on the vehicle side is *Type 2*, figure 44b. The triple-phase plugs main area of distribution is Europe, and is considered to be the standard model. In private spaces, charging power levels of up to 22 kW are common, while charging power levels of up to 43 kW (400 V, 63 A, AC) can be used at public charging stations. Most public charging stations are equipped with a type 2 socket.

8.1.2 Mode 3

The mode 3 charging cable, figure 45 is a connector cable between the charging station and the electric car. In Europe, the type 2 plug has been set as the standard. To allow electric cars to be charged using type 1 and type 2 plugs, charging stations are usually equipped with a type 2 socket. To charge your electric car, you require either a mode 3 charging cable from type 2 to type 2.

Figure 45: Mode 3 cable

8.1.3 Mode 4

In Europe, there are present two standards for the fast charging mode: CHAdeMO and CCS (Combined Charging system).

In case of Mode 4, the cable is always attached to the charging station so there is no plug on the station side.It's only necessary to have the right plug on the vehicle.

The CHAdeMO, figure 46a, was designed in Japan and later it was adopted in all the world. The maximum power is 100 kW but it can be used just for the DC charging. The vehicles that have this standard are usually provided with another connector for the charging mode 2 and 3. Due to its origin, many Asian car manufactures promote the CHAdeMO standard and implement it on their vehicles.

The CCS standard is a connector that include the type 2 plug, as is possible to see in figure 46b. It's used for the AC and DC charging modes allowing the vehicles to have just one plug for all the recharging options, reducing the costs of implementation. This standard can go over 100 kW of power. Even if the CHAdeMO is highly used also in Europe, the CCS standard has been chosen as the only connector for the DC modes, so the Japanese plug will be abandoned.

(a) CHAdeMO

(b) CCS

Figure 46: Mode 4 standards

8.2 Charging infrastructure in Europe

One of the factors that surely influence an electric vehicle's buyer is the capillarity of the infrastructures of his own country. Specially if the owner of the vehicle has not his own garage where to install a Wallbox. According to this, it is easy to observe that the the countries with the largest number of charging stations are also the ones with the highest registration of EV.

It is important to distinguish between the AC and DC charging station. Even if the DC mode is the best way to recharge a vehicle, the technology required is rather expensive. The AC charging station is cheaper and for this reason has a better capillarity in Europe.

The data available from the European Alternative Fuels Observatory (EAFO) states that in Europe there are actually almost $150'000$ public charging station divided into:

- $130'000$ Mode 3, charging up to 22 kW;
- $5'000$ Mode 3, charging up to 43 kW;
- $12'000$ Mode 4, divided by CHAdeMO and CCS.

Surely not enough, only in Italy there are $21'000$ conventional refueling stations.

In figure 47 it is possible to see the growth of the public charging infrastructures in the last years. As mentioned in the previous paragraph, the CCS standards is growing faster (CAGR from 2014 equal to 77%) than CHAdeMO (CAGR[4] from 2014 equal to 49%) because has been chosen as reference for the Mode 4.

Is worthwhile to mention that the Tesla infrastructures have a different plug, reserved only to the Tesla user. Anyway, they are just a small percentage of the total in Europe.

[4]CAGR, Compound Annual Growth Rate

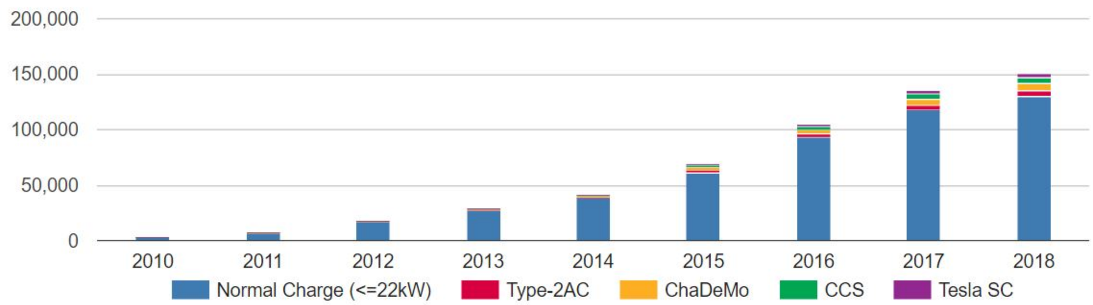
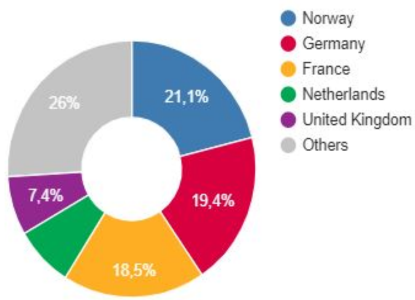


Figure 47: Charging stations in Europe [units], source [9]

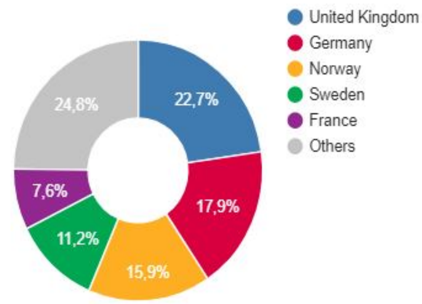
The division of the actual charging stations by countries is shown in table 1. It is possible to check that the public infrastructure are diffusing where the PEV market is becoming stronger, see figure 48. Then there is a good correlation between sales and infrastructures. In the table only the top 7 countries in these markets have been inserted.

AC [unit]	**Mode 2**	**Mode 3**	**Total AC**	**DC** [unit]	**Mode 4**
Netherlands	32500	800	33300	**UK**	790
Germany	22000	3200	25200	**Norway**	650
France	14300	9100	23400	**France**	380
UK	11400	2600	14000	**Germany**	350
Norway	8100	2100	10200	**Netherlands**	320
Spain	4100	4400	8500	**Spain**	80
Italy	1800	400	2200	**Italy**	30

Table 1: Share for major markets, AC and DC, source [7]



(a) Share BEV



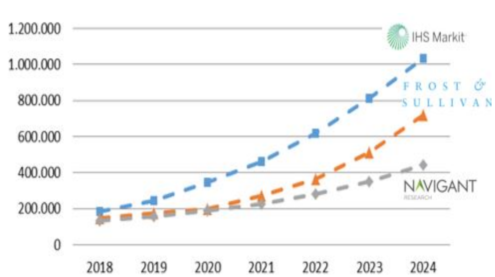
(b) Share PHEV

Figure 48: Share BEV and PHEV new registrations by country in the last 12 months

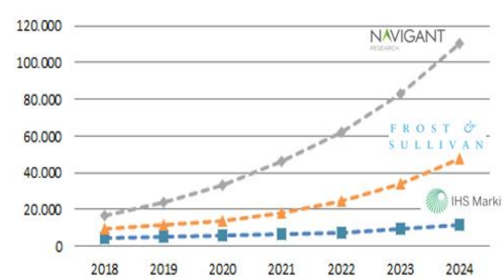
Even if the public and semi-public infrastructures play an important factor in the EVs market, there are some particular cases. Norway is one of the countries where the markets of electric vehicles is growing fast but has a low number of public charging station, 20 PEV per each point. This because it has the highest number of domestic charging ports in all Europe, 168′000 units.

8.2.1 Forecast

According to many service providers, the charging infrastructures will have a relevant growth in the following years. The AC stations will grow faster due to the low cost and the simpler implementation. In the figure 49 reported the previsions of IHS, Frost&Sullivan and Navigant Research. Each one of them has a proper idea for the future, the truth will be probably in the middle.



(a) Forecast AC



(b) Forecast DC

Figure 49: Public charging infrastructures forecast [unit], source [4], [6], [7]

Not all the countries are investing on infrastructures in the same way, because of different reasons: one is the insufficient electric power to supply a high amount of vehicles. Another reason is the inadequate electric distribution system that does not allow to reach the desired power.

On the technological side, in addition to charging stations always more advanced and efficient, the wireless charging will be the next step. With this system the vehicles could be recharged while driving at constant speed on a specially designed road or as they stop at traffic light. It could be also used for public or home charging.

The technology is based on inductive charging, figure 50, which involves electricity being transferred via an air gap between two magnetic coils. It is similar to how wireless phone chargers work, but here the scale is significantly larger. Therefore, the car has to be in proximity to the charging coil and the energy transfer process can begin. The technology is still being developed because the efficiency of the energy transfer and distance between magnetic coils needs to be increased. Potential use cases are that the charging coils can be located in strategic parking spots or even on the roads to allow for charging while the vehicle is moving. This could reduce the needs for charging stations, which is the primary way we currently charge our electric vehicles.

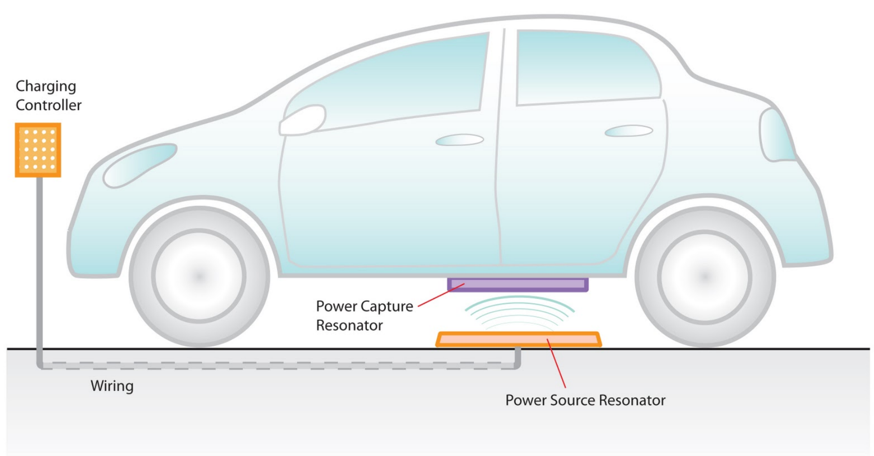


Figure 50: Scheme of wireless charging

When wireless charging is implemented to its full potential a number of benefits will be offered, which includes:

- **Full autonomy**: The application of autonomous vehicles is yet to be fully realized because they are still being developed. However, if there is no need to stop in order to charge autonomous vehicles, they can move indefinitely or at least until repairing is needed. This may increase the scope and efficiency with which they can be utilized.
- **Charging station not required**: There is no need to insert a cable with wireless charging, which means it is a more user-friendly approach. You can go around your day without even thinking about charging the car and it will automatically take care of itself.
- **Smaller battery units**: The increase in charging points means the size of the battery pack could be reduced. This reduces the cost and weight of the vehicle.

It is important to have a balanced overview of any technology, and wireless electric vehicle charging is going to have teething problems just like many new technologies:

- **Energy loss**: There is the potential for 90-93% energy efficiency, but there will still be energy loss during the transfer. Over a larger scale, this leads to a lot of wasted energy that increases the total amount of electricity required to run the vehicles.
- **Building the infrastructure**: When considering adding wireless charging to roadways, implementing the infrastructure may not make economic sense. To start, it might be restricted to densely populated urban areas, which will limit the user to predefined locations.
- **Health effects**: The magnetic fields created may be harmful or it may not. More investigation is required to ensure that long-term exposure to weak magnetic fields will not be an issue.

9 CO_2 compliance and OEMs strategy

Due to the new regulation regarding the CO_2 targets and because of the ongoing transition to a new vehicle emissions test, the Worldwide Harmonized Light Vehicles Test Procedure (WLTP), all the automotive sector is changing the approach for the production of the following years. The new rules are influencing even the world of LCV. In the next pages a brief report of the most important factors try to explain why the OEMs are moving towards EV (car and LCV).

9.1 CO_2 targets

Background

On November 8, 2017, the European Commission (EC) published its regulatory proposal for post-2020 carbon dioxide (CO_2) targets for new passenger cars and light-commercial vehicles (vans). The proposed regulation would be the third set of mandatory vehicle CO_2 performance standards in the European Union (EU).
The first set of regulations, implemented in 2009 after a voluntary commitment by the auto industry to reduce average vehicle CO_2 emissions had failed to produce adequate results, established average targets of 130 grams per kilometer (g/km) for new passenger cars in 2015 and 175 g/km for vans in 2017. Vehicle manufacturers met both targets several years in advance. A second set of regulations, passed in 2014, requiring average CO_2 emissions of new cars to fall to 95 g/km by 2021. For new vans, the target value is 147 g/km by 2020. This second regulation also required the EC to review CO_2 emission targets and prepare a regulatory proposal for the post-2020 period. This review was to have been completed by the end of 2015.

New Proposal

In contrast to previous vehicle CO2 regulations, the new EC proposal does not specify CO_2 targets in absolute g/km terms but instead defines CO_2 reduction requirements in percentage terms. Because of the ongoing transition to a new vehicle emissions test procedure, WLTP, the EC argues that it is difficult to predict future emission levels and therefore prefers percentage reduction values from a 2020/21 baseline.

Under the EC proposal, average new-vehicle CO_2 emission levels would have to fall by 15% by 2025 and 30% by 2030. These percentage reduction requirements are the same for both cars and vans, but the starting point varies slightly (2020 for vans and 2021 for cars). If a manufacturer were to fail its CO_2 reduction requirement, the EC proposal stipulates a penalty of 95 euros per g/km of exceedance for each newly registered vehicle, the same penalty imposed under the 2020/21 standard. Although in principle percentage reduction targets are the same for every manufacturer, the regulatory proposal provides flexibility with regard to the distribution of effort among manufacturers. The heavier a manufacturer new-vehicle fleet is, the higher its target values (in g/km) in 2020/21, 2025, and 2030 will be. The EC proposal achieves this by comparing the average weight of each manufacturer's fleet with the average weight of the entire European Union fleet. The CO_2 target is raised for each kilogram by which a manufacturers fleet average exceeds the EU fleet average. For example, in the case of cars registered by 2024, an additional 0.0333 g/km of CO_2 per kilo of additional average weight would be allowed. Conversely, if a manufacturer's fleet is lighter than average, its target is lowered. This weight adjustment mechanism is, in principle, the same as in current regulations. However, from 2025 onward the WLTP test mass, rather than mass in running order as defined under the New European Driving Cycle (which tends to be a lower value for the same vehicle), will be used for all calculations.

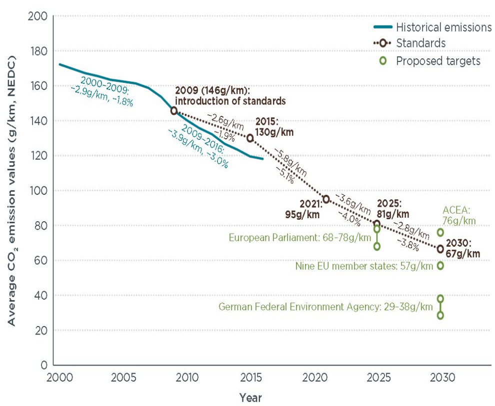
For vans, the EC proposes using two different slopes for the weight-based target calculation from 2025 onwards. Manufacturers with heavier-than-average van fleets would be subjected to a different adjustment factor than those with a lighter fleet. In comparison, the 2020 standard applies only one common factor, 0.0960 g/km of CO_2 for every additional kg.

The EC also proposes a novel mechanism that rewards manufacturers that sell greater shares of zero-emission and low-emission vehicles (ZLEVs) with less stringent CO_2

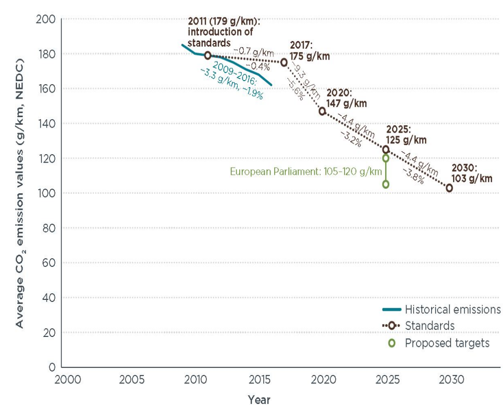
requirements. ZLEVs are all vehicles that emit less than 50 g/km of CO2 on a tank-to wheel (TTW) basis, namely BEV, fuel cell electric vehicles (FCEV), and some PHEV. The EC proposal sets a target ZLEV market share of 15% for 2025 and 30% for 2030. The lower the CO_2 emission level of a ZLEV is, the more it counts toward the market share target. A manufacturer exceeding these targets would see its CO_2 reduction requirements eased proportionally. The EC proposal defines an upper limit for this mechanism: If a manufacturer had more than 20% ZLEVs in 2025 and more than 35% in 2030, these additional ZLEVs would not be counted toward a further CO_2 reduction target adjustment. There is no penalty for failing to meet the ZLEV target, which is referred to as a one-way adjustment by the EC. A two-way adjustment would include a penalty for not meeting the ZLEV target.

Level and Timing of Targets

The proposed cars and vans standards set a reduction target of 15% for 2025 and 30% for 2030 relative to 2021 reference targets. Because the 2025 and 2030 targets are defined in terms of WLTP measurements, each manufacturer's 2021 reference target will be converted to WLTP by adjusting its 2020 New European Driving Cycle (NEDC) target by the ratio of WLTP to NEDC CO_2 emission levels in 2020.



(a) Passenger Car



(b) Van

Figure 51: Average CO_2 values and targets for cars and vans, all in NEDC; [3]

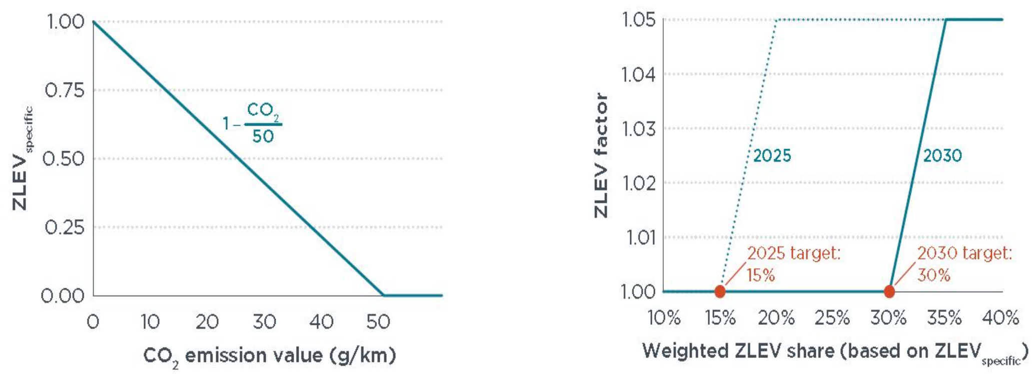
In figure 51 there is the evolution of the targets for both cars and vans for the next

years. All the value reported refers still to the NEDC.
For vans, the 2025 and 2030 targets are a notable improvement over the 2017 standard in terms of annual reduction rates, but they fall short in both absolute (g/km) and relative (percent) annual reduction rates compared with the 2020 target. On average, new van CO_2 emission levels would decline by about 4.4 g/km (3.5%) per year between 2020 and 2030, compared to about 9.3 g/km (5.6%) per year between 2017 and 2020.

Incentives for ZLEV

The EC proposal recognizes the strategic importance of electric power trains for car manufacturers, and calls for EU automakers to become global leaders in new technologies. To this end, the proposal includes sales targets and incentives for ZLEVs for both passenger cars and vans. ZLEVs are defined as vehicles with CO_2 emission values below 50 g/km.
The proposed CO_2 standard sets a 15% sales target for 2025−2029 and a 30% target for 2030. These targets are broadly in line with manufacturer announcements on EV sales. Major European manufacturer groups including BMW, Daimler, Renault Nissan, and Volkswagen have electric vehicle sales targets exceeding the proposed 2025 ZLEV target of 15%. Under the proposal, ZLEVs are counted proportional to their zero-emission capability: zero-emission vehicles count as full vehicles; vehicles with CO_2 emission values with 50 g/km count as zero; and vehicles between 0 and 50 g/km are assigned partial values according to a linear function based on CO_2 emissions, figure 52a.
To incentivize the transition to ZLEVs, manufacturers that outperform the sales targets will be rewarded with higher CO_2 emission targets using the so-called ZLEV factor. The ZLEV factor can range from 1, for manufacturers that fail to meet the ZLEV target, to 1.05, for manufacturers that exceed the ZLEV target by 5 percentage points or more. The ZLEV factor scales proportionally to the exceedance of the ZLEV target between these two limits. A ZLEV factor of 1.05 implies that

the emission target is increased by 5%, whereas a ZLEV factor of 1 implies that the emission target remains unchanged, figure 52b.



(a) $ZLEV_{specific}$ (b) ZLEV factor

Figure 52: (a) for the ZLEV share calculation; (b) to adjust CO_2 targets, [3]

This kind of incentives will surely help the implementation of ZLEV, but could give the possibility to car manufacturers to not decrease the CO_2 emission of conventional vehicles, because of the *bonus* given by ZLEV factor and super credits that make the CO_2 target higher.

Super credits

Past CO_2 standards included so-called super credits for ZLEVs. Super credits inflate the impact of ZLEVs in the calculation of car manufacturers' average CO_2 values. Both the 2015 and the 2020/21 passenger car standards included super credits, but their level was gradually reduced over time. In 2013, each low-emitting car counted as 3.5 cars. By 2022, each low-emitting car will count as 1.3 cars. Figure 53, shows the historical super credit levels and the maximum super credit equivalent of the ZLEV factor in 2025−2030. Super credit equivalents were determined by calculating the super credit level that would yield the same effect as the ZLEV factor on fleet-average CO_2 emission values. The calculation assumed that only zero-emission vehicles will be used to reach a ZLEV factor of 1.05, which returns the maximum super credit level. Depending on the fleet composition in 2025−2030, super credit equivalents could be lower. Figure 53 shows that the proposed 2025−2030 CO_2 standards would continue the trend of phasing out special treatment of ZLEVs, with super credit equivalents dropping off to 1.1 in 2030. The maximum impact of ZLEV incentives is also being phased out with the ZLEV factor: While the total impact of super credits was capped at 7.5 g/km per manufacturer in the 2020−2021 targets, the ZLEV factor is de facto limited to approximately 4 g/km in 2025−2030.

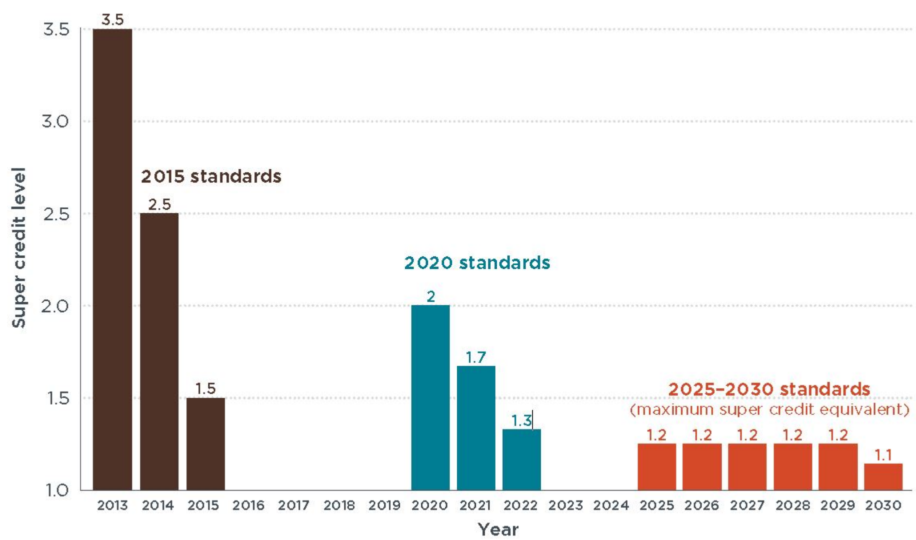


Figure 53: Historical super credit levels in EU CO_2 standards

Despite this progress, the proposed ZLEV incentives could be further improved. Because the ZLEV factor is limited to the range 1−1.05, manufacturers that fail to meet ZLEV targets are not penalized. Changing the range to 0.95−1.05 would increase pressure on car manufacturers to market low emission vehicles. In such scenario, car makers that failed to meet the ZLEV target would be penalized with a lower emission target.

WLTP

Beginning in September 2017, the WLTP is being introduced as the new vehicle emissions' testing procedure in the EU. On average, type approval CO_2 emission values are expected to be about 20% higher under WLTP than under NEDC. This is due to the use of a more dynamic speed profile, a more realistic vehicle test mass, lower ambient temperature, and other test conditions that reflect more closely typical real-world driving conditions.

With respect to the post-2020 CO_2 standards for cars and vans, the transition to WLTP introduces an element of uncertainty regarding the de facto outcome achieved by the regulation. While the percentage reduction targets in the EC proposal are fixed, the absolute CO_2 emission level to be met by a manufacturer in 2025/30 depends on the fleet average WLTP starting point of all manufacturers in 2021. This starting point, in turn, depends on the NEDC-WLTP adjustment factor, which is not fixed yet but will be determined for the 2020 new vehicle fleet.

It is conceivable that, until 2020, vehicle manufacturers will aim at deploying technologies that deliver higher CO_2 reductions in NEDC terms than in WLTP terms in order to maximize their respective NEDC-WLTP adjustment factor and thereby secure as high a WLTP CO_2 starting point for 2021 as possible. Figure illustrates the probable effects due to the introduction of the WLTP.

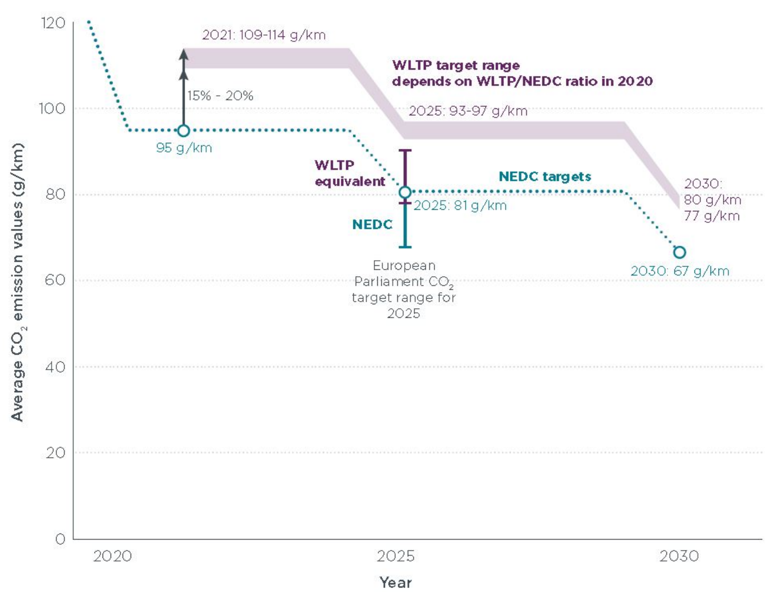


Figure 54: Illustration of the expected effect of the WLTP, [3]

9.2 OEMs strategy

The option to not pay the fine on the CO_2 targets, 95 euros for each gram over the target multiplied for each vehicles, consist in improvement or modification in the power-train of the vehicle:

- Make the vehicle platform lighter, in this way the efficiency should increase due to a better weight/power ratio.
- All the OEMs should increase the degree of electrification of their fleet. To the already present models on the market, in the next few years there will be others with different type of technologies available (BEV, PHEV, REEV).
- Diffusion of the automatic transmission replacing the manual one.

As widely explained in the previous paragraph, the most convenient option for all the OEMs is to increase the xEV (BEV, PHEV and REEV) models in their catalogue. Each EV does not count just ad a zero emission vehicles on the achievement of the CO_2 emission target but:

I) Each vehicle lowers the average of the fleet, specially if is a BEV (CO_2 emission equal to zero);

II) Thanks to the super credits each electric vehicle counts even more on the average of the fleets;

III) In addition, if the share of ZLEV is high enough the OEMs will have a bonus thanks to the ZLEV factor.

Many OEMs are already present on the market with different EV models, chapter **6**. To make a further step and increase the market share of these vehicles, is necessary to guarantee to the costumers a level of reliability and of functionality at least comparable with the conventional vehicle. The incentives given but each county and the discount made by each OEM will give the final shot to break down the distrust of the costumers.

10 Analysis of field data

During my working period spent in FCA, together with the analysis of the parameters that influence the market of electric vehicles like incentives, infrastructure, OEMs strategies, I was in charge of a post processing analysis of real usage data. The aim of this analysis was to understand how the LCVs are used by the different user/mission in order to choose which degree of electrification could better fit each mission.

The analysed vehicles, monitored for a period of sixth months, had been operating on the Italian territory. They belonged to all the segments from 1A (Panda or 500L) to 2G (Ducato). The analysis focused on small to medium fleet (large excluded)[5], including competitors. For each day the raw data consisted in an excel row with different information on the columns, an example is reported in figure 55.

CodCliente	Mission	Segmento	Modello	Data	Inizio attività (orario)	Fine attività (orario)	Durata attività (minuti)	Distanza (km)	Autostrada (km)	Strada extra-urbana (km)	Strada urbana (km)	Guida (minuti)	Sosta motore acceso (minuti)
A639511F89B8C32	UTILITIES (Service)	1B Large	DOBLÒ CARGO	28Aug2017	06:57:00	17:05:00	608	157,9	78,4	51,6	27,9	138	10

Figure 55: Example of the raw data

Before getting into the method of the analysis and the results obtained, it is important to give some more information about the classification by missions that has been used. Starting from the six macro missions defined in the chapter **3.2**, it is possible to subdivide the entire market of LCVs in *submissions*. This way makes it possible to classify better the final user purpose and have cluster of vehicles that have a similar usage.

Submission:

- General Haul - Transport of goods and/or tools as a non-core activity of individual or small enterprises;

  a) Craftsmen: usually, just one or two vehicles used to reach the jobsite (plumber) or to transport the product directly to the final costumer

[5] small = less than 20 vehicles, medium = between 20 and 100 vehicles

(woodworker). The vehicle is available for routes that are always different each.

b) Retail & Merchants: from few vehicles to small fleet, used for transport of goods in cities or suburban sites depending on the working area. Anyway delivery is not the company's core business. It is possible that the vehicle makes its daily distance in just few trips.

c) Rental: from small to large fleet. Vehicles are used by rather different users with very different needs, the rent out is just for short period (i.e. daily).

d) Utilities (Services): from small to large fleet. Are included all industries of maintenance services. The vehicles are used to transport the specific equipment for the given services (mostly working tool and spare parts).

e) Utilities (Distribution&Municipalities): Medium fleet. The usage is similar to the Utilities (services) but it refers to specific public goods: Gas, Energy and Water.

- Delivery - Professional freight logistics;

a) Urban Delivery: medium to large fleet. Distribution in cities or suburban sites of consumer goods from a central hub to selling points. Last mile delivery.

b) Parcel Delivery: medium to large fleet, used for extra-urban distances but occasionally for short urban trip. They are service companies - transportation of goods for own professional business or for fleets.

c) Food&Beverage: small to medium fleet. These vehicles are used to transport packaged products from warehouse to the shops or similar trips. This mission include also transport of drinks and liquid products.

d) E-food: medium to large fleet. These vehicles are used to transport specific products from shops to the customers houses. The orders are made from online website.

e) Thermo controlled & Refrigerated: Small to medium fleet, used to transport degradable and very specific products. Supplier of restaurants, bar, patissier and seller of frozen goods.

- Construction - Construction materials and equipment logistics to/from a job site;

a) Aerial: specific type of vehicles with a mechanical crane installed after market by external producer.

b) Construction: small to large fleet, used to transport the specific equipment needed to the construction site (companies or single worker) as: houses, buildings and others.

c) Road Maintenance: small to large fleet, used to transport the specific equipment, usually low load, needed for the construction site (companies or single worker) as: streets, public works or others.

- Special Equipment - Emergency vehicle/maintenance and special public;

a) Waste Collection: medium fleet, composed by specific vehicles for the collection of garbage in cities. Used also during night.

b) Car Recovery: mainly small fleet, used by professional worker that operate just in case of necessity/emergency.

c) Ambulance: small to medium fleet, used by hospital and voluntary company.

- Collective Transport - City/intercity, public/private people transport service;

(a) Shuttle Bus: small to medium fleet, used by entertainment and public activity for multiple purpose as transport of people (Hotels, schools, park to fly).

(b) Downtown Mobility: small to large fleet, used by company or single user, (taxi service, public mobility).

- Recreational - Leisure application such as vacation and camping;

The classification reported above is the most detailed. During the analysis only just some submissions had been taken inyo account, because some of the categories have a very low possibility to implement Electric vehicles, as for example Recreational and Ambulance. In addition only the missions with at least 30 vehicles in the sample have been take into consideration.

The vehicles were mostly of two segments: 1B and 2G. Each segment have a different use even if the submission is the same. In the next pages there will be a separation between them to better understand which users, for each segment, are more indicated to use eLCV.

Due to confidential needs the name of the submission will be changed in order to made it anonymous: SubMission 1, Submission 2, etc.

As already mentioned, the problems of BEVs are various. To identify which are the submissions that could fit the EVs characteristics, some threshold has been imposed:

A) Low highway usage, usually on this type of road the power required is very high and in this way the autonomy of the EV is strongly reduced. Moreover the maximum speed is lower than ICE.

B) High urban usage, the power required during urban usage is lower than Extra Urban or Highway and the high number of stops (light, traffic jam) improve the efficiency of the Electric Propulsion respect to a conventional one.

C) Average daily mileage under $150km$ and low dispersion, the EVs have an autonomy that cannot achieve the ICE one; moreover the repeatability of the mission gives the possibility to be independent from recharging infrastructures.

10.1 Segment 1B

The first analysis of the data was focused on the general information, table 2:

- Number of Vehicles and of costumers;
- Percentage of usage, computed referring to the total number of days in which the vehicle has been used and the total number of calendar days;
- Average mileage.

The total number of vehicles in this segment was about 1.800.

Parameters → **Submission ↓**	**Vehicles**	**Costumers**	**% of Usage**	**Avg. km**
Submission 1	1.073	426	67%	116
Submission 2	88	6	74%	65
Submission 3	211	184	69%	114
Submission 4	108	46	71%	121
Submission 5	100	89	78%	91
Submission 6	60	35	74%	121
Submission 7	46	33	79%	88
Submission 8	33	17	78%	66

Table 2: General parameters, 1B segment

It is possible to see that not all the submissions have a high number of vehicles in the sample. Anyway it is interesting to evaluate the different behaviours. From this general data it is possible to understand that Submission 2, 5, 7 and 8 have an high orientation towards BEV due to the low average mileage.
Figure 56, shows the road usage of each single submission; the green box indicates the ones which have an usage oriented to BEV. There again we have number 2 and 7; even number 8 have a quite low Highway usage.

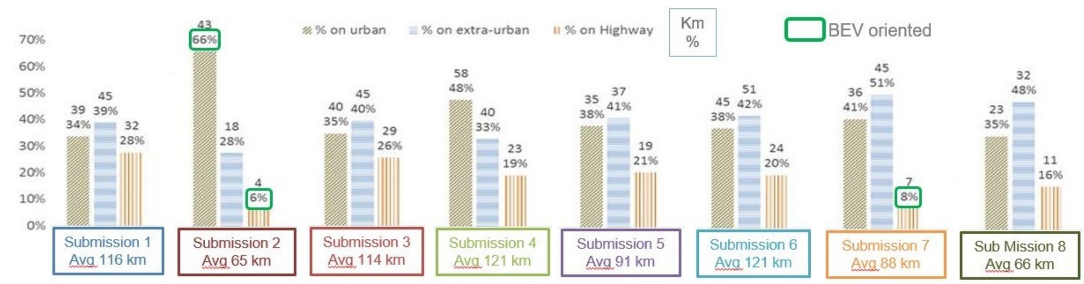


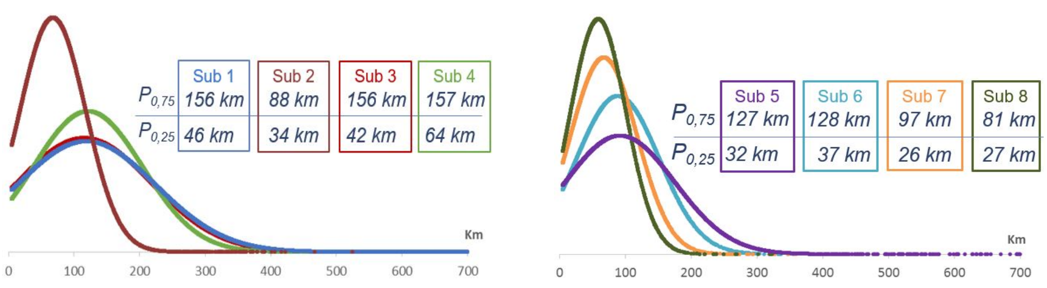
Figure 56: Road usage, 1B segment

The next step was to understand the usage distribution. The attention was focused on every single trip done by each vehicle. Putting together vehicles belonging to the same submission was possible to create a curve reporting the normal distribution of the monitored trips. Two assumptions have been taken into consideration:

I) Trips with mileage below 5 km have not been considered, because they could be trips just for logistic reasons and not for a working activity.

II) Rather long mileage has not been reported in the curve, because it has a very poor meaning and could be an outlier due to a wrong geolocation or trips done for reason out of the working scope.

Figure 57 reports the distribution of each submission. The values indicated as $P_{0,75}$ and $P_{0,25}$ are the third quartile[6] and the first quartile[7].



(a) Submissions from 1 to 4 (b) Submissions from 5 to 8

Figure 57: Distribution of the daily trip, Segment 1B

[6]The 75% of daily mileage are under $P_{0,75}$

[7]The 25% of daily mileage are under $P_{0,25}$

From the shape of the curves and with the value of $P_{0,75}$, is possible to an idea of which are the submissions with the lowest dispersion. The users belonging to 2, 7 and 8 seem to have an high repeatability of the mission under 200 km.

Then an analysis in terms of frequency and cumulative curves has been done, to evaluate which are the daily mileage range for each submissions.

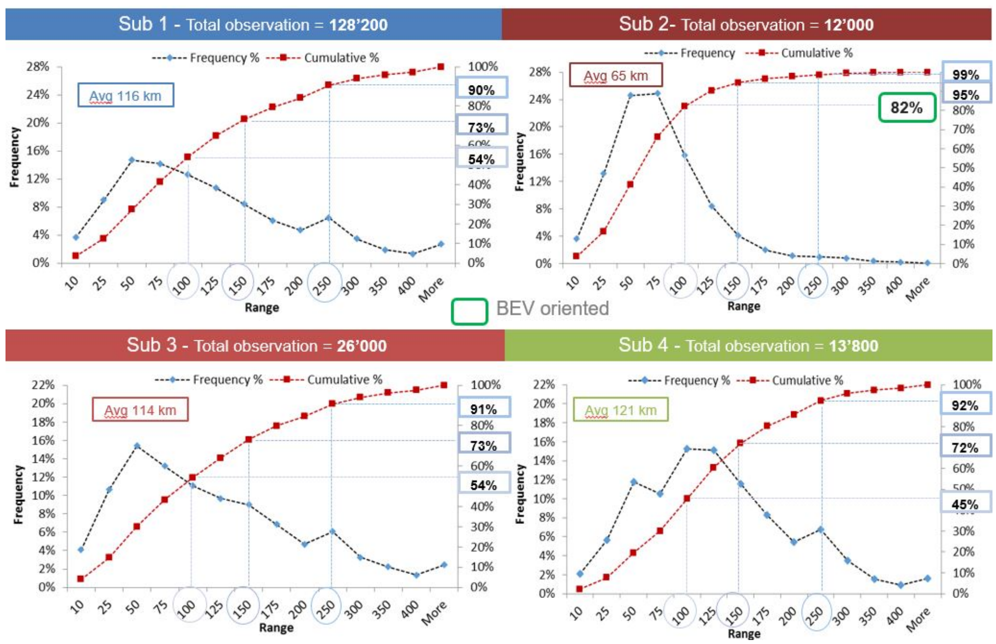


Figure 58: Frequency and cumulative curve, submissions from 1 to 4

Again, looking figure 58, mission 2 shows a high BEV potential because 82% of its trips had a mileage under 100 km. Also Submission 4 shows a high frequency of mileage between 100 and 150 km, but there are still too many observations over 200 km. This kind of behaviour could indicate a possibility to BEV implementation just for a cluster of users.

Figure 59 confirms the high BEV potential of submission 7 and 8, respectively 77% and 85% of the observations are below 100 km.

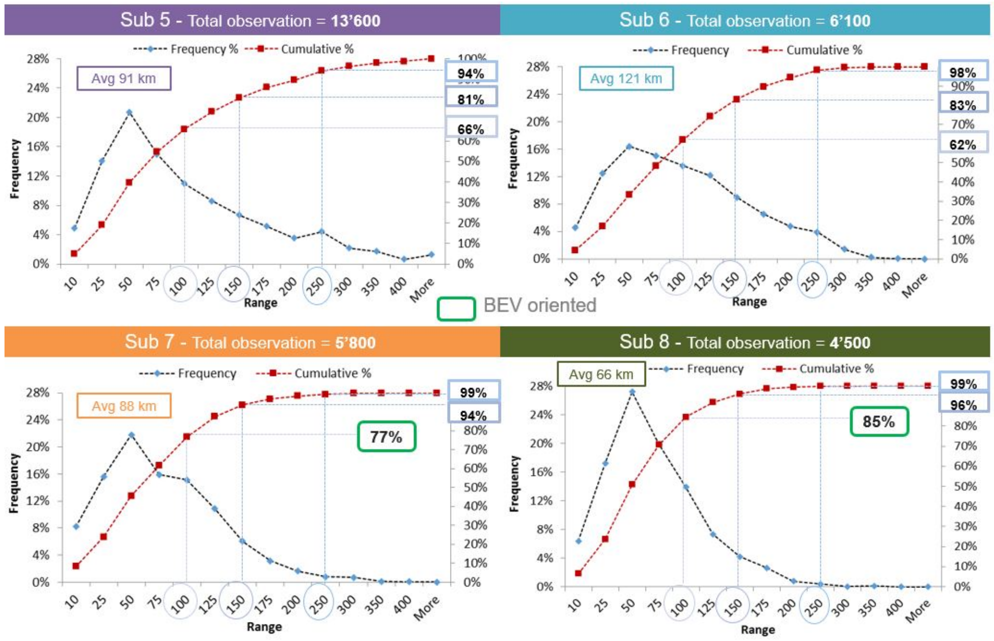


Figure 59: Frequency and cumulative curve, submissions from 5 to 8

To understand better the behaviour of each cluster of vehicles, the analysis moved from the focus on the single trips to the number of vehicles that respected some thresholds. The following graphs report:

A) Y-axis: the percentage of vehicles;

B) X-axix: percentage of usage days;

C) Three threshold curves: 100 km in Blue, 150 km in Orange and 200 km in Grey

Each point of the graph should be read in this way:

Percentage of vehicles that went over the mileage reported by the curve (blue, orange and grey) for at least the percentage of days reported on the X-axis.

On the left there is the percentage of vehicles that for least one day have done a mileage over the threshold; while, going to the right of the X-axis, the percentage decreases.

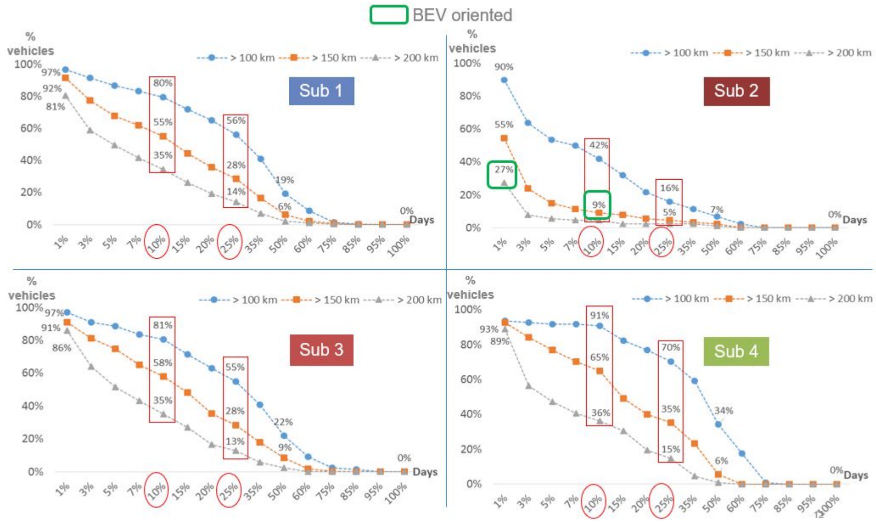


Figure 60: Percentage of vehicles over n-km for %-day, submissions from 1 to 4

Only 27% of vehicles belonging to submission 2 have done, at least once, more than 200 km, figure 60.

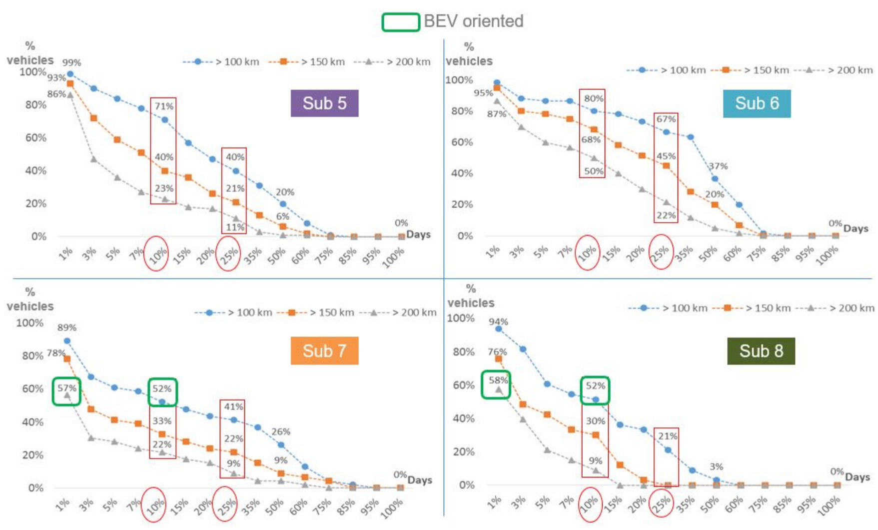


Figure 61: Percentage of vehicles over n-km for %-day, submissions from 5 to 8

For submissions 7 and 8 the percentage of vehicles that had a mileage over 200 km is still not high, 57% and 58%. If we consider 10% of days, the threshold curves, for both missions, decrease rapidly. Even for submission 5 the percentage of vehicles over 200 km decreases very fast.

The final purpose of this analysis was to find which submissions have a usage that could facilitate the use of eLCVs. Some parameters have been chosen as BEV potential indexes. These have been reported on the axes of a chart, figure 62.

- X continuous axis: percentage of Urban usage;
- Y continuous axis: Average daily mileage;
- X dashed axis: percentage of vehicles below 150 km for at least 90% of days;
- Y dashed axis: width of the trip distribution, $P_{0,75} - P_{0,25} = IQR$, Interquartile Range.

The solid axes indicate the values of interest to consider a submission BEV oriented; while the dashed axes give an idea of the dispersion of such submission. On the chart each ball represents one submission and the dimension of the ball indicates its market weight. The Full ball refers to the continuous axes, while the dashed ball refers to the dispersion axes.

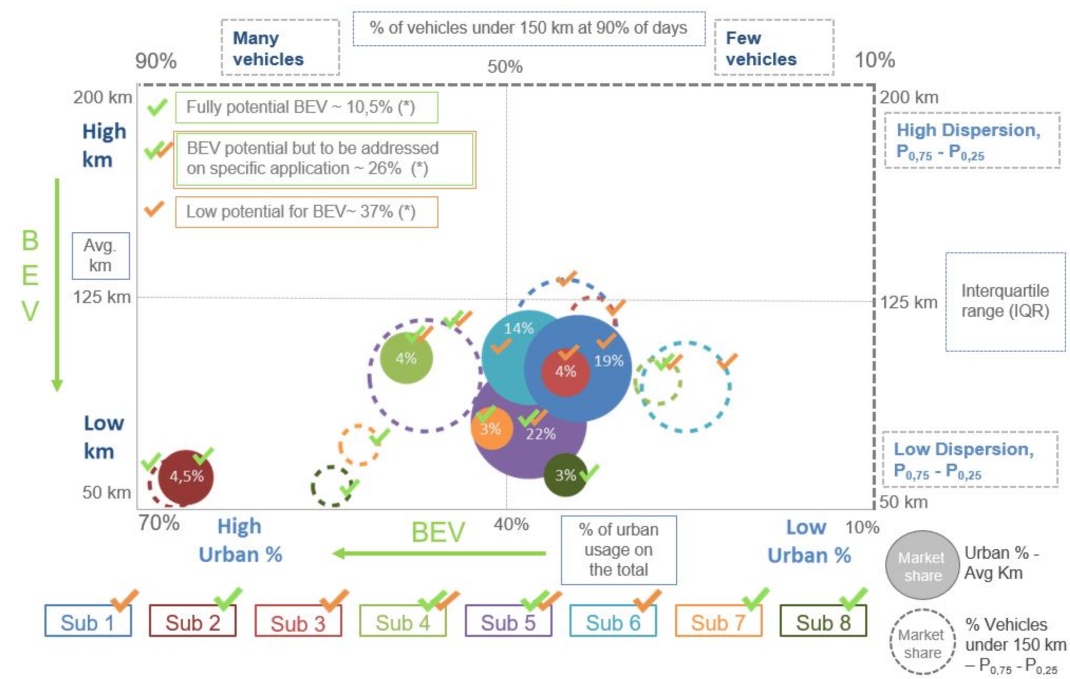


Figure 62: Distribution of the mission depending on their potential to BEV

Depending on the position of both balls it is possible to select the BEV inclination for each submission. In figure 62 is possible to see a recap of the results:

→ Submission **2, 7** and **8** are fully potential BEV, green flag. They have a low average km and a relatively high urban usage. On the dispersion side all of them have a tight Gaussian distribution, see *IQR* and figures 57a, 57b. Moreover they have an high percentage of vehicles that have been below 150 km for a high number of days.

→ Submission number 4 and 5 have a contradictory behaviour:

a) Number 4 has a high urban usage and a low average mileage but has an high number of vehicles with mileage over 150 km for more days, the dashed ball is on the right quarter.

b) number 5 has a low dispersion but the urban percentage is not so high.

For this reason they have a green and orang flag. The implementation of BEV vehicles could fit some users. The others could choose different xEV.

→ The other submissions have a low potential for BEV. This does not mean that it is impossible to utilize Electric vehicles for these users, but it means that the user should know accurately which are the limits of these vehicles and understand if they could still be included in the daily working activities.

10.2 Segment 2G

The number of vehicles monitored belonging to the 2G segment were about 1.300, even in this case only submissions with at least 30 vehicles have been take into consideration.

The analysis follows the same step done and showed in **10.1**, so starting from the general information, table 3, and from the road usage, figure 3, it is possible to select some submission as BEV oriented.

Parameters → **Submission ↓**	**Vehicles**	**Costumers**	**% of Usage**	**Avg. km**
Submission 1	530	198	63%	147
Submission 2	84	21	62%	159
Submission 3	300	130	66%	142
Submission 4	107	46	63%	142
Submission 5	83	32	73%	166
Submission 6	72	65	66%	133
Submission 7	50	7	81%	65
Submission 8	43	27	67%	113

Table 3: General parameters, 2G segment

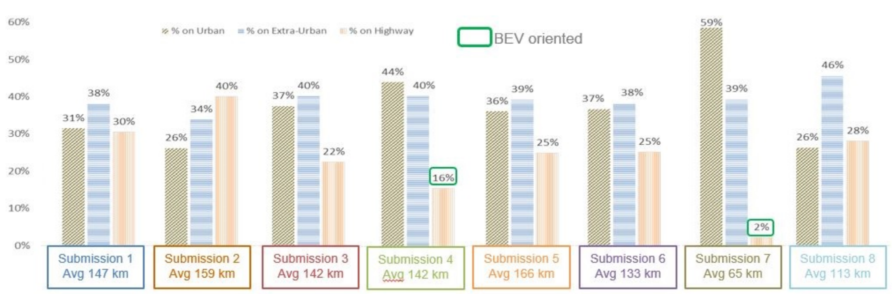
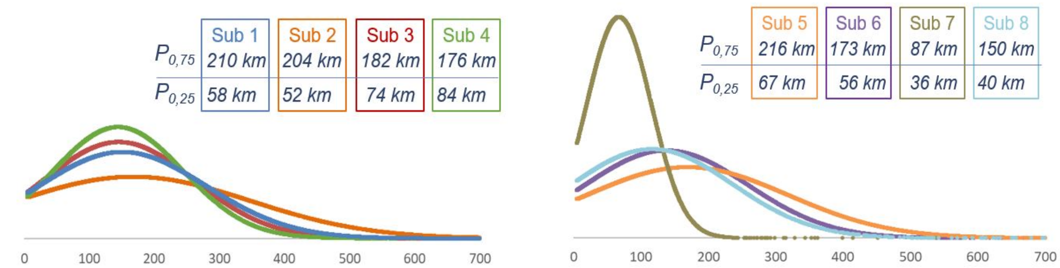


Figure 63: Road usage, 2G segment

Following the assumptions already explained in the previous paragraph, the usage distribution has been plotted, figure 64.



(a) Submissions from 1 to 4 (b) Submissions from 5 to 8

Figure 64: Distribution of the daily trip, Segment 2G

From the general information provided above, it is possible to guess that submissions number 4 and 7 are BEV oriented. They have a average mileage below 150 km, moreover they have a low highway usage. Looking to the distribution of the daily trips, number 7 seems to be highly predisposed to BEV, figure 64b; submission 4 has a non negligible number of trips over 200 km, figure 64a, anyway the 75% of the monitored trips were below 176 km ($P_{0,75}$). A particular case is represented by mission number 8: the average mileage and the value of $P_{0,75}$ are encouraging in terms of BEV orientation, but this submission has a high usage of extra-urban and Highway and so its orientation towards BEV needs a deeper analysis.

In the following figure there is the frequency of trips for different range and the respective cumulative curves. As already explained, these graphs try to give a better idea of the trip's distribution for each submission. Respect to the vehicles of the 1B segment, the data reported for these vehicles show a higher mileage that could discourage the implementation of BEV.

Submission 7 shows again a completely different behaviour respect to the other, figure 66.

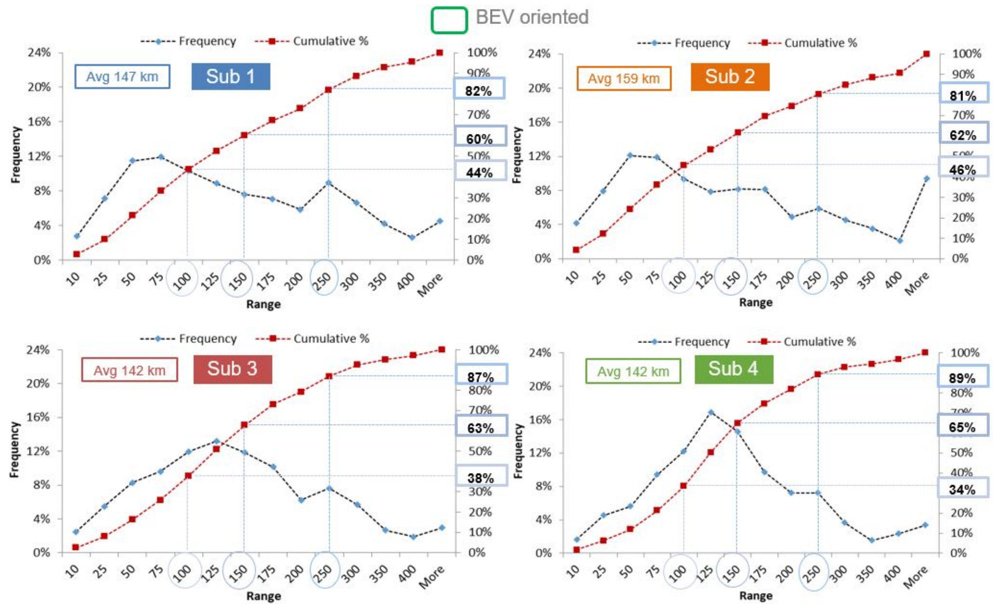


Figure 65: Frequency and cumulative curve, submissions from 1 to 4

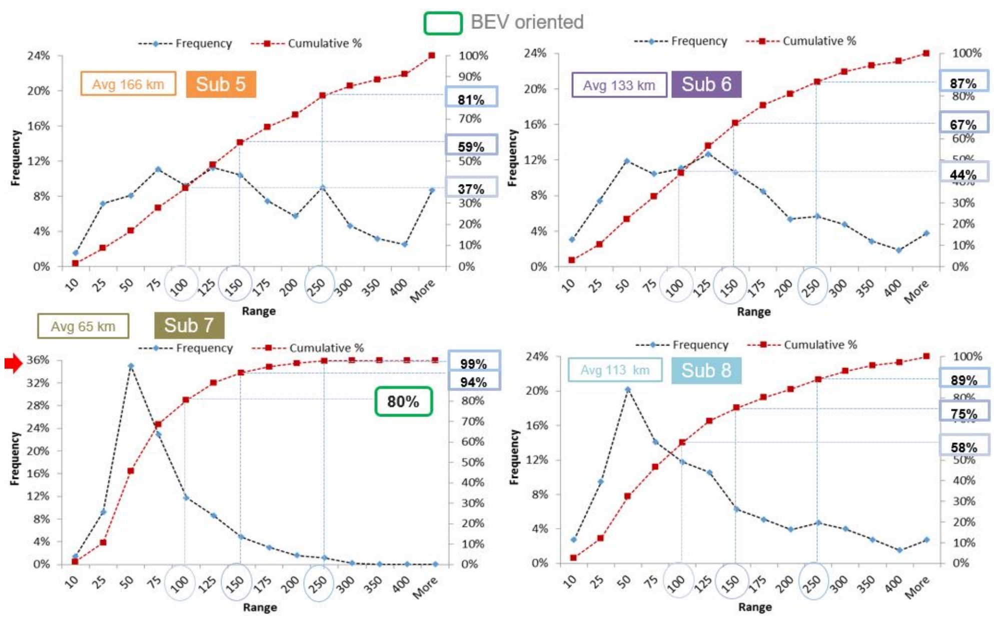


Figure 66: Frequency and cumulative curve, submissions from 1 to 4

The next analysis focus on the number of vehicles instead of the number of trips. In this case the graphs want to show how many vehicles go over a certain threshold and how many times.

Except submission 7, that fulfils all the index for BEV implementation, even number 4 shows some interesting aspects. The users belonging to this submission seem to travel every day in a range between 100 and 150 km, but not many of them go over 200 km. On the graph it is possible to notice that only the 31% had a mileage over 200 km for more than the 10% of the monitored days, figure 67.

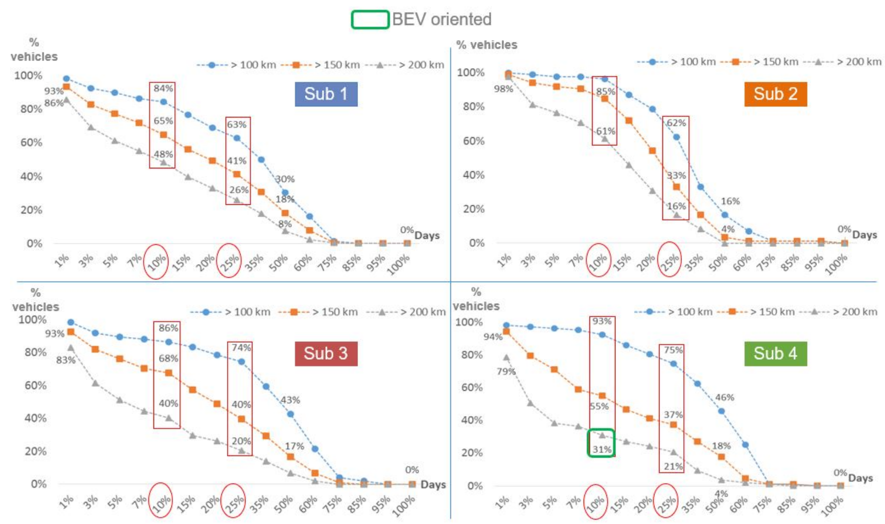


Figure 67: Percentage of vehicles over n-km for %-day, submissions from 1 to 4

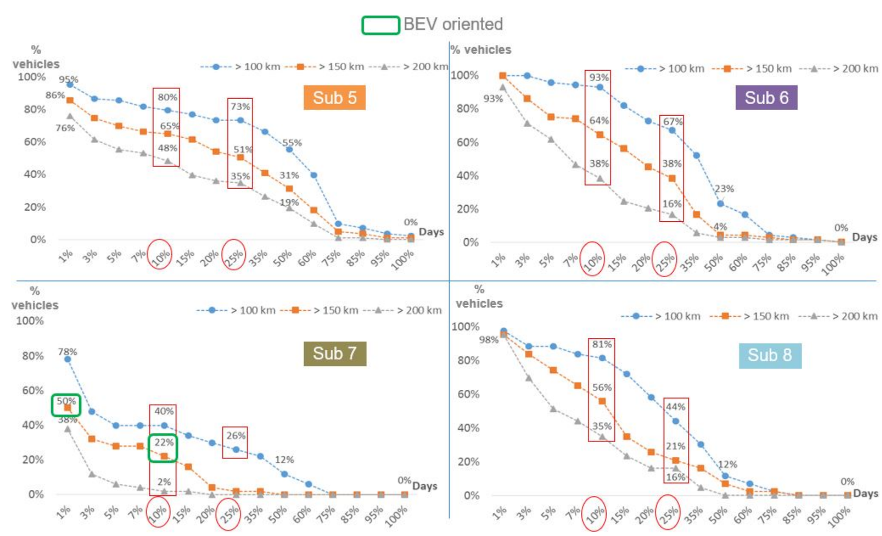


Figure 68: Percentage of vehicles over n-km for %-day, submissions from 5 to 8

A particular case is the submission 5, only 76% of vehicles had a mileage over 200 km for at least one day, figure 68; this is strange for a submission with an high average mileage like this one. Going into a deeper analysis it was discovered that a cluster of users had a completely different behaviour respect to the average. Then it is demonstrated that each submission could have a small percentage of users that could implement xEV even if the general behaviour of the submission is not BEV oriented.

Last step is to concentrate the information obtained in the final graph, figure 69.

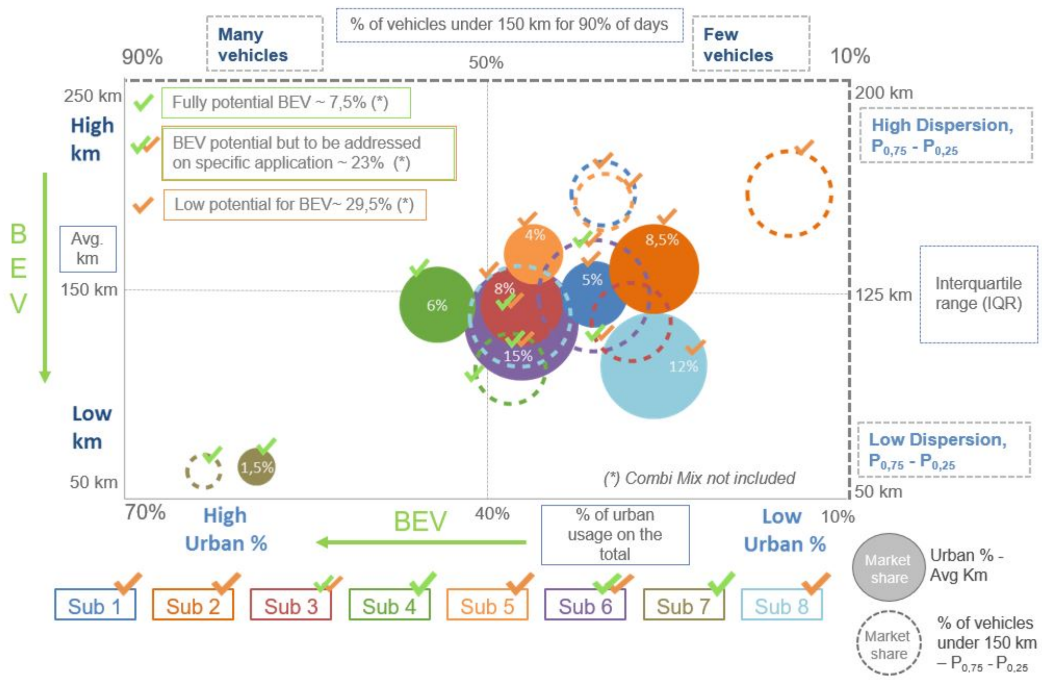


Figure 69: Distribution of the mission depending on their potential to BEV

The logic of the graph is the same as explained for the 1B segment.
In this case:

→ Submission **4** and **7** are fully potential BEV, green flag. In particular, number 7 is the most addressed to BEV. Number 4 has still a high BEV orientation thanks to the average mileage and the low usage on highway, the problem of this submission could be the autonomy of the electric vehicle, but with a slightly larger capacity of the battery pack the problem could be solved.

→ Submission number **3** and **6** touch the BEV quadrant:

a) Number 3 has a high urban usage and a low average mileage but has an high number of vehicles with mileage over 150 km for more days, the dashed ball is on the right quarter.

b) number 5 has a still sustainable average mileage, and a good urban usage but, the trip distribution curve is quite width (IQR high) and there are many vehicles that travel often over 150 km.

For this reason they have a green and orang flag. The implementation of BEV vehicles could fit some users. The others could choose a different xEV.

→ The other submissions have a low potential for BEV. This does not mean that it is impossible to utilize Electric vehicles for these users, but it means that the user should know accurately which are the limits of these vehicles and understand if they could still be included in the daily working activities. In particular submission **8** that has only the index of the urban usage that makes it fall beyond the BEV oriented quadrant.

11 Conclusion

Thanks to the data analysed it is possible to have a better view of the evolution of the electric light commercial vehicles. The most difficult aspect, as already explained, will be to fully satisfy the costumers' needs and to not change the most important aspects of a CV: Volume, payload and internal length of the loading area.

By changing the propulsion system from a conventional one to a fully electric one (BEV), another relevant factor will influence a lot the success of e-LCV and that is its autonomy. Since the beginning of this technology the maximum range achievable was one of the parameters that caused the decreasing interest in electric vehicles. During the years the technological improvements helped a lot in this field but more benefits are fundamental to close the gap with the ICE. Until all the doubts about the range anxiety[8] will not be solved, by improving the charging infrastructure and the battery performance, the world of BEV will be restricted to a limited number of costumers.

In addition to this disadvantage, it is also important to consider that nowadays the selling prices are still too high; as explained, for the next years the incentives from each country will be the most important factor to help the growth of the market. If the prices decrease, but still remaining higher than ICE, it may attract more people thanks to the advantages that EVs give nowadays and will give even more in the future: no banned zones in most of the urban city centers, lower cost of energy respect to conventional fuel, lower cost of maintenance and services.

The investments of many countries and OEMs are focusing towards this direction specially on the batteries that are one of the larger costs and that are also directly related to the autonomy. The best results will be to obtain batteries with a higher specific energy but also with a lower cost. This way the vehicle will have a lower weight but a higher range; moreover the cost will decrease. Actually the most used rechargeable battery is the *lithium-ion* that has a specific energy over 230 Wh/kg

[8] Fear that your vehicle has insufficient range to reach your destination

and a cost that goes form 280 €/kWh and 350 €/kWh. In the following years this technology will cost less, under 200 €, while the specific energy will increase. Anyway other solutions are already available on the market but are not used for different reasons, for example *Li-S* batteries have a higher specific energy 400 Wh/kg but must be improved on the safety side.

Independently to the future improvement, the EV are already suitable for a cluster of costumers. The aim of this thesis was to understand who between the final users can already change its conventional vehicle with an electric one. The analysis on field data demonstrated as different *missions* can use BEV without problems; thanks to the low variability of their trips and to the average mileage under 150 km and so below the actual autonomy achievable. As explained other kind of technologies are available and will be present on the market of CV in the following future but BEV is surely the most eco friendly choice.
It is worth to say that the conversion to e-LCV is different not only depending on the final purpose of usage but also depending on the number of vehicles belonging to the buyer. In particular, the companies with large fleet have the possibility to rotate the CV in their park and so to organize the daily work of each one even depending on the characteristics of the vehicle. Large fleets are surely an early adopter of EV thanks to the possibility of using both conventional and BEV. Workman, that usually have one or two vehicle for their business, buy a BEV mostly if their daily activity is strictly related with the access to the city centers and so an ICE could make them to lose business opportunities.
At the end from the analysis reported in chapter 10, it was possible to select some users as BEV oriented so the final purpose was achieved. Surely all the users that have an high percentage of urban usage and low number of trips with an high mileage, have a highly predisposition to BEV, independently of the *mission*. It is instead important to underline that from the results obtained, there is a slight difference between the usage of vehicle belonging to the 1B segment respect to the 2G ones.

It seems that larger the vehicleis, higher is the daily mileage. This means that it is worth to select carefully the correct characteristics package for each model, for example trying to offer different battery size or giving it the possibility to charge faster (Mode 4, chapter 8). This last option gives the possibility to the user who comes back to the warehouse during the daily activity, to recharge the vehicle while loading, in order not have issue with the range.

By the way the world of light commercial vehicles has surely a high potential for electric ones. The following years will be fundamental to take the right direction in order not be late respect to others manufacturers. At the same time, due to the technology evolution, it will be important to improve the characteristics of the vehicle in order to have a premium offer respect to the competitors and to satisfy a larger market share.
In this direction the analysis of the field data of the vehicle will even help in the following years to improve the electric vehicles so they may satisfy more costumers' needs.

11.1 Future analysis

My analysis of field data is actually on going but on other vehicles. In particular the next step is to focus the attention on a cluster of commercial vehicles running in UK and France. The data available have been given in a different format respect to the one analysed in chapter 10 because the number of vehicles is higher, around 30 thousand, and so the related information would be difficult to handle. However was not possible to have the raw daily data but anyway all the information are still extractable. As already done the focus is on average daily mileage and the distribution of it. A particular attention is also given to the percentage of the total mileage spent in urban area, in this way is possible to understand how much *urban* a vehicle is. Obviously all the vehicles are divided by submissions to better filter the different costumers. Another important aspect is that the data provided contains also vehicles belonging to large fleet. The main difference is the segment, in this case just vehicle of the 2G class are present so it will be possible to confront them with the vehicles already analysed for this segment.

In addition to this analysis, the next important step could be a focus on the daily activity of the vehicle, trying to go more into details and understanding:

I) the number of stop in which the engine can be turned off; very often the conventional vehicle are not turned off but keep running in idle to save time (specially during delivery).

II) the number and the duration of the parking moments during the day, that could be the moment in which the vehicle could be recharged.

III) the number and the duration of the loading time when the vehicle is back to the hub, this is interesting specially for food and other deliveries that often come back at least one time to the warehouse and so could be recharged with a faster mode if installed in the parking and loading area.

But also others information such as the speed could be very useful to understand if the limits of electric vehicle can at least partially fulfill the users' requests.

Independently from the analysis done, the electric vehicles already show a high potential of implementation in all the automotive sectors. Surely they have less performance respect to the conventional ones but thanks to the zero emission they can be the solution to the increasing pollution (NO_x, particulate emission and CO_2) specially in case of LCV that have a higher level of emissions respect to passenger cars. However without a production of energy from renewable and clean sources the problem of emission and pollution is just moved from the exhaust pipes to the beginning of the energy chain.
Without any doubts, with the right approach and the investments of all the parts involved the electric vehicles can be a valid solution for the future.

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