UNIVERSITÀ POLITECNICA DELLE MARCHE
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Masters' Degree in INTERNATIONAL ECONOMICS AND COMMERCE

La nuova frontiera dell'automotive: dai veicoli ibridi ai full-electric.

The new frontier of automotive: from hybrid to full-electric vehicles.

Relatore: Chiar.mo
Prof. Roberto Esposti

Tesi di Laurea di:
Alessandro Mazzanti

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SINTESI

L'obiettivo di questo elaborato è quello di illustrare l'attuale situazione del mercato e dell'industria automobilistica, e, più specificamente, di quella parte di mercato rappresentata dai veicoli alimentati da fonti alternative rispetto ai convenzionali carburanti (benzina e diesel) e i cui due principali esponenti sono i veicoli elettrici ed ibridi.

L'analisi di questa tesi parte dalla presa di coscienza dalle attuali criticità ambientali dovute in large parte ai cambiamenti climatici causati dalle attività umane. All'interno delle attività umane rientra per l'appunto anche il mondo dell'automobilismo e, per questo motivo, al giorno d'oggi i soggetti facenti parte di questo mondo stanno ricercando delle soluzioni di trasporto alternativo con l'obiettivo di raggiungere una mobilità sostenibile. Le tipologie di veicoli sopracitate (elettrici ed ibridi) sono attualmente viste come le alternative più promettenti per raggiungere questo obiettivo visto che sono, in parte o completamente, alimentate da un motore elettrico la cui elettricità può essere generata usando fonti di energia rinnovabili e meno inquinanti, quindi con un minore impatto ambientale.

In questa tesi, questi veicoli sono stati analizzati studiando le loro caratteristiche nel dettaglio, i loro dati di vendita attuali e le previsioni dei dati futuri, l'impatto ambientale che hanno durante il loro ciclo di vita, l'atteggiamento e la propensione

dei consumatori nei loro confronti. Inoltre, è stata svolta anche un'analisi di mercato volta a capire chi sono i soggetti che operano in questa frangia di mercato e quali strategie mettono in atto per essere competitivi e quindi aggiudicarsi una certa quota di questo. In particolare, si è svolta un'approfondita analisi della casa automobilistica americana Tesla che attualmente detiene la leadership di questo mercato grazie ai suoi innovativi veicoli elettrici.

Al termine di questa tesi si può affermare che appaiono chiare le potenzialità e le opportunità che questi veicoli offrono sia sotto il punto di vista della performance ma anche (e soprattutto) sotto il punto di vista della sostenibilità e dell'impatto che questi hanno nell'ambiente. In particolare, i veicoli elettrici sembrano essere la miglior alternativa viste le loro caratteristiche e pertanto sembra che saranno proprio loro a rappresentare la "nuova frontiera dell'automotive".

INTRODUCTION

During the last decades, and especially during the last one, the topics and the relative issues about environmental protection and sustainable development have started to be discussed all over the world among political leaders, and among other influential figures and organizations, gaining more and more importance throughout time.

In particular, with the concept of sustainability is meant the capability of the present generation to meet its own needs, without compromising the ability of future generations to meet their own needs, so that development can be achieved without harming future generations.

All of this implies the necessity of acting and taking decisions in order to protect and preserve the environment in which we live. That's why, the ongoing debate is not only about reducing the negative impact that human activities have on the planet by reducing waste and energy use, but also on developing and implementing processes that make human activities always more efficient and sustainable.

Of course, this discussion has not excluded the industry of automotive and transports, and the related subjects to them. As a matter of fact, countries have started to try to find ways to achieve sustainable mobility by reducing the vehicles'

emissions and their impact on the environment, other than trying to reduce the amount of them on the streets by favouring public transportations.

In fact, the automotive industry is one of the most important industries in the world economy, contributing to the growth of the modern society by satisfying the daily mobility needs of human beings. Despite its importance in the global scene, this industry has been accused of polluting too much and of harming the environment and public health. That's why a solution for achieving sustainable mobility is asked and required worldwide.

To the present day, the world major automakers and also newly created companies are researching and developing solutions in order to deal with the problem of sustainable mobility. All of this represents for them also an interesting opportunity to gain higher market shares in the new segment of "green" and ecological vehicles that is exponentially growing year after year, namely the alternative powered vehicles market. That is why they are investing in creating new technologies and vehicles to be released in the world market.

Up to date, two main typologies of more sustainable (rather than the traditional vehicles powered exclusively by fossil fuels) vehicles have been created and introduced in the world market: the full-electric and the hybrid vehicles. The particularity of these kinds of vehicles is that they are, partly or completely, powered by electric motors so that renewable resources could be used to generate

the energy needed to let them work, thus avoiding the emissions of CO2 and of fine dusts.

This master thesis will exactly deal with these kinds of vehicles, trying to analyze them and to hypothesize which one of them will more likely prevail and eventually represent the future of world transportation.

Particularly, in the first chapter it will be introduced the topic, looking at the current automotive market and at the data related to it with a deeper analysis and focus on the two different types of alternative powered vehicles mentioned before, on their evolution of sales data and market share in the recent years. Moreover, it will be also tried to consider the consumers' side, looking at their attitude towards the problem of sustainable mobility and at their willingness in adopting these new types of vehicles.

Afterwards, in the second chapter, it will be presented in detail the peculiar characteristics and features of both Battery Electric Vehicles (BEVs) and of Hybrid Electric Vehicles (HEVs) with a deeper focus on the most promising type of hybrids, namely the Plug-in Hybrid Electric Vehicles (PHEVs). In this chapter, it will also be provided an analysis of the market price of these types of vehicles.

Later on, in the third chapter, it will be analysed and assessed the environmental impact of full-electric and hybrid vehicles, trying to find out if they are really sustainable for the environment and so, if they can represent a viable solution and an alternative to the vehicles powered exclusively by fossil fuels.

Then the thesis will continue with the fourth chapter looking at the prospects and forecasts related to the alternative powered vehicles market in order to try to hypothesize which type of alternative vehicle will prevail in the future and what impact it is going to have in the general automotive industry and market. In order to formulate this hypothesis, it will be carried out even an analysis of the current alternative powered vehicles market, and, in particular, of the main automakers that are operating and wagering on these types of vehicles.

Afterwards, related to the previous topic, during the fifth chapter the focus will be placed on the potentially successful competitive strategies that automakers are adopting or that they could adopt in the near future to effectively compete in the evolving automotive market and to take a prominent role in this market segment. Noteworthy, in this chapter automakers will be divided in two different groups, namely the incumbent automakers and the newcomers, by taking into account their experience in the automotive industry.

Eventually, in the last chapter, it will be presented the nowadays iconic case of Tesla Motor Company, an American newcomer automotive firm established in 2003, which has wagered on the creation and commercialization of full-electric vehicles destinated to the great mass of world population since the beginning of its activity.

CHAPTER ONE:

THE EVOLVING AUTOMOTIVE MARKET

1.1 HISTORICAL BACKGROUND OF THE AUTOMOTIVE INDUSTRY

The history of the automobile as a functional and efficient mean of transport started officially at the end of the Nineteenth century. Unlike many other major inventions, the original idea of the automobile cannot be attributed to a single individual, and there is not even an exact date or year in which it is possible to affirm that the automobile was firstly created because its functioning was based on some models, theories, and inventions already discovered many centuries before, such as the *Fardier à vapeur*, which was the first ever prototype of a "car" activated by a steam engine, created by Nicolas Joseph Cugnot in 1771.

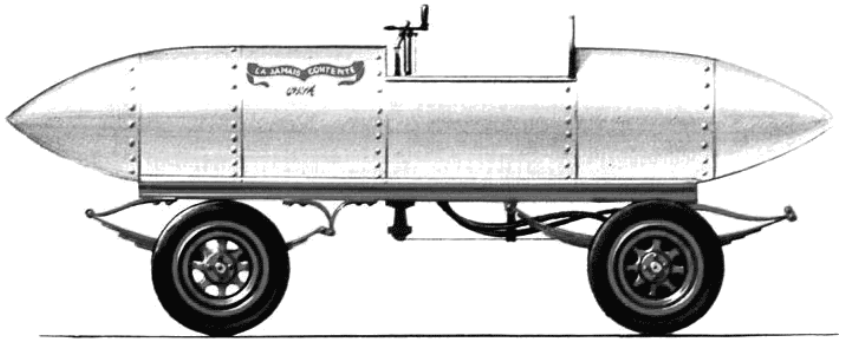
All of this is true also for electric cars. As a matter of fact, the first models of electric vehicles are traced back to 1830s when the Scottish entrepreneur Robert Anderson made the first rudimental model of electric carriage, and when during the same years the Dutch professor Sibrandus Stratingh and his collaborator Christopher Becker created the first ever project of an electric car.

Later on, at the end of the Nineteenth century, the competition in the automotive industry was based mainly on three different kind of powertrains: steam engines, electric motors, and gas engines.

Surprisingly, during the first phase of this newly created industry (more or less between 1890 and 1910), the electric powered vehicles were the most widespread ones worldwide by exploiting the weaknesses of the two other kinds of powertrains. In fact, at the time, the advantages of electric cars over the other existing powertrains (gas and steam) were significant. Indeed, electric cars had no vibrations from the engine and were extremely quiet compared to its competitors, plus they also didn't emit smoke or backfire frequently as gas powered cars did. Furthermore, they were also ready to go right when you sat in the car, unlike gas powered cars that needed to be cranked by hand to start; this was not only difficult, but it could also be something quite dangerous. Steam powered cars, on the other hand, at the time took up to 45 minutes to get going on cold days. The other large advantage of electric cars was not having to change gears, which was a hard thing to do in early cars, but something that wasn't really necessary in electric cars.

Moreover, electric engines were better than the other two also regarding the performance side at that time.

Figure 1.1 - La Jamais Contente, 1899.



In fact, the first ever automobile to reach and exceed the threshold of 100 km/h in 1899 was an electric car, the so-called *La Jamais Contente* (in English "The never satisfied") of which a drawing is represented in *Figure 1.1*.

Electric vehicles were preferred even regarding the reliability side. Indeed, it is estimated that in the 1920s there were on the streets of the world hundred thousands of electric vehicles used as private cars, but also as taxis, vans, busses, and so on.

One interesting example of this is that in New York, at the beginning of the Twentieth century, the 90% of the taxi cabs were electric vehicles built by the Electric Carriage and Wagon Company of Philadelphia; this is a quite interesting percentage if it is considered that in 2013 the former New York City mayor, Michael Bloomberg, aimed at electrifying one-third of the taxi fleet by 2020. Furthermore, it is estimated that the 34% of the vehicles circulating in New York, Chicago, and Boston were electric vehicles at the beginning of the previous century. However, as history teaches us, gas engines were the ones that dominated the automotive industry in the Twentieth century.

In fact, the main drawbacks of electric motors at that time (and partly also of nowadays) were the low autonomy of electric powered vehicles due to their not so efficient batteries, the amount of time needed to recharge them, and their relative low speed. All these drawbacks combined with the emergence of Ford Motor Company in the United States provoked the downfall of electric vehicles. As a matter of fact, Ford was the first automotive manufacturer that succeeded in

creating and commercializing relatively cheap and affordable cars thanks partly also to its innovative assembly line construction. Indeed, Ford was able to offer its cars, and especially the now iconic *Model T*, at a base price of around $500 a piece, equivalent to about $10,000 today, which made it affordable even for average people, thus transforming cars from a luxury good to a good accessible to everyone by making it cheap, versatile, and easy to maintain; something that had never been the case before. In contrast, at that time the average price of an electric car was around $1700.

Moreover, the 1920s saw the emergence also of the great European automakers such as Austin, Morris, and Singer in England, Fiat in Italy, and Citroën in France. Since that moment, the world automotive industry focused mainly in producing and developing the technologies used in vehicles powered by gasoline engines with automotive manufacturers spreading all around the world and becoming one of the most important and successful industries worldwide.

It is only at the end of the Twentieth century, and especially during its last decade, that a new and renewed interest in alternative powertrains emerged, mainly as a response to climate changes and to rising levels of pollution globally. In fact, it is during these years that major automotive manufacturers started to study and develop new electric and hybrid vehicles, first only as concept cars, but, alongside, they were also studying commercial strategies to introduce them in the vehicles' market. This new interest was also caused by the rising public policies and

incentives introduced by countries in order to reduce gas emissions and to limit the pollution created by cars and by the other means of transport.

Some notable events regarding this new tendency are the launch in the European market of *Fiat Elettra* by Fiat and of *Golf CityStromer* by Volkswagen in 1989, two of the first ever "new generation" full-electric cars released in the market, however without obtaining great success; another notable, and even more important event, is the launch of *Prius* by Toyota in 1997, the first ever commercialized hybrid car.

This new impulse towards electric and hybrid vehicles has not only stimulated major automotive manufactures to develop and design new models and prototypes, but it has also encouraged new manufacturers to enter this new segment of the automotive market, one for all Tesla Motor Company that launched in the market the first ever full-electric roadster car, namely the *Tesla Roadster*.

To the present date, the automotive industry and market are again changing with always more and more alternative powered vehicles present on the world streets at the expense of gas and diesel powered vehicles, commercialized by the traditional and historic automotive manufacturers, but also by a wide range of new players (such as Tesla, Rivian Automotive, BYD, NIO).

In the next paragraph, it will be analyzed the recent trends and the perspectives of the current automotive market in order to see at which degree electric and hybrid vehicles are now widespread around the world.

1.2 THE CURRENT AUTOMOTIVE MARKET

In 2019, a total of 91.5 million motor vehicles have been sold all over the world with a total estimated value of more than $2 trillion (these data come from the ANFIA report released in 2020 about the world sales of motor vehicles[1]). This number is not so good if compared with the total sales of the previous years; in fact, in 2019, -4.5% motor vehicles were sold with respect to 2018, year in which almost 96 million vehicles had been sold.

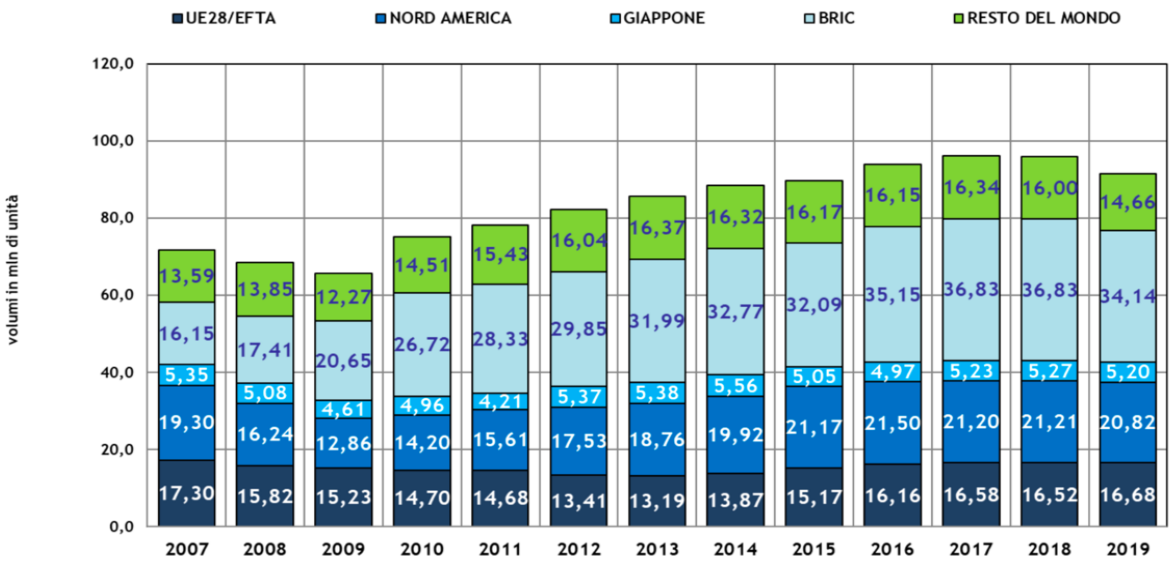
Nonetheless, if the entire decade is considered (as shown in *Figure 1.2*), it can be said that the total sales of motor vehicles passed from almost 75 million in 2010 to 96 million in 2017 (reaching its decade's peak), with a growth of 28%, which means 21 million new motor vehicles. However, then the market decreased to 95.8 million in 2018 and to 91.5 million in 2019.

The main reason of this decreasing trend can be found in the lesser amount of vehicles sold in Asia, and especially in China and India. As a matter of fact, 3.7 million (of the 4.3 million lesser vehicles sold in 2019) can be attributed to the Asian market. In particular, in China the demand for motor vehicles decreased of 8.1% with respect to 2018, and in India the demand for the same kind of good decreased of 13.3% with respect to the same year.

[1] The data found in the rest of this paragraph come from the same report too.

The reasons for the contraction of the Asian market are different and they primarily vary according to the treated country. For instance, in the Chinese case, the vehicle market was negatively influenced by a slowdown in the country's economic growth (GDP), which was positive (6.1%) but still lower than the double digit growth rates of the previous years; other than that, also the trade war with the USA and the continuous tariffs' threats had a role in decreasing the demand of vehicles. Last but not least, China introduced tough new emission standards in 2019 in order to lower its way too high level of pollutions. All these reasons created an uncertain climate both among buyers and manufacturers, thus a lower vehicles' demand. On the other hand, in the Indian case, the rising ownership cost and the country's ongoing liquidity crisis affected negatively its domestic vehicles' demand.

Figure 1.2 - World sales of motor vehicles in million units, 2007 to 2019.



Source: ANFIA (Associazione Nazionale Filiera Industria Automobilistica).

All of this is quite an interesting fact because most of the demand growth for vehicles in the last decade is due to the BRIC countries (Brazil, Russia, India, and China). Indeed, the contribute to the increased demand (16.5 million more units between 2010 and 2019) is to be attributed for the 45% to the BRIC countries, for the 51% to the West-European traditional markets, USA, Canada and Japan, and for the 4% to the rest of the world. Notably, the BRIC countries ten years ago represented the 36% of the motor vehicles world demand with 27 million motor vehicles sold, and in 2019 the 37% with 34 million, thanks especially to the growth of the biggest market of the world, China, which reached 25.7 million of new registrations in the last year; this means the 28% of the world overall.

Despite all these huge numbers regarding the world automotive market and all the new vehicles sold worldwide every year, it can be noticed that all of this did not generate a strong modernization of the vehicles circulating all around the world; as a matter of fact, some estimations show that in 2018 the average age of a vehicle was around 10.8 years, with even a higher average age in third world countries.

Regarding the composition of the motor vehicles world demand, it can be said that in 2019 the global demand of cars was around 64.27 million units (-6.4% with respect to 2018 volumes), while the demand for commercial and industrial vehicles was around 27.22 million units (+0.2% with respect to the previous year).

Furthermore, it can be noticed that in 2019 it changed also the demand for the different types of vehicles' powertrains available in the market. Indeed, it has been

registered a slowdown of 13.9% in the diesel cars sales, a growth of 5% for petrol cars and a quite huge increase of 41% for the alternative powered cars.

Alternative powered vehicles comprise exactly the ones that are the protagonists of this master thesis, namely electric and hybrid vehicles. It is precisely about these kinds of vehicles and their evolution on the world market that the attention will be focused during the rest of this chapter.

1.2.1 The alternative powered vehicles market

The alternative powered vehicles market, and especially the electric vehicles market, is relatively new, still in development, and surrounded by many uncertainties. The new available technologies deployed for translating from the traditional powered vehicles to the alternative powered vehicles are various, and automotive manufacturers are still not sure about on which one of them they should wager and put their money.

The fact that the automotive market is changing can be noticed also from the words of different managers of the world automotive companies. One example can be found in the words of the former CEO of FCA (Fiat Chrysler Automobiles), Sergio Marchionne, that before defined electric cars in an interview of 2017 as a "threat to the existence of our planet", but, after only few months, he changed his position affirming in another interview "By 2025, half of the world car production will be made of electric cars, (…), diesel and gasoline powered vehicles will give way to

electric and hybrid vehicles. Automakers have less than 10 years to adapt and reinvent themselves otherwise they will be swept away by the shift on the way of buying, driving, and building vehicles". This Marchionne's change of mind helps us to understand how crucial and revolutionary are these years for the automotive industry because they are going to mark its future, and because inevitably there are going to be winners and losers among the market players.

The fact that the world demand for alternative powered vehicles rose in 2019 is not something new.

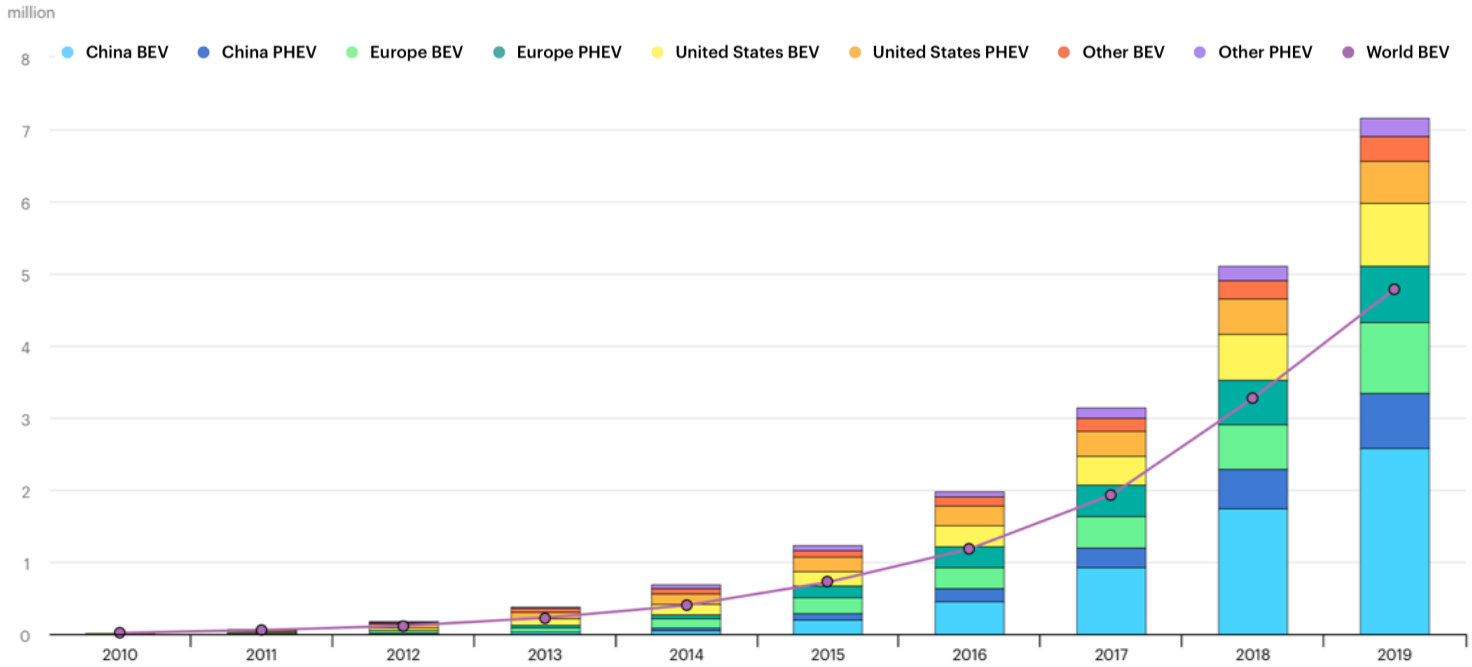
As a matter of fact, after entering the commercial markets in the first half of the decade, electric and hybrid car sales have soared. Only about 17,000 electric and hybrid cars were on the world's roads in 2010. By 2019, that number had augmented to 7.2 million, 47% of which were in China, as it can be noticed from *Figure 1.3*. Moreover, according to a report written by IEA[2] (International Energy Agency) in 2020, nine countries had each one more than 100,000 electric and hybrid cars on their roads, and in at least 20 countries, alternative powered vehicles reached market shares above 1%.

In general, it can be said that the 7.2 million electric and hybrid cars represented the 2.6% of the global car sales and about the 1% of the global car stock in 2019. If we

[2] The full report can be found at: https://www.iea.org/reports/global-ev-outlook-2020#policies-continue-to-support-electric-vehicle-deployment-and-are-evolving-to-a-more-holistic-policy-portfolio

want to consider also medium and heavy commercial electric vehicles, we need to add another 700,000 units to the global stock of electric and hybrid vehicles. The share leader is Norway where 56% of new car sales were full-electric or hybrid in 2019. Iceland came second with a share of 24.5%, and the Netherlands third with 15%. Among the larger economies, China led the ranking with an electric and hybrid vehicles share of 5.2%, UK with 3.2%, Germany with 2.9%, France with 2.8%, Canada with 2.7%. All the other countries' markets with over 1 million total sales showed 2% or less for 2019.

Figure 1.3 - Global electric and plug-in hybrid car stock, 2010 to 2019.



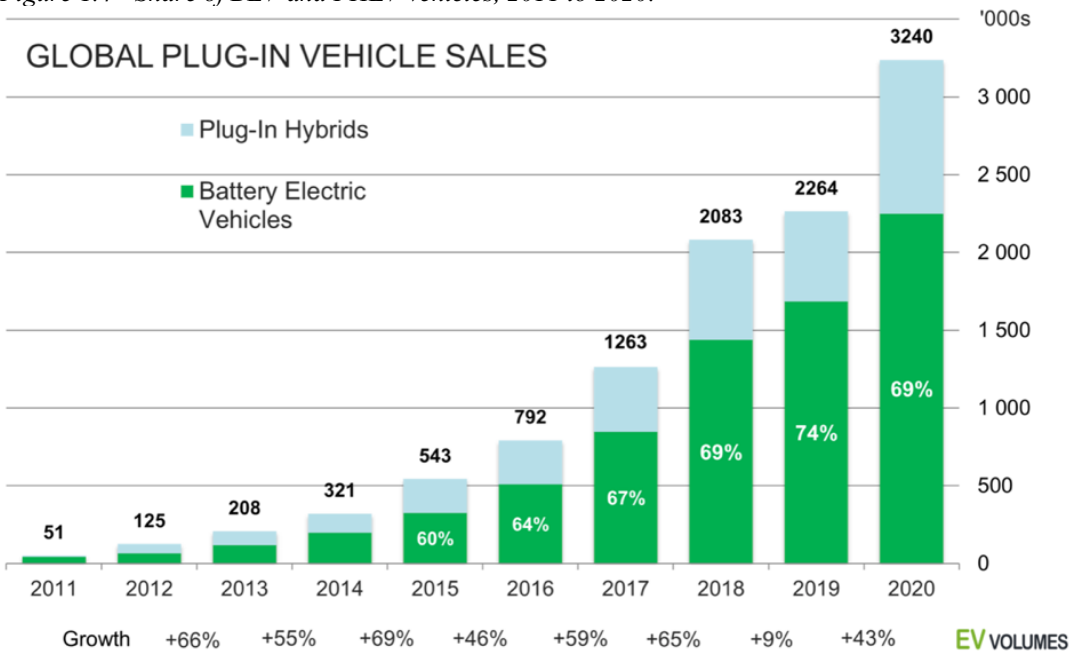
Source: IEA (International Energy Agency).

Indeed, as technological progress in the electrification of cars, buses, and trucks advances and the market for them grows, electric vehicles are expanding significantly. Moreover, ambitious policy announcements have been crucial in stimulating the alternative powered vehicles introduction in major vehicle markets in recent years. In 2019, indications of a continuing shift from direct subsidies to policy approaches, that rely more on regulatory and other structural measures (including zero emission vehicles mandates and fuel economy standards), have set clear long-term signals to the automotive industry and consumers that support the transition in an economically sustainable manner for governments.

Furthermore, up to the present date, it can be added that the majority of alternative powered vehicles, according to a report written by Irle R. (2020) for EV-Volumes, are Battery Electric Vehicles (BEVs, also known as full-electric vehicles), and only a residual part of the share is represented by the various Plug-in Electric Vehicles (PHEVs); namely their respective shares are estimated to be 74% for BEVs and 26% for PHEVs in 2019, as shown in *Figure 1.4*.

The reason of this could be due to the higher incentives reserved to BEV vehicles since they belong to the category of zero emissions vehicles, or also due to the inner characteristics of this kind of vehicles that will be analyzed later on in this master thesis.

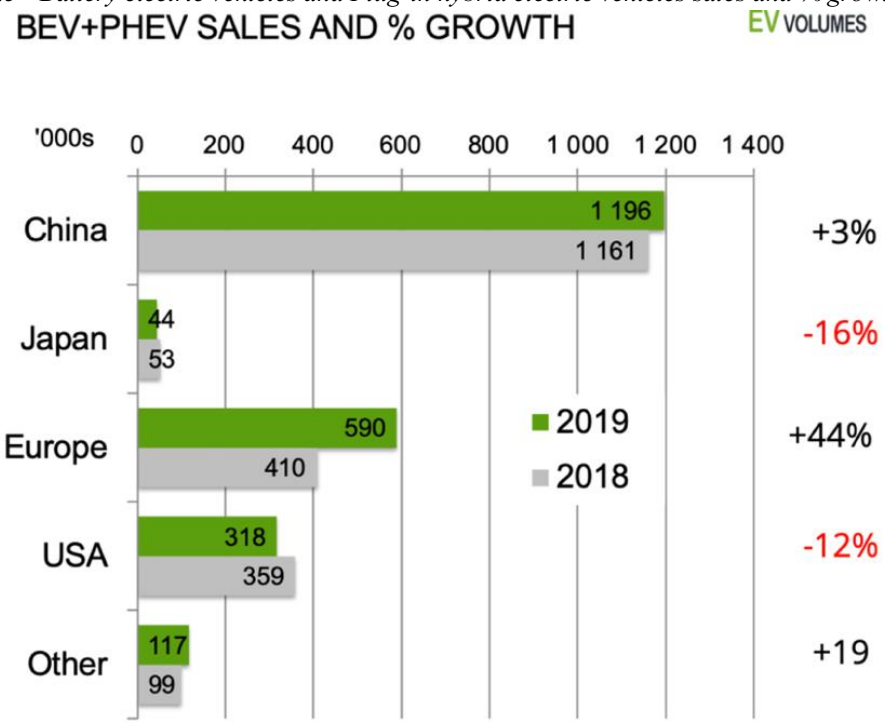
Figure 1.4 - Share of BEV and PHEV vehicles, 2011 to 2020.



Source: EV Volumes.

In particular, during 2019, 2,264,400 units of either electric or hybrid vehicles were sold globally (9% higher than 2018, and from first estimations this data will be exponentially higher in 2020, namely around +43%), corresponding to a total value of approximately $140 billion. As opposite to the previous years, Europe became the centre of 2019 electric vehicles sales with a 44% growth, even accelerating towards the end of the year, as shown in *Figure 1.5*. This result could be due also to the WLTP (*Worlwide harmonized Light vehicles Test Procedure*, a new stricter series of tests that automakers need to pass for commercializing their cars) introduction, that together with changes in national vehicle taxation and grants, created more awareness and demand for electric means of transport.

Figure 1.5 - Battery electric vehicles and Plug-in hybrid electric vehicles sales and % growth.



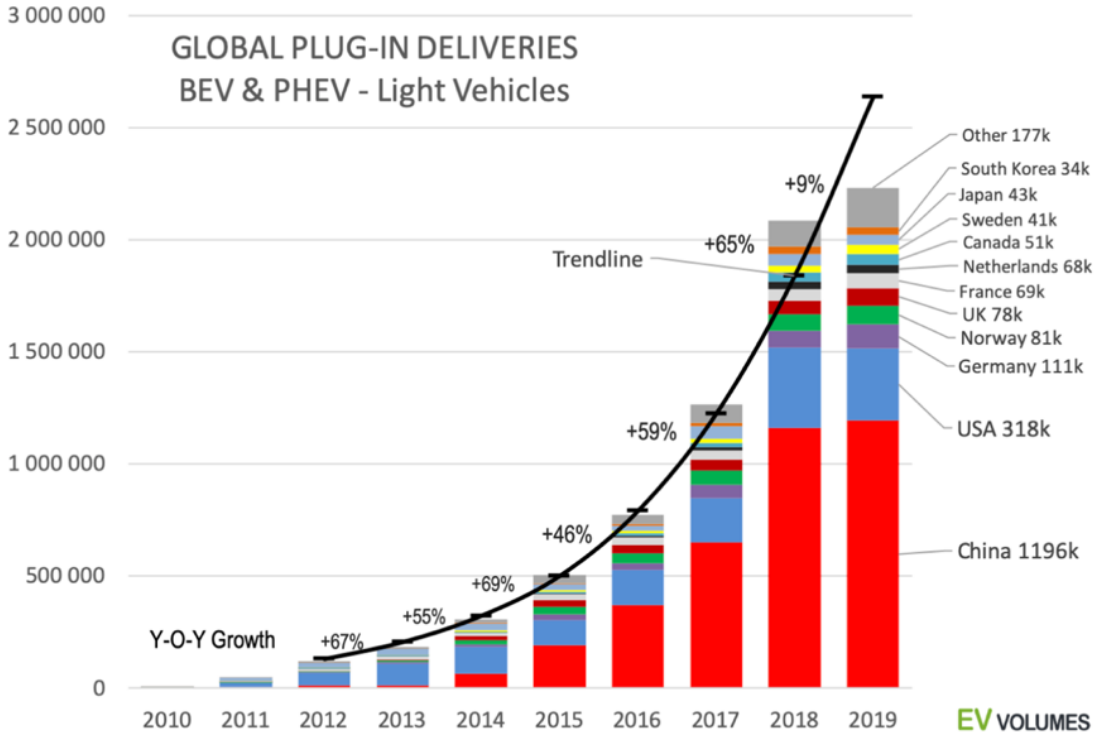
Source: EV Volumes.

However, despite all of this over half of the global volume of electric vehicles is still in China, followed by (with a quite wide gap, as it can be noticed from *Figure 1.6*) the United States of America and Germany.

The peculiar fact about the Chinese market is that this business is kept local there. As a matter of fact, according to the gathered data, only 4,700 units were exported from China to other countries, and only 56,500 units were imported to China from other foreign companies, 80% of which from Tesla. One explanation for this fact is that imported electric vehicles are burdened by import duties and in addition they do not receive national subsidies reserved to alternative powered vehicles. The only

way to sell at equal terms for foreign companies is to produce their alternative powered vehicles (including their batteries) in China. Data shows that recently foreign companies have started to practice this strategy since in 2019, 196,000 units of alternative powered vehicles were sold in China under foreign brand names, more than the double of 2018's volumes.

Figure 1.6 - Global Battery electric vehicles and Plug-in hybrid electric vehicles deliveries.



Source: EV Volumes.

1.3 CONSUMERS' ATTITUDE TOWARDS THE PROBLEM OF SUSTAINABILITY AND ALTERNATIVE POWERED VEHICLES

During the last decade, not only the behaviours and the strategies of automakers have changed to cope with the problem of climate change and of sustainable mobility, but also the attitude of the general public, and particularly of consumers, has changed in favour of a higher awareness about the topics of pollution and environment, and about the impact of their actions and choices on them.

One survey carried out by the Aarhus University (Denmark, 2015) shows that the importance of protecting and preserving the environment is essential for the majority of the interviewees: as a matter of fact, only the 4% of the respondents do not consider it important and do not care about its preservation.

In particular, among the environmental matters the one that worries most the interviewees is air pollution; indeed, the 56% of the participants gave this answer.

Furthermore, according to the responses of the interviewed, the main actions taken to cope with this problem are the deployment of ecological and sustainable alternatives.

That's exactly where the types of vehicles analyzed in this thesis enter the analysis. Indeed, they are considered as a more ecological and sustainable solution rather than internal combustion engine (ICE) powered vehicles, particularly Battery

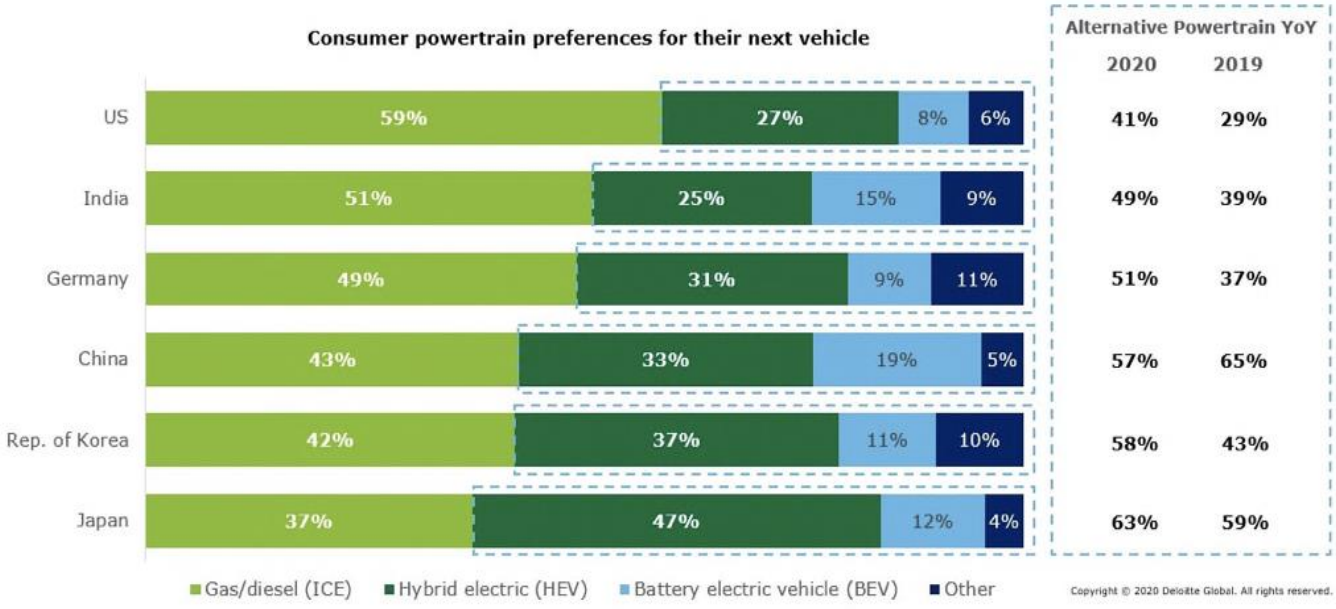
Electric Vehicles (BEVs) since they potentially could be zero emissions vehicles if powered through the usage of renewable resources.

Despite the fact that up to the present date the majority of the vehicles on the world's streets are still ICE vehicles as already showed before, a survey on more than 24,000 consumers from 23 countries carried out by Deloitte in 2020 shows us interesting results since its outcomes reveal how the attitude of consumers is changing in favour of more ecological and sustainable alternatives. Noteworthy to say is the fact that this changing attitude could be also due to the subsidies and incentives that nations give to buyers of alternative powered vehicles, and not only to the desire and willingness of people in helping to "save the planet".

In any case, the Deloitte's survey shows that a rising percentage of consumers is thinking about and is inclined towards buying an electric or a hybrid vehicle as their next vehicle.

For instance, as it can be noticed from *Figure 1.7*, in Japan the 63% of the consumers is propense in buying an alternative powered vehicle as their next one. Moreover, the country with the highest gap with respect to the previous year is the Republic of Korea, where in 2019 this percentage corresponded to 43%, and in 2020 this percentage augmented to 58%, thus resulting in 15% more consumers thinking about a more ecological solution as their next mean of transport.

Figure 1.7 - Consumer powertrain preferences for their next vehicle.



Source: Deloitte.

The only country with a decreasing trend is China since in 2019 the 63% of the surveyed consumers thought about an alternative powered vehicle, and in 2020 this percentage decreased to 57%; nonetheless, even if China showed this decreasing trend between the two considered years, the percentage remains quite high since more than half of the Chinese interviewed is inclined in buying an alternative powered vehicle rather than an ICE vehicle.

On the other hand, the ones that are still reluctant in choosing a battery electric vehicle affirmed, as it can be notice from *Figure 1.8*, that their top concerns regard the driving range of this kind of means of transport and the lack of charging

infrastructure; other concerns include safety (pretty important especially in China), the time required to charge the vehicle, and the cost/price premium.

Another reason that partly prevents consumers in choosing an alternative powered vehicle regards their expectations of further technology improvements and new models. Indeed, many consumers are reluctant in adopting a BEV or a HEV just because they think that in few years (sometimes even in just one year) new models more efficient and with better technologies will be released in the market. As a matter of fact, as improvements in technical performance and cost reductions continue rapidly, consumers are placed in the position of being attracted to a product but wondering if it would be wise to wait for the "latest and greatest model".

Noteworthy is also the fact that nowadays the lack of choice is no more a concern for consumers given the fact that the amount of electric (and also of hybrid) vehicle models to choose from is increasing year after year.

Figure 1.8 - Greatest concerns regarding all-battery powered electric vehicles.

Greatest concerns regarding all-battery-powered electric vehicles

Concern	United States	Germany	Japan	Rep. of Korea	China	India
Driving range	28%	28%	22%	11%	25%	13%
Lack of charging infrastructure	25%	22%	29%	32%	20%	26%
Cost/price premium	20%	16%	23%	17%	9%	16%
Time required to charge	13%	13%	15%	18%	13%	14%
Safety concerns	8%	12%	10%	19%	29%	25%
Lack of choice	4%	5%	1%	3%	4%	6%
Other	2%	4%	0%	0%	0%	0%

Top concern

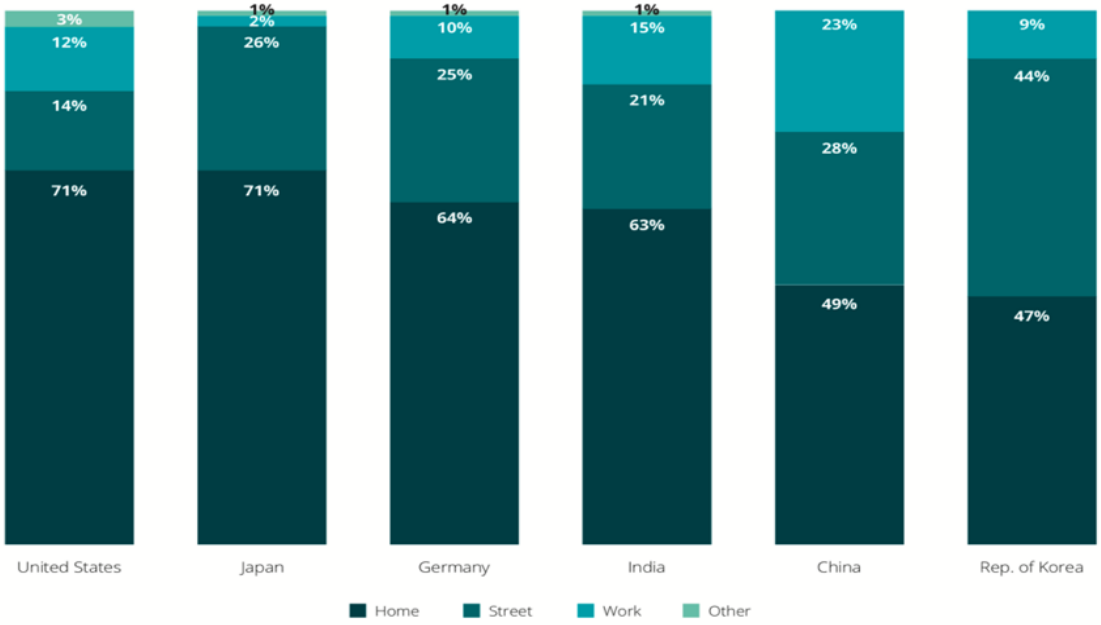
Q47: What is your greatest concern regarding all-battery-powered electric vehicles?
Sample size: Germany=779; United States=879; China=886; India=880; Japan=597; Republic of Korea=906

Source: Deloitte.

Specifically, the driving range concern is linked to "range anxiety". "Range anxiety" is defined as the fear that an electric vehicle has insufficient autonomy for reaching its destination and would thus strand the vehicle's occupants. Indeed, this one remains the top concern in mind for instance in the consumers of United States (28%) and of Germany (28%). This is quite an interesting result, if it is also considered that the average vehicle owner travels only about 27 miles per day, and the nowadays available electric vehicles released in the world markets can cover this range without any kind of problem.

Furthermore, "range anxiety" is strongly related to the other top concern of consumers, namely the lack of charging infrastructure. For this reason, enhancing the charging infrastructure would also mean reducing the fear regarding the driving range. However, the problem of who (automakers, privates, or nations) should provide charging stations is still unsolved and there is still an ongoing debate among the different counterparts involved, but what is interesting to show right now is that the majority of the respondent consumers intending to acquire an alternative powered vehicle expect to charge it most often at home as it can be noticed from the figure below (*Figure 1.9*).

Figure 1.9 - Location people expect to charge their electrified vehicle most often.



Q45: Where do you expect to charge your electrified vehicle most often?
Sample size: Germany=246; United States=185; China=352; India=244; Japan=314; Republic of Korea=411

Source: Deloitte

CHAPTER TWO:

CURRENT TYPES OF ELECTRIC VEHICLES IN THE WORLD AUTOMOTIVE MARKET

Up to this point, we have observed how electric vehicles have roots back in the past and how the current automotive market and industry are changing because of the emergence of this and other kinds of alternative powered vehicles. As a matter of fact, many different types of alternative powered vehicles have been mentioned without giving a proper description of them and on what they differ from each other. This is exactly the aim of this chapter. In particular, it will be described the Hybrid Electric Vehicles (HEVs), with a deeper focus on Plug-in Hybrid Electric Vehicles (PHEVs), and the Battery Electric Vehicles (BEVs) since they are, as mentioned before, the most widespread and popular options among the alternative powered vehicles.

2.1 HYBRID ELECTRIC VEHICLES - HEVs

Hybrid Electric Vehicles (HEVs) combine an electric powertrain together with a small to medium size Internal Combustion Engine (ICE), in this way merging the benefits of an elevated fuel economy and low emissions with the power and the autonomy of conventional powered vehicles.

At the moment of writing, there is a wide variety of hybrid vehicles produced and commercialized by the major automotive manufacturers of the world, such as Toyota, BMW, Ford, Volkswagen, Fiat, or Mitsubishi.

Despite the fact that most of the times HEVs are more expensive than internal combustion engine powered vehicles, part of their cost can be regained through government incentives and through the money saved from spending less on fuel.

Regarding their functioning, as said before, they are powered by a gasoline engine combined with an electric motor that uses the energy stored in the vehicle's batteries, so that the extra power provided by the electric motor can potentially allow for a smaller engine. Moreover, the battery can also power auxiliary loads and reduce engine idling when stopped. Together, these features result in better fuel economy without sacrificing performance. The particularity and the difference of conventional HEVs with respect to Plug-in Hybrid Electric Vehicles (PHEV) is that in this case the batteries are charged only through regenerative braking and by the internal combustion engine.

As a matter of fact, the regenerative braking system is one of the most advanced technologies that HEVs possess. Thanks to this system, the vehicle captures the energy normally lost during braking by using the electric motor as a generator and storing the captured energy in the battery. In this way, HEVs don't need to be plugged-in to be recharged, and they are also less inefficient since this is also a method to increase the driving range that this kind of vehicles can be capable of.

Other advanced technologies that hybrids use are the electric motor drive/assist and the automatic stop/shutoff (also known as start-stop system). In the former, the electric motor provides power to assist the engine in accelerating, passing, or hill climbing. All of this allows a smaller, more efficient engine to be used. Furthermore, in some hybrids, the electric motor alone provides the power needed for low-speed driving conditions, situation in which internal combustion engines are less efficient.

On the other hand, the latter automatically shuts off the engine when the vehicle comes to a stop or to a red traffic light, and then restarts it when the accelerator is pressed. This system prevents wasting energy from idling.

One first classification of hybrid electric vehicles is the one that refers to the degree of hybridization of these vehicles; specifically, there are three categories of HEVs:

1. *Micro hybrids*: in this kind of vehicles the functions performed by the electric components are essentially limited to providing the necessary power supply to the vehicle's electrical devices (such as the headlights or the dashboard lights), to the automatic stop/shutoff, and to recover some energy when braking;
2. *Mild hybrids*: in this kind of vehicles the electric components are able to do the work carried out by the category above, plus they can also provide power to the engine, thus helping the vehicle while it moves;

3. *Full hybrids*: this kind of vehicles have larger batteries and more powerful electric motors which can power the vehicle for short distances and at low speeds.

   Furthermore, these vehicles have enough electric power for vehicle's standing starts. Due to all these peculiarities, full hybrids can be driven using only the electric motor, thus becoming also zero emissions vehicles (ZEVs) since no exhaust gas are emitted while in the electric mode.

Noteworthy to say is also the fact that Micro and Mild hybrids are unable to power the vehicle using electricity alone, so that they primarily achieve a supporting role to the internal combustion engine. That's why generally these vehicles cost less than full hybrids and at the same time they provide less fuel economy benefits than the other. On the contrary, full hybrids are more expensive but they can guarantee better fuel economy benefits thanks to their possibility of being powered only by the electric motor.

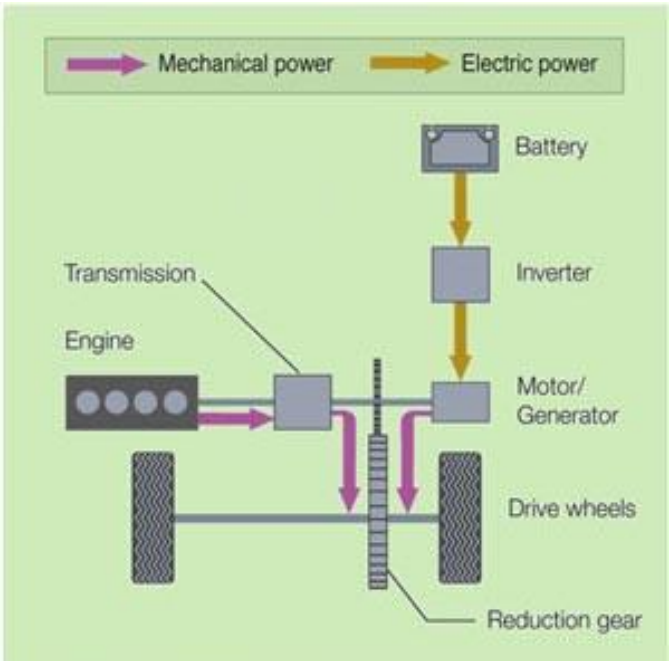
Moreover, full hybrid vehicles themselves can be subdivided in three other categories depending on the configuration of the HEV:

1. *Parallel hybrids*: this kind of configuration allows both the electric motor and the internal combustion engine to deliver power in parallel to drive the vehicle. This means that the electric motor and the ICE can drive, respectively, or together. All of this because the parallel hybrids connect the engine and the electric motor to the wheels through mechanical coupling,

so that both kind of powertrains can drive the wheels directly, as the functioning summary scheme in *Figure 2.1* shows.

Noteworthy to say is the fact this is the most common HEV design;

Figure 2.1 - Parallel hybrid configuration.

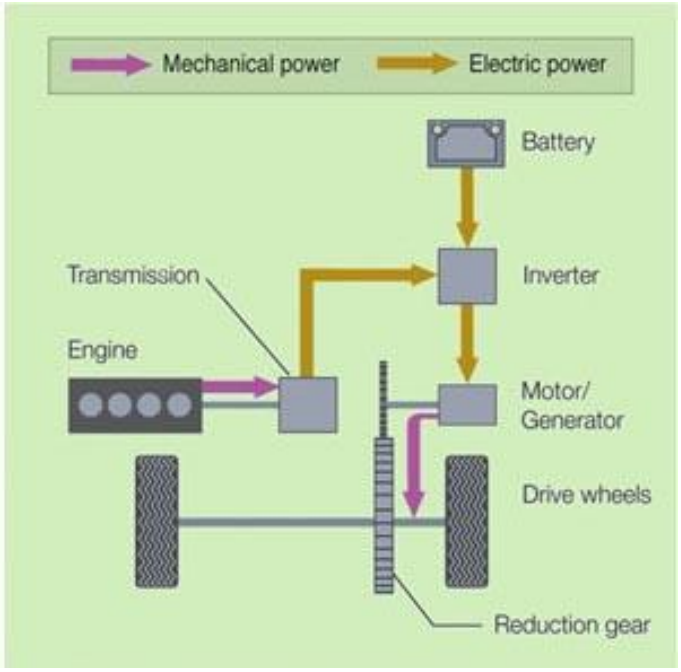


Source: Centre for Advanced Automotive Technology (CAAT).

2. *Series hybrids*: in this kind of configuration the internal combustion engine drives an electric generator instead of directly driving the wheels. In this way, the internal combustion engine only generates electricity to be used by the electric motor, so that eventually only this motor drives the wheels; thus, the only function of the gasoline engine is recharging the battery as shown in the summary scheme in *Figure 2.2*.

Worth mentioning is the fact that this kind of configuration is especially common in Plug-in Hybrid Electric Vehicles, a particular kind of HEV that will be properly introduced later on;

Figure 2.2 - Series hybrid configuration.



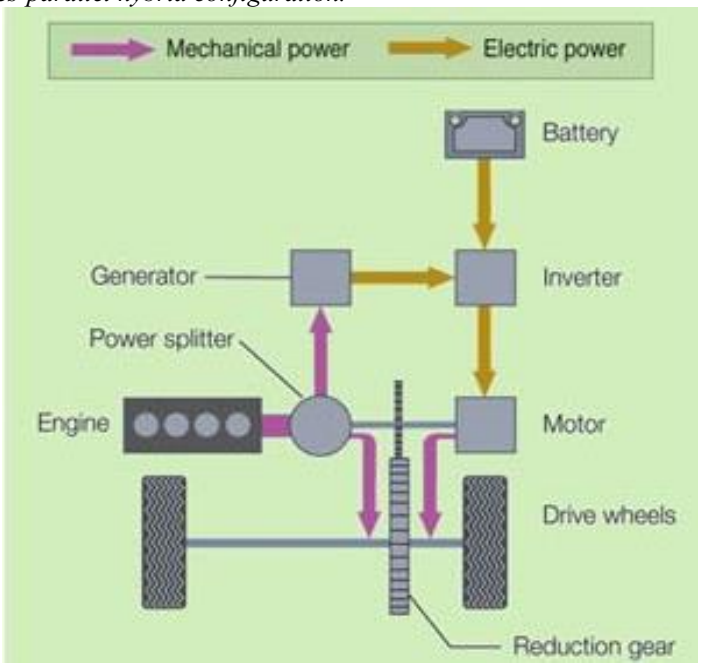
Source: Centre for Advanced Automotive Technology (CAAT).

3. *Combination HEV* (also known as series-parallel): in this particular configuration, the HEV incorporates the features of both series and parallel HEVs. In this way, vehicles can be powered by the gasoline engine working alone, the electric motor itself, or by both energy converters working together, as shown in the summary scheme in *Figure 2.3*. The power distribution between the internal combustion engine and the electric motor

is designed so that the engine can run in its optimum operating range as much as possible.

Of course, this kind of configuration is the most complex one because of its structure. Thus, its complexity leads to more costly manufacturing technologies, and so to higher prices for consumers. Nevertheless, this configuration is the most flexible in control, and that's why some automakers (such as Toyota) prefer to adopt it in their vehicles rather than choosing the others.

Figure 2.3 - Series-parallel hybrid configuration.



Source: Centre for Advanced Automotive Technology (CAAT).

2.1.1 Plug-in Hybrid Electric Vehicles - PHEVs

It will now be introduced another kind of hybrid electric vehicle, namely the Plug-in Hybrid Electric Vehicle (PHEV).

Plug-in hybrid electric vehicles use batteries to power an electric motor, as well as another fuel, such as gasoline or diesel, to power an internal combustion engine or another propulsion source. The peculiarity here is that PHEVs can charge their batteries through charging equipment and regenerative braking. With charging equipment, it is meant that PHEVs also have an inlet socket allowing them to be charged directly from an external electricity supply.

Using electricity from the outside grid to run the vehicle, most of the times reduces operating costs and fuel use, enhancing in this way the fuel economy relative to conventional vehicles. PHEVs may also produce lower levels of emissions, depending on the electricity source and on how often the vehicle is operated in full-electric mode.

As already written before, PHEVs have an internal combustion engine and an electric motor, which uses energy stored in batteries. PHEVs generally have larger battery packs than non plug-in hybrid electric vehicles. This makes it possible for PHEVs to drive moderate distances using just electricity (currently about 15 to 60-plus miles depending on the different models), commonly referred to as the "electric range" of the vehicle.

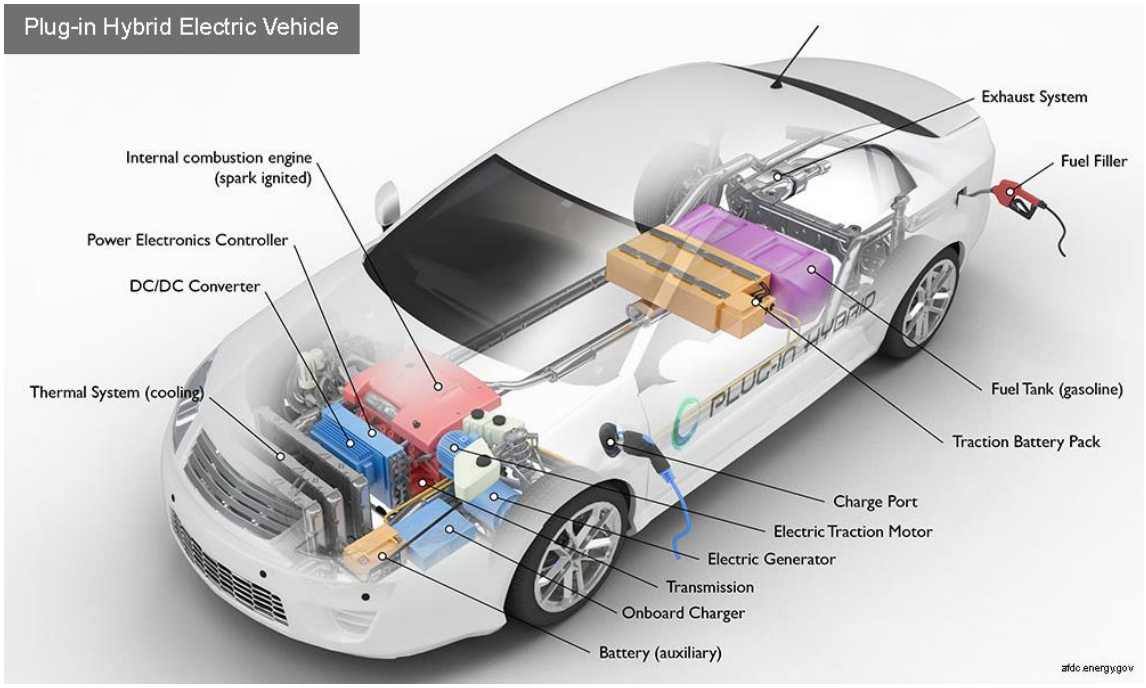
Having an electric motor that can be plugged-in and recharged reduces the distance between PHEVs and Battery Electric Vehicles (BEVs), since their only difference is that PHEVs still have an ICE, thing that BEVs do not have.

During urban driving, most of the PHEVs' power can come from stored electricity. For instance, a PHEV driver might drive to and from work on full-electric mode, plug in the vehicle to charge it at night, and be ready for another full-electric journey the next day. The internal combustion engine powers the vehicle when the battery is mostly depleted, during rapid acceleration, or when intensive heating or air conditioning loads are present.

PHEVs' batteries can be either charged by an external electric power source (such as from your home, office, or public charging station), by the internal combustion engine, or through regenerative braking. When braking, the electric motor acts as a generator, using the energy to charge the battery, thereby recapturing energy that would have been lost.

It is possible to observe the disposition of all the elements that commonly compose a plug-in hybrid vehicle in *Figure 2.4* which shows the typical structure of this kind of vehicles that usually have both the internal combustion engine and the electric motor on the front, whereas the fuel tank and the battery pack needed to power the electric motor are usually located on the back. This figure could also help the reader to better understand and appreciate the complexity of these vehicles.

Figure 2.4 - Plug-in Hybrid Electric Vehicle model.



Source: Alternative Fuels Data Centre (AFDC).

Worth mentioning is the fact that PHEV fuel consumption depends on the distance driven between battery charges. For example, if the vehicle is never plugged in to charge, fuel economy will be about the same as a similarly sized hybrid electric vehicle. On the other hand, if the vehicle is driven for a shorter distance than its electric range capability, and plugged in to charge between trips, it may be possible to use only the electric power. Therefore, consistently charging the vehicle is the best way to maximize the electric benefits.

Although PHEVs are generally more expensive than similar conventional and hybrid vehicles, some of their cost can be recovered through fuel savings, tax credits, or state incentives, as illustrated in the next subparagraph.

2.1.2 An insight on hybrid electric vehicles prices

Eventually, after having described the different types and the inner characteristics of HEVs (and PHEVs), it will be presented a final outlook regarding their price. Among the alternative powered vehicles, the average price of the hybrid ones is the closest to the one of conventional internal combustion engine vehicles. That is obviously due to the fact that they are also more similar to ICEVs regarding their characteristics with respect to BEVs.

Another noteworthy observation is that their prices primarily depend on the degree of hybridization, namely PHEVs are in general more expensive than conventional HEVs, and, among the latter, full hybrids are more costly than mild and micro hybrids. Other than that, other factors which influence the final price of these vehicles are for instance the size of the chosen vehicle model, its performance, the car manufacturer (thus the brand), and all the accessories and optional that the vehicle comes equipped with.

After having done these premises, it can be said after having looked on various websites (of different automakers and of auto experts) that the average price range of HEVs goes from around €18,000 for the simplest models, such as the *Hyundai*

Kona or the *Toyota Yaris*, to around €150,000 for the most complex and luxurious models, such as the *Acura NSX* or the *Lexus LS*.

However, despite the nominal price, what is really interesting is that the selling prices for most hybrid vehicles are around 20% higher than their non-hybrid petrol and diesel equivalents (according to a research carried out by Nextgreencar[3], 2017). An example of this is represented by the hybrid *Hyundai Sonata*. The nominal price for the conventional model is $22,050, whereas the same vehicle in the hybrid version costs $26,000, clearly illustrating the price discrepancy. This price discrepancy is mostly attributed to the fact that hybrid vehicles cost more to build since also the battery has to be installed in these vehicles, so that this additional cost is passed on from the manufacturer to the buyer.

On the other hand, as already written before, part of this higher cost will be regained through fuel economy benefits that some estimations assess to be around €600 each year (of course this estimation cannot be 100% accurate due to the many factors that influence it, such as the driven distance, the driving modes, the gas cost volatility, …), and through other incentives (such as tax incentives) and advantages that vary according to the different countries granting them and to the different manufacturers. However, most of the incentives granted by countries are reserved

[3] The full article can be found at: https://www.nextgreencar.com/hybrid-cars/buying-guide/

only to PHEVs, and, only in some exceptions, incentives are assigned also to conventional HEVs.

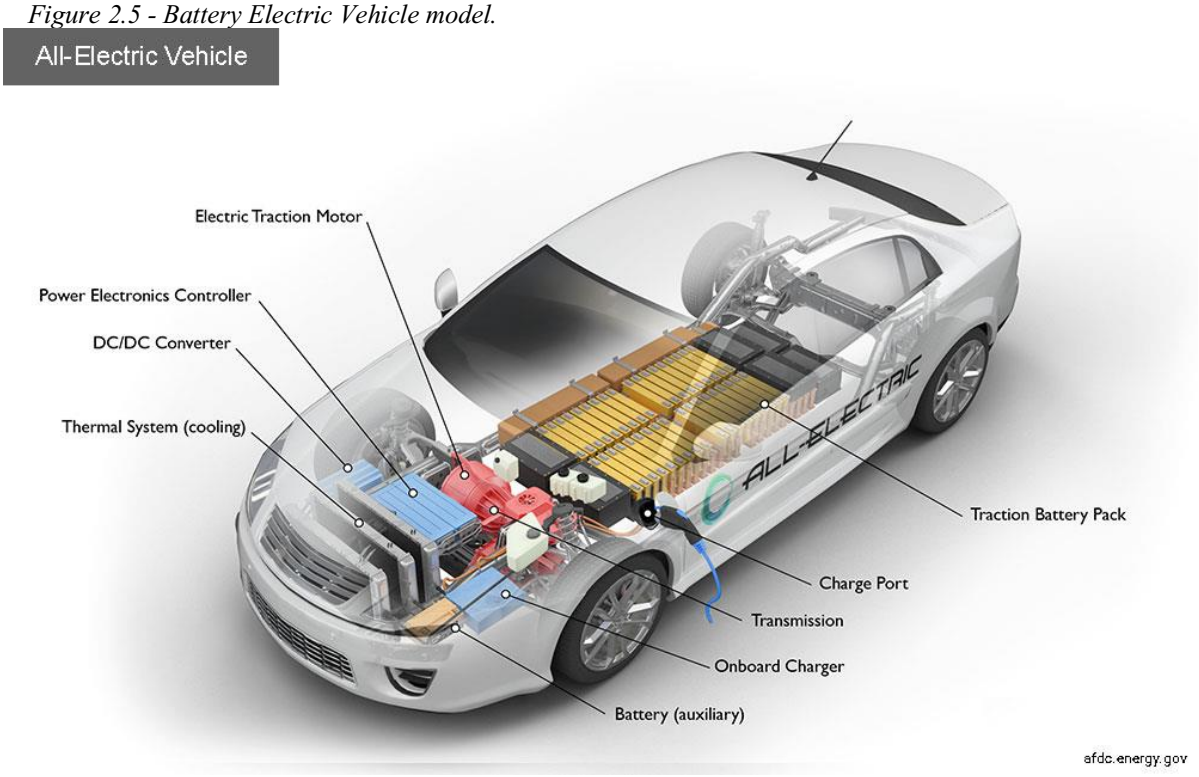
Last but not least, noteworthy to mention is the fact that, during the last few years, the prices of hybrids are going down as more of them are being produced and sold in the world market.

2.2 BATTERY ELECTRIC VEHICLES - BEVs

Battery Electric Vehicles (BEVs) (also referred to as All-Electric Vehicles or "EVs") are full-electric vehicles with rechargeable batteries and without an internal combustion engine. Battery electric vehicles store electricity onboard with high-capacity battery packs. Their battery power is used to run the electric motor and all the onboard electronic components. Due to the fact that the batteries alone have to carry out all the tasks needed to run a vehicle, BEVs are equipped with big battery packs (bigger than the ones present in hybrid vehicles), as it can be noticed in *Figure 2.5* where all the main components composing a BEV are displayed.

Moreover, BEVs use the same advanced technologies employed by their hybrid counterparts in order to maximize the efficiency of the electric motor, namely the regenerative braking system and the stop/shutoff system.

Figure 2.5 - Battery Electric Vehicle model.



Source: Alternative Fuels Data Centre (AFDC).

In addition, BEVs do not emit any harmful emission and hazard caused by traditional gasoline or diesel powered vehicles thanks to the absence of conventional engines. BEVs are charged by the electricity coming from an external source and by the regenerative braking.

Electric vehicle chargers are classified according to the speed with which they recharge an EV battery. The classifications are three, namely level 1, level 2, and level 3 (also called “DC fast charging”):

1. *Level 1* EV charging uses a standard household (120v) outlet to plug in to the electric vehicle and it takes over 8 hours to charge an electric vehicle for approximately 75-80 miles. Level 1 charging is typically done at home or at the workplace. Worth mentioning is the fact that this type of chargers has the capability of charging most EVs on the market;
2. *Level 2* charging requires a specialized station which provides power at 240v. This kind of chargers are typically found at workplaces and at public charging stations and it takes approximately about 4 hours to charge a battery that can cover a range of 75-80 miles;
3. *Level 3* charging (or "DC fast charging") is currently the fastest charging solution in the electric vehicles market. DC fast chargers are found at dedicated EV charging stations and they are able to charge a battery that can cover up to 90 miles range in approximately 30 minutes.

Although electricity production may still contribute to air pollution, usually BEVs are categorized as zero emissions vehicles by countries' public institutions because they do not produce directly exhaust or tailpipe emissions.

As a matter of fact, one peculiarity of BEVs is the total absence of the exhaust pipe and of transmission and gears determined by the fact that there is only the electric motor that does not need this kind of components.

Today's electric vehicles generally have a shorter range (per charge) than comparable conventional vehicles have (per tank of gas). However, the increasing

range of new models and the continuing development of high-powered charging equipment is reducing this gap. Indeed, up to the present day, there are BEV models that are said to have an autonomy of around 400 kilometers by their automakers, such as Tesla that affirms that its *Tesla Model S 90D* has a drive range of 346 miles (corresponding approximately to 550 kilometers) thanks to its 90 kWh battery capacity.

Despite all of this, the efficiency and the driving range of full-electric vehicles vary substantially based on the driving conditions. Just as an instance, extreme outside temperatures tend to reduce the range, because more energy must be used to heat or cool the vehicle. Besides, BEVs are more efficient under city driving than highway travel; indeed, city driving conditions have more frequent stops, which maximize the benefits of regenerative braking, whereas highway travel typically requires more energy to overcome the increased drag at higher speeds. In addition, compared with gradual acceleration, rapid acceleration reduces the vehicle range. Moreover, hauling heavy loads or carrying many passengers also have the potential of reducing the range. Eventually, also strong headwinds or driving uphill tend to reduce the driving range of BEVs.

Again, also for BEVs is true the fact that they are typically more expensive than similar conventional and hybrid vehicles, despite the fact that some of their cost can be recovered through fuel savings, tax credits, or state incentives, as it will be clearly illustrated in the next subparagraph.

2.2.1 An insight on battery electric vehicles prices

The last topic of this chapter will be an insight on battery electric vehicles selling prices. As a matter of fact, after having described how this particular technology works and its potentialities, it is right also to give a look on how much it costs to buy one of these vehicles that do not use any kind of combustion engine, but they just rely on the power of their electric motors.

The first thing worth mentioning is that it is difficult to do direct comparisons with other types of vehicles, such as ICEVs and HEVs, because most of the BEV models commercialized by the various automakers do not have a conventional or hybrid counterpart. However, as also expressed by many market researches, such as the ones carried out by the NRDC (National Resources Defense Council) in 2020 or by JATO in 2019, on average battery electric vehicles are more expensive than both internal combustion engine vehicles and hybrid electric vehicles. Indeed, according to the NRDC research, the average nominal price of an electric vehicle is $19,000 higher than the price of an ICE vehicle.

As a matter of fact, it is not difficult to find out through an internet research that the price range of BEVs goes from around €20,000, such as for the *Volkswagen Up*, to around €190,000, such as for the *Porsche Taycan Turbo S*.

Again, as for the hybrid case, even among the battery electric vehicles the price is influenced by many factors. In this case the major component which contributes in raising the price of this kind of vehicles is the battery pack. Indeed, the additional

cost of buying an electric vehicle instead of a conventional one primarily comes from the battery which alone can make a difference of several thousand euros. The main reasons of this are found in the raw materials used in the battery as well as in the expensive processes involved in batteries production. Moreover, having a good battery pack equipped in these vehicles is crucial for guaranteeing longevity and performances that could compete with the ones of conventional vehicles. Indeed, the electric vehicles that have a lower autonomy and that need more time to be charged usually are also the ones that cost less.

In addition, other factors that influence the selling prices of battery electric vehicles are again the accessories and optional equipped in the vehicle, the brand of the automaker which designs the auto, the size and type of the vehicle, and other characteristics directly related to the peculiarities that each model possesses.

However, despite their higher prices, BEVs are also the ones that enjoy the highest number of incentives and advantages because of the fact that they are currently considered the cleanest type of vehicles since they do not emit any kind of exhaust gas, thus being zero emission vehicles as already stated above. As a matter of fact, many countries reserve different kind of incentives to the buyers of BEVs; just as an instance, BEVs buyers in the United States could get a tax incentive of up to $7,500.

Nonetheless, even considering all the incentives and other benefits reserved to BEVs, currently their selling prices are on average always higher than their comparable[4] counterparts, namely HEVs, PHEVs, and ICEVs.

On the other hand, battery electric vehicles owners enjoy some advantages in term of money savings even after the purchase of the vehicle. As a matter of fact, they experience fuel economy benefits since they do not have to spend any money on petrol or diesel, but they just have to spend some money on the electricity needed to recharge the vehicle, and electricity is cheaper than the other two fuels (petrol and diesel) in the majority of world's countries. Just as an example, according to the U.S. Department of Energy, the cost of fueling a BEV is about half the cost of fueling an ICEV, with an electric "e-gallon" costing $1.24 and a gallon of gas costing $2.64 on average.

Other than that, another advantage which BEVs owners enjoy is the lower maintenance costs that electric vehicles have with respect to the other kind of vehicles. Indeed, BEVs have fewer fluids to keep topped up, such as oil, fewer moving parts, such as spark plugs, and timing belts that need to be regularly replaced in an internal combustion engine vehicle. Even if the precise savings are hard to pin down, New York City has reported huge differences in numbers for its city fleet; in fact, in 2019, the city spent between $204 and $386 maintaining each

[4] With comparable, it is meant to compare two vehicles of the same size, with same accessories and optional, same performance, and so on.

of its electric vehicles, compared to more than $1,600 for the average gasoline powered vehicle.

In conclusion, after having taken into account all these aspects, it can be said that currently is difficult to affirm if it is really worthy to buy a BEV with respect to the other types of vehicles even because the choice depends to a large extent also on the driving habits and on the needs of the buyer. However, the convenience to buy a BEV rather than other vehicles will fully materialize only in the next years as the cost of batteries (and so also of vehicles themselves) decreases.

2.3 SUMMARY OF THE MAIN FINDINGS

This chapter will now end with a final comparison of the main characteristics of the alternative powered vehicles presented and analysed during the course of this chapter, namely of Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Battery Electric Vehicles (BEVs). This final comparison will help the reader in having an overview on where this thesis has arrived so far before continuing with the next chapter dealing with the assessment of the environmental impact of these vehicles.

Table 2.1 - Overview comparison of alternative powered vehicles.

	HEVs	**PHEVs**	**BEVs**
Type of powertrain	They come equipped both with an electric motor and a conventional engine.	They come equipped both with an electric motor and a conventional engine.	They come equipped only with an electric motor.
Functions of the electric motor	It mainly powers the electric devices and assists the conventional engine in moving the vehicle; in the most advanced models (the so-called full-hybrids), it can also emanate enough power to run the vehicle at low speeds and for short distances.	Thanks to the bigger battery pack, it can power the vehicle for moderate distances (between 15-60 miles depending on the model), other than powering the electric devices of the vehicle.	Here the electric motor has to carry out all the tasks needed to run a vehicle, from powering the electronic components to emanating enough electricity to run the vehicle at any speed and at any distance that the driver has to cover.
How to recharge the batteries	Batteries are charged only through the regenerative braking system and by the internal combustion engine.	Batteries are charged through regenerative braking, by the conventional engine, and also by an external source of electricity thanks to the socket that these vehicles have.	Batteries are charged by the electricity coming from an external source and by the regenerative braking.

Price	Their price range goes from €18,000 to €150,000 depending on the different models; on average their price is 20% higher than their conventional counterparts. Eventually, the higher the degree of hybridization, the higher the price (on average).	Their price range goes from €20,000 to €190,000 depending on the model. They have higher prices with respect to hybrid and conventional vehicles, but they also enjoy higher incentives and tax credits.

CHAPTER THREE:

THE ENVIRONMENTAL IMPACT OF ALTERNATIVE POWERED VEHICLES

Up to this point it has been analysed the functioning of Battery Electric Vehicles (BEVs) and of the different types of Hybrid Electric Vehicles (PHEVs and HEVs). Moreover, it has been assumed that these kinds of vehicles are less polluting and harmful towards the environment because they are powered, partly or fully, by an electric motor which does not produce any kind of emission during its deployment. For this reason, they are considered as a viable solution for reaching sustainable mobility and for fighting climate change, thanks to the reduction of the greenhouse gasses (GHG), and especially of CO2, emitted by these vehicles.

However, is all of this actually true? Are alternative powered vehicles really more sustainable than their conventional counterparts?

That is exactly the topic that will be tackled in the rest of this chapter of this master thesis.

3.1 LIFE CYCLE ASSESSMENT (LCA) ANALYSIS

In order to answer to the questions previously posed, it is necessary to introduce and to perform the Life Cycle Assessment (LCA) analysis for alternative powered

vehicles. As a matter of fact, LCA is currently recognised as the best existing technique for answering to questions that are related with the environment and with its sustainability.

Indeed, the life cycle assessment is a methodology, commonly used for the environmental assessment of any good or service, and thus also of vehicles and of their employed technologies. This is due to the fact that LCA studies consider all the environmentally significant processes throughout the life cycle of vehicles, from raw material extraction, production of components, assembly, transport, vehicle use to the end of life treatment (see also *Figure 3.1*). Moreover, since all the life stages are covered from the so-called "cradle to grave" perspective, LCA prevents problem shifting with other products or services.

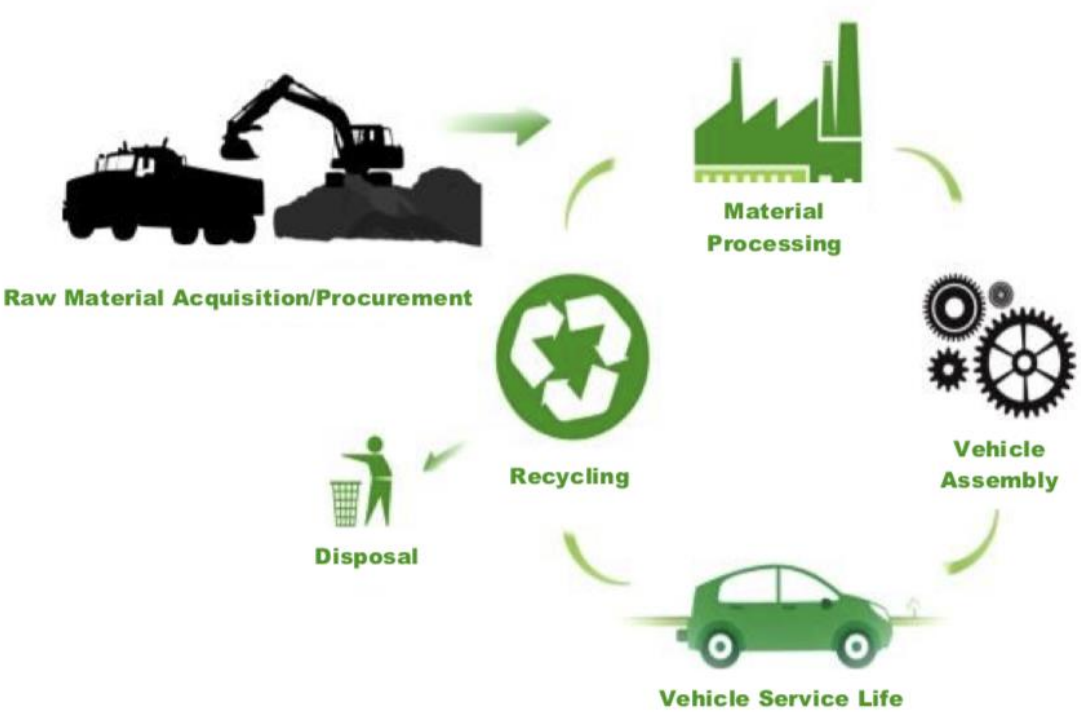
The functioning of LCA studies consists in gathering data for inflows and outflows of each stage of the product. Then, by linking processes within the system from cradle to grave, a model is made on how the flows are connected and on how they influence each other. This results in an inventory of inflows to the system in terms of natural resources and outflows in terms of emissions to the surrounding natural environment. The inventory is then analyzed to indicate the potential for environmental impacts in various categories of interest of the study such as global warming, human toxicity, and terrestrial acidification.

Thanks to all of this, it can then be computed the trade-off between the benefits and the drawbacks of a good or service in order to decide if it is worth to produce them

or not. Furthermore, it can be found also the so-called “hot spots” that are the aspects of a good or service which need some modifications or adaptations in order to have a lower environmental impact.

In any case, LCAs are a good tool because they can help different stakeholders to assess different policy options, to compare technologies or understand trends and emission hotspots.

Figure 3.1 - Vehicles life cycle assessment scheme.



Source: EPA (USA Environmental Protection Agency).

3.2 LCA OF ALTERNATIVE POWERED VEHICLES

Especially during the last decade, many life cycle assessments regarding alternative powered vehicles (especially for BEVs) have been performed by many researchers and institutions in order to evaluate the real environmental impact of this kind of vehicles and to compare it with the environmental impact of internal combustion engine vehicles. This kind of comparisons has been performed for eventually determining which powertrain has the least possible impact on the environment.

The different results published by the researchers have been topic of controversies among them because many times their results differed. The fact that results did not correspond among them could be due to many different reasons related to the way in which each LCA was carried out. As a matter of fact, researchers could have used: different methods for gathering data, variations in their systems boundaries, differences in the assumed electricity mixes used for measuring data, different assumptions of the inventory of the components that constitute the so-called "glider" (all the vehicle's parts excluding those that compose the powertrain), or different lifetimes of the vehicles. Just as an instance, choosing a shorter lifetime for a vehicle, such as 150,000 km instead of 200,000 km, increases the relative importance of the vehicle production stage. Finally, also choosing the lifetime of the battery is of key importance in determining the results of an alternative powered vehicle life cycle assessment.

Another noteworthy thing that should be considered when comparing different studies is the time in which they were carried out. In fact, since the technology used in electric vehicles is quite new and it is in continue development year after year, data regarding these vehicles could differ in studies carried out in different years because their technology could have simply changed and improved over time.

Despite all these premises, LCA studies carried out on alternative powered vehicles are still very useful and relevant in order to evaluate this kind of vehicles because, in any case, some general truths regarding these vehicles can be extracted from the different LCAs, and so they should be taken into account in the analysis.

As a matter of fact, since it is impossible for myself to carry out my personal life cycle assessment on these vehicles, during the rest of the chapter it will be tried to review and exhibit the main results and conclusions of other more renowned researchers that carried out LCAs of our interest.

In particular, the analysis will be focused on the impact of battery electric vehicles and hybrid electric vehicles on three different categories of interest, namely on climate change, resources depletion, and human toxicity.

Noteworthy to mention is the fact that hybrid electric vehicles will be taken into account only at the end of the analysis of each category, since the literature concerning these vehicles is quite limited due to the fact that they are considered as a middle ground between internal combustion engine vehicles and battery electric vehicles.

3.2.1 Climate change

Perhaps, the climate change impact is the most important category to analyse since this is the one category that is directly related to the impact that alternative powered vehicles have on the changes of the world climate and on the emissions of greenhouse gasses in the atmosphere.

In particular, this category is measured through the Global Warming Potential (GWP) indicator; this indicator characterises and calculates the impact of greenhouse gases based on the extent to which they enhance radiative forcing. GWP values for specific gases (developed by the Intergovernmental Panel on Climate Change, IPCC) express the cumulative radiative forcing over a given time period (usually 100 years) following a pulse emission in terms of the quantity of carbon dioxide (CO2) giving the same effect. Therefore, eventually, the GWP value is expressed through the unit of measure gCO2e/km (grams of CO2 equivalent per km).

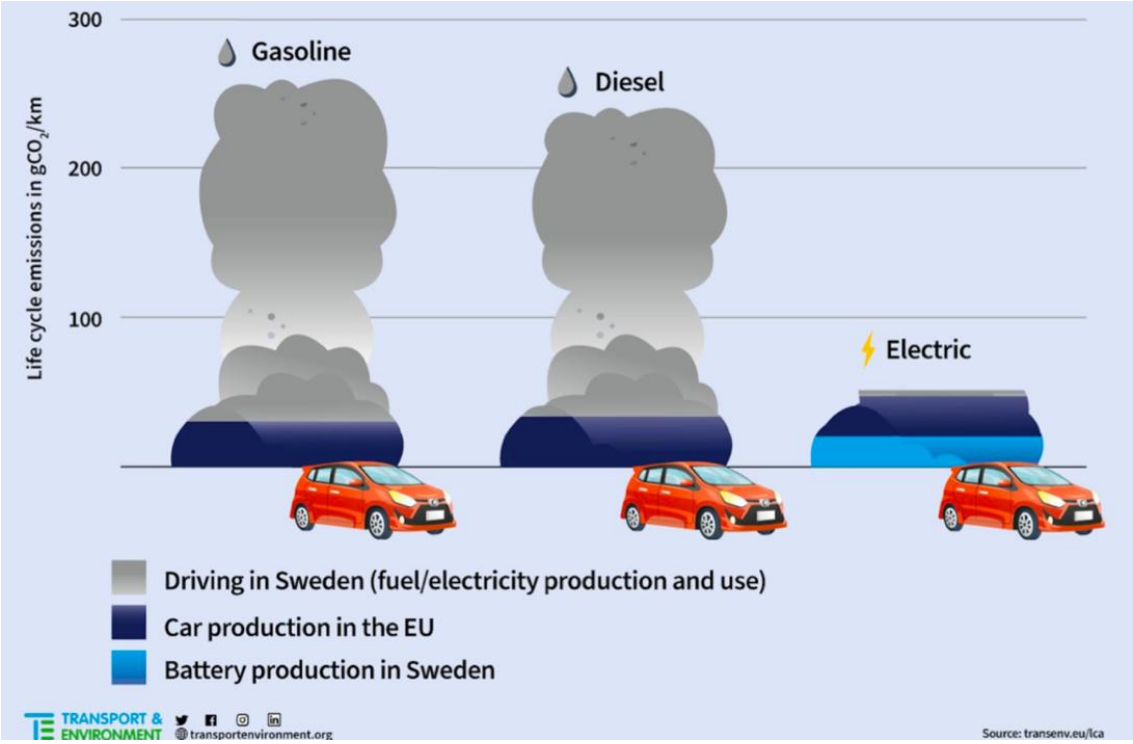
Many studies have been carried out regarding the real effect that alternative powered vehicles have on this category and interesting results have been discovered by researchers and international organizations.

As a matter of fact, according to a study carried out by the "European Federation for Transport and Environment" (2020), a medium-sized average electric vehicle emits about 90 gCO2e/km over its lifetime, while a diesel counterpart emits 234 gCO2e/km and a gasoline vehicle 253 g/km, including upstream emissions. Over

the entire lifetime this is respectively 20 tons of CO2 (and equivalents) for BEVs, 53 tons for diesel vehicles, and 57 tons of CO2 for gasoline vehicles. In other words, on average in the EU, a BEV emits about 2.7 times less CO2 than the conventional car in 2020 (2.6 times less than diesel and 2.8 times less than gasoline).

Moreover, if it is assumed that the battery is produced with clean electricity, the impact of electric cars decreases to 86 gCO2e/km or 2.7-3.0 times less than ICEVs.

Figure 3.2 - GWP comparison, best case scenario.



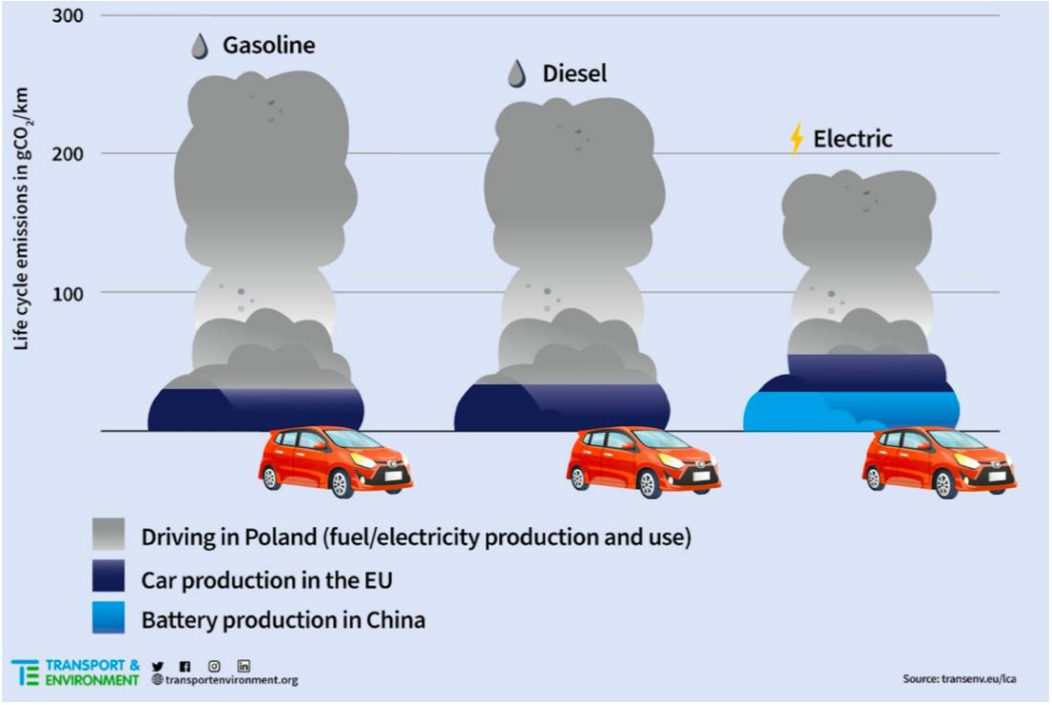
Source: Transport&Environment.

Particularly, considering the best case scenario of all that is the one in which the battery is produced with clean electricity and battery electric vehicles are run by

clean renewable electricity (for instance consider the Sweden hydro power), then the GWP impact decreases to 11 tons of CO2 (47 g/km) which is 5.0 and 5.4 times less than diesel and gasoline equivalents (see the above *Figure 3.2*).

However, what is really interesting is that even in the worst case scenario, namely the one in which the battery is produced using electricity derived from fossil resources and also battery electric vehicles are run by electricity generated through non-renewable resources (for instance, the battery is produced in China and the electricity to run the vehicles arrives from Poland), even in this worst case scenario overall BEVs would be cleaner than ICE vehicles.

Figure 3.3 - GWP comparison, worst case scenario.



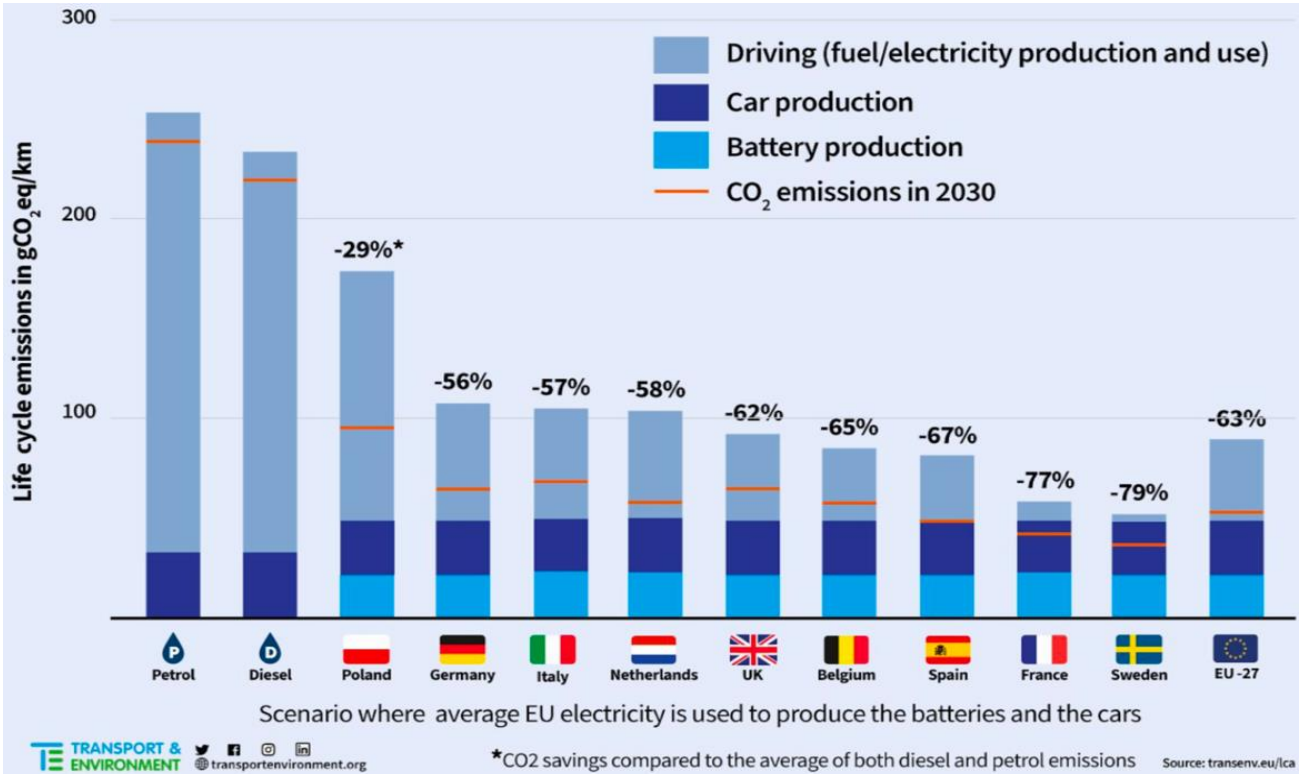
Source: Transport&Environment.

Indeed, in this worst case scenario, the lifetime impact of a battery electric vehicle increases to 41 tons of CO2 (182 g/km), thus BEVs would still be 22% cleaner than the diesel counterpart and 28% cleaner than the gasoline counterpart (see also *Figure 3.3*).

As it can be possible to notice, the electricity used to charge the vehicle over its lifetime is the one factor that has the highest impact on determining its global warming potential. According to the previous study, the researchers tried also to compare the GWP values on the basis of where the BEV is used in the various European countries.

The results obtained are quite interesting; in fact, if a BEV is recharged in Poland, which has one of the most carbon intensive electricity grids in Europe, a BEV is still 26% cleaner than a diesel car (31% cleaner than a gasoline car). In the Netherlands, Germany, and Italy a battery electric vehicle is slightly more than two times cleaner than a conventional vehicle while in low carbon France and Sweden the impact is up to four or even five times smaller (around 50g/km), as illustrated by *Figure 3.4*.

Figure 3.4 - Comparison of BEVs emissions according to the country where it is used and recharged.



Source: Transport&Environment.

Other than the electricity mix used to recharge the vehicle, there are many more factors that influence the GWP value of a battery electric vehicle. Some of these factors, which are worth mentioning, are the following.

Firstly, it should be taken into account the various driving modes, namely urban, suburban, and highway driving. Urban driving refers to slow driving with many starts and stops in highly congested traffic, suburban driving refers to a scenario with less congestion, thus allowing for higher speeds, and eventually the highway driving refers to high speed driving on the motorways, without any stop. Results of

many studies clearly show that the electrified vehicles prove to be beneficial for driving in an urban context, where there are many stops, due to traffic and congestion. The benefits of regenerative braking to recover energy while braking can maximize the energy performance of BEVs. On the contrary, results show that highway situations are the ones in which the electrified vehicles display the worst performances in terms of energy consumption.

Another factor that needs to be considered is the way in which the driver drives the vehicle, namely the so-called "driving profile". The driving profile takes into account the different driving modes (aggressive, normal and ECO) together with the different settings for the climate control (A/C off, A/C in cooling mode and A/C in heating mode). The aggressive driving profile differs from the normal driving profile mainly in the acceleration and braking phases, where the aggressive has fast accelerations and sudden braking to maximize the energy consumption. The ECO driving profile is characterized by slow accelerations, lower top speeds and the braking is mainly due to the regenerative braking in order to minimize the overall energy consumption.

According to a study carried out by Faria et al. (2013), an ECO driving profile is more efficient than an aggressive one, which can reduce the driving range of a BEV up to 90 km due to the increased energy consumption. Furthermore, the use of climate control has also a significant impact, increasing the energy consumption of 24% in cooling mode and of 61% in heating mode for the ECO driving profile. All

of this has not a relevant impact on GWP if the vehicle uses an electricity mix constituted for a high proportion of renewable resources, whereas it becomes something quite relevant in the GWP computation if the electricity mix is highly based on fossil resources.

Eventually, the last factor that influences the global warming potential value is the size of the vehicle and the weight that it carries. Of course, many studies agree that the bigger the size of the vehicle and the higher the weight that it carries, the more energy will be consumed to power it.

Finally, noteworthy to mention is that regarding only the raw materials extraction and production LCA phases, greenhouse gasses emissions are typically higher for a BEV than for its ICEV equivalent, as it can be noticed from *Figures 3.2* and *3.3*. This is related to the fact that the energy requirements for raw materials extraction and processing as well as for producing are higher for BEVs due to the presence of the batteries that require an extra effort in their manufacturing (moreover for them also the location of their manufacturing is crucial in terms of the electricity mix adopted). However, the largest potential reduction in GHG emissions between a BEV and an ICEV occurs in the use phase and results clearly show how BEVs perform better than ICEVs, since the advantages related to the BEVs use phase can more than offset the higher impact of the raw materials extraction and production phases. On the other hand, for the end of life stage the emissions from both BEVs

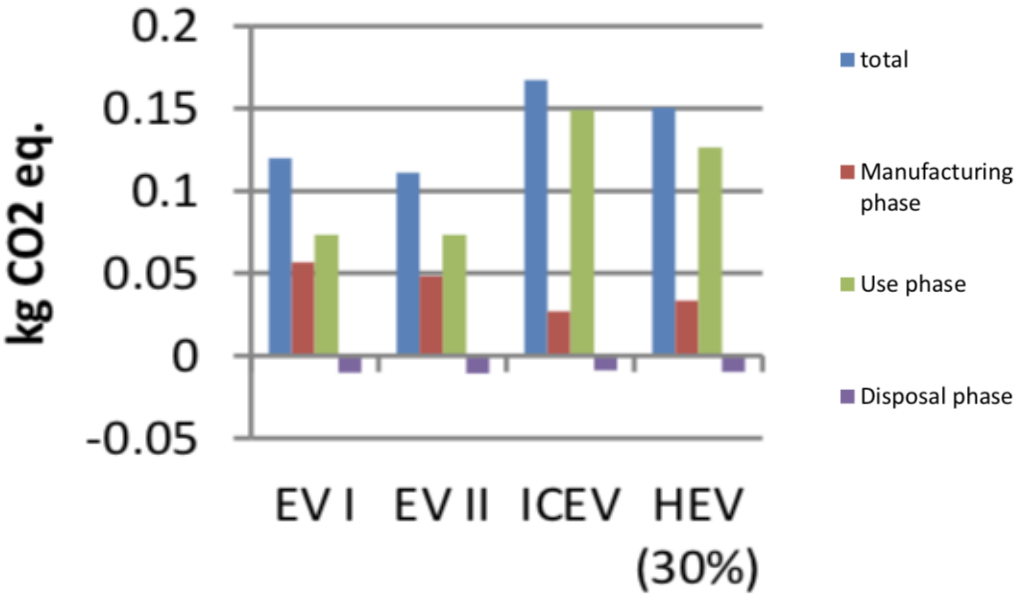
and ICEVs are low and not so relevant if compared with the other stages of the life cycle.

As a conclusion, this subparagraph will end by taking into account hybrid electric vehicles and by making a final remark about them. As already stated before, the amount of life cycle assessments performed on the different types of hybrid electric vehicles is quite limited because this category of vehicles is considered as some sort of middle ground between conventional internal combustion engine vehicles and battery electric vehicles. In fact, thanks to their particular characteristic of having both an internal combustion engine and a small electric motor, this kind of vehicles in all the LCAs carried out on them shows that they perform always somewhere between their "derivative" vehicles.

Indeed, according to the LCA carried out by Tagliaferri et al. (2015), it can be noticed from the below *Figure 3.5*[5] that in the climate change category, so in their Global Warming Potential, HEVs place somewhere between ICEVs and BEVs.

[5] In *Figure 3.5,* there are two BEVs on the graph, namely EV I and EV II, because in the LCA by Tagliaferri et al. the analysis was carried out using two different BEV models which led to almost the same result.

Figure 3.5 - GWP (Global Warming Potential) scores comparison.



Source: "Life cycle assessment of future electric and hybrid vehicles: a cradle-to-grave systems engineering approach", Tagliaferri et al. (2015).

Note: KqCO2eq. stands for kilograms of CO2 equivalent emitted per km and it is the unit of measure employed for measuring GWP.

In fact, it is possible to notice that an increase in the ratio of the electric motion determines a decrease in the total GWP. This result is due to the opposite trend that ICEVs and BEVs have in which BEVs are the best options regarding the GWP. Furthermore, some estimations (again computed by Tagliaferri et al.) show that a decrease in the hybridisation factor could determine an increase of the GWP of up to 25% for hybrid electric vehicles when compared to BEVs. Therefore, the more the vehicle is "hybridized", the more its GWP value is similar to the one of BEVs, and also the opposite is true.

In particular, in the analysis carried out by Tagliaferri et al., it was taken into account a hybrid vehicle that has a 30% hybridization factor, as it can be noticed from the above figure. This value of hybridization is commonly referred to HEVs, whereas PHEVs are commonly referred as having a hybridization factor of 60%, so that the latter would be even more similar to BEVs regarding their assessments.

3.2.2 Resources depletion

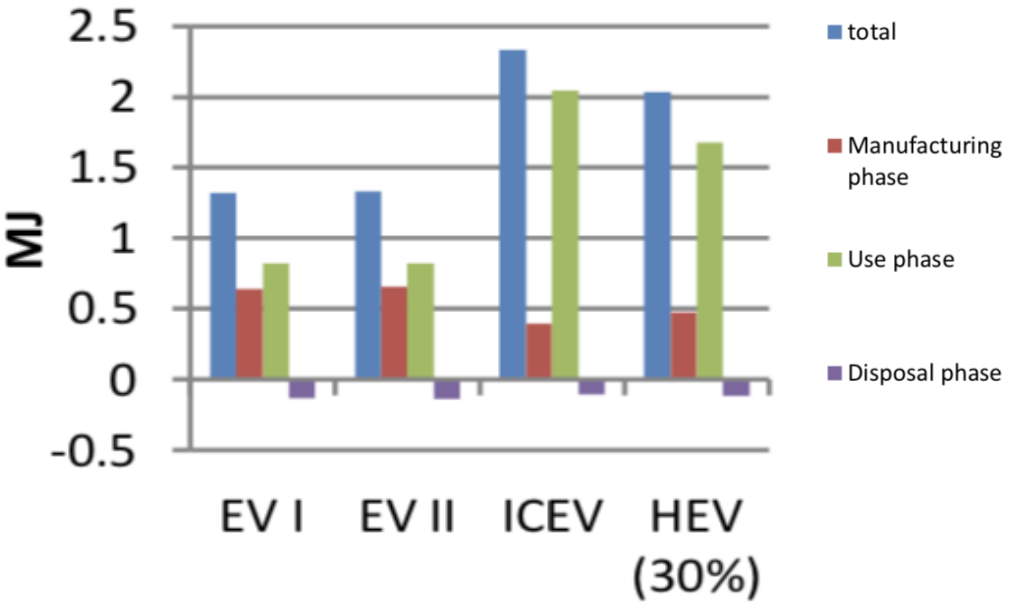
Another category that is worth analysing in life cycle assessments concerning vehicles of different nature is the impact that these vehicles have on resources depletion.

This category is measured through the abiotic depletion potential (ADP) that addresses the environmental problem of diminishing the pool of resources. In fact, it focuses on the depletion of non-living resources such as metals and oils. The measurement unit of abiotic depletion is MJ (mega Joule) since the majority of non-renewable resources represent energy sources.

According to the LCA carried out by Tagliaferri et al. (2015), the impact of battery electric vehicles on this category is almost the half of the impact that their ICE counterparts have on it (as it can be noticed from *Figure 3.6*[6]).

[6] See *note 5* at page 63 for clarifications regarding EV I and EV II.

Figure 3.6 - ADP (Abiotic Depletion Potential) scores comparison.



Source: "Life cycle assessment of future electric and hybrid vehicles: a cradle-to-grave systems engineering approach", Tagliaferri et al. (2015).

Note: Mj stands for mega Joule and it is the unit of measure employed for measuring ADP.

Moreover, the main contribution to the total depletion of resources is during the use phase. In particular, in the case of ICEVs, this is associated to the diesel or gasoline consumption (hence fossil resources). On the other hand, for the case of BEVs, the impact of the manufacturing phase is practically comparable to the impact of the use phase. In the former, the burden is almost equally spread among the battery manufacturing and the manufacturing of the rest of the vehicle, whereas in the latter its amount is almost all associated to the electricity mix used to charge the vehicle.

As for the global warming potential, also in this case the ADP value is influenced by some factors, and in particular by the choice of the battery, and so by the materials that the battery requires for its production. As a matter of fact, in most of the cases batteries are composed by rare earth materials that are difficult to extract and that require lots of energy and resources consumption. Nowadays, the most common type of batteries used in alternative powered vehicles are lithium batteries since they are considered the most efficient currently existing in the market.

Again, as for the climate change category, this subparagraph will end by taking into account HEVs and by making a final remark on them. As it can possible to notice from the above *Figure 3.6*, HEVs place somewhere between ICEVs and BEVs showing and proving again how this type of vehicles is some sort of middle ground between conventional and electric technologies, even though with respect to this particular category, it can be said that hybrids are a bit more similar in their behaviour to ICEVs, but again it should be considered that in the analysis was taken into account a hybrid with a 30% hybridisation factor, so that this could have influenced this result.

Anyway, all of this means that HEVs are a worse option rather than full-electric vehicles, whereas they are a better option with respect to conventional ones.

3.2.3 Human toxicity

The last category that will be analysed in this part of the analysis is the impact that battery electric vehicles have on human beings.

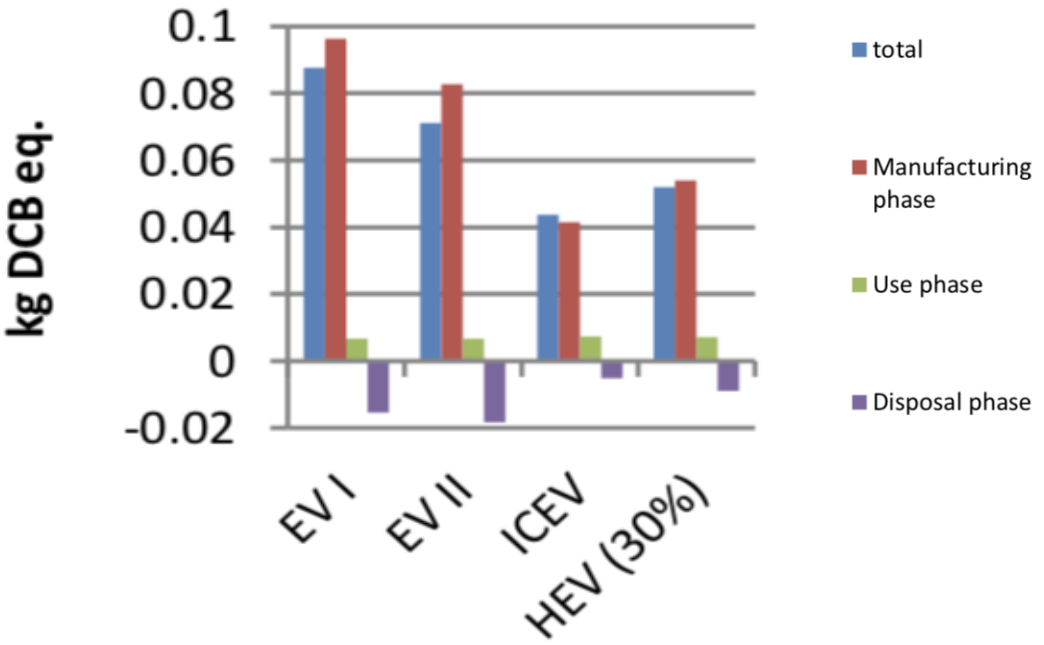
As a matter of fact, the human toxicity potential (HTP) reflects the potential harm of different chemical species released into the environment, based both on the inherent toxicity of a compound and on the potential human exposure. In particular, this indicator is measured through the units of dichlorobenzene equivalents emitted (kgDCBeq.).

It is interesting to notice that this category shows a different trend with respect to the other two. Indeed, again according to the LCA carried out by Tagliaferri et al. (2015), the total HTP of BEVs is higher than the total HTP of ICEVs in opposition to what has been shown for ADP and GWP. Therefore, with respect to this category ICEVs can be considered better performing than alternative powered vehicles.

In this case in particular, as it can be noticed even from *Figure 3.7*[7], the manufacturing phase of BEVs is the main contributor to this indicator. In fact, the processes associated with the chemicals and metals production, used in the manufacturing phase, determine more emissions contributing to the toxicological impacts than the emissions associated with the production of electricity required during the electric vehicle use.

[7] See *note 5* at page 63 for clarifications regarding EV I and EV II.

Figure 3.7 - HTP (Human Toxicity Potential) scores comparison.



Source: "Life cycle assessment of future electric and hybrid vehicles: a cradle-to-grave systems engineering approach", Tagliaferri et al. (2015).

Note: KgDCBeq. Stands for kilograms of dichlorobenzene (DCB) equivalent units emitted and this unit of measure is employed for measuring HTP.

Another interesting point is also the fact that in this category the disposal phase of BEVs is more than the double in value with respect to the disposal phase of ICEVs and this is due to the fact that some parts of the batteries could be recycled and reused in other devices; however, even though thanks to recycling the HTP for BEVs reduces in the disposal phase, it does not decrease enough to offset the negative contribution given by the other phases.

Therefore, this difference in values between BEVs and ICEVs can be almost all attributed to the components specific for the electric powertrain of BEVs that together contribute to almost half of the overall impact.

Eventually, if also HEVs are taken into account, it can be noticed how (as usual) this kind of vehicles scores always somewhere between the conventional ones and the electric ones. All of this means that with respect to the Human Toxicity Potential, HEVs can be considered as a better option rather than BEVs, whereas they are a worse option rather than ICEVs. Moreover, as found out by some estimations carried out by Tagliaferri et al. (2015), the HTP decreases up to 28% for HEVs with a decrease of the hybridisation factor when compared to BEVs.

Finally, worth mentioning in this subparagraph, even if not directly related to the human toxicity impact category, are few other categories that are related in any case to human health, namely the freshwater ecotoxicity and the terrestrial acidification potentials. The former refers to the impact on freshwater ecosystems, as a result of emissions of toxic substances to air, water and soil; indeed, freshwater is a vital component in the global ecosystem and also for human life, therefore its pollution not only poses a risk to the environment, but it can impact human health as well. On the other hand, the latter is characterized by changes in soil chemical properties following the deposition of nutrients (namely, nitrogen and sulfur) in acidifying forms.

According to a study carried out by Hawkins et al. (2012), in both these categories BEVs score higher values than their ICEV counterparts, with particular higher results especially in the category of freshwater ecotoxicity. The results in both categories are particularly influenced by the production phase of BEVs batteries and by the use phase of this kind of vehicles.

Because of all these categories in which battery electric vehicles perform worse than internal combustion engine vehicles (mainly because of their batteries usage and production), the transition to alternative powered vehicles could be slowed down and that's why scientists, countries, and car manufacturers will have to work towards finding cleaner solutions in order to decrease the harmful potential effects that these vehicles can have both on humans and on the earth.

3.3 FINAL CONSIDERATIONS

After having analysed the different results obtained in the life cycle assessments of alternative powered vehicles, a summary table which compares BEVs, ICEVs and HEVs on the categories taken into account during this chapter will be presented to give a general overview of the topic, and few final considerations will be made regarding these vehicles and where their future should focus.

First of all, the potential of alternative powered vehicles, and especially of battery electric vehicles, for mitigating greenhouse gasses emissions (and therefore for

fighting climate change) is crystal clear. Indeed, for instance it is worth recalling that today on average BEVs are close to three times cleaner than diesel and petrol vehicles.

However, it has been also highlighted how the electricity mix used for powering and producing them (and their components) is crucial, and that's why national and international institutions, both public and private, should put much effort in shifting the generation of electricity from fossil resources to renewable and clean resources. Secondly, it has been noticed how alternative powered vehicles are still worse than conventional vehicles with regard to their impacts on both the human health and on some aspects of the environment (see for instance freshwater ecotoxicity and terrestrial acidification potentials). As shown before, these effects are mainly due to their batteries and to the extraction of the materials needed for their manufacturing. That's why in the immediate future, in order for helping the transition from internal combustion engine vehicles to alternative powered vehicles, efforts should be made for enhancing the efficiency and the lifetime of these batteries, but also for improving the recycling processes and methods with the aim of reducing the (highly polluting) extraction of the elements needed for manufacturing them and of augmenting the ways in which these batteries could be reused for powering other devices.

Table 3.1 - BEVs, ICEVs and HEVs comparison with respect to their GWP, ADP, and HTP.

	BEVs	**ICEVs**	**HEVs**
Climate change	These vehicles are the best performing ones with respect to this category. Moreover, the "cleaner" the energy mix used where they are recharged, the better they perform, arriving to be up to five times better than their conventional counterparts.	Conventional vehicles are the worst performing ones considering their global warming potential. This is something pretty logical and reasonable considering that they are powered only through the deployment of derived fossil resources (gasoline or diesel).	Hybrids are considered as some sort of middle ground between ICEVs and BEVs. Due to the fact that they both have an electric motor and a conventional engine, in all the categories taken into account they perform somewhere between BEVs and ICEVs. Furthermore, the more the vehicle is "hybridized", the more its results are similar to the ones of BEVs, and also the opposite is true.
Resources depletion	Electric vehicles are again the best performing ones also with respect to this category. Indeed, the impact of BEVs on this category is almost half of the impact that their ICEV counterparts have on it.	ICEVs are the worst performing ones with respect to this category. This result is mainly due to the diesel and/or gasoline consumption (hence the consumption of fossil resources).	
Human toxicity	In this particular category, BEVs are the worst	ICEVs are the best performing type of vehicles in this	

	performing kind of vehicles. The reason of it is primarily associated with the processes used during their manufacturing phase.	category. This result is ought to be attributed to the fact that they are not equipped with an electric motor.	

CHAPTER FOUR:

ALTERNATIVE POWERED VEHICLES MARKET MAJOR PLAYERS AND FUTURE FORECASTS

After having analysed the environmental assessment performed to alternative powered vehicles through the life cycle assessment method, and after having found out that this kind of vehicles can actually help in fighting the climate change thanks to their lower levels of greenhouse gasses emitted in the atmosphere during their lifetime, it is now time for tackling another fundamental topic both for the automotive industry and for this thesis, namely how automakers around the world are changing, and what are their strategies in order to conform to the current evolving automotive industry which seems at the verge of a brand new phase.

4.1 TRENDS AND FORECASTS OF THE ALTERNATIVE POWERED VEHICLES MARKET

It has already been analysed the market share and how many units of both battery electric vehicles and plug-in hybrid electric vehicles have been sold around the world up to now. In fact, just to make a quick recall, it has been found out that 2,264,400 units of BEVs or PHEVs were sold globally in 2019; among this total amount, in particular the 74% were BEVs while the 26% were PHEVs. Moreover,

it can be said that, thanks to this huge number of units sold in 2019, the total amount of alternative powered vehicles arrived at 7.2 million units in that same year, representing more than the 1% of the total global vehicles stock share.

Now, the aim of this paragraph is to make some forecasts about how and why the alternative powered vehicles market segment will progress in the near future.

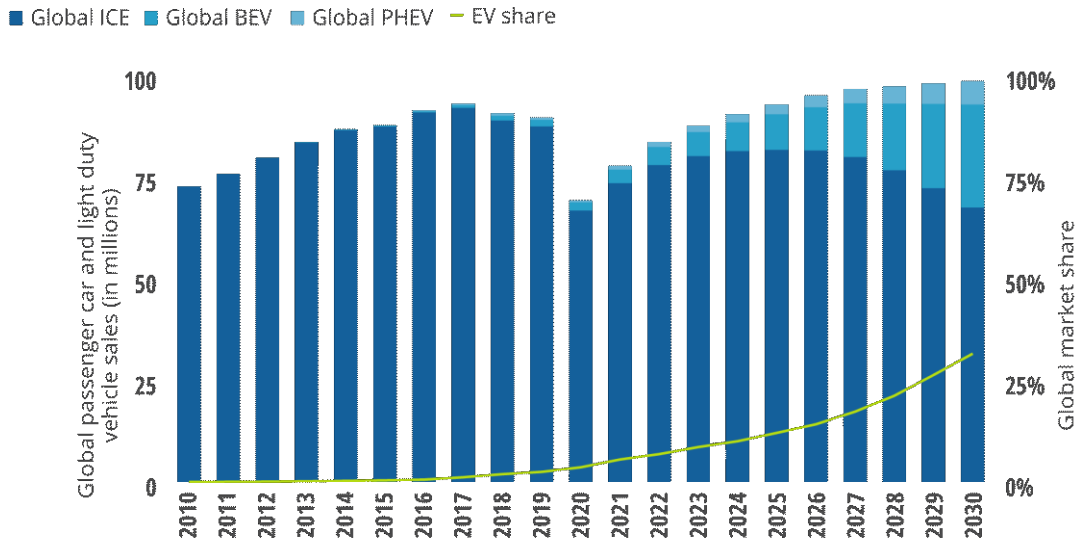
As stated by a research carried out by Deloitte (2020), the amount of BEVs and PHEVs sold globally is expected to grow, gaining an always higher share of the global vehicles sales year after year. Particularly, this growth will be more pronounced for BEVs rather than for PHEVs. As a matter of fact, it has been already noticed that BEVs outperform PHEVs globally, and in addition it has been estimated that BEVs will likely account for 81% of all the new alternative powered vehicles sold, whereas PHEVs sales are expected to account for 19% by 2030.

These percentages are expected to correspond to 25.3 million units sold for BEVs and to 5.8 million units sold for PHEVs, reaching together an impressive amount of 31.1 millions of alternative powered vehicles sold in just one year. This is something quite interesting considered the total amount of BEVs and PHEVs present nowadays on the world's streets (namely 7.2 million units).

All of this means that the estimations performed by Deloitte expect BEVs and PHEVs to have altogether a compound annual growth rate equal to 29% achieved over the next ten years. Supposing that this will happen, the total alternative powered vehicles sales would grow from 2.5 million in 2020 to 11.2 million in

2025, then reaching 31.1 million units by 2030, in this way representing approximately 32% of the total global market share for new car sales. It is possible to notice the graphical representation of this growing market share of BEVs and PHEVs in *Figure 4.1*.

Figure 4.1 - Global annual car sales, from 2010 to 2030.



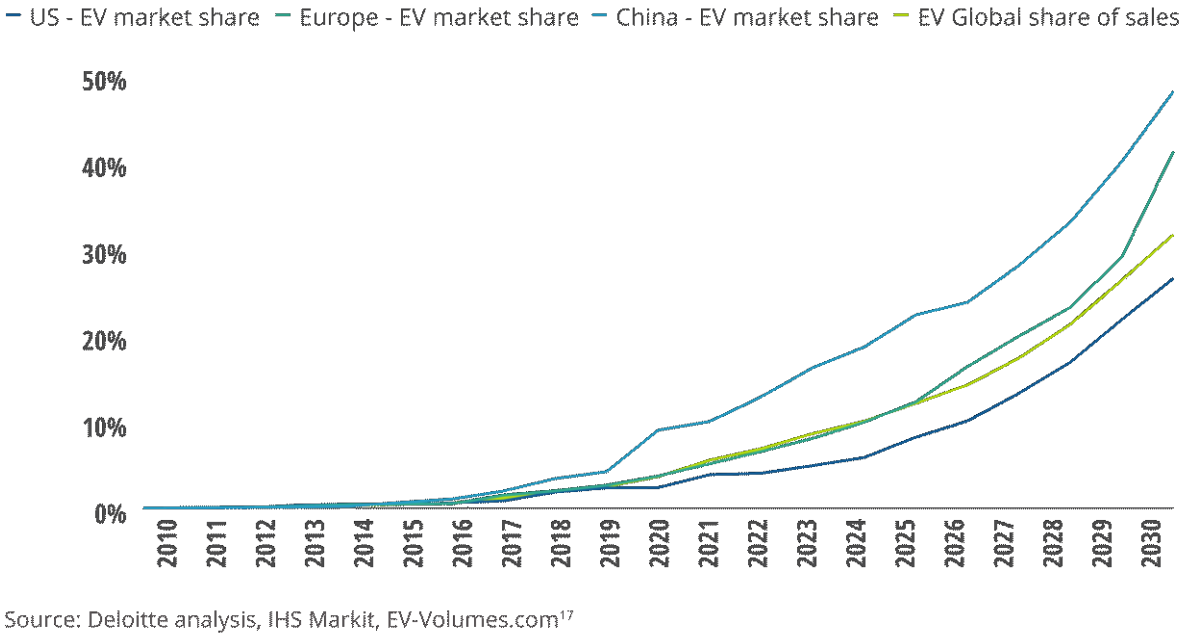
Source: Deloitte.

Regarding the way in which these vehicles will be split around the world, it can be said (always according to the Deloitte's study) that China will hold 49% of the global EV market, Europe will account for 27%, and the United States will hold 14% in 2030, as also represented in *Figure 4.2*.

Worthy is also giving a little overview of what will probably happen after 2030. As a matter of fact, as stated by Deloitte (2020), alternative powered vehicles will

continue to gain market share but with lower growth rates. The reason of it is that some markets will be unable to support the transition to hybrid and electric vehicles in the same way that wealthier nations will do over the next decade. Indeed, beyond 2030, one of the key factors in sustaining growth will be the implementation of suitable charging infrastructure, and this requires multibillion dollars capital investments. These investments could be achievable in some markets through a combination of public and private funds, nevertheless they are unlikely to be achieved uniformly around the world. In countries that cannot invest in charging infrastructure, it is expected that the market for ICE vehicles to remain predominant for some more time in the future.

Figure 4.2 - Alternative powered vehicles share by major world regions, from 2010 to 2030.



Source: Deloitte.

4.1.1 Factors driving alternative powered vehicles growth

The quite impressive growth that alternative powered vehicles are experiencing and will continue to experience also in the future is driven by some critical factors that help it to be faster and consistent. In particular, 5 factors are considered to be the most important ones:

1. *Changing consumer attitude*: it has already been talked about consumers' attitude towards alternative powered vehicles, noticing that consumers have some concerns about this kind of vehicles, such as the driving range and the lack of charging infrastructure. However, throughout time all the existing concerns are expected to decrease in their repulsive power as the technologies deployed in these vehicles and the infrastructures related to them enhance thanks to the increasing investments, and as their number of sales boosts so that more of these vehicles could be seen on the streets by potential customers. Indeed, direct personal experiences (such as seeing them on the streets) are expected to positively affect the perception that people have on these vehicles;
2. *Policy and legislation*: governments' interventions play an important role in driving alternative powered vehicles sales. Indeed, the positive environmental impact, which these vehicles have, has made the widespread adoption of BEVs and PHEVs a necessary step towards achieving climate change goals, such as those set by the 2015 Paris Agreement. That's why

several policies and regulations are being employed by governments in helping to encourage the growth of hybrids and electrics adoption. Many of these policies are related to fuel economy and emission targets, to city access restrictions, and to financial incentives. Regarding the first, it can be said that these targets differ across markets and are under constant review and consultation by governments; in general, they consist in some target level of CO2 that cannot be overcome or otherwise a fine will be issued. One example is the new European CO2 emission target that will be fully introduced in 2021 and that is shaping automakers strategies in order to avoid fines and negative reputational impacts, as it will be analysed later in the next chapter. In any case to meet all these mandated targets, the alternative powered vehicles market will have to grow significantly.

Regarding the second, it can be said that many city governments around the world (such as Madrid, Seattle, Paris, or Mexico City) are announcing bans on gasoline and diesel cars which will become effective by 2030 or sooner, or they are imposing punitive taxes on users of older combustion engines, thus addressing in these ways the increasing concerns about toxic air pollution. Furthermore, many cities are also creating zero or low emissions zones. This trend is expected to continue also in the future years as more cities around the world will have to deal with air pollution.

Regarding the last point, many governments have offered and are still offering compelling financial incentives to favour the electric switch, such as providing cash subsidies to consumers buying low or zero emissions vehicles, reducing taxes on hybrid and electric vehicles owners, and increasing or maintaining taxes on ICE vehicles. Just as an instance, the German government has lowered the VAT (Value Added Tax) from 19% to 16% on low emission vehicles and it has issued subsidies of $7,000 on alternative powered vehicles that cost less than $45,000.

3. *Automakers' strategies*: this particular factor will be dealt more in depth later in the next chapter. What is important to mention now is that more and more major and non-major vehicle manufacturers are announcing strategic commitments towards alternative powered vehicles. Indeed, many automakers have set production and sales targets for these vehicles, and at the same time many new models have been announced in the world markets.
4. *Corporate companies*: sales of new cars to businesses represent a significant share of all the cars sold. Just as an instance, Deloitte (2020) estimated that companies would account for 63% of total new car sales across Western Europe by 2021. Furthermore, an increasing number of companies are trying to differentiate themselves by acting as a force for positive change, thus positively affecting their brand by presenting themselves as firms that care about the environment and its preservation. Moreover, since travelling

has an important role in most companies, they are trying to reinvent their travelling schemes by shifting from using ICE company cars to hybrid and electric company cars. All of this will help them not only to alleviate emissions, but also to enhance cost savings and employee satisfaction in these companies.

5. *Reaching price parity*: experts estimate that reaching price parity among electric vehicles and ICE vehicles will help to boost alternative powered vehicles sales worldwide. As a matter of fact, as both the battery costs decrease thanks to more efficient processes, technologies, and economies of scale, the price of electric vehicles is expected to decrease accordingly. In particular, as affirmed by Bloomberg (2019), price parity will be reached in 2024 as both BEVs and PHEVs will reach market maturity.

   To be truthful, even nowadays sometimes price parity has already been achieved, depending on the considered world region and on the chosen alternative powered vehicle model (so principally in countries that offer more and higher benefits, and for the least expensive models), thanks to the various cited benefits that states offer to buyers of these vehicles.

4.2 MAJOR PLAYERS IN THE MARKET

It has already been slightly anticipated in the previous chapters how the world famous automotive brands, such as Volkswagen, BMW, Toyota, or Hyundai, have started to introduce alternative powered vehicles in their product portfolios since the beginning of the last decade. They have done that partly to ride this new environmental trend and to acquire market share in this segment of the automotive market, and partly to fulfill the emission targets imposed by many national or international institutions and organizations (such as the one issued by the European Union for 2021), as it will be possible to understand better later.

4.2.1 Current market conformation

Currently the global market of alternative powered vehicles is dominated by Tesla Motors. Tesla is an American auto company and it is one of the first established automakers with the aim of manufacturing only battery electric vehicles. It has gained success worldwide thanks to its innovative product designing, for the technological enhancements that it has introduced, and for the quality of its cars. As a matter of fact, as affirmed by EV-Volumes (2020), only in 2019, Tesla sold approximately 368,000 units of its cars globally (+50% with respect to the year 2018), outpacing in this way all the competitors. Its major markets were the United

states with 145,000 units sold, followed by China and the Netherlands, with 34,000 and 30,000 units sold, respectively.

Thanks to all these vehicles sold, it can be affirmed that Tesla Motors commanded the 16% share of the global alternative powered vehicles volume in 2019; moreover, this percentage increases up to 22% if only BEVs are taken into account.

Very important to mention are also the Chinese car manufacturers due to the fact that China represents the world's largest automotive market, as already stated in Chapter One. Indeed, the Tesla leadership is followed by two Chinese brands, namely by BYD (Build Your Dreams) Auto Company and by the BAIC Group (officially known as Beijing Automotive Industry Holding). Regarding the first, it can be said that it sold around 225,000 units worldwide, even if its main market is the Chinese one, whereas, about the second, it can be said that it sold around 160,000 units of alternative powered vehicles worldwide, even if again its main market is the Chinese one. Here it is also interesting to mention the fact that the BAIC Group is directly owned by the Chinese government.

Other than these two automakers, there are many other Chinese players that, even though they have a lower market share, they are still notable and relevant among the world players. Some of these companies are for instance SAIC (Shanghai Automotive Industry Corporation), the Geely Holding Group (which possesses also the Volvo Motors among its brands), or the GAC Group (officially known as Guangzhou Automobile Group Motor).

One interesting characteristic that all the Chinese automakers have in common is that they were almost all established at the end of the 1990s or at the beginning of the 2000s. The only exceptions are represented by the NIO car company and by Xiaopeng (also known as XPeng) which were both founded in 2014.

Thanks to their quite short "lives", all these companies can be considered as newcomers in the automotive market and industry, and one factor that helped them in being successful is their propension in designing alternative powered vehicles since their establishments (newcomers will be deeply analysed in the next chapter).

Regarding the auto manufacturers more renowned in the Italian and European markets, worth mentioning in the world rankings are the German BMW Group, the Volkswagen Group, the Daimler AG, and the French Renault. In particular, the first two mentioned are noteworthy since they placed respectively fourth and fifth globally in 2019, and notably Volkswagen experienced a 70% growth with respect to 2018.

An overview of the global electric and hybrid vehicles ranking sales can be observed from the below *Figure 4.3* which provides the ranking by automaker in 2019 and in addition it shows also the variation with respect to the previous year.

On the other hand, if the auto models are considered instead of the car manufacturers, it can be noticed (always according to EV-Volumes estimations, 2020) that Tesla Motors dominated this ranking too thanks to the introduction of its *Tesla Model 3* worlwide of which almost 300,000 units were sold globally. Tesla

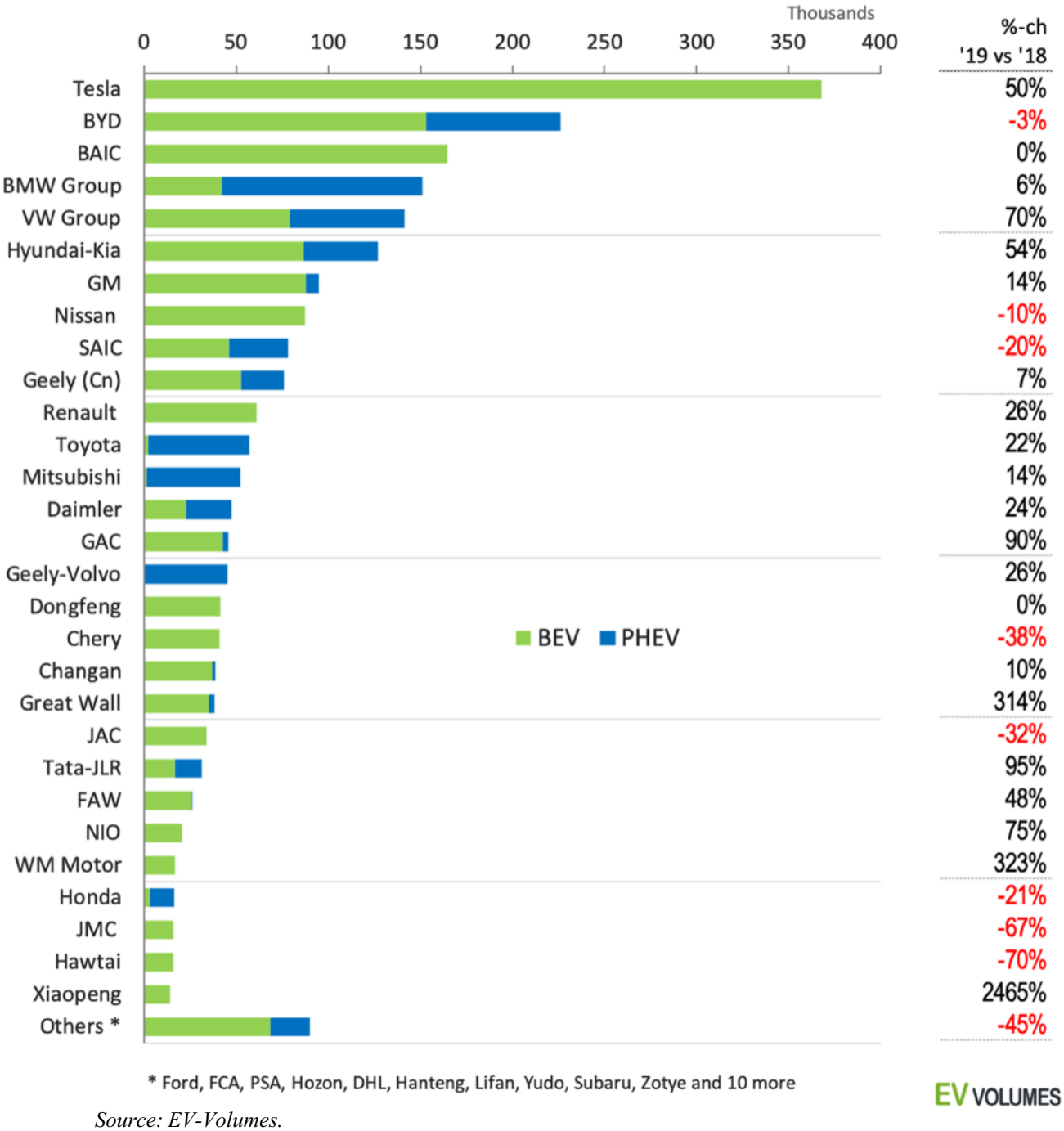
Motors appears in this ranking also with *Tesla Model X* of which 40,000 units were sold globally.

Other models that appear in this ranking are for instance the *Nissan Leaf*, the *Renault Zoe*, the *Hyundai Kona*, and the *BMW i3*; all models that were released by world major vehicle manufacturers.

However, despite all these models what is really most interesing to mention is the fact that there is only one PHEV among the top 10 models, namely the *Mitsubishi Outlander* which places at the sixth position with 50,000 units sold globally. This could be considered as one proof that helps in demonstrating the battery electric vehicles dominance over the other kinds of alternative powered vehicles (however, this idea will be better expressed in the next paragraph).

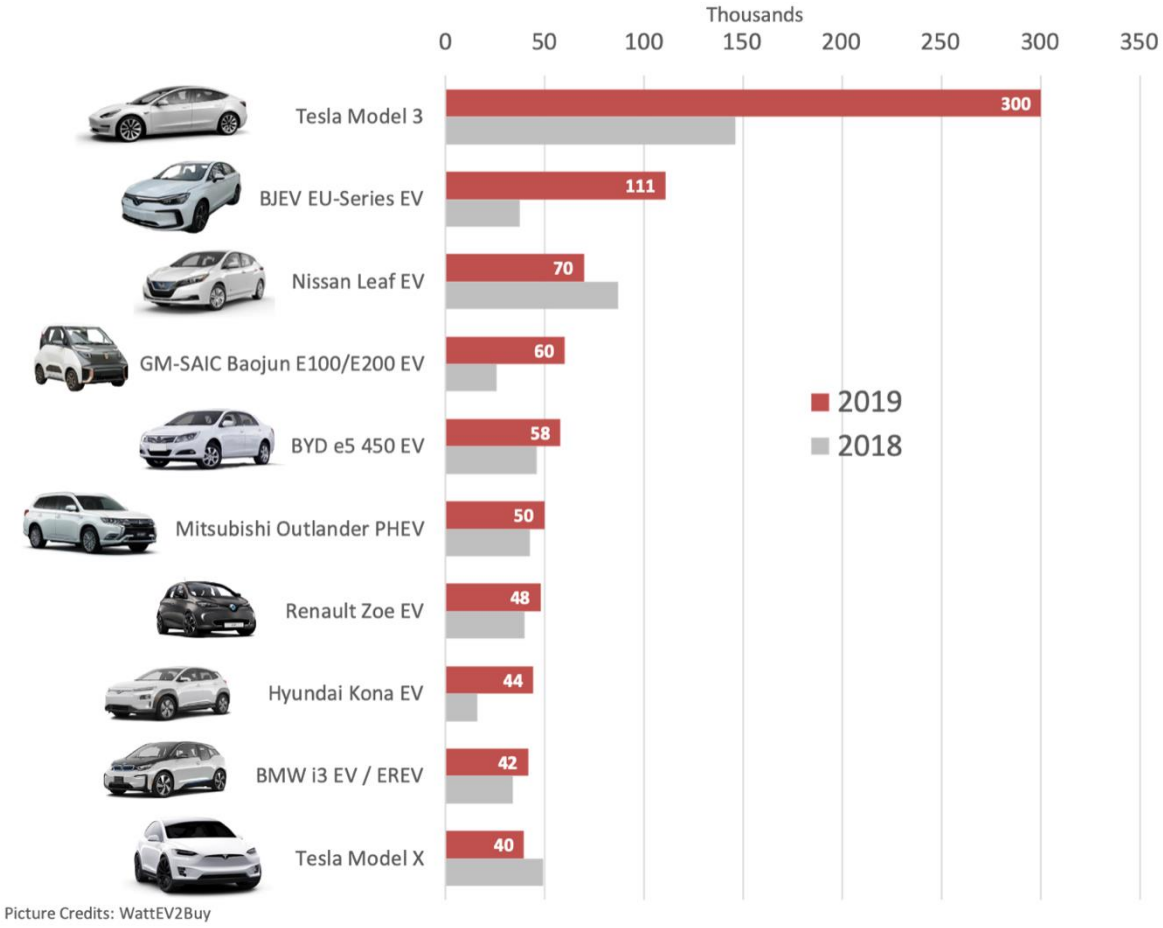
The entire ranking can be observed from the below *Figure 4.4* which shows the top 10 alternative powered vehicles models sold globally in 2019, comparing them also with their 2018 data.

Figure 4.3 - Global alternative powered vehicles ranking by automakers, 2019.



Source: EV-Volumes.

Figure 4.4 - Top 10 alternative powered vehicles models sold, 2019.



Source: EV-Volumes.

Despite the current equilibria in the world market of alternative powered vehicles, these same equilibria are probably destined to change in the next few years. The reason of this is related to the fact that an always higher number of automakers have been announcing to introduce new BEVs and PHEVs models in the near future, and also new players will enter the market with their brand-new models. As a consequence, all of this will enhance the competition in this market segment.

That's why, the equilibria in this market will change accordingly on how both incumbents and newcomers will play their cards in the next future.

Just as an instance, according to the European Federation for Transport and Environment, T&E, (2019), around 330 new BEVs and PHEVs models will be introduced only in the European market by 2025, of which the majority (about 60%) will be battery electric vehicles. Moreover, this estimation is conservative because they considered only major car manufacturers in their computations, therefore it is possible to hypothesize that the actual number of new models will be even higher than 330.

4.2.2 Who are the current alternative powered vehicles buyers?

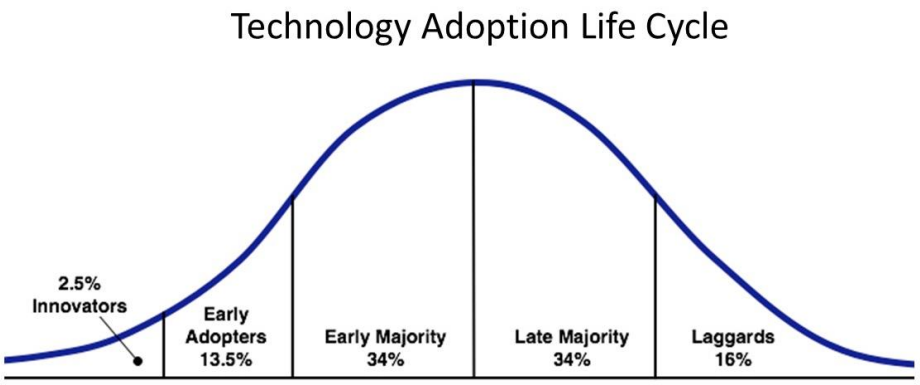
After having analysed the current market conformation of alternative powered vehicles, looking at who are the major market players and at their sales data, it will now be investigated who are the current buyers of these kinds of vehicles.

Before starting, it is necessary to mention the fact that data about the buyers of alternative powered vehicles are still limited, and probably they will be more specific and detailed only in the next years. However, it is still possible to detect some interesting facts from the few data available from the market.

As a matter of fact, as stated by the Strategic Business Insight (2018), the alternative powered vehicles market is translating from the "innovators" phase to the "early

adopters" phase in the so-called "technology adoption life cycle" (introduced for the first time in 1962 by E. Rogers), as also shown in *Figure 4.5* below.

Figure 4.5 - Technology adoption life cycle.



Source: Strategic Business Insight.

In particular, the technology adoption lifecycle is a description of the customer behavior related to the acceptance of a new product or feature, which is often broken into five phases, namely innovators, early adopters, early majority, late majority and laggards. Each category is divided based on the percentage of the total population that has already started to adopt the new product or that it is going to adopt that product very soon in time.

For what concerns alternative powered vehicles, it can be said that nowadays its category is closer to the "early adopters" phase than to "innovators" phase. Nevertheless, who are the early adopters of these vehicles?

It is difficult to give an answer which could be valid worldwide since only few data are available. However, it can be said that, according to TrueCar, early adopters in the United States are mainly represented by the Generation X, which accounts 39.8% of the alternative powered vehicles sales, and the Millenials, which accounts 34.9% of the same sales. In particular, the Generation X comprises people born between 1965 and 1980, whereas Millenials comprises people born between 1981 and 1996, thus both groups comprise relatively "young" people.

Moreover, it has been found out that these kind of owners usually have higher education levels and incomes with respect to the rest of the population. In addition, they were reported to have a higher car use and to have more knowledge about electric cars and hybrids, and about their pros and cons as compared to owners of conventional cars. Eventually, they also have a higher level of understanding of the negative environmental effects of car use, thus they feel more responsibility to do something about it.

Nonetheless, this is just a phase that will translate to the next one, namely "early majority" with 34% of the population, over time. Usually the diffusion of a new technology occurs naturally, nevertheless sometimes the diffusion is encouraged and influenced even by third parties as in the case of alternative powered vehicles where both national and international institutions, and to some extent even automakers themselves are trying to encourage the adoption of electric and hybrid vehicles. Indeed, as time passes and as the electric technology evolves and

develops, even the rest of the population will increasingly start to adopt alternative powered vehicles because they will be more used to them and they will have more knowledge of them since more of these vehicles will be on the streets, and even because many of the barriers that inhibit the purchase of an alternative powered vehicle, such as the high upfront price, will likely disappear throughout time.

4.3 BEVs OR PHEVs: WHICH IS MORE LIKELY TO PREVAIL IN THE FUTURE?

Before continuing with the rest of the thesis, it is now time to express a consideration about which type of alternative powered vehicles, namely BEVs or PHEVs, is more likely to prevail and survive in the next future in the world automotive market at the expense of the other.

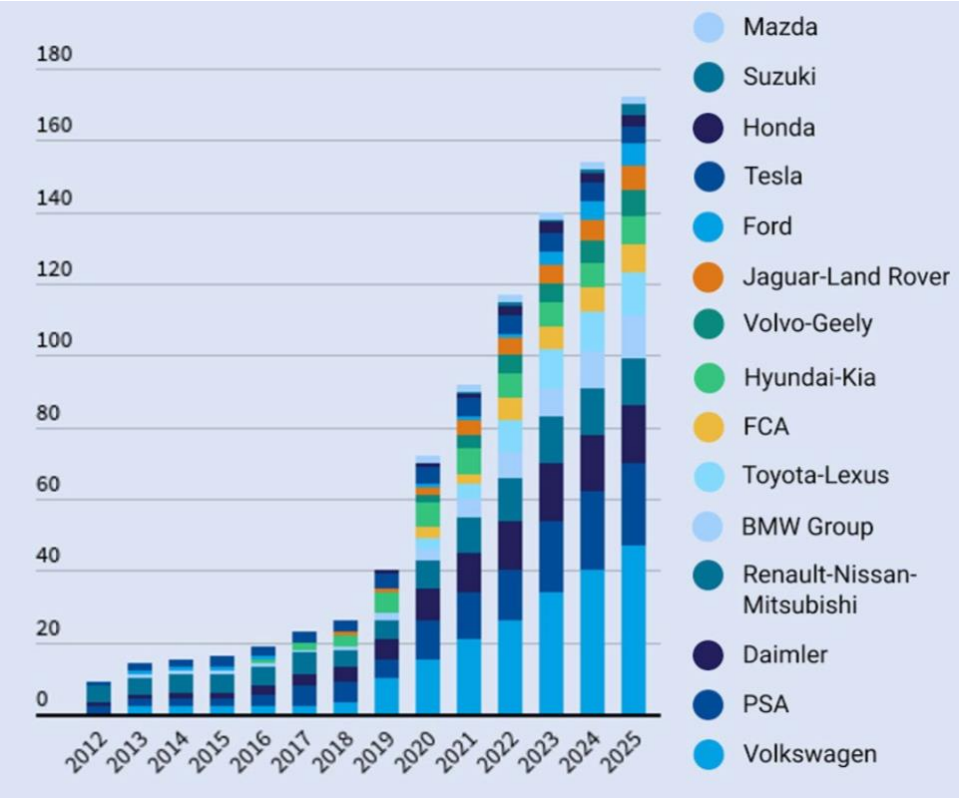
As a matter of fact, during the course of this thesis many times battery electric vehicles and plug-in hybrid electric vehicles have been mentioned and analyzed looking at their characteristics, trends, market shares, sustainability, and so on, however it has never been mentioned nothing regarding their future. Now, I think that enough evidences and data have been gathered in order to give an opinion and an interpretation about where the world automotive market and automakers are directed.

Without lengthen the discourse too much, what data and evidences show is that battery electric vehicles are more likely to prevail in the future as a sustainable and ecological alternative to conventional vehicles.

Indeed, BEVs are already prevailing over PHEVs on several sides as already previously mentioned. Just as few instances, BEVs represent almost two thirds of the alternative powered vehicles share while PHEVs represent only one third, more units of BEVs are sold rather than PHEVs, in addition the majority of the incentives and subsidies benefit BEVs rather than PHEVs showing the will of states and institutions to prefer the former, and eventually BEVs have a lower environmental impact with respect to PHEVs as previously demonstrated with the LCAs analysed. As a matter of fact, hybrids are mainly seen as a good transitional technology by automakers, but also by researchers, scientists, and governments. They are seen as a middle ground between electric and conventional vehicles, as an acceptable alternative while the technology is premature and not enough developed. Therefore, sooner or later they are destined to exit the automotive market, specifically when they will be considered no longer useful. This point of view will fully materialize sooner or later in the future. Indeed, data shows how PHEVs are going over the hill in favour of BEVs. In fact, one example of this point of view is represented by the fact that, as stated by the European Federation of Transport and Environment T&E (2019), in the next years the number of PHEVs that will be introduced in the market will be always lower year after year, whereas the number of BEVs introduced will

augment following a strong linear upward trend, thus eventually increasing the gap among these two types of alternative powered vehicles. This example is graphically represented by the next *Figure 4.6* and *Figure 4.7*[8] which show respectively the number of new BEV and PHEV models available at least in the European market in the next few years.

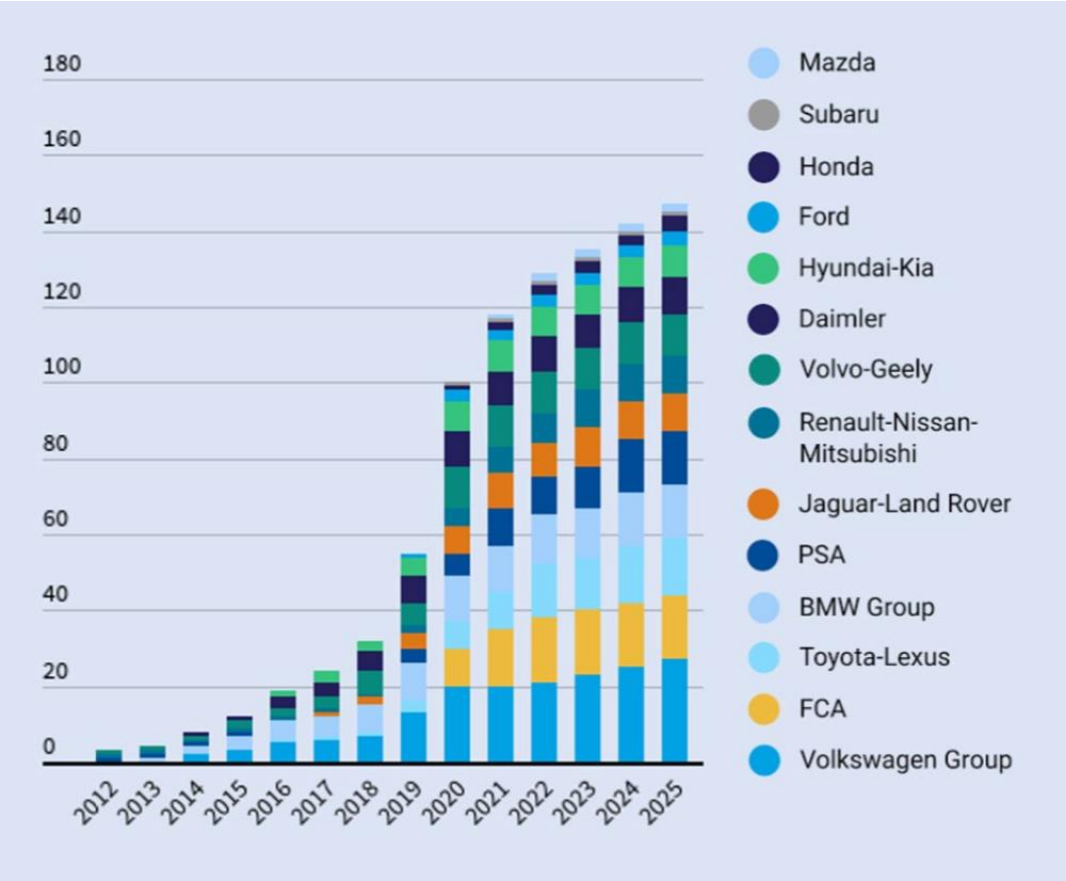
Figure 4.6 - Number of BEV models in the European market (in units).



Source: European Federation for Transport and Environment (T&E).

[8] The analysis performed by T&E considers only major car manufacturers.

Figure 4.7 - Number of PHEV models in the European market (in units).



Source: European Federation for Transport and Environment (T&E).

This fact is corroborated also by the previous cited Deloitte analysis (2020) in paragraph 4.1 in which it was affirmed that BEVs would represent the 81% of the total alternative powered vehicles sold in the world market by 2030.

As a matter of fact, as battery electric vehicles become more reliable and the technologies deployed in them improve, as their costs reduce, and as the policy and regulations become more and more strict throughout time, the alternative powered

vehicles market and its automakers will always focus more on BEVs rather than on PHEVs.

Moreover, noteworthy is also to mention that PHEVs were also preferred at the beginning (and sometimes they are still preferred) by major automakers because they were considered the best available option according to their characteristics and know-how. In fact, they were preferred because automakers had to take into account also their rigidity due to their production scales, their infrastructures, and the size of their business, thus according to them PHEVs were easier to design and produce since they are equipped also with a conventional engine that automakers already know how to produce and exploit efficiently.

That's why even nowadays many automakers choose hybrids to meet the compliance of national policies and targets, and to avoid the quite huge fines potentially imposed if the required targets are not respected, as it will be analysed more deeply later.

CHAPTER FIVE:

AUTOMAKERS STRATEGIES TO TACKLE THE EVOLVING AUTOMOTIVE MARKET

It is now arrived the time to deal with one of the main topics of this thesis, namely the different ways and strategies which automakers use to deal with alternative powered vehicles and to tackle the climate change and environmental issues.

Automakers will be divided into two separate categories: incumbents and newcomers. With the term incumbents are meant the car companies established long time ago that have already a solid position in the world market, whereas with the term newcomers are meant the car companies established not so long ago that only recently have entered the automotive market, therefore they still have to gain a solid position, and a certain relevant market share and brand awareness.

Firstly, in the next paragraph it will be analyzed incumbents and their potential strategies, and only afterwards newcomers and their potential strategies will be taken into account too.

5.1 INCUMBENTS' ANALYSIS

It is not anymore something surprising when an incumbent company announces that it will add some kind of alternative powered vehicle to its auto portfolio, usually

mainly composed by ICE vehicles until recently. Indeed, always more and more incumbent car manufacturers are being added to the list of automakers that have already made this kind of announcement.

In this paragraph, it will be tried to present the main reasons that induce automakers in making this decision, afterwards it will be presented the main strategies that they could adopt, looking also the difficulties that they could encounter in carrying out this transition, and eventually it will be shown few real examples of what some automakers are actually doing.

5.1.1 Reasons that influence incumbents in making the "green choice"

Let's start the analysis by presenting the main reasons for which automakers are introducing alternative powered vehicles in their auto portfolios, in this way pushing them towards the greener alternatives.

Firstly, one reason, that partly has been already presented previously, is the fact that incumbents want to exploit the potential advantages that this market segment can offer in the long run. As a matter of fact, it has been already presented the exponential growth that alternative powered vehicles have experienced and are still experiencing in the world automotive market, and how significant their market share will be in just few years from now (namely 32% of the global car sales in 2030). Therefore, automakers cannot ignore these data and have to deal with the evolving automotive market in order to try to capture some of the alternative

powered vehicles' market share which could become very profitable as the deployed technologies improve, so that eventually they could try to capture as much advantages as possible.

Another reason, partially related to the first one, is that introducing this kind of vehicles, which have been mainly re-proposed and promoted to fight climate change and to preserve the environment, could help incumbent automakers in being seen and perceived as eco-friendly companies that care about the future of the Earth and about the consequences that they could directly have on it. Indeed, it has been already presented how more and more consumers are trying to buy products which have the least possible impact on the environment, so that products' environmental characteristics have become a consumers' driver of choice, thus influencing their choices.

The last reason that is worth mentioning because it is often not considered or underestimated by journalists is that for more and more car manufacturers adding alternative powered vehicles in their portfolios is becoming something essential if they do not want to incur into a fine. In fact, an increasing number of states governments and international institutions are imposing certain emission targets to their national car manufacturers which they have to respect or, otherwise, they would have to pay a fine which is usually quite big in its amount. Just as an example, even the European Union has set to automakers a target aiming at cutting carbon dioxide emissions by 40% between 2007 and 2021. However, just few years ago

automakers were collectively far short of this goal mainly because of the popularity among drivers of heavy, polluting models such as SUVs.

Moreover, EU lawmakers have set a general target that emissions from all new cars sold by an automaker should on average not exceed 95 grams of CO2 per kilometer by 2021. Nevertheless, the target for individual automakers varies because it takes into account the starting weight of each companies' fleet in the base year of 2007.

Figure 5.1 - Automakers gap with the European standard.

Source: Atradius.

However, despite the presence of this policy, many major car manufacturers were far from reaching the imposed emission targets just few years ago, as also shown by *Figure 5.1* which illustrates the actions required by some automakers (namely

Daimler, BMW, FCA and PSA that now have merged and become Stellantis, Renault, and Volkswagen VW) in 2018 in order to achieve the EU emission target by 2021.

According to a research carried out by JATO (2018), the potential total amount of the fine for European automakers amounted up to €34 billion in 2018. That's why many companies introduced and are still introducing BEV and PHEV models in the most recent years in the fastest possible way in order to lower their emissions and to reach the European target, thus avoiding huge fines.

5.1.2 Potential successful strategies to compete in the alternative powered vehicles market

This subparagraph will be devoted to the strategies that incumbents could adopt (or, in some cases, are already adopting) to successfully compete with the other players, both incumbents and newcomers, in the alternative powered vehicles market.

Related to the last mentioned reason in the previous subparagraph, there is the first strategy adopted by many incumbent automakers for developing alternative powered vehicles in a faster way. This strategy consists in signing alliances and cooperating with other automakers, but also with other companies or institutions (such as universities), for jointly researching and developing new technologies and systems to be used in alternative powered vehicles.

Just as an instance, Ford and Volkswagen signed a partnership in 2019 aimed at cooperating in many joint projects that involve electrified vehicles and autonomous drive systems. Another example is the one regarding BMW and Jaguar that agreed to cooperate in developing drive systems for electric cars. One last example comprises Subaru and Toyota that teamed up for building midsize and large segment battery electric vehicles under each brand.

According to the EV consulting firm Atlas Public Policy, a total of 36 companies investing in transportation electrification have established some type of partnership with at least another automaker worldwide, and more partnerships are likely coming up in the next future.

In fact, cooperation helps to shorten the development timeline while at the same time it reduces the risks and the amount of money to be invested individually since these two are split among the partnership's participants. Moreover, thanks to them, new technologies can be introduced in the market more rapidly.

Critical for incumbents will be also signing partnerships with battery manufacturers, in the case in which they do not produce batteries on their own. That's because, there is the real risk of "supply bottlenecks" which happens when the demand of something is higher than its supply so that the whole production slows down. Cases of "supply bottlenecks" have already happened as Audi had to slow down production of electric cars at its plant in Brussels due to a battery cell shortage, as stated by Reuters in one of its articles (2020).

Another strategy that incumbents should follow and apply is the one consisting in focusing and exploiting their brands' power. Indeed, one of the greatest strengths, that an existing incumbent has, is the established customer base and the ability to access markets across the world. In addition, many incumbents have the advantage of having already built a solid trust among its customers over a number of years.

However, relying on an existing brand and reputation has its risks. Environmental sustainability is a key selling point for alternative powered vehicles, and incumbents without credible green credentials, especially those that have had negative press in the last few years over environmental matters, may want their electric and hybrid vehicles to be viewed separately from their core brands. Incumbents aiming for success in the alternative powered vehicles market will have to assess carefully the value of their existing brands in the context of this market. If their green credentials are not considered satisfactory, persevering with an existing brand strategy may end up being a waste of money, time and effort.

Nevertheless, incumbent automakers could also wager on their mainstream and most iconic models, and propose their electric version models which could have a positive impact on nostalgic consumers who have some kind of emotional connection with particular car models, so that they could be induced and convinced in buying the electric or hybrid version of their beloved auto as their next vehicle.

In any case, if incumbents succeed in applying successfully this strategy, they will have an advantage with respect to newcomers which, in contrast, cannot rely on the

power of their brands at least at the beginning, since they are automakers that have no history of vehicles manufacturing behind them.

Related to brand loyalty, there is the need to create a solid customer experience both during the sale process, the in-car driving experience and the aftersales matters. Incumbents have an advantage with respect to newcomers also regarding this side since they have already gained experience in dealing with customers and in offering them the best possible service depending on their needs.

Furthermore, many incumbent automakers, thanks to the fact that they are all experienced companies with solid infrastructures and with a certain production size, could try to apply lower prices to their electric and hybrid vehicles, thus being both more competitive with respect to the other players, and more appealing to the consumers' eyes since, as already been mentioned, the high upfront price of these vehicles is one factor that inhibits many consumers in choosing and buying them. In this way, they would aim at applying a strategy based in achieving and sustaining cost leadership thanks to the exploitation of many things such as scale economies, the use of patents, preferential access to raw materials and other factors.

However, despite these advantages that incumbents could and should apply on their strategies, they must also deal with some difficulties in their transition from conventional vehicles to alternative powered vehicles.

As a matter of fact, incumbents suffer the consequences of being incumbents, meaning that they suffer the rigidities due to their conventional pattern of production.

First of all, incumbents are companies that usually have a lot of production sites and facilities around the world that need a certain amount of money every year in order to survive and to continue operating. A complete shift to alternative powered vehicles would create relevant problems on several sides. The first problem is related to the profitability of electric and hybrid vehicles. Indeed, incumbent automakers still earn almost all of their revenues from cars with internal combustion engines, and they must maintain their entire factory networks that could run into financial difficulties when not running at capacity.

As a matter of fact, both electric and hybrid vehicles are currently much less profitable than similar conventional vehicles. Indeed, according to a research carried out by McKinsey & Company (2020), on average BEVs and PHEVs cost $12,000 more to produce than comparable vehicles powered by ICEs. Furthermore, automakers often struggle to recoup those costs through pricing alone. In particular, in the same research, a survey was posed to automakers, asking them about their expectation of BEVs profitability, and the results were quite interesting. In fact, only 18% of the respondents expected a profit margin above $3,000 per vehicle, whereas more than half expected a margin of less than $1,000 per vehicle.

Another problem for incumbents related to the transition to hybrid and electric vehicles is directly related to their production sites and facilities. As a matter of fact, if they choose to operate this kind of transition, the consequence is that they should also reconvert their factories in order to equip them with the right machines and equipment for producing vehicles powered by batteries. All this process is very costly in terms of money that should be invested for acquiring all the required stuff. Moreover, it should not be ignored also the fact that even workers would need to be trained again in order to acquire the knowledge needed to deal with the electric technology. Again, this would be very costly for automakers, and in any case these companies should also have to employ new high-skilled workers who have a solid knowledge in dealing with batteries and with electronic equipment, such as engineers.

Noteworthy is also the fact that a transition to electric vehicles would have a negative impact on jobs demand. Indeed, a study carried out by FTI Intelligence (2018) affirmed that battery electric vehicles are less labour intensive than conventional vehicles, whereas plug-in hybrid electric vehicles are more labour intensive than all the others since they have both a conventional engine and an electric motor. However, it has already been noticed how BEVs will be predominant in the next future, whereas PHEVs will decrease in importance. Moreover, a research carried out by Ford (2018) found out that electric vehicles will require 30% fewer hours of labor per vehicle and 50% less factory floor space.

All of this means that a lower number of workers and of production sites will be required by incumbents as they transit to producing electric vehicles rather than conventional ones or hybrids, and this will represent also a relevant social problem considering the number of workers employed by them worldwide that would risk to lose their jobs.

For all these reasons, each incumbent will have to do its own considerations regarding what it is better for itself, and as a consequence on how it is better to move into the alternative powered vehicles market.

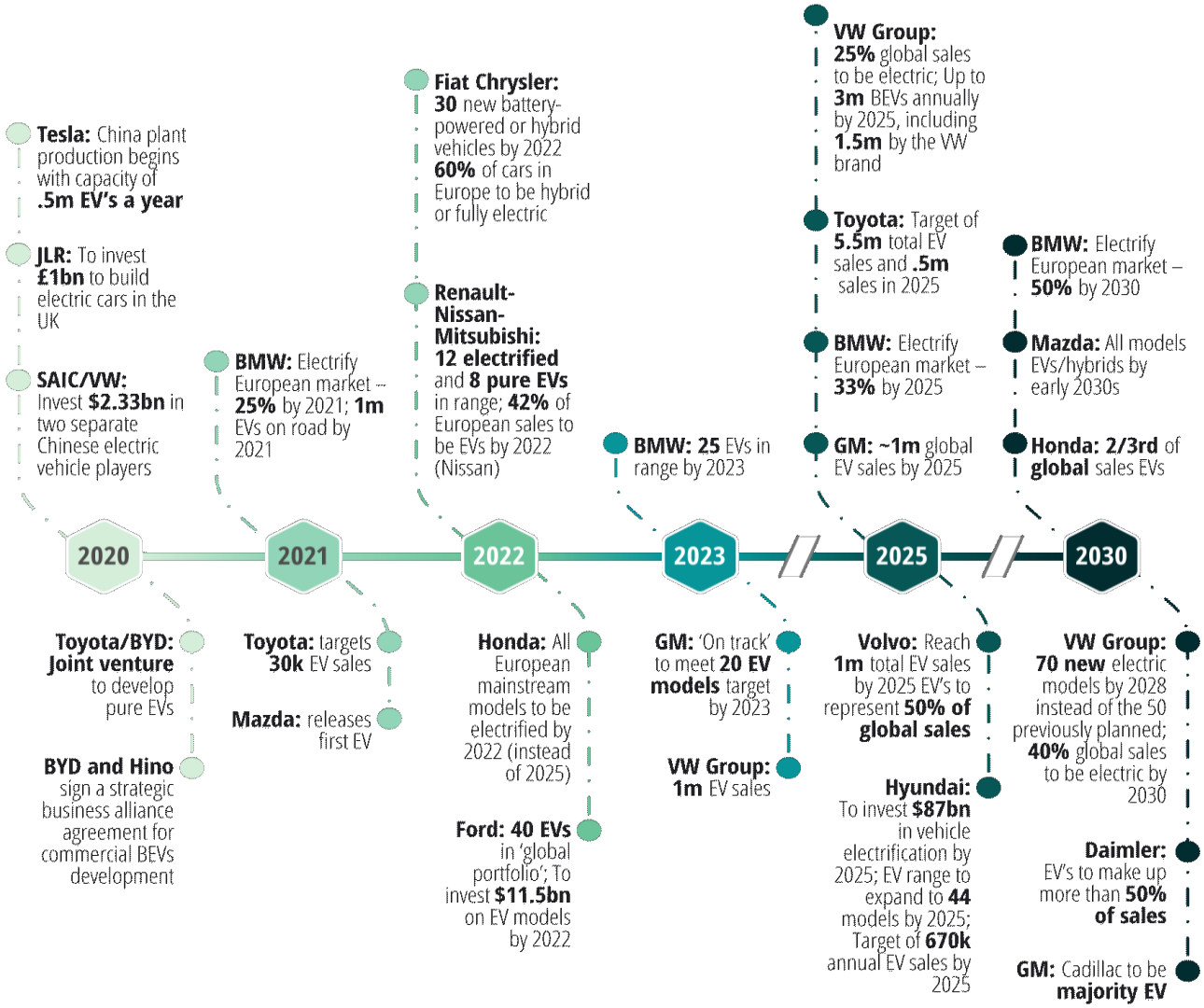
5.1.3 Few real examples on how some major incumbents are actually planning and taking decisions

This first part of the analysis will now end with this subparagraph which presents few real examples showing how some major incumbents are moving into the alternative powered vehicles market.

In the below *Figure 5.2*, it is possible to notice a general overview of some incumbents (such as BMW, Ford, Volkswagen, and others) strategies and targets regarding alternative powered vehicles to meet throughout the years up to 2030. The information included in this figure are based on a Deloitte's research (2020) which analysed also the announcements made by some world famous automakers. As it can be noticed, the figure includes also Tesla Motors, which is not a proper incumbent, but in any case, it currently is the major market player so that it is worth

taking it into account. However, despite the individual plans what this figure really wants to show is how the majority of incumbent automakers are taking actions towards an "electric future".

Figure 5.2 - Some incumbents' strategies and targets over time.



Source: Deloitte.

As it can be noticed, the most common plans and strategies undertaken by these automakers involve mainly three kind of activities: investing, setting targets, and releasing new models in the world's markets.

The first activity refers in investing amounts of money (usually huge amounts in the order of billions) into research and development activities in the field of the electric and battery technologies, and in the realization of alternative powered vehicles (see for instance Jaguar Land Rover JLR 2020, Ford 2022, and Hyundai 2025). On the other hand, setting targets consists in defining a certain number of alternative powered vehicles to be sold by a prechosen year, or in generating a determined revenue deriving from this kind of vehicles (see for instance BMW and Toyota in 2021). Last but not least, releasing new models in the world market consists for incumbents in having a certain number of electric and/or hybrid models in their portfolios to be sold in the various world's markets (see for instance Fiat Chrysler 2022 and General Motors GM 2023).

In particular the last two can be seen as a way for different automakers to set an inner benchmark to understand if they are in line with their plans, or if they need to modify something in their strategies in order to achieve their targets.

As it is possible to understand, all these activities are complementary since they do not exclude each other, but instead they can all be seen as necessary in the different automakers' planning activities.

Moreover, as it can be noticed from the above figure, the further these different objectives are placed in time, the more they are ambitious. This is something quite interesting since it shows the will of incumbent automakers to enter and affirm their presence in the alternative powered vehicles market in a more persistent and solid way year after year.

It will now be analysed more in depth the strategies of three important world incumbent automakers, namely Volkswagen, Ford, and Hyundai.

Let's start with Volkswagen that has planned to introduce 70 new electric and hybrid models in the next ten years stating that it aims at having the 40% of its global sales electric by 2030. Moreover, it has announced that it will install 400 fast-charging stations along Europe's major roads and highways for helping and boosting the transition to electric and hybrid vehicles. Related to Volkswagen is worth mentioning also its subsidiary Electrify America which is a society founded by this company after its diesel emissions scam settlement with the USA and California. Electrify America has the aim of building hundreds of stations and putting thousands of chargers in place all over America, and, in addition, it has to spend $2 billion in this kind of facilities by 2026, as a part of the settlement between Volkswagen and the USA. The obvious final aim is to encourage the electric transition in the USA by providing the needed infrastructures for alternative powered vehicles to its citizens. What is more, Volkswagen itself can take

advantage of this unwanted opportunity by introducing electric and hybrid vehicles in the American market.

Another important incumbent is represented by Ford. Indeed, this American historic company has announced that it will invest $11 billion in the electric technology and that it will have 40 hybrid and electric models in its portfolio by 2022. In fact, Ford aims at being one of the "protagonists" in the alternative powered vehicles market, as also stated by its CEO, Jim Farley, who said during an interview "We're not going to cede the future to anyone". In particular, Ford wagers on its *Mustang Match-E* for boosting the sales of its alternative powered vehicles, since *Mustang* is a world iconic car model renowned and appreciated worldwide. Indeed, Ford's strategy is mainly based on being dominant in segments in which they already are, as again stated by its CEO, "Our electric strategy is very specific. We're going to invest in segments where we're the dominant player and we have scale, like the *F-150*, the *Transit van*, our *Mustang*".

Furthermore, Ford has already announced publicly its ambitious commitment to sell only electric cars in Europe by 2030, making this decision by looking and analysing primarily its sales data for the previous years. In order to achieve this purpose, Ford will invest $1 billion for modernising and renovating its vehicle assembly facility in Cologne, Germany. The investment will transform the existing vehicle assembly operations into the Ford Cologne Electrification Center for the manufacture of electric vehicles, Ford's first such facility in Europe.

Last but not least, Hyundai Motor Company made some importance announcements. In fact, it stated its willingness to become one of the three largest electric car manufacturers worldwide. In order to achieve this target, Hyundai aims at introducing 44 new alternative powered vehicle models which, according to its estimations, should account for 670,000 units sold yearly by 2025. Moreover, this Asian company has announced that it will invest about $87 billion to enhance its leadership in vehicle electrification, autonomous driving and mobility services.

These three companies represent just three examples of how incumbent automakers are planning to enter and become predominant players in the alternative powered vehicles market, but nevertheless they are sufficient to show how incumbents are seriously thinking about putting in place an electric transition in the imminent future.

Worth mentioning as a conclusion is the new racing competition dedicated only to electric vehicles, namely the *Formula E*. This championship was ideated in 2011 and it started officially in 2014 with its first edition. Year after year this championship has become more relevant and it has increased its number of supporters and followers all around the world. The same values also for the participants. Right now, some automakers, that are participating to the current championship, are for instance Audi, Porsche, Mercedes, Nissan, Jaguar, or NIO (a Chinese newcomer), and an increasing number of automakers wants to take part in it for multiple reasons. Firstly, this competition is a nice way for automakers both

to promote their electric vehicles and to let the general audience aware of their intention of producing electric vehicles, since this championship is globally broadcasted through many television channels (such as Italia 1 for Italy), so that the participation to the competition also becomes a great marketing practice for the various car manufacturers. Moreover, the automaker that wins the championship can take advantage of it because being the winner is a sign of its ability in manufacturing and designing these vehicles. Secondly, automakers use this opportunity as an occasion for developing and testing their new technologies and components to study if then they could ever be applied also for street vehicles.

Finally, and most importantly, the *Formula E* represents itself a clear and loud message to the world affirming that is time to move on and to start considering seriously alternative mobility solutions.

5.2 NEWCOMERS' ANALYSIS

It is now time to take into account the "other side of the medal" with respect to incumbent automakers, namely newcomers.

Indeed, newcomers are car manufacturers established and founded in the recent years, so that they are considered as new players in the automotive market, therefore they still have to gain a solid position, a relevant market share, and the consumers' loyalty.

In particular, it has been possible to detect two different types of newcomers in the specific case of the automotive industry: new start-ups or newly founded companies, and already solid companies in other sectors that want to enter also in the automotive one.

The formers are, as their name says, completely new companies who succeeded in raising enough money to start the business and to enter in the automotive market, whereas the latter are already solid and well-known companies in other sectors, such as in the information technology (IT) sector, that want to enter in the automotive market with their own vehicle since they believe that they could compete with both incumbents and other new entrants due to their already gained know-how in the production of something else that could result useful also in the production of vehicles.

For instance, examples of the first type of newcomers are Tesla Motors (which will be deeply analysed in the last chapter of the thesis), Rivian Automotive, NIO, BYD, Nikola Motors, and many other companies mostly based either in the United States or in China. On the other hand, examples of the second type of newcomers are Apple or Dyson (actually Dyson has suspended this project at the moment of writing) which both announced their will of producing an electric car, and according to a research carried out by Deloitte (2019) even some major battery packs manufacturers are aiming at entering the automotive market with their own designed electric cars. Interesting to cite here is a quotation by Akio Toyoda, the

president of the Toyota motor company, who affirmed during an interview "Our competitors no longer just make cars. Companies like Google, Apple, and even Facebook are what I think about at night because after all, we didn't start out by making cars either!".

Despite this inner classification of newcomers, it could be said that in general both categories have the same advantages and disadvantages with respect to incumbent automakers, therefore also the potential strategies, which they could adopt, are the same among all the newcomers, and that is why they will not be divided according to the different type of newcomers.

Moreover, it will not be mentioned here the reasons why these companies try to enter the alternative powered vehicles market since they are the same already listed for incumbent automakers in the previous paragraph, namely that this is an expanding market which is expected to exponentially grow in the next few years pushed both by national states, international institutions, and consumers.

5.2.1 Potential successful strategies for new entrants in the alternative powered vehicles market

Let's start by examining on what newcomer companies should wager in order to be competitive in the alternative powered vehicles market.

Firstly, one advantage, that all these companies have and should exploit with respect to incumbents, is their flexibility. As a matter of fact, newcomers do not

have all the constraints that incumbents have and need to consider. Indeed, newcomers have the advantage of not having already a series of infrastructures and workers behind, so that they can adapt, design and equip their production lines and sites in order for them to be the most possible efficient and effective according to the market needs.

This is an important advantage that should not be underestimated since it has been already outlined how incumbents have to generate a certain yearly revenue in order to run all their infrastructures and facilities, so that they have to make all their decisions also by taking into account these constraints.

Other than that, newcomers should segment the market and focus only in few preferred segments. Indeed, segmenting the consumers market could represent a successful strategy for new entrants. As a matter of fact, by segmenting the consumers market, newcomer automakers could discover what certain consumers need, require and want in their vehicles. In this way, newcomers could focus and target only just one or few segments that they believe to be the most profitable and convenient for them, thus they could design and create vehicle models that have all the characteristics required to satisfy the targeted segments. The result of this strategy theoretically should be convincing the aimed target in choosing and buying the vehicle models which directly address them. The application of this strategy is believed to be critical for newcomers because, otherwise, if they choose not to apply the segmentation strategy and so to produce for a general public, it could be difficult

for them to compete with incumbent automakers. This is also due to the fact that newcomer brands are usually not enough developed and recognized to be chosen and trusted by consumers just because of their loyalty, thus the brand awareness of newcomers needs still to be built.

Related to the segmentation, there is also another characteristic in which new entrants should wager on for becoming known in a faster way in the alternative powered vehicles market, namely differentiation. Indeed, being somehow different is something of essential importance especially for new entrants in the market because it could help them to become more known both to other players and to consumers. At the same time, the fact that in this way you become somehow unique with respect to the others could also allow you to apply premium prices, if your peculiar characteristics are something valued by consumers, so that they are willing to pay more to have them.

A newcomer can differentiate itself in many different ways, such as by segmenting the market, as already said above, because in this case a firm seeks to be unique in the automotive market focusing on some dimensions that are widely valued by buyers, therefore it uniquely positions itself to meet those needs; another way to be different is applying new innovative business models that other companies do not apply, as it will be analysed below.

Indeed, thanks to their flexibility, newcomers could also change their business models in order to adapt to consumers' needs. As a matter of fact, as outlined by a

study carried out by McKinsey & Company (2017), the evolving consumers' needs and necessities require a transition from traditional business models. Indeed, consumers are increasingly looking for mobility solutions that offer greater flexibility, more convenience and cost effectiveness than before, for example they tend to prefer "usership" over ownership. Newcomers in the automotive market have an advantage in this area over their traditionally less agile incumbent rivals. In fact, unrestricted by previous market relationships and technology partnerships rooted in commercial deals, new entrants in the automotive market can build their customer base focusing in business models from the ground up. The reason of it is that offering new and innovative solutions based on consumers' needs could be the key to successfully compete and gain relevance in the alternative powered vehicles market.

Many of this innovative new business models are related to the new trend of shared mobility which is growing especially in urban areas, such as metropolis, and reduces the dependence on privately owned cars and the costs associated to it. Indeed, as stated by an article by Futurebridge (2020), the world is getting increasingly urbanized as currently around 55% of the population lives in urban areas, and this percentage is expected to increase to 68% by 2050. Because of this, road traffic jams have reached new heights for major cities around the world, and that is one of the reasons that induces consumers in looking for mobility alternatives with respect to using a private owned car.

Some of this innovative business models on which newcomers could wager are respectively e-hailing, car sharing, and peer to peer (P2P) car rental.

E-hailing is a service which allows people to order a car, a taxi, a limousine, or any other form of transportation pick up via a digital device (such as a laptop or a mobile phone) in exchange for a previously arranged fare. Just as an instance, two major players in offering e-hailing services are Uber and Lyft. Given the lower costs of both electricity and maintenance in alternative powered vehicles, managers that operate in e-hailing services may prefer to deploy electric or hybrid models over ICE models. That's why, newcomers could offer to this kind of companies more competitive sales and/or leasing options that point out the lower operating costs compared to ICE variants. Moreover, as stated by the previous cited study carried out by McKinsey & Company (2017), a promising sign for this business model is that nowadays consumers are excited about alternative powered vehicle models for e-hailing. Indeed, in their research, more than 30% of consumers affirmed that they would prefer an electric or hybrid model over an ICE model when using e-hailing services. In addition, the research indicates that around 35% of those consumers said they would pay a premium for a ride in an alternative powered vehicle.

On the other hand, with regard to car sharing, it can be said that it is a model of car rental where people rent cars for short periods of time, often by the hour, through the payment of a monthly or mile based subscription fee. Newcomers could try to provide this kind of service directly to consumers or they can provide to other

companies, which already offer this type of service, their alternative powered vehicles through partnerships and collaborations. Moreover, consumers who subscribe to a car sharing program could be incentivized to choose alternative powered vehicles for instance by offering free charging with the service. Indeed, this business model offers to consumers a flexible choice of vehicles based on their needs and does not require consumers to pay a high upfront price for a hybrid and, especially, for an electric vehicle. Just as an example, as a daily commuter, a consumer could pick up a small BEV model during the week, but then trade it in for a larger model for a weekend road trip. In this way, by allowing consumers to change different vehicles, automakers can meet and satisfy all the consumers' needs and necessities.

Last but not least, newcomers could offer peer to peer (P2P) car rental opportunities for their customers. This business model consists in offering the possibility for private individuals to rent out their vehicles when they are not using them. Providing a way to owners of an alternative powered vehicle to share the vehicle they own with other consumers can offset the higher upfront cost of a more capable BEVs or PHEVs equipped also with larger batteries. Furthermore, the P2P model ensures an additional income for these owners and improves the utilization of their cars. Indeed, typically vehicles remain unused more than 96% of the time as affirmed in a study of McKinsey & Company (2017). In fact, vehicles with higher utilization have a much lower total cost of ownership due to lower maintenance,

energy, and driver costs. Newcomers that provide (or partner with) a platform for owners to share their BEVs or PHEVs after purchasing them could remove the cost barrier for buyers who cannot afford these types of vehicles thanks to the additional P2P sharing income. Just as an example, some Tesla owners already use this model today, renting out their cars on P2P sharing apps usually for one week per month.
All the facts mentioned above in this subparagraph should be patiently taken into account and analysed by newcomers when they choose what kind of strategy, they want to use to be effective and successful in the market. As a matter of fact, it would be of fundamental importance to wager on the best possible strategy according also to their characteristics in order to make profits, to gain relevant market shares, to improve brand awareness from consumers, and, most of all, to be able to successfully compete with major automakers.

5.2.2 Few real examples of how some newcomers are moving for consolidating their presence in the automotive market

Again, as for the incumbents' paragraph, also this one will end with few examples of newcomer companies' strategies for the next few years (Tesla will not be included here since this company will have a dedicated chapter right after this one).
Let's start by analysing the Rivian Automotive strategy. This American car company was established in 2009 by the engineer Robert J. Scaringe with the idea of developing and designing sustainable vehicles. In 2017, they announced that they

were developing an all-electric SUV and the first ever all-electric pick up to differentiate from other automaker competitors. Both these models should enter the market between this year and the next one, and they both have caused huge curiosity and received attention from both media and the automotive market players. Furthermore, Amazon decided to invest in this company by funding the creation of its own delivery van designed and produced by Rivian, even though it will be branded Amazon. Indeed, Amazon plans to have 10,000 new electric delivery vans from Rivian on the road as early as 2022 and 100,000 of the vehicles on the road by 2030. Anyway, this partnership could help Rivian in increasing its brand awareness among consumers since Amazon is one of the most renowned and important company in the world.

Another characteristic that differentiates Rivian Automotive from its competitors is the so called “Rivian Remote Care” which enables the company to perform comprehensive diagnostics from afar thanks to its connected vehicle platform; thanks to it, most issues can be identified proactively thanks to their suite of onboard sensors and associated predictive algorithms, so that they can often notify a problem before the consumer even notices it. In this way, Rivian could prevent its consumers from waiting for substitute parts and components, thus reducing the maintenance time.

Rivian Automotive, as stated before, could be considered as an example of the first type of newcomers, namely amongst the new start-ups category.

On the other hand, an example of the other type of newcomers, namely already existing and operating companies in other sectors, is represented by Apple.

As a matter of fact, Apple is investing money in the creation of its own *Apple Car* which is expected to enter the market in the next few years (approximately in 2025). The project started in 2014 under the name “Project Titan” and Apple tried to keep it as secret as possible, but they failed since there has been many leaks over time. As some rumors heard by JP Morgan analysts stated, Apple’s will is to apply a “go big or go home” approach in the automotive market, meaning that their will is to control the pace of innovation to differentiate the *Apple Car* and position it in the growing market of BEVs that are fully autonomous. Indeed, the *Apple Car* is designed to be a full self-driving electric vehicle. Moreover, Apple analyst Ming-Chi Kuo believes this car will be the company's "next star product" with Apple capable to offer a better and deeper integration of hardware, software and services than potential competitors in the automotive market, thus aiming at creating a 360 degrees Apple ecosystem with its other products.

These two companies represent just two examples of how newcomer automakers of different types are planning to enter and become competitive players in the alternative powered vehicles market. They will be able to do that thanks to their ability of planning an effective strategy based on the exploitation of their strengths and on the differentiation from their competitors based on some kind of innovation that would justify and permit them to apply premium prices to their vehicles.

5.3 THE "EXPECTATION GAP"

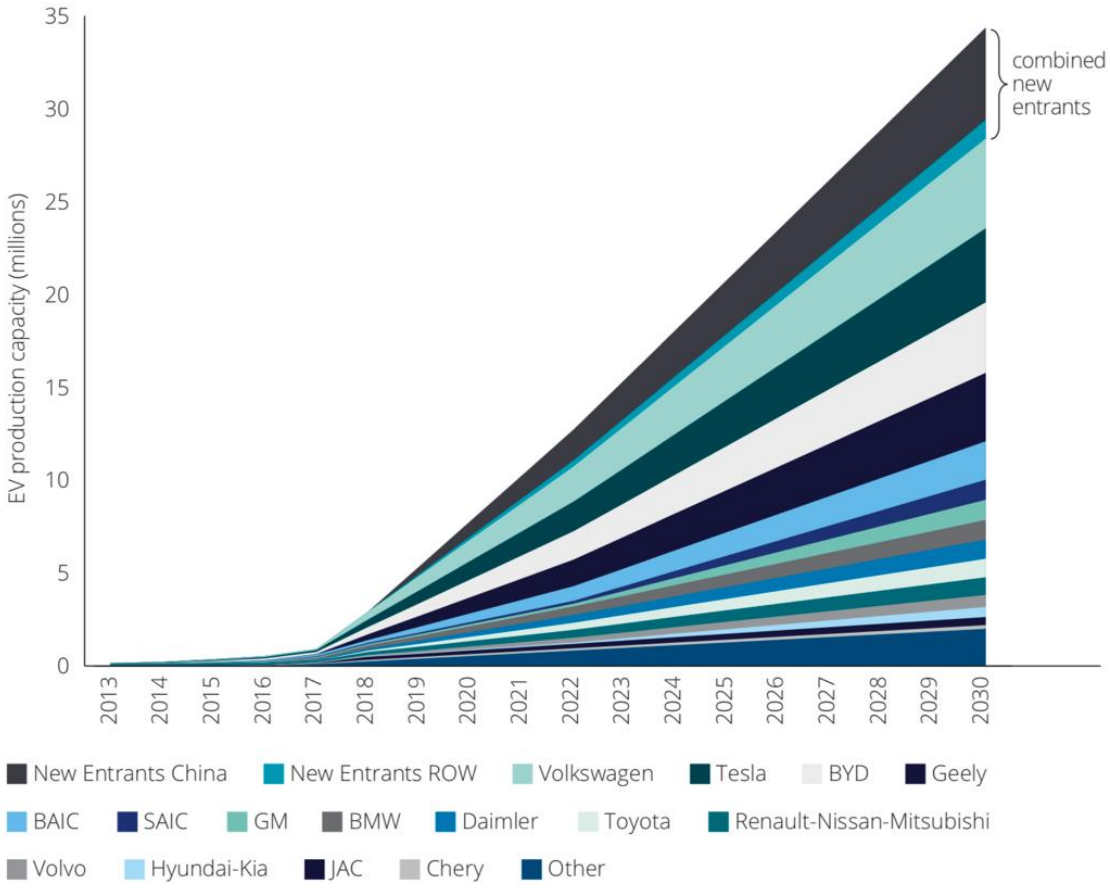
This chapter will now end by describing a potential threat that could affect both incumbent and newcomer automakers. As a matter of fact, in the alternative powered vehicles market is very likely that there will be winners and losers which are destined to exit this market or, in the worst case, to declare bankruptcy.

The reason of this threat is related to the fact that nowadays almost all of the major incumbent automakers have planned to enter this market to exploit its opportunities, and the same values also for newcomers as a lot of start-ups have been founded with the aim of entering this market and eventually even other popular companies have announced their will of entering the automotive market. All of this will result in a discrepancy among the supply and the demand side of the market; this discrepancy goes under the name "expectation gap".

In fact, according to forecasts computed by Deloitte (2019), the alternative powered vehicles production, dominated by BEVs, will reach 35 million units in 2030, as represented in *Figure 5.3*.

However, the problem is that the market demand will not grow with the same pace ending up in generating a discrepancy between the supply and the demand sides.

Figure 5.3 - Alternative powered vehicles production forecast of major incumbent and newcomer automakers.



Source: Deloitte.

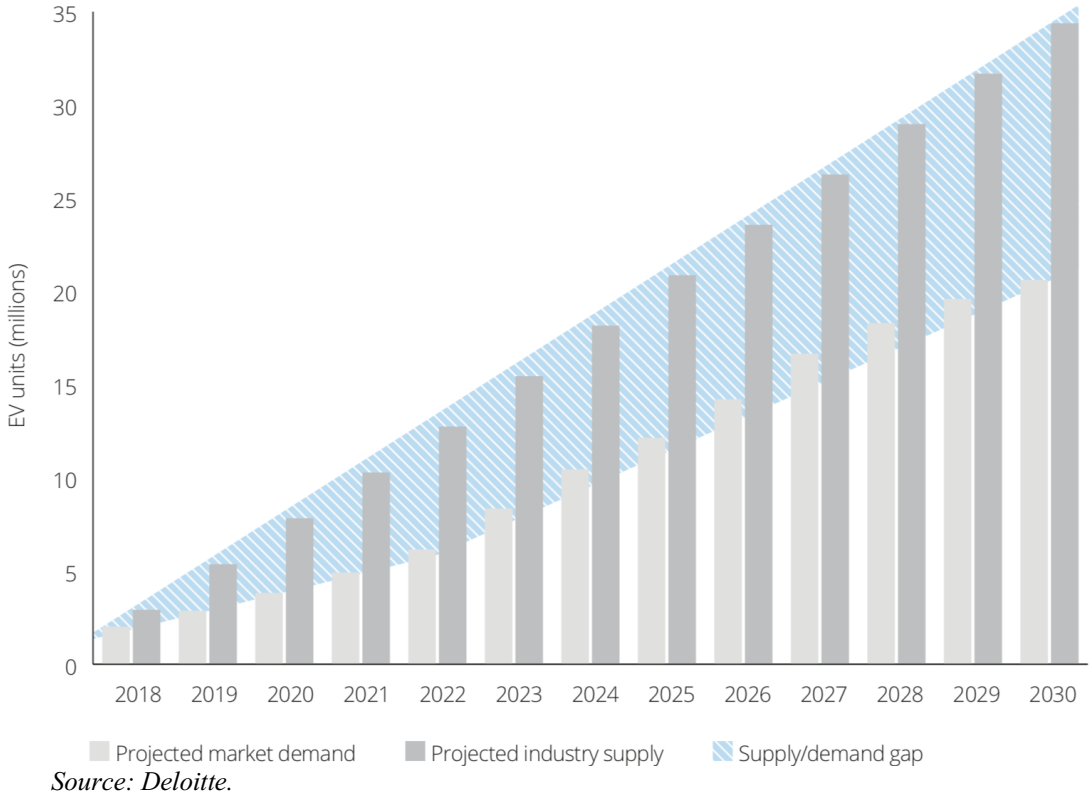
Newcomers also represent a substantial threat to incumbents' status-quo; indeed, their combined market share will be the largest in the world, with the majority of them coming from or operating either in China or in the USA. With many incumbents planning a significant increase in the level of BEVs and PHEVs production over the next decade, the number of potential manufacturers appears

unsustainable. Based on Deloitte forecasts, the overall industry capacity, shown in *Figure 5.3*, is approximately 14 million units above the forecasted consumer demand for alternative powered vehicles in 2030 as it can be noticed in *Figure 4.1*. This discrepancy is expected to grow year after year as this market grows throughout time; the growing gap between demand and capacity could be graphically observed in the below *Figure 5.4*.

That's why based on these figures and forecasts, it is not inconceivable that some incumbent automakers will be out of business beyond 2030, while it is highly likely that not all the newcomer start-ups will survive. Indeed, since the beginning of last decade, many electric vehicle start-ups tried and failed to create a sustainable electric car; some of the most notable are Bright Automotive, AMP, Aptera, Coda, Detroit Electric, Fisker Automotive, and LeEco. What is interesting is that while some of them were seriously underfunded, others were able to raise and generate plenty of cash. Just as an instance, Fisker, one of the most popular and debated case, raised more than $2 billion in cash and, unlike some of the other start-ups, did manage to put a vehicle, the plug-in hybrid *Karma*, into production. Each start-up ran into unique issues, however underestimating financial needs is believed to be the common thread running through many of these electric vehicle companies' failures. In fact, the various start-ups have found out that building a car is a lot more complicated than they thought, even if an electric powertrain is simpler than a conventional powertrain.

On the other hand, those companies that survive will undoubtedly face major changes to their existing business models and strategies for adapting to the new needs and necessities that consumers have about mobility and to appear as the best and the right choice at the consumers' eyes, as already deeply described in the previous paragraphs.

Figure 5.4 - Alternative powered vehicles: market demand vs industry supply.



Source: Deloitte.

5.3.1 Factors and characteristics that could determine the success or the failure of automakers in the alternative powered vehicles market

After having described and analysed what is the "expectation gap" and why it could represent a threat both to incumbent and newcomer automakers, it will be tried to outline some factors which could determine if a car manufacturer will be able to survive and succeed in the alternative powered vehicles market, or if, on the contrary, a car manufacturer will fail in affirming itself. The choice of the factors will be based on the previous considerations and reasonings made both during this chapter, but also during the rest of the thesis in order to be sure to treat all the important matters. In particular, seven factors have been detected as the most important ones: adaptability, price, signing partnerships with key subjects, ability to differentiate, ability to innovate, promptness in responding to market trends, and exploiting and understanding strengths. The companies, which will be able to understand and to exploit as many factors as they can in the most efficient ways, are the ones that most likely will survive and become relevant players in the alternative powered vehicles market, whereas the others are the ones that will find more difficulties in remaining into this market as they will be in the so-called "red ocean", the market position in which there are more direct competitors. That's because these companies will not be able to somehow differentiate and have some competitive advantages with respect to the other market players.

All the factors that are going to be taken into account in this final analysis will be considered from the point of view of the two types of players present in the examined market, namely incumbents and newcomers, in order to investigate how important they could be for them, therefore how relevant they should be to them. Moreover, this final analysis will be presented on a table with the purpose of making it both easy to read and understand, but also to give instantly to the readers the tools needed to compare the two types of players in the alternative powered vehicles market.

Table 5.1 - Factors that could determine the success of an automaker in the alternative powered vehicles market

	Incumbents	**Newcomers**
Adaptability	Most incumbents lack of adaptability in the near term due to the presence of all the rigidities and constraints that they suffer from the production of conventional vehicles. The faster they will be able to adapt to the new patterns required by alternative powered vehicles (and especially by BEVs), the more the probabilities to succeed and effectively compete.	New entrants in the market have as one of the main advantages their inner adaptability to the new market in which they want to enter. This derives from the fact that they are new players, thus they can immediately adapt and adopt the structures that the market requires since they have not established them yet. They should exploit this factor as much as they can to be

		quicker than the other players in applying the best possible business models.
Price	One factor that could be of critical importance for incumbents is their ability of applying lower costs with respect to other competitors. Thanks to their already existing scale economies and their experience in producing vehicles, they have this possibility which they should use it in order to apply the so-called "cost leadership" strategy.	Newcomers do not have the same means and opportunities of incumbents. That is why they should not try to compete with other players basing their strategy on applying lower prices.
Signing partnerships with key subjects	Both for incumbents and newcomers will be extremely important to sign partnerships to succeed in this market. Partnerships help market players to develop better vehicles in less time. Indeed, signing partnerships with key subjects, such as battery packs manufacturers, could be one of the main critical factors since they could help you in having the best possible components for a vehicle, and, more importantly, you could have them also in periods when it is hard to find them (see the phenomenon of "supply bottlenecks"). All of this will probably be easier for incumbents since they are more renowned than newcomers and they could potentially offer better counterparts. Thanks to this fact, they will probably have a higher bargaining power.	
Ability to differentiate	This factor will be of less importance for incumbent automakers since they are already well-known for the	The ability to differentiate from other competitors will be of vital importance for new entrants because this

	production of conventional vehicles. However, they should not underestimate this factor, but, on the contrary, they should also try to differentiate themselves from other competitors.	could represent a way for them to be unique, but also to become known and recognizable among other market players at the consumers' eyes. This practice could consist also in segmenting the market and in targeting specific segments. Those, who perceive the ways in which you are different and find them valuable, could be willing to pay a premium price for your vehicles.
Ability to innovate	The ability to introduce an innovation could be of primary significance and relevance for succeeding and becoming a major player in the market, especially in new growing markets as the alternative powered vehicles one. Innovations could be of different kinds and of different importance (such as enhancing a component of the vehicle, increasing the batteries' performance, or introducing a new type of vehicle), but, in any case, they can definitely help a company to flourish and prevail over other competitors. In particular, regarding this factor, it will be worth to keep an eye on the sphere of autonomous and self-driving vehicles since many automakers have already expressed their interest on them (see for instance Ford or Apple).	
Promptness in responding to market trends	Thanks to their well affirmed and established presence on the world's markets through their retailers' networks and commercial deals, incumbents can detect in a faster way the various trends	New entrants still have to establish a solid communication network. They often receive different markets information in a slower way and that could represent a disadvantage for

	in the different world's markets and they can try to exploit them to be successful also in the alternative powered vehicles market. Just as an instance, they could be able to detect what market is more profitable and flourishing, therefore if it is better to focus their attention, efforts, and investments for example in the European or in the American markets, looking on how the consumers' demand changes and evolves over time.	them. However, they could try to overcome this problem through some kind of collaboration or partnership with market analysis companies for gaining as much information as they can.
Exploiting and understanding strengths	Both incumbents and newcomers should carry out an internal analysis of their strengths and weaknesses in order to understand what is the best possible strategy that they should adopt to achieve the best possible performance according to their characteristics. In fact, if a company does not understand its peculiar characteristics (both the positive and the negative ones), it would always be underperforming and it could apply a strategy not suitable to it, so that it could experience problems and it could not be so much competitive in the market, thus eventually it could have to exit it or, in the worst case, it could have to declare bankruptcy.	

CHAPTER SIX:

TESLA CASE STUDY: THE STORY OF A SUCCESSFUL NEWCOMER

This master thesis will now end with a final chapter which is going to narrate the case of the most successful newcomer in the alternative powered vehicles market, namely Tesla, inc. (formerly Tesla Motors).

Particularly, this chapter has the aim of explaining how this company was established and how it has developed and expanded up to the present day. Furthermore, a deeper analysis will be carried out to show which were the strategies adopted by this company to achieve such great results in such a short period of time.

6.1 THE ROAD FROM A START-UP TO A MARKET PROTAGONIST

This first paragraph has the aim of introducing the Tesla company, narrating briefly how and when this start-up was established and telling what have been the main steps that marked its history up to the present day and that contributed to the creation of the iconic car company that Tesla is nowadays.

Particularly, the first subparagraph will cover from the establishment of Tesla up to the achievement of full brand awareness by global consumers with the introduction of the *Model S*; on the other hand, the second subparagraph will deal with the rest

of Tesla's history describing how it has developed from that moment until nowadays.

6.1.1 From the foundation to achieving brand awareness

Tesla was founded in the Silicon Valley by Martin Eberhard and Marc Tarpenning in 2003. Soon after, they were joined and funded by Elon Musk, who has served as chairman since 2004. Musk was already exposed to entrepreneurial endeavors, notably as a co-founder of PayPal, SpaceX, and SolarCity. The company's initial goal was to produce full-electric sports cars that were compelling for their performance, aesthetics, and sex appeal. That is why, the company specialized in producing electric vehicles using lithium-ion battery for energy storage and subsiding the establishment of solar panels. Compared to the traditional vehicles that rely heavily on the combustion of fossil fuel gas to supply energy to vehicles, Tesla pioneered the use of renewable energy to generate clean energy to power its vehicles, laying out a strong foundation for the development of the electric vehicles industry.

The vision was to manufacture mass market battery electric vehicles that offered a compelling customer value proposition including long range and recharging flexibility, energy efficiency, low cost of ownership and high performance without compromising design or functionality, and, ever since its establishment, Tesla has undergone rapid market development worldwide due to its influential role in the

alternative powered vehicles market and thanks to its advanced technological innovations regarding batteries and electric vehicles.

Initially, Tesla debuted in the world market with the Tesla *Roadster* in 2008. The *Roadster* was a premium BEV sports car based on the Lotus *Elise* platform. The intent was simply to replace the internal combustion engine (ICE) powertrain with an electric one. That is because at the beginning Tesla did not plan to develop a vehicle from scratch, and for this reason, they set up a design competition whose winner was Lotus presenting a vehicle similar to the Lotus *Elise*. Since then, a close partnership between Tesla and Lotus lasted for many years.

Musk had a critical role in designing and developing the first prototypes of the *Roadster* which were introduced to the public in 2006 and achieved an unprecedented range of 394 km on a single charge during company tests.

The market launch was accompanied by intense media attention and backed by many celebrities such as Leonardo DiCaprio, Jay Leno, and George Clooney, who paid $109,000 in advance to receive one of the first 100 *Roadsters*, which were scheduled to be delivered in 2007. However, the first *Roadster* was not delivered before 2008.

Tesla had the *Roadster* in its catalogue from 2008 and 2012, period in which it sold an approximate total amount of 2,450 units of this model.

In the meanwhile, Tesla started to work on the *Model S* in 2007 and by March 2009 it had finished the prototype design. In contrast to the approach used with the

Roadster, Tesla hired a team of experienced automotive engineering and manufacturing specialists to design and develop this new model, with experience at companies such as Audi, BMW, GM, Jaguar, Mazda and Toyota. Therefore, engineers from leading automobile companies were hired, alongside with engineers with electrical, electronic and IT backgrounds from the leading Silicon Valley firms.

In 2010, 2011, and 2012 Tesla had, respectively, 899, 1417, and 2964 employees. Of a total of 1417 employees (which the company had at that time), Tesla had 315 (22%) employees working in R&D and 216 (15%) employees working in Design and Engineering, which was a much higher percentage than the one of a traditional car company.

The characteristics of the *Model S* were a sleek design with an all-aluminum light weight body. Tesla abandoned the conventional ICE layout and equipped the battery packs on a large rigid and flat floor. This led to a low center of gravity and to a good weight distribution between the front and rear axles, which in turn gave very good handling. The electric motors and the gearbox were located at each wheel and designed around the battery packs. The number of moving parts was very small, reducing noise and vibration. The *Model S* design choices led it to achieving the highest safety ratings in history and the car becoming the most awarded car of 2013. The large floor space enabled Tesla to install battery capacities up to 85kWh, so that the car could run for up to 300 miles with a single charge. Thanks to these

characteristics, the *Model S* was the first luxury BEV sedan with high performance, accelerating faster than many sports cars, with some models reaching 60mph (100 kmh) in just 3 seconds.

The *Model S* also incorporated at lot of innovation from the IT sector, including an electronic dashboard and a 17" touch screen, which enabled all controls of the car to be manipulated. The embedded IT functionality, allowed features such as the summon feature, auto parking and autopilot to be incorporated. The combination of a heavier use of electronic components, fewer moving parts and online connectivity, meant that Tesla vehicles could be upgraded via software easily and much more substantially than conventional ICE cars. The *Model S* was officially released in the market in 2012 and since that time 350,000 units have been approximately delivered all around the world. The release of the *Model S* in the world's markets permitted Tesla to become renowned also not only by the car experts and enthusiasts, but also by the more general public. All of this because of the peculiar and unique characteristics, listed above, that this car model possessed. Thus, Tesla passed from being only one of the many start-ups to becoming one recognized player of the automotive industry and market.

However, Tesla had also to deal with some problem and difficulties that threated the existence of the company itself. Indeed, the period during which the *Model S* was being designed (2007-2012) was a tough period for Tesla because it had to deal with financial difficulties which risked the company to declare bankruptcy. As a

matter of fact, when the economic crisis hit in 2008, and the financial markets dried up, Tesla cash reserves reached a critical level. Despite the continuous improvement of financial figures due to increased production efficiencies and renegotiated supplier contracts, the company was facing "near-death experience". That is one of the reasons that induced Tesla to sign partnerships of different types and with different aims with other companies, such as Daimler, Toyota and Panasonic, which invested on the Tesla vision and ideas. Other than that, the company received a loan of $465 million by the US Department of Energy (DOE) in 2009 few months after having unveiled the *Model S* to support engineering, production and assembly of the new model and for the development of a manufacturing facility to build electric vehicle powertrain components. Moreover, in June 2010, Tesla conducted an initial public offering (IPO) on the New York Stock Exchange, becoming the first new US automobile company to do so since Ford in 1956. In this way, Tesla raised $226 million from the IPO, valuing the company $2 billion.

Another essential step for the company during this period was the purchase of the NUMMI factory in California for $42 million from Toyota in 2009. The factory had a productive capacity of up to 450,000 cars per year that helped Tesla to expand its production capabilities. In addition, Tesla adopted a vertical integration model to a much larger degree than other automobile companies. This approach helped Tesla to learn quickly and to maintain control of all the key design details and of all the critical phases of the production process. As it will explained later, Tesla went

further by vertically integrating also its distribution channel and by building its own network of charging stations, the so-called “Superchargers”.

6.1.2 Becoming a protagonist

From this moment, Tesla started to expand its market by designing and introducing to the world’s markets new models in order to compete in all the different customer segments and to become an automaker not restricted only to a niche market and few potential customers. The market strategy adopted by Tesla permitted the company to expand gradually throughout time and to become always more acknowledged by the consumers’ audience, and relevant to the other global automakers. Eventually, as it will be possible to notice at the end of this subparagraph, Tesla became a protagonist and one of the most important players of the alternative powered vehicles market.

After the *Models S*, firstly Tesla developed the *Model X*, a mid-size BEV luxury crossover, developed from the full-sized sedan platform of the *Model S*. The prototype was unveiled at Tesla's design studios in Hawthorne (California) in 2012; thereafter, it was officially released in the market in 2015.

In this same year, Tesla announced the *Model 3*. This model represents another breakthrough in Tesla’s history since it represents the first “affordable” electric car by Tesla designed for the mass market since it costs approximately only $35,000, much less than the other Tesla models. Noteworthy is the fact that during the *Model*

3 unveiling event in 2016, Tesla affirmed that over 115,000 people reserved the *Model 3* in less than 24 hours prior, more cars than Tesla had sold by that time. Twenty-four hours after opening reservations, Tesla had advanced orders for over 180,000 cars. Two days later, Tesla affirmed they had 232,000 reservations. The *Model 3* was then officially launched into the market in 2017, becoming one of the most sold alternative powered vehicles in the global market (actually the most sold in 2019 as already written in the previous chapters). The last model released by Tesla is the *Model Y*, an electric compact crossover utility vehicle (CUV) unveiled in 2019 and subsequently introduced into the market in 2020.

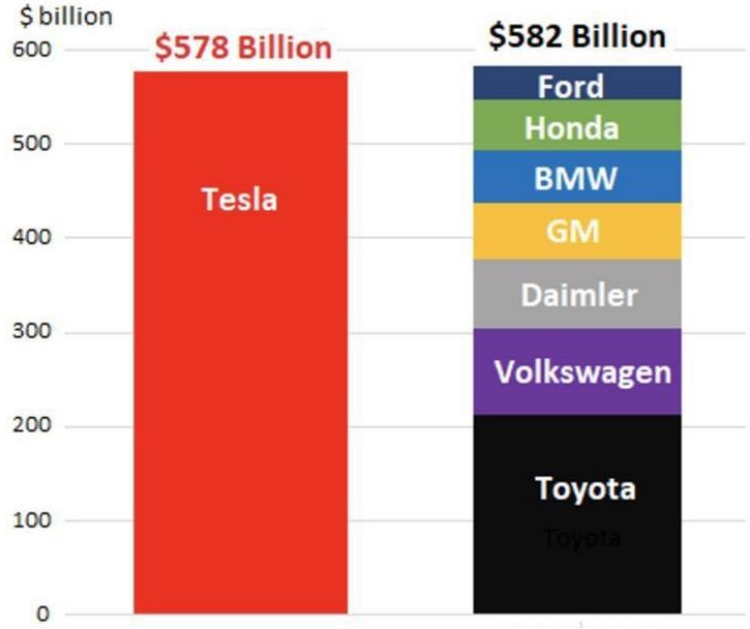
At the moment of writing, Tesla has already announced other models that will be part of its catalogue and that will be started to be sold in the next few months or years, depending on the model. In particular, the models already announced are the Tesla *Cybertruck*, a new version of the *Roadster*, and the Tesla *Semi*. Noteworthy is that the *Cybertruck* received an astonishing amount of 200,000 pre-orders within the first month in which it was presented in its unveiling event in 2019, and it is expected to enter the market sometime between 2021 and 2022. The new Tesla *Roadster* was unveiled as a concept car in November 2017, and it is stated by Musk that the second-generation *Roadster* outperforms its predecessor by adding two small rear seats, by significantly more driving range, and by a much higher level of performance. Indeed, Musk boasted about a 1.9 second 60mph (100kmh) time and a 250mph (400kmh) top speed.

What is interesting to add after having briefly exposed Tesla's history as automaker is that this company not only produces and commercializes vehicles, but it also produces batteries that it sells to other companies all around the world and even to other car companies. Moreover, this company offers also energy solutions by producing and commercializing Solar Panels, Solar Roof, and the Powerwall. These are all devices that exploit solar energy which will be stored in order to use it only when necessary.

Currently, Tesla produces all its products in the so-called "Gigafactories" which are located in various regions of the world; as of today, there are four "Gigafactories", namely two in the USA, one in Germany and one in China, plus the Tesla Factory in California and the Tesla facilities in the Netherlands. Moreover, new "Gigafactories" are already planned to be built in other world's locations in the next years.

As of 2021, Tesla reached a market capitalization of $655.79 billion becoming in this way the world's 8th most valuable company and scoring better than most of the renowned incumbent automakers, such as General Motors or Ford. Actually, thanks to this incredibly huge value, Tesla is more valuable than the next five largest automotive manufacturers combined, including some of the world's largest, such as Toyota, Volkswagen, and Daimler, as it is possible to notice from *Figure 6.1* which shows the value of 2020.

Figure 6.1 - Tesla market capitalization comparison in USD, 2020.

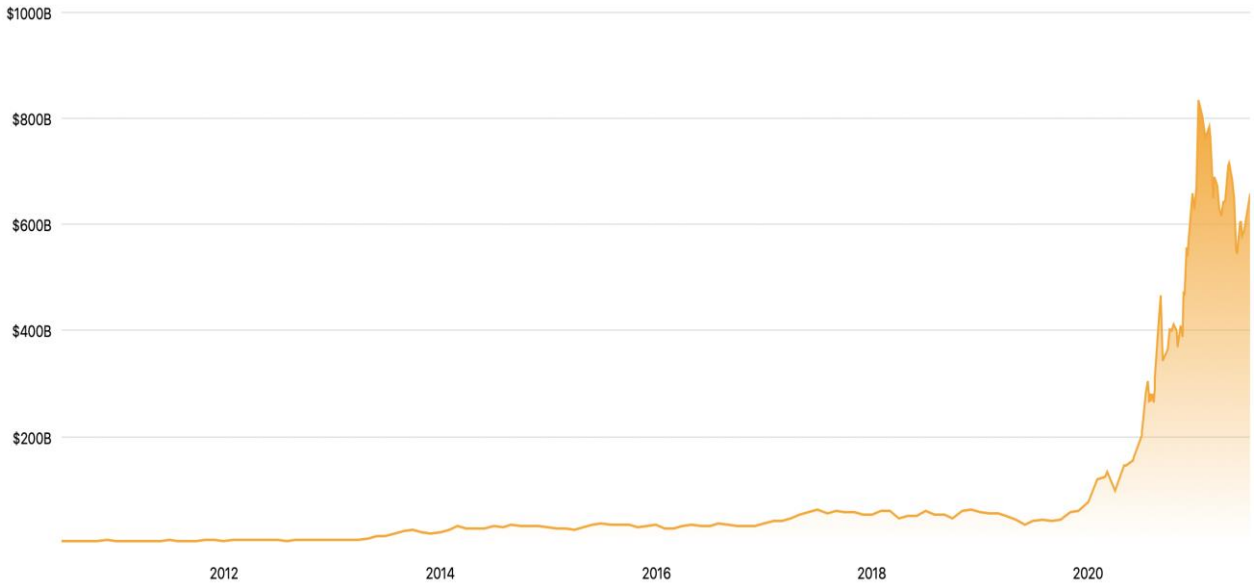


Source: Wolfstreet.

What is also interesting to analyse is the spectacular growth that Tesla experienced since its entrance in the stock market. As a matter of fact, from 2010 where its market capitalization value amounted to around $2.20 billion, it passed to the current value of about $650 billion exhibiting a huge growth in a relatively short period of time.

In particular, Tesla took off during 2020 where it experienced a growth of 783% with respect to the previous year. The stunning growth that tesla experienced could be better understood by looking at *Figure 6.2* which shows exactly Tesla's growth curve throughout time.

Figure 6.2 - Tesla's market capitalization throughout time.



Source: Companiesmarketcap.

Moreover, Tesla has been awarded as one of the most innovative companies of the world according to the prestigious ranking of the Boston Consulting Group (BCG). Notably, in 2020 Tesla ranked 1st among the world's automakers regarding its innovation performance, while it ranked 11th if all the different types of companies are taken into account. After Tesla, the second automaker that can be found in the general ranking is Volkswagen which ranked 32nd in the same year, with a gap of 21 positions with the American company.

This is just a brief story which narrated the journey that Tesla undertook to evolve from just one of the many start-up companies to one of the most important automakers of the current period, being also the most important one with the best

performance if it is considered only the alternative powered vehicles market, as already stated in the previous chapters.

In the next paragraph, it will be analysed what strategies Tesla adopted to achieve all these stunning results and how it is innovative and different with respect to the other automakers operating in the market.

6.2 HOW TESLA BECAME SUCCESSFUL

After having briefly narrated the story of how Tesla passed from being just one of the many start-ups in the automotive sector to holding the leadership of the alternative powered vehicles market, it is now time to try to explain what caused Tesla to obtain all this success and how it has been able to grow in such an astonishing way up to the moment of writing.

Let's start by stating the fact that Tesla is considered by many not just as a simple automaker, and indeed it is much more. In fact, many financial analysts and investors consider Tesla more as an IT company since it does much more than just producing and commercializing vehicles. As a matter of fact, as already stated before, even though producing cars is Tesla's main activity and it is the one activity that generates the highest revenue stream (according to Investopedia around the 94% of the total revenue), Tesla is also into the energy generation and storage

market with many products, such as the Solar Roof or the Powerwall, which generate the remaining of the Tesla's total revenue.

Specifically, it will now be examined in the rest of the chapter all the innovations (or at the least the majority of them), which Tesla, and in particular Elon Musk, adopted during all these years, that permitted this company to be placed among the most innovative, important, and successful firms of this historical period.

6.2.1 Tesla business idea

"Our goal when we created Tesla a decade ago was the same as it is today: to accelerate the advent of sustainable transport by bringing compelling mass market electric cars to market as soon as possible." (Elon Musk, 2013)

These are the exact words used by Elon Musk to describe the mission of Tesla. However, Musk was aware of the fact the Tesla could not have entered the mass market since the beginning with an affordable car potentially purchasable by the large audience. As a matter of fact, this was simply impossible to achieve for a start-up company that had never built a car and that had one technology iteration and no economies of scale. Indeed, acknowledging the fact that Tesla was not able to design and commercialize a cheap vehicle due to the fact that it could not have been able to compete with the other automakers operating in the global markets, Tesla decided to adopt a peculiar approach to establish itself in the market. Instead of trying to build a relatively affordable car that it could mass-produce and market, it

took the opposite approach, focusing instead on creating a compelling and unconventional car which would create a demand for electric vehicles.

In fact, both Musk and Tesla knew that their first product was going to be expensive no matter what it looked like, so they decided to build a sports car, namely the Tesla *Roadster*, as that seemed like the best way of trying to be competitive with its gasoline alternatives.

Indeed, the strategy adopted by Tesla was to enter at the high end of the market, where customers are prepared to pay a premium, and then drive down market as fast as possible to higher unit volume and lower prices with each successive model. That is exactly what Tesla did. Indeed, it entered the market in 2008 with the *Roadster* that had a starting price of around $110,000. Afterwards, it continued by designing and commercializing vehicles with lower prices but always with great performance and characteristics throughout time, and it ended up in commercializing the *Model 3* that has a current starting price of about $35,000. Now the company wants to continue in this direction in order to offer compelling vehicles to the different market's segments in order to satisfy all the different needs and necessities that each potential customer could have.

6.2.2 Vertical integration and strategic partnerships

Vertical integration is the process of acquiring and controlling different phases of the same production process.

The choice to be vertically integrated could be made for many different reasons, including to reduce uncertainty and dependency on other third parties, to build faster and with lower costs, to improve your control on the most important phases of the supply chain (such as in the definition of the vehicle architecture or in the production process and product quality), and to optimize the delivery time.

Tesla initially decided to apply this strategy because of the many advantages listed above, but also because it believed that it had no other way other than integrating products vertically to push innovation as high as possible. Indeed, Elon Musk believed that the production of strategic products in-house was the key to success. Other than that, there will be no dependence on the various suppliers, so that the company does not risk suffering the consequences of the so-called "supply bottlenecks". Noteworthy to mention is that initially the cost of vertical integration is higher, but once you set it up, you will make more money.

At the present day, thanks to vertical integration Tesla has much more control over its manufacturing process, it has a faster response to the changes needed, and all at a lower cost by cutting out the intermediaries and the suppliers. As a matter of fact, Tesla makes by itself the most fundamental parts of its vehicles, and indeed it manufactures its own batteries, electronics, and most of the other vehicles' components as the car seats. Moreover, Tesla has also its own showrooms, the so-called "Galleries", ensuring that it can control all the aspects of the customer experience. All of this allows the company to build highly customized and superior

components. However, it's not just about quality as in 2016 Elon Musk said that Tesla would be increasing vertical integration in order to "have the ability to produce almost any part of the car at will" and "alleviate risk with suppliers ... if 2% of suppliers aren't ready, we can't make the car".

Nevertheless, even though Tesla believes in the vertical integration approach, the company has signed many different partnerships with other strategic companies for facilitating its growth. Particularly, Tesla has been following three main strategic alliance types, namely supplier alliances, R&D alliances, and OEM (Original Equipment Manufacturer) alliances with other automakers. The worthiest notable partnerships are the ones signed with Daimler, Toyota, Panasonic, and Lotus.

The one signed with Lotus is a partnership of the first type since Tesla wanted to exploit both the Lotus' knowledge and facilities to develop its first vehicle (the *Roadster*). The partnership with Panasonic is of the second type because it deals with battery packs, maybe the most important component of an electric vehicle. They agreed to collaborate in R&D activities regarding batteries and its components. Last but not least, the partnerships signed both with Daimler and Toyota are of the third type. In fact, in the former, Tesla agreed to cooperate in the developing of electric drive and battery systems as well as in individual vehicle projects (such as the full-electric Smart) believing that in this way both companies benefit from each other's know-how. On the other hand, in the latter, Tesla agreed to collaborate in order to develop production systems, BEVs, as well as providing

engineering support. In particular, Tesla helped Toyota to design the full-electric *RAV 4*.

6.2.3 Distribution channel and customer centrality

Related to the vertical integration approach, there is the distribution strategy which Tesla decided to adopt. As a matter of fact, the distribution strategy can be considered as the last phase of the production process, and Tesla decided not to outsource this last phase to intermediaries, but rather it decided to take care of it.

Indeed, Tesla utilizes a direct to customer sales model. All of this means that this company sells its vehicles to customers directly through company owned stores, the so-called "Galleries", instead of selling them through auto dealers. In addition, customers can also buy their vehicles directly on the Tesla website. This gives them the possibility to build their own car, add features, choose different color combinations, and various financing options.

This type of distribution model can be seen as an unconventional one compared to other car manufacturers where the final sale is made primarily via car dealerships which are not tied to the company, but according to Musk's words "the benefits we receive from distribution ownership enable us to improve the overall customer experience, the speed of product development, and the capital efficiency of our business".

As a matter of fact, customers are considered central at Tesla, and that is why the company wants to offer them a unique shopping experience even if it is more expensive than the "conventional" distribution strategy used in the automotive sector. Another reason why Tesla took this decision was because in this way it could educate and enable potential customers to place orders, but primarily as a long-term objective to educate consumers about the brand and the potential of electric vehicles.

Noteworthy to mention is that as of today, Tesla owns 438 "Galleries" and 98 service centers throughout the world, even though the majority of them are located in the United States.

Furthermore, Tesla thought and understood that the key to create long lasting brand loyalty is transparency. Indeed, every company wants to build long lasting relations with their buyers and one way to achieve this goal is by using open communication, and, in the automotive sector, no one does this better than Tesla. In fact, the company has increased its reputation for quality customer support by reaching its consumers through the Tesla blog and social media. Particularly, in the blog on its website, customers can publish articles and reviews to talk about their experience with a Tesla vehicle and they could also make suggestions that the company will then consider if interesting. Thanks to this transparency, buyers feel as they are personally connected to the automaker. Just as an instance, in 2014 two Tesla drivers presented an open letter to Elon Musk through a Californian newspaper in

order to propose some changes to be made to the vehicles. The CEO himself answered them on Twitter saying that some of the changes would be included in future production vehicles.

What is more, Tesla gave the opportunity to its "superfans" to be the first to drive the *Model S* before its launch. Tesla did it because this kind of supporters are willing to tolerate mistakes and a car that doesn't function 100% as it should. Indeed, these early adopters didn't run to the media to complain, but instead they sat with Tesla Product Managers and had deep discussions on their driving experience with Tesla cars. Tesla does all of this to have the most possible direct feedback from its customers, so that the company can have an idea on where and how it has to enhance since they know what customers want from Tesla vehicles.

Finally, the fact that this company is so fan-oriented granted it to rely on a solid customer base (actually it could be seen almost as a real fan base) that is always ready to support the company itself, its products, its decisions, and its commitment to innovation.

6.3 DEALING WITH INNOVATIONS

This paragraph will talk about how Tesla manages its innovations and about how this company operates in order to discover new technologies to adopt on its vehicles. As a matter of fact, Tesla can be considered as a 360° innovative company

due to the fact that not only it created innovative vehicles and technologies which have revolutionized the alternative powered vehicles industry, but this company is innovative also in the way in which it treats its employees and its own innovations.

6.3.1 Innovative vehicles and the Superchargers

Other than the many different effective strategies related to the management style and to the business model exposed in the previous paragraph, what most contributed to Tesla's success is the innovative features and characteristics of its electric vehicles and the innovative technologies deployed on them.

As a matter of fact, its innovative battery packs, designed and produced internally with the collaboration of Panasonic, permit Tesla vehicles to cover impressive range with just a single charge. Particularly, according to a company's report (Tesla, 2016), the *Model S* and *Model X* guarantee the longest range of all the sedans and SUVs in the world as they can cover almost 400 miles with a single charge. Thanks to this, Tesla electric vehicles can travel further than the other electric vehicles manufactured by its competitors in the automotive industry.

Noteworthy is also the fact that Tesla not only cares about the performance (which can be compared to the one of many sports car models) when designing a new vehicle, but it pays attention to any single detail in order to make its vehicles compelling to the eyes of its potential customers and to maximize the perceived value by them. Indeed, Tesla vehicles are equipped with the largest automotive

touch screen in the world which contains a software that permits innovative car repair and performance updates without having to go to a mechanic.

All of this allowed to change the previously held conception of electric cars which were considered slow, unreliable and uneconomical, therefore unworthy. Moreover, the company offers different ways to customize a vehicle by giving the choice to decide different interior colors, options and external characteristics; a buyer can even decide to buy its vehicle with a different battery option and with multiple configurations (for instance each vehicle can be ordered with one or two engines and the car can be set as rear-wheel drive or all-wheel drive). This varied lineup is a strategic factor that increases the value perceived by customers.

One factor that helped Tesla to come up with these innovative vehicles is its peculiar business structure and the way in which its employees are perceived and treated. As a matter of fact, Musk believes that everyone should have the opportunity to talk and to express his opinion with whoever he wants. Indeed, in a famous email to Tesla employees, Musk describes how harmful communication hierarchies can be to effective problem solving, and, instead, he affirmed that "Anyone at Tesla can and should email or talk to anyone else according to what they think is the fastest way to solve a problem for the benefit of the whole company, (…), moreover, you should consider yourself obligated to do so until the right thing happens."

The reason behind this open communication approach is that Musk believes that problem solving relies on effective communication, and hierarchies can prevent the

correct flow of information, thus they could prevent the company to solve a problem or to introduce an innovation in a fast and effective way.

What is more, Tesla employees (especially engineers) collaborate with employees of other companies related to Musk, such as SpaceX and SolarCity, in many different activities. In this way, they share their knowledge, and this is done to encourage the innovative process and to eventually come up with new and better solutions. In particular, these companies cooperate in R&D activities, and, interestingly, according to a study carried out by Wrolstad R. (2017), as of 2017, Tesla operated on approximately 1,300 team projects worth $70 million in 37 global locations for technology, research, finance and marketing.

Furthermore, despite the fact that Tesla models can cover long distances with one single charge, the company has set up a network of Superchargers, mainly in the United States and Europe, which permits Tesla's consumers to recharge their vehicles for free and to other BEVs or PHEVs users to recharge their batteries by paying a fee. In this way, the company sells energy through these stations that are totally powered by solar energy and are eco-sustainable. Currently, there are approximately 14,000 Superchargers globally deployed (quite an impressive amount considering that this project started less than 10 years ago, in 2012); the whole network is well developed in North America and in most parts of Western Europe, but plans forecast growth in other strategic markets (such as China) to further broaden the infrastructure.

The Superchargers allowed the company to diminish customers' "range anxiety" which is, as already in the previous chapters, one of the main reasons that discourage people from choosing an electric alternative. Moreover, these chargers are very effective since they are capable of charging a Tesla vehicle enough to give it almost 200 miles range in just 30 minutes.

Worth mentioning is that the creation of this network gave to Tesla an important competitive advantage with respect to its competitors since it is the only automaker that provides this kind of service, besides it does it for free.

6.3.2 Patents deployment

Last but not least, it is pretty interesting to analyse the behaviour that Tesla has with regard to its patents, thus with one of the instruments that the company has to protect its discoveries against its competitors. As a matter of fact, a patent is the granting of a property right by a sovereign authority to an inventor. This grant provides the inventor exclusive rights (especially the sole right to exclude others from making, using, or selling an innovation of some kind) to the patented process, design, or invention for a designated period of time in exchange for a comprehensive disclosure of the invention.

As opposed to the other automakers around the world, in 2014 Tesla decided not to protect its patents and to let other automakers use its knowledge and technologies

without initiating “patent lawsuits against anyone who, in good faith, wants to use our technology” (Elon Musk, 2014).

The reason behind this “open source” approach is to accelerate the transition to electric vehicles and, more generally, to sustainable transport; that is why filing patents or other intellectual property rights could have exactly the opposite effect since they could inhibit others in designing alternative powered vehicles. As a matter of fact, Musk affirmed in 2014 “Electric car programs (or programs for any vehicle that doesn’t burn hydrocarbons) at the major manufacturers are small to non-existent, constituting an average of far less than 1% of their total vehicle sales. (…) Given that annual new vehicle production is approaching 100 million per year and the global fleet is approximately 2 billion cars, it is impossible for Tesla to build electric cars fast enough to address the carbon crisis. By the same token, it means the market is enormous. Our true competition is not the small trickle of non-Tesla electric cars being produced, but rather the enormous flood of gasoline cars pouring out of the world’s factories every day”. Actually, the situation is now changing, as already written in the other chapters, as almost all the major car manufacturers of the world are starting to design and commercialize alternative powered vehicles.

Nevertheless, what is important to note is that Musk and Tesla believe that all the global automakers should cooperate to develop more rapidly the batteries and the technologies deployed in alternative powered vehicles, and that everyone would benefit from this particular approach to innovation and evolution.

Worth mentioning is the fact that many analysts were surprised by this "open source" approach as they believed that patents could represent a competitive advantage for Tesla against its competitors.

However, this peculiar strategy could have also some pros for Tesla. Firstly, as already stated above, it could convince also other automakers to design and commercialize alternative powered vehicles as they would have the access to the technologies needed to design this type of vehicles. Related to this first point, there is the fact that in this way Tesla would become some sort of "standard" since the other automakers would inspire themselves by looking at how the American company designs its vehicles. Therefore, overall, the leadership position of Tesla in the alternative powered vehicles market would be strengthened. Last but not least, Tesla benefits from this approach because it appears that Tesla is free to use any improvements made to its technology by any other automaker.

To conclude this subparagraph, it is interesting to mention that as of 2018 Tesla had 1,229 patents globally, of which 736 were published in the United States and 183 in European countries.

6.4 A CONCLUSIVE THOUGHT

After having exposed the Tesla case and how it has passed from being just one of the many start-ups present in the automotive market to being one the major players

in this same market basically in less than 20 years, few final comments will be made in order to conclude this chapter.

First and foremost, it could be noted how Tesla represents a real-life example of what it has already stated in the previous chapters about the dualism between incumbents and newcomers. As a matter of fact, Tesla is the most famous newcomer of the automotive industry, and it showed that it is not impossible and unrealistic for a new founded company to become an important player and to gain a relevant market share even in markets in which it could be difficult to enter because of the many market barriers, just like the automotive market and industry.

Moreover, what is interesting is that Tesla gained all the successes that it earned not by copying and imitating the moves and strategies applied by other automakers operating in the alternative powered vehicles market. On the contrary, the American company decided to wager all its resources on designing an electric vehicle (the *Roadster*) which would have been the first of its kind in the automotive market. Indeed, Tesla has always been successful because it knew what were its strengths and competitive advantages (such as its innovative battery packs) with respect to other automakers, and because of its will to innovate and differentiate from its competitors by offering to its customers unique vehicles that combined top-notch performances with all the comforts that a driver could desire and require from a vehicle.

In addition, the innovations adopted by this company are not limited only to its products, but instead they comprehend also the way in which the company is managed. All of this is done by Elon Musk in order to create a stimulative working environment for his employees which could help them to work both more efficiently and effectively.

In conclusion, the Tesla case showed that in an evolving market, just like the automotive one and more specifically the alternative powered vehicles one, not only the incumbents could be successful because of their resources and knowledge, but also new players and companies could have their own word and become relevant. In order to reach this aim, they have to find and apply the right strategies to compete, which could convey them some competitive advantages with respect to the other players, and, above all, they must understand what are their strengths and exploit them in order to differentiate from the competitors and to become in some way unique at the consumers' eyes.

CONCLUSIONS

The objective of this master thesis was to outline the current situation of the automotive market and industry, and more specifically the one of the alternative powered vehicles which are mainly represented by two different types of vehicles, namely the Battery Electric Vehicles (BEVs) and the Hybrid Electric Vehicles (HEVs) which again are mainly represented by the Plug-in Hybrid Electric Vehicles (PHEVs), the most promising and clean type of HEVs. Subsequently, after having analysed the current situation of the market and industry, the aim was to try to lay out forecasts and predictions about what is most likely to happen in the next years and about what kind of alternative powered vehicle is most likely to take over the others, thus becoming the main representative of this category of vehicles.

Worth mentioning is that all the considerations and comments stated during the thesis were based on data and studies carried out by experts and researchers either of the automotive field or of other related fields.

The starting point of the thesis was the acknowledgement of the current environmental issues and of the ongoing climate change that is affecting our planet which needs to be preserved and protected. For these reasons, even human activities and habits need to change in order for them to become as sustainable as possible and to minimize the negative impact that they have on the environment. Within the human activities, it is inevitably comprised also the industry of automotive and

transports with the consequent aim of designing and finding less polluting transport solutions for eventually reaching and achieving the goal of sustainable mobility. That is why both automakers, national and international institutions are trying to find viable solutions to reach this aim and to reduce the pollution caused by the production processes and by vehicles themselves.

At the moment of writing, the most promising alternatives to the traditional vehicles, powered by an Internal Combustion Engine (ICE) which utilizes fossil fuels that contribute to the emission of greenhouse gasses (especially of CO2), are the possibilities given by the application of an electric motor. Particularly, there are two different types of electric vehicles, namely the hybrids (which are equipped with both a conventional engine and an electric motor) and the full-electrics (which are equipped only with an electric motor).

The benefits offered by these two types of vehicles compared with the traditional ones are crystal clear as it was possible to notice thanks to the many Life Cycle Assessments (LCAs) carried out throughout time. As a matter of fact, a full-electric vehicle can be up to five times less polluting than a conventional powered vehicle regarding its CO2 (or equivalents) emissions during its lifecycle. On the other hand, a hybrid vehicle with regard to this indicator places somewhere between a BEV and an ICEV depending on the value of its hybridization factor. Obviously, this quite impressive result is influenced by the electricity mix used to charge the batteries with the consequence that, on this side, an effort is required also to the various

national governments to carry out the transition from fossil resources to renewable energy resources.

To be intellectually honest, it must be mentioned the fact that alternative powered vehicles have even some drawbacks in major part due to the production process of the batteries needed to power these vehicles. However, these drawbacks could be partly overcome with the development and improvement of this technology, and of the manufacturing and recycling phases.

By looking at the market data, it is evident the striking growth that the alternative powered vehicles have had in the world's markets, especially in the last few years. Indeed, these vehicles exhibited a quite relevant growth rate regarding their sales throughout time; just as an instance, it could be mentioned that in 2010 only few thousand units of these vehicles could be found on the world's streets whereas in 2020 this number augmented to more than 10 million units of which almost 3.2 million units were sold between 2019 and 2020, corresponding to +43% units sold with respect to the previous year. Furthermore, estimations suggest that alternative powered vehicles will exhibit a compound annual growth rate equal to 29% in the next ten years arriving eventually at covering approximately the 32% of the total global market share for new car sales. Particularly, BEVs are expected to be the prominent type of alternative powered vehicles (81% share within 2030) whereas PHEVs, or in general HEVs, will represent only a marginal share since they are

mostly seen only as a transitional technology from conventional vehicles to full-electric ones by automakers.

The growth cited above is partly due to the fact that global consumers are increasingly becoming aware of the environmental issues, so that they are starting to prefer cleaner solutions as their mean of transport, even because governments are offering more and more incentives to encourage the adoption of alternative powered vehicles and because the electric technology itself has arrived to a point in which most of the barriers, which inhibit consumers in adopting these vehicles (see for instance the "range anxiety"), fell or will fall in the next few years. Moreover, governments are also issuing stricter laws and rules to automakers (but also to other industries and parties) to reduce the level of pollution of their countries and cities.

For all these reasons, an increasingly amount of automakers are deciding to enter in this new market by releasing electric and/or hybrid vehicles depending on what is the best to do for them according to their characteristics.

Indeed, there are two different categories of manufacturers in the alternative powered vehicles market: the incumbents and the newcomers. The incumbents are the already settled automakers that want to enter in this market segment, whereas newcomers are mostly newly founded companies, such as Tesla, or companies that usually operate in other fields, such as Apple, that want to exploit the opportunities offered by this market. As mentioned above, Tesla is the most appropriate example of the second category of automakers since it is the most renowned newcomer

which has succeeded to pass from being just a start-up to becoming the current market leader of the alternative powered vehicles market thanks to its innovative full-electric cars.

In conclusion, it seems quite clear what would be the "new frontier of automotive" at the end of this thesis as the outlined path for this industry appears to be already defined by the necessities that our world requires us to satisfy. In particular, full-electric vehicles appears to be the best viable solution to reach the much-trumpeted sustainable mobility; moreover, they would become even a more compelling solution as the electric technology improves and as even the last barriers, that inhibit consumers from adopting them, fall.

"Environmentally friendly cars will soon cease to be an option... they will become a necessity."

Fujio Cho, honorary Chairman of Toyota Motors, 2004.

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