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The Electric Vehicles Revolution

A real innovation or a temporary trend?

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Summary

Introduction

The automotive industry represents one of the most important industries in the whole world economy. In the last few years this industry is showing a constant recovery both in production and sales but, nevertheless, is experiencing also deep and rapid structural changes. Consumers' behaviour concerning automobiles is changing fast and more responsible and eco-friendly attitudes are becoming increasingly important for the success of the product. If previously the attention was mainly focused on the car performances (speed, CV, acceleration, etc.), today, due to the increase of oil prices, some of the most important drivers of competitiveness are represented by their fuel consumptions and emissions rates. The main challenge for the OEMs in these years is to develop and produce vehicles that can, at the same time, maintain a good level of performances while lowering emissions and fuel consumptions.

For this reason almost all of the most important automakers of the world are starting to offer, together with traditional gasoline-powered vehicles, hybrid, plug-in hybrid and pure electric versions of their models and, furthermore, other important actors (i.e. Tesla Motors and BYD) are entering in the automotive industry thanks to this "electric revolution".

The electric phenomenon could represent an important chance for the automotive industry to improve its performances and to offer to the costumers a good alternative to traditional vehicles. Nevertheless, electric vehicles are still very far from being at the same level of internal combustion engine vehicles and it is not sure that they will never be. As we will see, there are plenty of factors that impede them to seriously compete with traditional cars: EVs initial cost is rather high if compared to latter ones, their autonomy range is sensibly lower (300 km on average), they need a set of complementary products and services for an efficient working (i.e. the recharging system) and, despite the fact they are zero emissions vehicles, pollution has moved from the final product to the manufacturing process only partially solving the environmental problem.

In the first chapter will be analysed all the theoretical aspects that underline this thesis and will be explained all the characteristics that concern the technology and innovation

management both from the organizational and costumer point of view. In order to understand if electric vehicles will actually be future of the automotive industry, it useful to understand all the factors that can contribute to the diffusion of an innovation inside the market. One of the most important drivers for the success of a new technology is represented by the diffusion and adoption of the innovation. Using the model provided by E.M. Rogers (2003), will be analysed all the phases a product can meet during its diffusion process and will be described the correlated categories of adopters. The s-curve model results very useful to analyse simultaneously these two dimensions and to understand if an innovation is on its early stages, if it is or not succeeding on the market and if it will have some chances in the future.

Furthermore, will be described the advantages and disadvantages a company can encounter when decides to commercialize for the first time an innovative technology and to enter in a completely new market/segment like the one of electric vehicles. Particular emphasis will be put in the discussion about bearing the bulk of research and development costs and about the elaboration of a new consumers' awareness.

Finally, during the first chapter will be explained the important role that complementarity has in the success of a new technology. The availability of complementary products and services and the complementarity between internal and external organizational operations are key strategic factors not only for a widespread diffusion of an innovation but also for the success of the whole company.

The second chapter is all focused on the whole automotive industry and its main characteristics with the aim of giving an overall actual view of the argument we are going to talk about. After an historical introduction about the industry and its most important business models (Fordism, Lean Production, etc.), will be analysed some economic and financial data, such as world production rates and sales amount, in order to asses the economic dimensions and the actual trends of the whole industry. For the continuation of the thesis it is also useful to explain the dynamics regarding supply chain management and marketing and distribution strategies, which are at the basis of the most important companies inside the industry and represent among the most critical aspects when dealing with the electric revolution.

Along with an efficient supply chain and an effective marketing and distribution strategy, one of the most important drivers in the recovery of the automotive industry is

surely represented by the technological progress. During the second chapter will further demonstrated the fundamental role the innovation has in the attempt to satisfy increasingly sophisticated costumers' needs. Will be explained all the different types of innovations and their systems of protection, providing also some practical examples of each one of them. Finally will be enlighten the evolution of the industry towards an open and less protected innovation system: this represent also a fundamental prerequisite for a faster and cheaper development of electric vehicles and their production process.

In the third chapter will be in depth analysed the electric segment, one of the most important and interesting part of the modern automotive industry and the main focus of this thesis. Will be explained the different types of electric vehicles (HEVs, PHEVs and BEVs) and the main characteristics of this sector.

The electric segment is slowly growing in its importance so that in 2015 it overcame for the first time one million of circulating units. During this chapter will be analysed how costumers perceive electric vehicles and, using a Well-to-Wheel (WTW) analysis, will be tried to asses the green house gasses emissions of these cars. Although pure-electric vehicles are considered zero-emissions cars, the pollution system has moved from the final product to the manufacturing process. The production of electric energy, the manufacturing of adequate battery-packs and the development of complementary product and services, not only increased the environmental impact of the production plants, but also caused a rise in the total costs of production and induced a strong re-organizational process. So will be explained all the most important changes that the production of electric vehicles implies in the organization of an efficient supply chain and its main differences in relation to a traditional automaker's supply chain.

Finally, resuming the discussion about the role of innovation in the automotive industry, will be demonstrated that an open innovation system is the most adopted one and will be explained that companies usually decide to collaborate together in the development and production of electric vehicles. The use of collaborative agreements, such as partnerships and joint ventures, is seen as an opportunity to save important research and development costs and a chance to share specific knowledge for a more easily diffusion of the technology.

The fourth, and last, chapter is all dedicated to three different approaches regarding electric revolutions. The first example to be mentioned is related to Tesla Motors. The

American company is one of the most important actors when talking about this segment and, for its innovative approach entirely focused on pure electric vehicles, represents surely a good model in support of a future electrification of the whole mobility.

The second example is provided by BMW, one of the most elderly automakers of the world. This company is very interesting because represent a completely different approach to the electric revolution and, as we will see, differently from Tesla Motors, it decided to juxtapose not only electric vehicles but also plug-in electric vehicles to traditional gasoline powered models.

Fiat Chrysler Automobiles (FCA) represents the third, and last, example of this thesis. The Italian-American company is extremely particular because, among the most important automotive groups of the world, it is the only one to be highly sceptical about the electric vehicles and not yet convinced about the real convenience of this cars.

All the three examples are treated following the same path in order to simplify the understanding and to make the discussion more fluent and intuitive. First of all will be briefly described the whole history of the company with some actual data about its financial situation (total revenues). In a second moment will be described the principal products of each company, underlying all the most important features and technologies at the base of each vehicle. Finally will be explored and analysed all the complementary products and services (if there are any) developed and commercialized by the companies in order to foster a more widespread adoption of their products.

The end of the thesis is composed by personal conclusions regarding the possible future of the automotive industry and, following all the data and features presented during the dissertation, the destiny of electric vehicles. These are only personal supposition based exclusively on secondary data and on authoritative sources related to the automotive industry and to managerial disciplines.

Chapter 1 – Theoretical Framework

In the whole administration of a company, especially if it is involved in highly technological sectors, technology and innovation management is undoubtedly an important driver for the success of its market strategy and could represents a crucial issue for the determination of its future.

The first chapter of this thesis is dedicated to the discussion, from a managerial perspective, of all the theoretical frameworks underlying an innovation – like could be electric vehicles for the automotive industry – and the management of new products' technologies. In the following pages we are going to talk about the phenomenon of technology diffusion and the ways through which a company can firstly understand and, then, influence it. Technology diffusion is strongly related to consumers' perceptions and attitudes toward a particular innovation and it is measured using the rate of adoption in the market. During this chapter will be described, exploiting the studies of E.M. Rogers, all the phases of adoption and the consequent categories of adopters regarding a new technology. These categories are important to understand the whole technology life cycle of a product (s-curve) and to analyse all the different steps encountered in a diffusion process, which could culminate with a widespread adoption of the innovation or, on the contrary, with a failure of the same.

Subsequently we focus our attention toward the difficult, and strategic, choice a company has to make, when decide to enter for the first time in a market: being the absolute first mover in the development and adoption of a particular technology, with the possibility to grab monopoly rents or, rather, be one of many followers with the near certainty of success. Each one, obviously, has its own advantages and disadvantages and, depending on the objectives and characteristics of the company, each one is more suitable in some cases rather than others.

It is clear that all this variables, and the way through which companies decide to implement them, have also implications on the market strategies and on the resulting approach to the market. As will be seen during this script, there are different opinions and also different strategic approaches concerning the development and commercialization of electric vehicles. Every company makes it own evaluations and decisions on which technology adopt, how, and when enter into the market on the basis of their characteristics and their objectives.

1.1 Technology Diffusion

Technology diffusion constitutes an important argument when discussing about technology and innovation management. E.M. Rogers (2003) define the diffusion as the process thanks to which innovations or new technologies are communicated over time, through the adoption of some communication channels (both interpersonal and media), among the members of a social system.

There are mainly two systems that contribute to help the diffusion of a particular innovation. In the first method, also known as centralized diffusion system, decisions regarding how, through which networks, and when a determinate technology should be diffused, are taken by a small number of persons and/or technical experts. In a decentralized diffusion system, instead, all these decisions are more commonly shared by the costumers and/or by the potential adopters. In this latter system the potential adopters are only just responsible for the self-management of the diffusion of innovations and horizontal networks among the costumers constitute the principal instrument for the diffusion of new technologies.

In management literature the diffusion of a technology is usually described thanks to an S-curve. This kind of graph is obtained by matching together the total number of adopters of a particular technology and the range of time (starting from the time when technology was firstly commercialized).

The adoption rate at the beginning is very low because costumers are still unfamiliar with the just marketed technology; when the technology starts to be better understood and more utilized by the mass market, the adoption rate accelerates and, finally, when the market becomes saturated, the rate of new adoptions begins to decline.

S-curves in technology diffusion are often explained as a progression between different categories of people adopting the technology at different times. On the basis of these assumptions, it is clear that the degree of technology diffusion is strictly correlated to the technology adoption issue. Everett M. Rogers, the father of innovations' diffusion theory, proposed his own categories of adopter (**Figure 1**) in which he tried to match both the s-curve of technology diffusion and the bell-shaped curve representing the various stages of adoption.

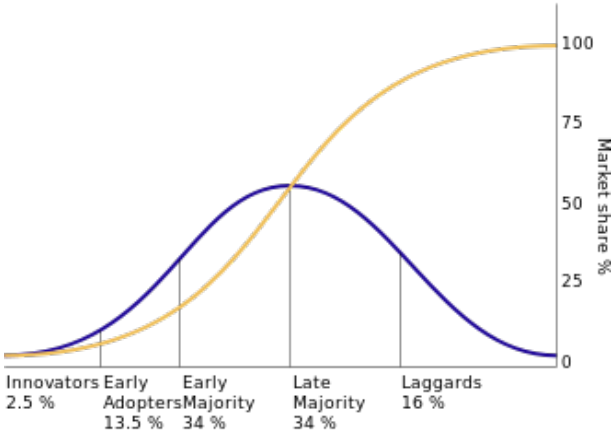

Figure 1 - E.M. Rogers' diffusion of Innovation Model
Source: EM. Rogers, Diffusion of Innovation, Free Press, 2003.

He identified mainly five categories of adopters that are strictly correlated to the improvement of market share over the time. The first category of adopters, defined as the "Innovators", comprehends all the individuals that implement an innovation first. They are typically costumers with high financial possibilities and, especially for this reason, they can afford to sustain an eventual loss of money due to a scarce success of the innovation. These individuals are considered pioneers in their purchasing behaviour and usually are pretty comfortable with a high level of complexity and uncertainty. Innovators play a fundamental role in the diffusion of new technologies because they bring new ideas into the whole social system but, following Rogers, only the 2,5% of the market share is comprised in this category.

The second category appears when the new technology demonstrates the first signals of growth and is composed by the so-called "Early Adopters". They are usually individuals well integrated in their social system and, for this reason, they have the greatest potential for opinion leadership[1]. As a consequence other new potential users address early adopters to gain more information and suggestions, giving them a sort of missionary role for the diffusion of new technologies. Individuals included in this

[1] Following EM. Rogers, *Opinion Leadership* is the degree to which an individual is able to influence informally others individuals' attitudes or overt behaviour in a desired way with relative frequency.

category are respected by their peers and are aware that, to preserve this respect, they have to promote continuously their innovation adoption decisions. It is estimated that the 13,5% of the market share regarding the adoption of a new innovation is situated in this category.

After the early adopters' category, Rogers identified the "Early Majority" and, looking at the image above, can be seen that this category fills the first 34% of the market share. The costumers inside this category adopt new technologies just before the average member of a social system; they interact frequently with their peers but, however, they are not able to strongly influence other individuals' attitudes.

The "Late Majority" constitutes the following 34%, in the middle of the curve, and represents one-third of the individuals in a social system. Costumers included in this category are usually quite sceptical in their approach to new innovations and may not adopt the new technology until they are completely convinced by their peers. Usually, late adopters are individuals with scarce financial resources and this contributed to make them unwilling to make a strong investment for the adoption of a new technology until it becomes more reliable.

The last category defined by E.M. Rogers are the "Laggards" and includes all the individuals that are at a first impact extremely dubious about new innovations and the figure of innovators in general: before they adopt a new technology, they must be sure that it will not fail and that it will represent a sure investment. Laggards characterize the last 16% of the market share and they don't possess opinion leadership in that they usually base their decisions on previous experiences and/or are influenced by the opinions of other adopters.

Electric vehicles, even if there were previous appearances at the end of 19th century, are a relatively new innovation for the automotive industry and this automatically implies that, before registering a widespread diffusion in the market, it has to overcome all the phases and difficulties related to the technology diffusion model just analysed.

Nowadays electric vehicles are slowly reaching a higher level of diffusion in the market (more than 1 million of units) but they are already very far from being as popular as traditional cars. Costumers and organizations are yet very sceptical about the reliability, performances and real sustainability of this kind of vehicles and, due also to the high level of financial resources required, only a restricted part of costumers (Innovators and

maybe Early Adopters) and firms can afford a similar investment. From an organizational point of view, as will be widely discussed, the production of electric vehicles implies not only huge amount of financial resources but also new organizational capabilities in order to manage a partially different production process and value chain.
However, if complementary technologies evolve and the amount of financial resources required decreases, electric vehicles could make improvements on their s-curve of diffusion and become more popular also among that costumers less likely to risk and sceptical about new innovations.
Furthermore, it is not to be underestimated the important role that traditional vehicles already play in the whole automotive industry. As long as the oil is widely and simply available all around the world and the total cost of ownership and performances of ICE vehicles are lower than EVs, it will be difficult for these latter ones to improve their market share.

1.2 First Mover Advantages and Disadvantages

Talking about important and complex innovations, like electric vehicles are, means also focusing on decisions taken by the companies concerning the right time of entry in the market. New entrants, depending on their time of entry, are divided into three categories. The first category, and also the most important, is the one of "First Movers": they are the first to enter in the market with a completely new product or service. In the following lines will be in depth analysed both the advantages and disadvantages of being a pioneer company in the market. The "Early Followers" constitute the second category of entrants and are the direct followers of the first movers: they decide to enter quite early in the market but they are not the first in absolute because of their scarce attitude to risk. They can't benefit from the absolute competitive advantage of the first mover but, at the same time, they can save important organizational costs and avoid financial risks involved in the development of a radical new innovation. Finally there are the "Late Entrants" who are completely adverse to risks and uncertainty and, for this reason, they usually decide to enter in the market only when the product or service at issue begins to demonstrate its first signals of good penetration on the mass market.
Here we focus our attention especially on first movers because they represent the most interesting and important figure when discussing about new innovations and

technologies. The appearance of electric vehicles on the automotive industry represents an important innovation both for companies and costumers: for a company, being a first mover in this segment could represent an important source of competitive advantage but, at the same time, could imply important economic efforts for new products development and commercialization.

Brand loyalty and technological leadership are among the advantages of being a "First Mover". If a company is the first to develop and sell on the market a determinate new technology, it can gain the reputation of the leader in that technology for a long period of time with all the advantages that follow. A strong leadership and a good reputation support the company facing the possibility that rivals introduce in the market comparable products and have an extremely positive impact on its competitiveness (image, brand loyalty and market share). Moreover, being a technology leader allows the company to influence costumers' needs and expectations about fundamental aspects of the product or service, such as the price and/or the its complementary technologies. If those aspects related to the new technology are difficult to be replicated by the competitors, thanks also to the protection of patent or copyrights, as a consequence the leadership in a determinate technology could lead to the production of constant monopoly rents[2].

Another important advantage of being the first mover on the market is made up by the exploitation of buyer switching costs. Once a costumer has decided to adopt a product (with its particular technology), it is difficult for him to switch to another good without facing other important costs. For example, initial costs and the following costs of purchasing complement goods can be both considered switching costs. Moreover, if a product is considered more complex in comparison with the previous one, costumers have to spend further time in order to become familiar with the new technologies and operations: this "waste" of time is considered itself a switching cost and can contribute to make the costumer more reluctant to change product and technology.

[2] *Monopoly Rents* can be defined as additional returns a firm can exploit from being a monopolist coming from the setting of higher prices, the lowering of total costs and/or the increasing bargaining power over suppliers.

Obviously, in presence of high switching costs, the first company who is able to capture new costumers probably can easily maintain them, even if innovations with a superior value proposition and a more modern technology will be introduced.
Finally, especially in an industry characterized by increasing returns to adoption, being an early provider of a new technology can be of crucial importance for the success of the same. The timing of investment in a new technology might be extremely critical for the likelihood of success: a technology that is adopted earlier in the market than others has more time to reinforce its competitive power through feedback mechanisms, which can lead the same technology to become a dominant design and contribute to strengthen the competitiveness of the whole company.
Nevertheless being a first mover implies also some disadvantages, which can prevent a company from not entering in the market too much early. First movers usually have to sustain the great majority of research and development costs for their product or services. The first company to develop a new technology is also responsible for the additional costs of developing and initializing an adequate production process and, as we will se further, of producing complementary goods that aren't already available on the market. For these reasons being a first mover and commercializing an unproven technology is an expensive and risky business. Later entrants, on their side, are not obliged to invest in R&D function and can exploit the work previously done by the first mover. Competitors can also observe how the new technology makes its debut on the market, which characteristics are more valuable for costumers, and afterwards focus theirs efforts on developing the more suitable product. Furthermore, first movers have to organize a completely new and efficient network of suppliers and dealers. Companies have to establish new business relationships with all of them and be able to maintain a constant exchange of information in order to plan every aspect of the new technology. These operations are obviously expensive both in terms of financial resources and in terms of time. Later entrants, instead, can benefit of an already efficient and usually well-qualified network of suppliers with experiences and capabilities functional to the production of that particular technology. In this way, companies that decide to postpone their entry have the opportunity to save important costs and exploit the organizational expertise of companies already inside the market. Next to the lack of adequate supply and distribution channels, sometimes first movers necessitate to rely on other

producers of enabling technologies. The majority of the products need complementary goods to be useful and valuable; automobiles, for example, require adequate services, gasoline and roads in order to be completely suitable to costumers needs. When an innovation is firstly introduced in the market, a widespread adoption of the same could be obstructed by the partial absence of important complements. Looking at the electric vehicles, as we will see, can be perceived that the lack of adequate infrastructures and complementary technologies (i.e. recharging infrastructures, battery swapping stations, etc.) could represent an important obstacle to a more widespread diffusion of the same technology and can constitute a serious barrier for the early movers inside the segment.

Finally, the last important disadvantage of being a first mover is represented by the necessity of developing a completely new consumers' awareness. When a new technology appear for the first time on the market, the majority of costumers is, at the beginning, very sceptical and uncertain about what product features they really desire and how much they are intentioned to pay for them. This implies that first movers, despite their efforts to satisfy all clientele's needs, could discover their products offering is inadequate and must be revised as soon as the market begins to evolve revealing more specific costumers' preferences. Anyway, first movers can influence costumers' preferences by investing in their education. This operation can result quite expensive and complex and, in the long run, if added to the other expenses mentioned above (R&D and Value Chain creation costs), can become unsustainable and disadvantageous for the company.

Being a first mover in the electric segment, a highly technology driven sector, requires a lot of financial resources and organizational capabilities. As we will see in the next chapters, companies that are intentioned to enter in the EVs' market have to revisit all their supply chains and at the same time become familiar with technologies not previously within their competences. Tesla Motors, even if it is not the first company to bet in the electric mobility – Toyota produced the first electric vehicle (Toyota Prius) in 1997 – is anyway considered the first mover in the electric segment and has been able to exploit this position to gain a strong competitive advantage over direct rivals. Differently from the other automakers (Toyota over all), Tesla Motors was able to implement a personal network of enabling technologies, such as the "Superchargers" and the battery

swapping stations, and focus its efforts on building relationships with efficient and qualified suppliers (i.e. Panasonic, NVidia, etc.).

However, it must be emphasized that behind the success of this famous company there is the fundamental financial support of one of the richest persons of the world, Elon Musk, which assures to the company not only continuous financial investments but also an innovative and, in a sense, revolutionary vision.

1.3 Complementarity

Another important issue when discussing about new technologies and innovations is their complementarity with already developed and well-established products and services. There are plenty of products that are valuable and functional for the costumer only if they are flanked by a set of complementary goods and technologies.

Certain companies are able to produce both a good and its complements independently by your own; the majority of the firms, however, must rely on other companies for the production of complementary products or services that can foster a larger adoption of their products.

Products with a large installed base[3] are sensibly favoured in attracting developers of complementary goods and, at the same time, the widespread availability of this kind of goods influences costumers' choice among rival products and concurs to increase the size of the installed base. This can be considered a self-reinforcing cycle that contributed, with the flow of time, to the diffusion of new technologies.

Otherwise, another possibility companies have to influence leading technology's choices, is the establishment of coalitions around a selected technology. The automotive industry, and also the electric segment, is full of these agreements among firms. Just think about the recent collaborations among automakers for the implementation of platform strategies to produce more standardized vehicles and ease the production of more complementary products.

An important role in fostering the complementarity of a particular technology is also played by government regulations. The state is able to strongly influence the development and diffusion of an innovation: incentives or tax exemptions can be important instruments for influencing the behaviours of both companies and costumers.

[3] The *Installed Base* is composed by the total number of users of a particular technology.

Looking at the electric vehicles can be noticed that they represent a completely new and revolutionary technology for the automotive industry. From the company point of view, the production and commercialization of electric cars requires the manufacturing of completely new complementary goods. An electric car, a part of the chassis and its interiors, is very different if compared with traditional vehicles: mainly, it must be assembled with an electric engine, a battery-pack and a motor controller. All these new features and characteristics are not complementary with the already existing technologies related to traditional ICE vehicles; automakers that are intentioned to develop their own electric automobiles must also be able to provide all the complementary products and services need for an easier diffusion of this innovation, such as a compatible recharging system and/or performing battery-packs.

Up to now, as we will see in the dedicated chapter, only Tesla Motors was able to develop an adequate network of complementary goods and services in the electric segment. Beside the range of different electric vehicles available on the market (Model S, Model X and Model 3), the company offers to its clientele also important services and goods that can ease the use of the principal products. Tesla Gigafactory represents one of the most important examples of inbound production of complementary goods. This project was implemented in 2014 directly by Tesla Motors, with the help of Panasonic, in order to develop and produce internally best performing battery-packs, which represent a fundamental component for the improvement of overall vehicles' performances and for creating a wider consensus among costumers.

Nevertheless, also the other automakers, such as Toyota, BMW and Nissan, are trying to provide costumers with all the necessary enabling technologies. However, because also of the large amount of organizational expenses required, they have to rely on external suppliers or to sign agreements among themselves.

Today, in fact, an important issue in the whole innovation management process is the optimal integration of internal and external knowledge within firm's innovation process in order to be able to exploit the advantages of every innovative activity. An efficient management of the complementarity between different innovation activities can represent an important source of sustainable competitive advantage.

Chapter 2 – The Automotive Industry

The automotive industry is probably one of the most important and developed economic sectors of the entire world economy.

Automotive industry comprehends all those companies and activities involved in the manufacturing of motor vehicles, including most components, such as engines and bodies, but excluding tires, batteries, and fuel. The industry's principal products are passenger automobiles and light trucks, including pickups, vans, and sport utility vehicles. Commercial vehicles (i.e., delivery trucks and large transport trucks, often called semis), though important to the industry, are secondary.[4]

This industry has its roots in the late 19th century when hundreds of manufacturers pioneered the "horseless carriage", the first car prototype without the driving force of an animal, and the development of the gasoline engine was finalised. For many decades, the United States led the world of the automotive thanks to their great size of internal market that permitted a huge size of production. In 1929, before the Great Depression, the world had about 32.028.500 automobiles in use, and the U.S. automobile industry produced over 90% of them. At that time the U.S. had one car per 4.87 persons.

After World War II, the U.S. produced about 75% of world's auto production. In 1980, the U.S. was overtaken by Japan but became world's leader again in 1994. In 2006, Japan narrowly passed the U.S. in production and held this rank until 2009, when China took the top spot with 13.8 million units. With 19.3 million units manufactured in 2012, China almost doubled the U.S. production, with 10.3 million units, while Japan was in third place with 9.9 million units. From 1970 (140 models) over 1998 (260 models) to 2012 (684 models), the number of automobile models in the U.S. has grown exponentially.

However, in the last few years a new phenomenon emerged in the automotive industry. Starting from 2015 the total production of electric and hybrid vehicles experienced a huge growth and, for the first time in history, the amount of circulating electric cars overtakes 1 million of units. This could represent an important phase in the whole automotive industry, opening new horizons and new opportunities both for the companies and for the consumers.

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[4] *Automotive Industry; A.K Binder, J.B. Rae; www.britannica.com*

This brief history of the sector explains the international attitude, the size and the numerous occasions that this industry can offer the entire world of researchers.

In the following chapter will be explored in a deeper way the dynamics and the organizational characteristics at the base of the automotive industry. First of all will be analysed the main characteristics of this industry such as the explanation of the data regarding the last few years, the most important trends up to now (from fordism to the famous, Japanese, lean production and the outsourcing phenomenon), the supply chain strategies and management, and the possible future scenarios deriving from the evolution of the market.

In a second moment will be explained the role innovation can play inside this industry and how the actors involved can protect and, when necessary, share their innovations. Much attention will be paid to new digital technologies and the possible ways through which automakers can be exploit them. In the last few years can be registered a sharp increase in the development of the infotainment inside the vehicles and a more intense use of the social media as a marketing and advertising tool.

Another important argument that will be addressed during this chapter is related to the difficult and strategically critical choice related to the adoption of an open instead of a more closed innovation system: each one of these two systems presents some drawbacks and benefits depending also from the strategy pursued by the company and from the characteristics of the particular segment involved.

Automakers must be flexible as much as possible and be able to respond quickly to technological innovations emerging on the market. Today every car, from the super luxury to the standard models, must have a minimum level of comfort and technology in order to satisfy the variety of needs expressed by the costumers. Innovation, therefore, has become one of the most important drivers of competitiveness in the automotive industry.

2.1 Main Features of Automotive Industry

The automotive industry is not only financially important for the whole world economy but it is also extremely important and interesting from an organizational and managerial perspective.

Technological and managerial developments occurred in the ultra-secular history of this sector allow the production of different models, equipped with outstanding comforts and services, and permit the development of new kind of vehicles to satisfy an exigent and always changing demand. Electric automobiles are, in these last few years, the most important and discussed trend of the automotive industry. Electrification of cars represents an important phenomenon that bring with it significant changes both from a managerial and technical point of view. The management of an entire value chain engaged in the production of electric vehicles implies, as will be observed further in this thesis, substantial differences if compared with a traditional automotive one. Technological capabilities required are totally changed; suppliers are usually belonging also to other industries and costumers' needs are partially different from the ones who purchase traditional cars.

However, to analyse this market trend, it's important to explain in a sequential way the origins of the most important managerial and organizational strategies that, somehow, gave remarkable contributions to the achievement and evolution of new solutions for the future of this industry.

When discussing both of automotive and management the first thing that comes into our mind is related to the phenomenon of Fordism, introduced by Henry Ford in 1913, and that has its roots on the concepts previously introduced by Frederick Taylor (1856 - 1915).

At the end of 19th century, Taylor began a series of experiences and experiments about the concept of working inside plants. These researches led him to define, about a decade after, what it's now called "*the one best way*" in the organization of work.

Taylor decided to implement some basic rules about how must be organized the whole fabrication process in order to maintain a certain, high, level of efficiency. These rules allowed the diffusion of the "*Scientific Management*", also know as Taylorism.

The "Taylorist - Fordist Model" represents a formidable breakthrough if compared with the neoclassical model, in which the management of processes and the choices of "*What*", "*How*" and "*How Much*" to produce were subordinated to the conditions of competitive market. With this new model, instead, the application of scientific criteria to management techniques allows to individuate the optimal operative procedures to be implemented.

On the basis of these assumptions, Henry Ford developed his model that represents an important step, not only for the history of the automotive industry, but also for the whole economics and managerial history.

Henry Ford was one of the pioneers who really understand the drawbacks of the craft production, the leading model at that time (19th century). The craft production has essentially these characteristics: (1) a work force highly skilled in design, machine operations, and fitting; (2) Organizations that were highly decentralized; (3) the use of general-purpose machine tools; and (4) a low production volume (1000 or fewer automobiles a year).

The most important creation of H. Ford was the famous Ford "Model T" (24 September 1908), produced in the plant of Piquette (Detroit) with the first implementation of the assembly line technique, which allowed a huge mass production.

This automobile achieved, at the same time, two important and strategic objectives. On one hand, Ford developed a car that could be easily manufactured, thanks to the implementation of the assembly line; while, on the other hand, it was considered also a user-friendly model (almost anyone could drive and repair it).

The achievement of the mass production, however, was made possible not only by the moving of the assembly line but, also, by the discovery of some manufacturing innovations. Among these innovations, the most important were the complete and consistent interchangeability of parts and the simplicity of attaching them to each other. These two factors allowed Ford to cut a large amount of production costs and, at the same time, to eliminate the skilled fitters that represented the bulk of every assembler's labour force.

In this kind of manufacturing process (the assembly line), the assemblers/fitters performed the same kind of activities at their stationary assembly stands over and over. This process was already in use at that time, but Ford's applied to it an important innovation: the parts needed by each workstation, previously obtained and filed by each worker, were now delivered automatically to the place without the need of moving through all the plant. The assemblers could remain at the same position all day and, in this way, the whole production process could gain in efficiency.

Around 1908, with the coming out of the "Model T", H. Ford finally achieved perfect part interchangeability. He planned that the single employee would implement only a fixed

task and will move from vehicle to vehicle across the assembly line. By 1913, just before the introduction of the moving assembly line, the whole task cycle for an average Ford's assembler had been consistently reduced from 519 to only 2.3 minutes.

The whole process, however, was not already efficient: walking around the plant to follow the production process of every single car took time and jam-ups are very frequent (i.e. faster workers overtook the slower workers in front of them).

In 1913, Ford finally introduced the moving assembly line, which brought each car component to the stationary worker: this innovation further cut the cycle time from 2.3 to 1.9 minutes. Still today the moving assembly line is an effective method used in the plants of the most important automakers of the world: vehicles are transported along the various stations of the production process by means of mechanized and coordinated robots and are progressively assembled in their entirety under the supervisions of few qualified persons.

Solved the problem of the production process efficiency, another problem emerged for Ford: there was the willing to produce the whole car in one place and, from that place, sell it to the entire world. The shipping systems of that time, unfortunately, were unable to transport such a huge volume of automobiles and trade barriers represent another important problem to take into account.

To solve this problem Ford decided to design, engineer, and produce his parts internally into the plant of Detroit (US) but to outsource the entire assembly phase to remote locations around the world: by 1926 Ford automobiles were assembled in more than thirty-six cities in the United States and nineteen foreign countries.

The Ford Model T, despite everything, was considered a standard product and was not able to completely satisfy the costumers' expectations. Especially in the European market, the Model T didn't obtain too much success: this car was considered too much massive for the crowded cities and narrow roads of Europe and, further, the poor variety of available colours (« *Any customer can have a car painted any colour that he wants so long as it is black.* » - H. Ford) was an important limit for the satisfaction of the costumers' needs.

The solution to this important limit, however, came from another important historical actor of the automotive industry at a worldwide level: General Motors Corporation.

The innovative thinking of Alfred Sloan, president and chairman of General Motors, seemed to resolve the conflict between the need for standardization, in order to cut manufacturing costs, and the product diversification required by consumers.
He achieved both these goals by standardizing many mechanical items of the car, also to simplify the planning of each different model, and by producing these over many years with dedicated production tools. At the same time he constantly changed the exterior design of each car and introduced a wide range of new and innovative features (radio, air conditioned, automatic transmission), that can be constantly revisited and which primary function is to satisfy the consumer needs. A policy that represents an obvious and fundamental prerequisite for the actual automotive market, which is now able to offer a multitude of different lines of vehicles available, from SUVs to station wagons, and a wide range of incredible comforts at disposal of the customers, such as the security systems offered by Volvo Cars or the auto-pilot of Tesla Motors.
Thanks to the implementation of this production system, the US car companies dominated for decades the world automotive industry and the US market accounted for bulk of the world's auto sales.
However, in the next decades, the Fordism system and the correlated mass production phenomenon gradually lose their competitive advantage, leaving enough space for new ways of managing the entire production process.
Japanese emerged as new important actors in the automotive industry after the World War II and set out to change the rules of the game. Especially thanks to the small size of market demand (if compared to the US) and to a pioneer, as Taiichi Ohno[5] was, a famous company like Toyota could be able to implement a new system of production based essentially on the absolute elimination of waste. The two main pillars of this new production strategy could be identified in "just-in-time" and in "autonomation".
The just-in-time approach revisited the traditional way of thinking a production process transforming it from the classical "push" approach to, a completely different, market "pull" attitude. This means that the whole production system is based exactly on what

[5] Taiichi Ohno (Dalian 1912 - Toyota 1990) was a famous Japanese engineer, specialized in mechanics, and considered the father of the production system typical of the Toyota factories: the *"Toyota Production System",* also known as Lean Production. He wrote many books about this particular system of production; among them the most famous is "*Toyota Production System: Beyond Large-scale Production (1978)*".

the market needs, both from a quantitative point of view and from a qualitative perspective: the times of reaction of the actors involved must be as faster as possible and the quality level of each component must be so high to allow the avoiding of monitoring controls.

The "autonomation", "*jidoka*"[6] in Japanese, instead, is a technological innovation that allows machines to work in harmonic way with their operators. Human attention is required only when an imperfection is discovered; in this case the problem is faced as soon as possible even if this imply the interruption of the whole production process. This approach also led the employees to anticipate problems before they become so serious to force the stoppage of the production chain.

These two phenomena can be, therefore, compared with two very important strategies widely described by the organizational literature: Vertical Integration (Mass Production, Ford) and Horizontal Integration (Lean Production, Toyota). It is of extremely high simplicity to identify, on one hand, Vertical Integration with Ford and the "fordism": the moving assembly line implies that the product moves through various subsequent stations inside the plant. All the production process, from the development to the final assembly, is carried on inside the company and so the benefits of the economies of scale can be fully exploited.

On the other hand, instead, it is almost obvious to compare the Horizontal Integration with Toyota and the related phenomenon of the lean production: the just-in-time philosophy involves that the production process is entirely based on the market demand and, consequently, the company must be as flexible and efficient as possible. To reach the needed flexibility and respond quickly to the changes of the market, the company must also rely on first tier and second tier suppliers, a network system also know as "Vertical Keiretsu[7]", committing some important parts of the production process to external organizations. Today this system is already widespread not only among the

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[6] Introduced in 1924 by S. Toyoda, founder of Toyota Industries, when he invented an automatic loom that stopped working if even a single thread breaks, thus allowing one employee to control several looms.

[7] "Keiretsu" is a Japanese term to indicate networks of firms, operating in different sectors, but linked together by business relationships and shareholdings. There are two different types of Keiretsu, Horizontal and Vertical, depending on the kind of network relationships among firms. One of the most famous Keiretsu (Vertical) is represented by Toyota, as a leader, and by its multitude of suppliers. Mitsubishi, instead, is considered a good example of Horizontal Keiretsu.

Japanese automakers and, with the fundamental contributes of an open innovation system, contributed to the birth, development and consequent diffusion of new kind of vehicles like, for example, the electric ones. The technologies below these cars are developed, as will be explained when talking about the electric segment, thanks to the contribution of highly specialized suppliers not always belonging to the same industry (i.e. Panasonic for the development of high performing batteries).

However it is wrong to strictly identify, on one side, Japanese with lean production and, on the other side, the western actors with the mass production approach. There are many examples of Japanese companies that are not so lean as Toyota and also many important plants in developing countries show that a lean production approach can be implemented anywhere in the world, also in western countries.

After having discussed about the two most important historical organizational strategies that invested and helped to determine what the automotive industry actually is, the following steps are to describe and understand the meaning of Outsourcing and Modularity: two important phenomena linked to the supply chain management, which contributed to the strategic evolution of this sector and, sometimes, make trouble to the persons who have to take important decisions inside it.

When discussing about automotive industry, these two phenomena are not seen as complementary but, rather, they are considered two alternative strategies depending on some important variables like knowledge and vertical integration of the actors involved.

Outsourcing happens when an organization procures some services or products from another actor rather than producing them in-house.

A firm decide, or is in a certain way forced, to outsource the whole production process, or only some parts of it, when it doesn't have the competencies, the facilities, or the scale to perform all the value-chain phases and to develop new innovations in an efficient way.

The most important European automotive companies such as Volkswagen, Porsche, Fiat (FCA), Mercedes and BMW decided to outsource the design, the manufacturing and the assembly of some components of their products to independent vehicle suppliers, also called Full Service Vehicle Suppliers (FSV).

As every strategy, also the outsourcing has its advantages and disadvantages. Outsourcing, on one side, favours the possibility for the firm to concentrate all its efforts

on the "core business"; decreasing, in this way, the number of activities carried on directly in-house and, consequently, the size of investments needed. In this way the firm results more flexible and can meet possible unexpected variations of the market size and, of course, of the demand derived from it.

On the other side, the drawbacks of the outsourcing are essentially two. First of all, if an organization decides to outsource its production, it may loose a lot of important learning opportunities, especially in the long run. The partial disinvestment policy of R&D function, which may be caused by the outsourcing, could influence the future development of new products: the firm will face important skills and resources shortages. New important challenges, like could be the one of the electric vehicles, require an in depth knowledge of every technical aspect to develop and commercialize an acceptable and reliable product. The electric car, as previously said, presents many differences if compared with a normal, gasoline-powered, car: the competences developed in the fields of batteries, engine composition or others technical aspects are not recyclable to produce an electric-powered car and this refocuses the attention to a strong and professional R&D function inside the company. In the following dedicated chapter will be showed how Tesla Motors and Toyota, two of the most important players in the electric segment, pay much attention to this argument and allocate a large amount of their budget to R&D projects. These efforts are made to hire the best engineers of the market and to continuously test and prototype new discoveries, in order to guarantee high levels of performances and quality on their vehicles.

Another important disadvantage is the possible creation of significant transaction costs for the leading firm: the actors involved in the outsourcing strategy must communicate constantly among each other and specify all the aspects (product design, costs, quantity requirements, etc.) needed for a good fulfilment of the final product. Obviously if the relationship between outsourcer and outsourcee is not correctly and honestly established there will be rooms for opportunism and for information asymmetries implying additional organizational costs and, over the long run, leading to the failure of the business relation.

The concept of modularity, instead, starts from the assumption that "big" products like automobiles, planes, or mobile phones are complex systems composed by many components with a lot of interactions between them. Moreover, the allocation of the

functions of a product to its components is called "*architecture*" (Ulrich, 1995) and the modularity is a concept that helps to describe and to conciliate different product's architectures.

The literature offered a wide range of definitions about modularity during the years, but all of them have some important points in common. First of all, the modularity of a single product depends on the degree of modularity of its components (Sosa, Eppinger e Rowles, 2007; McCormack, Rusnak, e Baldwin, 2008). Second, the modules are all characterised by a high level of independence among each other. The independence of each module, also known as *loose-coupling*, can be obtained by reducing the functional interdependences between modules (every module carry out its function independently and in an exhaustive way) and by defining ex ante the interfaces, or matching protocols, of each module.

The degree of modularity of car's components has become of growing importance in the last few years, especially when the majority of car manufacturers decide to allocate in outsourcing not only the production of their components but also their entire process of development. This trend implied huge de-verticalization processes and also stimulated the growing of even more bigger and specialized suppliers, in literature called "*Global Mega-supplier*[8]".

One of the main examples of the use of modularity in the automotive industry is represented by Tata Motors: the Indian car manufacturer that in 2008 introduced into the market an ultra low-cost vehicle (only $2500). The "Tata Nano" is essentially a set of components that, thanks to the modularity, can be sold and distributed in kits all around the world and then assembled by local entrepreneurs. This innovative configuration enables a faster and more efficient distribution of the Tata Nano and, at the same time, allows a better penetration on remote rural markets.

Other important characteristics of this sector are related to the "Supply Chain Management" and to the "Marketing and Distribution Strategies". However these two arguments will be discussed more in depth in the following pages in order to analyse all the aspects characterising this sector.

[8] Sturgeon & Florida (2004).

2.1.1 Automotive Industry Trends

After the important period of crisis, which involved the automotive industry in the years between 2008 and 2012, the sector experienced a constant recovery during the last few years.

Analysing the world productivity level in this period of time, can be noticed a constant growth in the production of vehicles (**Table 1**). The 2009, the worst year because of the tangible effects of the economic crisis, represents an exception.

Usually, after a huge period of crisis as the one mentioned above, the market demand experiences a gradual recovery and, as a consequence, companies are brought to positively review their market strategies raising the production level in order to meet this important increase of the market demand.

In the following analysis of the automotive industry's world productivity (number of vehicles manufactured) are taken into consideration both cars that have private/familiar purposes and commercial vehicles, which represent an important part of this market.

The 2009, as previously said, represents without any doubt the darkest year of this decade. It can be considered the lowest level reached by the industry due to the economic crisis: the total world production counted 61,76 million of vehicles (47,77 cars and 13,99 commercial vehicles). A huge decreasing (more or less -12,7%) if compared with the previous year (2008).

Nevertheless, starting from 2010, in conjunction with the slow recovery of the world economy, also the automotive industry noted a sensible and constant resumption.

In 2010, in fact, the whole world production of the industry reached 77,58 million of vehicles; of which, about 58 million were represented by cars, while 19 million were commercial vehicles. A huge growth if compared with the preceding year (2009): a positive percentage change of more or less the 25,6%. This year can be considered an important step toward the ending of the crisis.

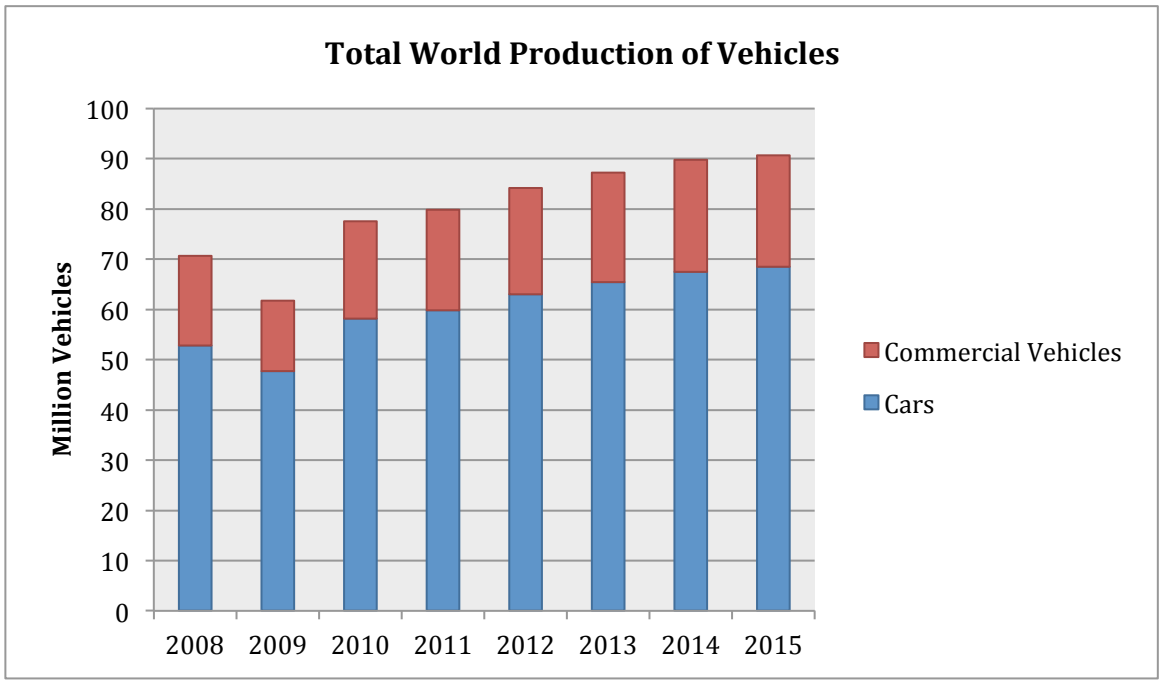

Table 1 - Total World Production of Vehicles
Source: Data from http://www.oica.net.

This increase in the production remains almost steady in the subsequent years; in particular can be noticed only slight positive percentage changes and a constant growth in the manufacturing of both the commercial vehicles (stably over 20 million of units) and the familiar cars (always over 60 million).

Finally in 2015, after some prosecuted years of positive increments, can be asserted that the automotive industry is definitely out of the economic and financial crisis.

The world production of vehicles reached never seen quantities: more or less 90,7 million of automobiles; 69 million was the quantity of normal cars while commercial vehicles counted 22 million of units. An emphatic increase approximately of 17%, compared to the total world production of the 2010, the first year of the economic recovery. An important contribute in the upturn was surely given by the emergence of new product innovations, like the mobile connectivity, and by a renewed attention to the eco-sustainability of the whole mobility, which fostered the diffusion of electric and hybrid vehicles. In 2015, as will be afterwards appreciated, the production and sales of electric vehicles (both battery electric vehicles and hybrid electric vehicles) grew considerably if compared with the previous years. Already a paltry number if compared to the totality of the gasoline-powered circulating automobiles.

Consumers, nowadays, are more willing to spend part of their budget for products that assure lower consumption rates and are more eco-friendly but, at the same time, able to guarantee greater reliability and high quality comforts.

This important period of economic recovery can be further confirmed by sales numbers reached by the automotive industry, starting just from 2010, on a worldwide level (**Table 2**).

Thanks to the analysis of sales of new vehicles regarding the last few years, can be better understood the various stages, already anticipated with the production volume analysis, crossed by this sector.

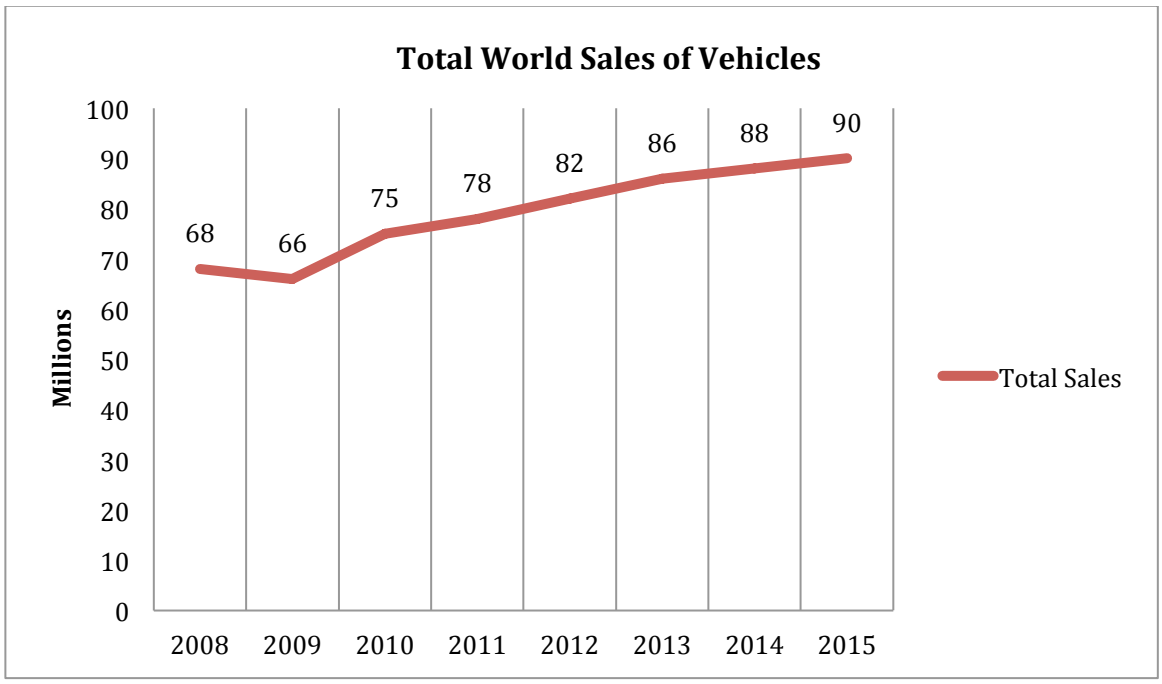

Table 2 – Total World Sales of Vehicles
Source: Data from http://www.oica.net.

The negative effects of the crisis, as already said, seriously affected the automotive industry in the years between 2008 and 2009. Analysing OICA (International Organization of Motor Vehicle Manufacturers)[9] data, can be seen a decrease not only on the production but also on the world sales of vehicles. Between 2008 and 2009, in fact, was registered a substantial reduction in sales of automobiles equal more or less to 2 million units; from 68 million in the 2008 to the 66 million vehicles sold in the 2009.

[9] http://www.oica.net/category/sales-statistics/sales-statistics-2005-2015/

From 2010 onwards even the world total sales, as in the case of the total production, experienced a clear and huge recovery. Can be noticed, in fact, a clear gap between 2009 and 2010: in the 2010 were counted 75 million of vehicles sold all around the world, an increase approximately of the 14 per cent if compared with the 66 million sold in the 2009.

The growth experienced in 2010 cannot be considered an isolated and temporary phenomenon; in fact, it goes on until the 2015 with a rise in sales amount of 3,8%, on average, every year.

In the 2015, in fact, the total amount of sales reached more or less 90 millions of circulating vehicles: a difference of 30 million units if compared with the worst period of the analysed decade. This growth, round 36%, further confirms the definitive ending of the crisis and the clear recovery of the demand inherent to the automotive industry.

This important restarting, as reported from a study made by McKinsey[10], is due principally to the appearance on the scene of new important markets and to their affirmation on the world economy. Among the most important emerging markets must be mentioned China, India, Russia and Brazil (the so called "BRICs").

In 2015 the Asiatic and Middle East regions accounted for more o less the 50 per cent of the whole world economy regarding the automotive industry; both for sales quantities (21,4 million) and concerning the productivity level (47,8 million of vehicles).

Especially China, thanks to a consistent growth in 2015 regarding both the production rate (+3,3%) and sales rate (+1,5%), is considered the main protagonist of the entire oriental region. However, must be underlined that some eastern countries, like Japan and Indonesia, recorded a decrease in productivity respectively of about 5,1% and 15,4%. China, as we will se in the next pages, will also have a fundamental role in the development and production of electric and hybrid vehicles: starting from 2015 it will become the first world market for electric cars (BEV and PHEV).

Europe, instead, despite a constant but feeble growth, in the 2015 continued to be under the levels of pre-crisis years. The total production of automobiles, commercial vehicles included, was of about 21 million of units while sales amounted to more or less 9,8 million. In this region the most performing countries, looking at the production

[10] "The Road to 2020 and beyond: what's driving the global automotive industry"; McKinsey; 2013

quantities, are Germany and Spain respectively with 6 and 2,7 million of vehicles manufactured; while, looking at sales quantities, Germany (1,7 million) and France (1,2 million) stand out among the others.

The American market, even if registered a slight loss if compared to 2014, confirms to be solid; it can count on a total production of vehicles of 21 million (-1,2% in 2015) and on sales for 12,6 million of vehicles (slightly better than 2014). The countries of the NAFTA area (Canada, Mexico and US) play an important role inside the whole American market: they accounted more or less for the 80% of the total production and sales of the continent.

The little decrease of the production registered in the 2015 is principally due to the countries of the South of America and especially to Argentina and Brazil, the biggest one. These two important countries experienced an important decline in productivity respectively of the 13,5% and of the 22,8% if compared with the previous years.

Looking at a recent study made by Charles Chesbrough, analyst of HIS Automotive, the worldwide level of sales will continue to grow until they reach the amount of 100 million of vehicles in 2023. In the next few years this growth will continue to be powered by the emerging markets – China among the others – and will reach a growth rate of 3,2% per year in 2019 and then it will decelerate in the following years.

The prices decrease of raw materials (steel, plastic, glass, rubber and others) necessary to manufacture an automobile is among the most important elements that, in the last few years, pushed up the growth of the automotive market: after having reached the maximum peak of 2.200 dollars for unit in the 2008, their cost diminished on an average of 51 per cent in 2011.

Chesbrough's research forecasts that, between 2016 and 2023, will be sold more or less 230 million of new vehicles in China and that the annual growth rate in the period between the 2015 and 2023 will be of 3,5 per cent: it will be higher than the entire world rate but, at the same time, lower than that of the 2005-2015 decade, a period of huge growth for the Chinese automotive market (+16,2 on average).

Following IHS Automotive, thanks to the low level of prices, to low interest rates on loans and to government incentives on the purchase of small vehicles, in China the sales of new automobiles will grow for the 5,5% to reach more or less the amount of 25,5 million of units in 2016. The most important factor in the Chinese growth is still the low

connection between population rate and number of vehicles: 120 automobiles for 1000 habitants; lower if compared to 275 of Argentina and Mexico and to more than 800 in the United States.

IHS estimates that, in the next years, the entire world automotive market will continue to grow – as occurred from 2010 onwards – and will reach the amount of 100 million of vehicles in the 2020.

The relative growth will have a peak of 3,2% in 2019 and then will start to decrease since reaching 2% in 2022.

In accordance with this study, more "mature" markets will have a lower rate of growth: in conjunction with the end of the actual recovery, Europe and US economies will start to decline and some countries will experience a saturation of the number of vehicles, a diminution of the population and a more efficient and cheaper public transport system.

Moreover, in 2019, IHS predicts that the actual difficulties of the emerging markets will be resolved and that total sales of that markets, pulled by the increment of incomes, will start to rise again. Their improvement, however, won't be sufficient to balance the fall of Europe and of United States of America.

2.1.2 Supply Chain in the Automotive Industry.

The study of the supply chain was, and still is, of strategic importance to understand the dynamics inside the automotive industry. There are numerous studies about the supply chain management and a lot of related case studies regarding this sector; this demonstrates the importance of this industry from an academic point of view and as a model for the development of other important sectors in the world economy.

The supply chain is defined as "*a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer*"[11]. Supply chain activities, therefore, involve the transformation of natural resources, raw materials and components into a finished product to be delivered to the final customer.

[11] Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). Defining Supply Chain Management. *Journal of Business logistics*, *22*(2), 1-25.

The discipline that, inside the company, is responsible for the strategic administration of the numerous supply chain relations is known as Supply Chain Management (SCM).

The most important activities carried out by the SCM are: (1) identification of possible strategic suppliers; (2) definition and consequent adoption of adequate criteria for the selection and evaluation of suppliers; (3) delineation of different supply policies depending on the type of furniture; (4) negotiation and definition of supply contracts; (5) formulation of quality control mechanisms and organization of relationships with suppliers; (6) efficient organization of logistics' operations and management of warehouses; (7) definition of common programs with suppliers aimed at creating value (process and product innovations, but also improvement of services to the final customer).

Usually the most important choice, regarding supply strategies, is related to "*make or buy*". These two strategies are very different between them and, of course, imply different evolutionary scenarios. On one side, because of recent evolutions of the markets and with the related implementation of new technologies, the choice to *make* (produce) internally every single aspects of the product implies, for the organization, some important problems and costs; thus making the process of vertical integration somewhat risky. Complex products, like cars, are often the result of a multipart combination of different technologies that obviously require specific and in depth scientific knowledge. Of course, huge investments and a strong organization are needed to gain these specific capabilities and not every organization is able to sustain, in an efficient way, this strategy. Gigafactory[12], an idea born from the partnership signed between Tesla Motors and Panasonic, constitutes an actual and proper example of "make" internally. The goal of this special project is the exploitation of the economies of scale in order to decrease rechargeable batteries' production costs and, consequently, lower the price of the final product, with the aim of fostering a more widespread diffusion of it. It can be considered a sort of return to the past: this vertically integrated strategy belonged previously to Ford in the 20th century, with the production of the Model T, and, also in the case of Gigafactory, requires important financial efforts and a huge organizational structure from the two companies involved.

[12] https://www.tesla.com/en_GB/blog/gigafactory

On the other side, when the organization doesn't posses the necessary know-how to produce inside the company the whole product or, otherwise, is able to buy goods or semi-finished goods on the market at a minor cost, it is convenient to adopt a "*buy*" strategy: that is, the organization outsource the production of some parts of the product to another, more specialized, company while maintaining inside the only production phases with the highest value added.

Producers of complex manufactured goods, as described by Langlois and Robertson (1992), decided to abandon the vertical integrated approach increasing, at the same time, the volume and scope of their outsourcing. As already said, among the outsourcing advantages there is the possibility for the company to focus mainly on its core business and, at the same time, to exploit the technological expertise of its specialized suppliers.

Therefore, an essential point concerning the management of an efficient and effective supply chain is the development of adequate and in-depth relationships with the entire pool of suppliers. Today, this could imply the creation of strategic partnerships like, for example, the one between Tesla Motors and NVIDIA for the development of every digital instrument inside a Tesla[13]; the early involvement of suppliers in the process of product development; a more open and inclusive innovation process and an increased adoption of modularity.

Especially in the automotive industry a factor of key importance is represented by logistics and, at the same time, the organization and shipping of various components are of strategic importance for the entire management of the supply chain. It is of primary importance for the OEMs to conclude long-term partnerships with the most suitable operators. They must be able to guarantee adequate and prompt responses to the evolution of the markets and they should constitute good partners for the implementation of new innovative solutions in the fields of logistics and supply chain management.

A good example is represented by FERCAM: founded in 1949 in Bolzano (Italy), it is now one of the most important and international Italian companies. Thanks to its huge and long lasting experience in the logistics and transportation industry, it manages on behalf of other important companies all the aspects related to the in-bound logistics thanks to

[13] http://www.nvidia.com/object/tesla-and-nvidia.html

the organization of transport, the provisions and the daily withdrawal of original parts and components from national and international suppliers.

In order to comprehend how much crucial are the choices of the logistic partners in the automotive industry, is enough to think about the strategic role that is played by *Just-In-Time* deliveries: a firm cannot stop all the production process and, consequently, penalize the *time-to-market*[14] because of organizational problems in the delivery terms. This could have serious implications on the competitiveness of the company.

Is therefore essential that the logistic partner is able to guarantee an efficient transport system: highly qualitative and, at the same time, always available when there is the need.

FERCAM, for example, provides to its clients a synchronized service between supplier and the principal manufacturing plant setting, through a contract, a precise time of delivering for every supplier's area.

However, FERCAM is not the direct supplier of automotive components but only an important shipping company that assure the efficient and punctual flow of raw materials and components from first or second tier suppliers to the final assembler.

The automotive industry is principally characterized by the so-called OEMs, the assemblers of the finished product, and then by a multitude of first and second tier suppliers who are highly specialized in the development and production of particular components. Usually the OEMs are big companies or groups (Volkswagen, FCA, BMW, Daimler, Ford, GM, etc.) that cannot be vertically integrated for obvious reasons. Nowadays a vertical integrated structure, like the one adopted by Ford in the 19th century, would be no more sustainable from an economical and organizational point of view: despite the possibility for the company to gain a more in-depth knowledge about its core business (core competences) and an easier internal coordination and communication; a huge vertical structure implies, on one side, important bureaucratic and production costs while, on the other side, it damaged the degree of flexibility of the company.

[14] The period of time that pass from when a product is being conceived until is being available for sale is called Time-to-Market.

The majority of the OEMs, therefore, are "obliged" to commit the whole production process, or only some parts, to external suppliers. Suppliers can be classified into different categories depending on the level of provision they served: usually they are categorized in first tier and second tier suppliers (**Figure 2**); however there can be also other levels beyond second.

First tier suppliers are those who are directly linked to the OEM and have a direct and constant exchange of information regarding the product development.

Second tier suppliers instead are those companies that, although they are considered in its supply chain, don't have a direct relationship with the OEM: they communicate only with the first tier supplier.

In such an extensive and important industry like that of the automotive there are plenty of important and famous suppliers. Often these companies are as big as the OEMs and they can be also leaders in their own sectors.

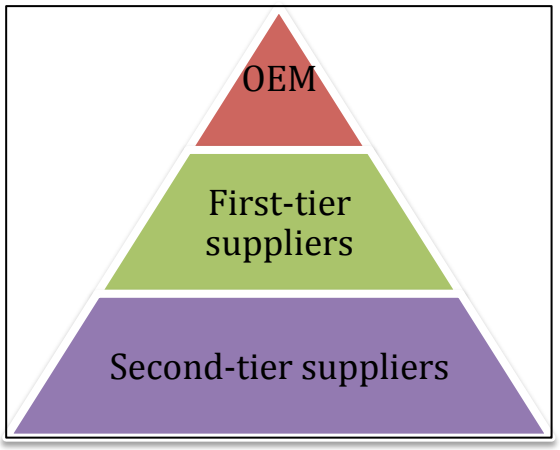

Figure 2 - Supply Chain Pyramid
Source: Personal knowledge

In 2015, following Statista[15], the most important supplier for the automotive industry, from the point of view of revenues, was Bosch: the German producer of the majority of car components, among which the most famous are windscreen wipers, batteries and braking systems, could count on 41.7 billion euros of revenues. In the second place there was Continental, famous mostly for its production of high quality tires, with 39.2 billion euros of revenues. At the third place can be found a famous Japanese company, Denso, which is renowned for the production of components related to the cooling system and which, in 2015, recorded 34.3 billion euros of revenues.

The list of automotive suppliers could be almost endless and the majority of them are important and well managed multinational companies (Bridgestone, Goodyear, Delphi, etc.). Here it's not possible to mention every one of them but, looking at the mentioned

[15] https://www.statista.com

suppliers and at their revenues, can be understood the importance of the whole network of suppliers and the consequent flow of money that this industry induces on the world economy.

In the last few years, this historical trend (the outsourcing) was in part criticized by industry experts and by academic researchers. The fundamental point of this critic was the increasing amount of outsourcing activities, even of strategic phases of the production process, undertaken by car manufacturers: does the high level of outsourcing has a positive impact on car manufactures? Is a good choice for the OEM to outsource activities like design and engineering over the long-term?

Complex products, like cars, are composed by components of large dimensions (like the engine, the radiator, the front end, etc.) and by smaller parts such as brake discs or windows. This complexity implies a certain level of technical experience and an adequate architectural knowledge to manage the interdependences between every single component.

The mass outsourcing phenomenon that overwhelm the automotive industry between the end of 20th and the early 21th century caused a substantial lack of technological competencies in key areas and altered the concept of system integrations. Managers perceived that it was becoming increasingly difficult to integrate such complex systems without having an in-depth knowledge of the technologies that composed each single system. Moreover engineers needed to have an understanding of the components composing a car, a quality that was progressively disappearing with the decrease of learning-by-doing possibilities caused by the huge outsourcing phenomenon of critical activities.

More or less in 2005, as reported by Zirpoli and Becker (2011), the management of FIAT, the most important Italian automaker (now FCA), tried to solve this progressive lack of specific-knowledge giving also an important opportunities to the other actors of the same industry. The management of the company started to reorganize its approach to outsourcing strategies and to decrease the amount of design works it moved outside the firm. Managers and the board directors realized that their company, whatever it is, must keep in-house the activities that have direct impacts on product performances and, furthermore, has to maintain a strict control over those activities that are highly interdependent with the technologies related to development of the product.

When the interdependence between activities is high and when the components or systems affect the overall performances of the product, the company must try to re-acquire as much knowledge as possible from its suppliers. On the contrary, when these aspects are of low importance, components and/or systems can be outsourced without any problems and can be integrated later in the production process.

Today companies must organize them in order to be able to develop, maintain and re-establish components specific knowledge described above and, moreover, must be able also to experiment, test and use trial and error across the whole product in order to guarantee an high level of performances.

Another interesting argument of widespread importance in the automotive industry is related to the modularity and the modular supply. This strategy, which focuses mainly on the interdependence of each "module", on one side is particularly recommended for the physical integration but, on the other side, it is not adequate for the correct assessment of performances.

Volvo constitutes a good example of adoption and implementation of a modularity strategy.

Fredriksson (2002) decided to implement a research over the performances of modular assembly units (MAUs) in the automotive industry and decided to bring as a case study Volvo Car Corporation. The modular assembly unit performances depend essentially on three factors: (1) Ownership (outsourcing vs. vertical integration); (2) Location: if the modular unit is placed inside or outside the assembly plant of the OEM; and (3) Degree of Control: if the car manufacturer has a high or a low control over the modular assembly unit. Obviously there is no one best way for the balance of these three factors and the best solution possible depends essentially on some characteristics of the module: labour intensity and interdependence structure.

If a module is labour intensive and it does not require extensive interactions between the MAU and the final assembly line, then for the company it will be better to "outsource" some phases of the production process rather than adopting an "inside pre-assembly" strategy. Furthermore, Fredriksson (2002) gave some importance at the interaction between the degree of control and the other two factors (the ownership and the location). He stated that, even if different ownership and location strategies can influence positively or negatively the performances of each MAU, the degree of control

adopted by the automaker is of fundamental importance for the implementation of the other two parameters.

Volvo applies a modularity strategy on its plants of Goteborg (Sweden) and Gand (Belgium) and the production of entire modules is committed to suppliers, whose assembly plants are placed nearby the Volvo plants and supply them with pre-assembled parts.

The positioning of the suppliers near the OEM's production plant takes with him a series of advantages. First of all this facilitate a rapid and responsive delivery, also in case of modules that are bulky or critical for the configuration of final product variants. After that, the proximity of the car manufacturer favours the implementation of tacit knowledge transfers and the creation of new joint activities.

Fredriksson research discovered that there are good combinations of these parameters under which the outsourcing strategy has not the problems discovered above in the chapter and that, sometimes, especially when there is an external sourcing with a low degree of control from the OEM, product modularity corresponds also with organizational modularity.

2.1.3 Marketing and Distribution Strategies

As we have just seen in the previous chapter, in such an important industry like the one of the automotive the establishment and the management of an adequate and efficient supply chain is of primary importance for the competitiveness of the entire company.

Equally important for the growth and the good administration of a company are an efficient organization and a virtuous management of the post-production phases: it is of fundamental importance the implementation of effective marketing and distribution strategies.

The marketing strategies of every company, not only the ones of the automotive industry, have their roots on the "*4P Paradigm*" theorized by Jerome McCarthy: Product, Price, Place and Promotion.

In the last few years, with the progressive recovery of the sector and the growing importance of the combination between image and real quality of the product, the automotive industry became an example for other industries.

It is very important to emphasize how in the automotive industry occurs a huge segmentation of the clientele on the side of the economical possibilities of each costumer. This is strongly linked to the large amount of investments required by the product: cars are goods with a high degree of durability but, at the same time, they initially have a strong impact on the budget of the consumer.

Therefore, on the basis of these assumptions, the price is still a determinant variable in the whole process of promotion and purchase of the vehicle.

In the last few years, in fact, a lot of new under-brands, strictly linked to the main automakers, were born with the aim of satisfying that category of consumers, which are not intentioned to spend large amounts of money but still focused on an acceptable level of quality and on performances offered by the product.

Dacia, an under-brand linked to the Renault Group, is a suitable example of this actual trend.

Since many years, even before Renault acquired it, Dacia's main production plant was situated in Mioveni, a small town in the south of Romania. This place represents a key factor in order to analyse the company's strategy: the delocalization of the production process to those countries located in the east of Europe, allows the company to hit development and manufacturing expenses thanks to a lower labour cost.

Renault implemented a rigorous "cost-to-design" approach, using fewer components than a typical Western car, offering a limited range of exterior colour options, redesigning the windshield to reduce production and installation costs, and creating a vehicle that could be easy and cheaper to maintain.

An engine made by Renault powers Dacia's cars, this factor guarantees the same performance standard of every original Renault model. What makes them different is that they have less comfortable and aesthetics interiors. However, they can guarantee some services nowadays essential in the whole automotive world, such as the steering wheel remote control, the Bluetooth, and an Lcd touch screen able to manage radio, navigator and smartphone.

As an example, Dacia Sandero, which belongs to the same segment of the Fiat Punto or the Volkswagen Polo, is commercialized in Italy with a starting price of 7450 euros[16].

[16] http://www.dacia.it/X52-reveal/sandero/

This price is clearly much more competitive if compared respectively to 14.300 euros of the Punto and to 13.500 euros of the VW Polo. However it is to be highlighted that, especially regarding the VW Polo, the quality of the mechanical components (engine, transmission, etc.) and of the interiors is notoriously of another level if compared with the Dacia Sandero.

The price is one of the key points of Dacia strategy, which allowed the company to conquer year after year more market shares and gain an important competitive advantage over direct rivals of about the 30% (in terms of price). It is important to understand that exists a particular segment of the clientele, which pays special attention to the economical aspect when purchasing a car, and it is as much important to recognize that a low price is not always a synonym of poor quality. Exactly this factor is one of the causes, with the lack of adequate supporting infrastructures, which obstructs a wide diffusion of all-electric vehicles. These autos can be in some cases very expensive (more than 100.000 euro) and ensure a significantly lower autonomy if compared with traditional ones. The Well-to-Wheel analysis implemented in the following chapters will demonstrate that, nowadays, it is not worthy to spend a large amount of money for a vehicle that, including all the expenses, doesn't imply clear economic advantages. Only when this economic and performance gap will be filled up, the electric car could constitutes a real alternative to traditional ones and so gain significant market shares.

Therefore in a high-segmented industry like the one of the automotive it is important for the OEMs to offer a broad variety of products with a wide range of technical skills and prices.

The final customer and the particular relationship that it has with the product are the core of the company's assessments and strategies. The final product represents one of the most important elements, maybe the most important, for the company; it constitutes one of the "four P" at the roots of the marketing mix and, for this reason, it must be able to satisfy all the needs revealed by the costumer at the purchasing moment.

Especially when analysing the last few advertising and marketing trends, it can be easily noticed that a high degree of alertness is paid to the digital technologies and to the interactions between vehicle and mobile devices. Today almost every model of car, even those not luxury or high comforts equipped, owns the adequate technologies to enable an intuitive and more safety use of the smartphone when the user is driving. It is enough

to think about the numerous and important partnerships signed between the most important automakers and the giants of the information and communications industry, such as Samsung, Google, Apple Inc., and others. For example, almost all the most important automotive companies signed strategic market agreements with Apple Inc. in order to provide all their cars with its new developed system – also known as CarPlay – instructed to interact directly with the iPhone or the iPad. The system enables the consumer to manage everything that is related to or inside the smartphone (incoming calls, messages, music, and recently apps) without looking at it or picking it up, but simply connecting the device via Bluetooth to the car and then using the equipped touch screen. Looking at this particular initiative, it is clear the purpose of the companies to meet one of the most deep-rooted needs inherent the modern "digital" consumer: the "pathological" necessity of being always connected with the smartphone and all the functions related to it, such as e-mails, social networks and photos. Nevertheless, this innovation was partially criticized in the last few months because it was blamed of the high rate of accidents caused by the distraction of the driver.

A key role in the automotive industry is played also by the distribution strategy. This element could represent the "Place" mentioned in the marketing mix and it is important mainly for two reasons. On one hand it constitutes a fundamental part of the entire value chain: industry experts generally estimate its cost between 25% and 30% of the vehicle list price[17]. On the other hand, the distribution mechanism is an important element for the effectiveness of the whole automotive system, because it contributes to the creation of value. The vehicle itself and its intrinsic characteristics (engine power, fuel consumptions, comfort, etc.) are not enough to obtain a good feedback from the consumer but, it depends also on the characteristics and the services provided by the sales point during and post the purchasing process.

The distribution strategy can be considered the trait d'union between the supply chain and the final consumer (the demand of vehicles).

In the last few years the distribution strategies are profoundly changed and, with them, it is also changed the role of the distributor. Even if, in the past, the distributors were mainly "passive" subjects directly and exclusively at the dependences of the OEMs, now

[17] Towards a New Business Model for Automotive Distribution; L. Buzzavo; 2013

they have become more proactive entities, independent businesses, able to implement an efficient and effective management of the available resources. Distributors now have the necessary flexibility in order to respond quickly to the constant changes of the market, finding new profit opportunities.

In the past, the dealer was responsible only for the activities of ordering and selling vehicles; today, instead, the activities committed to the dealers are enriched with the management of the territorial marketing strategies, the administration of sale forecasts and all the other activities related with the mobility sector (car rental, used cars sale, financing opportunities and post-selling assistance).

The role of the dealers has become of fundamental importance especially regarding the geo-marketing strategies: the OEMs are not more able to implement on your own marketing and selling strategies according to the necessities of a particular region. Nowadays this task is entrusted to the distributors, which have to abandon the mass-marketing policy in favour of more targeted initiatives and must be skilled enough to implement more professional and complex marketing strategies.

However, the dealers remain dependent by their original automaker for all those aspects regarding the final price of each vehicle: they have to respect the directives on costs and prices imposed by their main company.

It should be specified that the role played by the distributors is becoming more and more bordering also because of the advent of digital technologies. Actually, almost the majority of the consumers are no more interested to visit the distributor's showroom to gain more in depth information about the characteristics and the price of the vehicles proposed; they directly search them through internet websites or social media and, only after this, they address the seller for ordering the preferred car.

In the last few years the totality of automakers, that choose the social media marketing as a rapid and direct communication tool to transmit company's values and initiatives, has constantly increased.

Audi, in relation to this, represents one of the most virtuous examples of application of the social media marketing.

The famous German company of Ingolstadt has always been and, is still, very able to exploit the power of social networks to acquire its clientele and make it faithful, thanks to the use of sensational virtual experiences, contents, and relations.

Audi Italia has decided, since some years, to sign an important partnership with the "Federazione Italiana Sport Invernali (FISI)". Its ambition is to promote and combine the typical characteristics of the country (the dolomites) with the advanced technology provided by the company (i.e. Audi "Quattro"), through spectacular contents shared via YouTube and the principal digital communication tools (Facebook, Instagram, Twitter, etc.).

The Chief Marketing Officer (CMO) Council argues that, at a worldwide level, the 38% of the hypothetic costumers looks at the social media to gain information and to assess the purchasing of a new car, while the 23% of the users is willing to share on the social channels its own post-sale experience. As Donovan Neale-May, the Executive Director of the CMO Council, pointed out: "*social represents an important marketing frontier for the automotive industry*"[18].

Therefore auto dealers must be able to face this incumbent "threat" and, as a consequence, extend their range of services for the final costumer, especially those regarding the post-sale, the certified assistance, and the sale of used cars and/or the rent opportunity. Internet and new digital technologies are not already able, and maybe they will never be, to supply these kinds of services due to the strong specific technical and manuals capabilities required. Another possible and already implemented solution is to take inspiration from other industries and develop official stores, which can foster a direct relationship between the company and the costumer. They are not traditional dealers, but they are rather mono-brand stores, also known as "factory-based galleries".

Developed firstly by Tesla Motors and positioned in strategic places, they allow the consumer to know and experience the product at 360 degrees. They cannot be considered properly stores or shops but, rather, real showrooms since the only sales channel is the e-commerce one and their main purpose is to help the consumer in the perfect customization of its product.

However, as already anticipated by Amazon.com[19], these competences could not be enough for the dealers to survive in the future: the threat of a possible online sale of cars, as a simple commodity, is seriously scaring the insiders of the sector.

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[18] https://www.cmocouncil.org/media-center/press-releases/4727

[19] For more info: http://uk.businessinsider.com/morgan-stanley-amazon-could-sell-cars-2016-8?r=US&IR=T

2.2 The Role of Innovation in the Automotive Industry

Another important aspect of the automotive industry regards the innovation.

When developing and producing a complex product, the correct management of innovations and technological know-how deriving form it, is of fundamental importance for the competitiveness of the company.

Before discussing about innovation inside the automotive industry and provide some practical examples, it is useful to introduce some important literature explanations that can allow to better understand and analyse this argument.

There are different types of innovations that an organization could implement; each one of these requires a certain level of underlying knowledge and has a specific impact on the dynamics of the whole industry.

Usually innovations are categorized into four dimensions:

- *Product Innovation vs. Process Innovation.*

  Product innovation focuses mainly on the outputs of the organization and it is related to the development and subsequent commercialization of new or, simply, redesigned products or services (i.e. a new car model). Process innovation, instead, focuses its attention on the procedures and on the techniques through which the company carries on the production process. Its main objective is to improve the efficiency and effectiveness of the production by reducing or, when possible, eliminating slowdown factors. Usually these two innovations can be implemented together at the same time: new products development, often, implies the development of new processes and, vice-versa, a new process can bring to the development of a new generation of products.

- *Radical Innovation vs. Incremental Innovation.*

  These two different types of innovation are referred to the degree of which a selected innovation is different from previous solutions or practices implemented by the company. It is defined as radical that innovation which is new and very different from previous solutions. Occasionally could result risky for the company to implement such a kind of innovation because takes with it a certain grade of uncertainty and, sometimes, implies additional costs.

  An incremental innovation, instead, involves a minor degree of change from previously existing processes or solutions and, moreover, it is an innovation that

can be previously known by the firm or the industry, but that was not adopted in the past.

However the degree of radicalness obviously can change over time or according to different observers. An innovation that emerged in the market as radical may become incremental with the flows of the time and as the knowledge base underlying this innovation becomes common (the steam engine is an example of this).

- *Competence-Enhancing Innovation vs. Competence-Destroying Innovation.*

  This classification concerns the effects that the implementation of an innovation has on the competences, on the know-how, already in use by the company.

  When discussing about a Competence-Enhancing innovation we are talking about developing and implementing new solutions on the base of previous existing knowledge and skills. On the other side, an innovation is defined as Competence-Destroying if it is not based on competencies already on the hands of the company or if it makes them obsolete. Obviously this conception of innovation will vary depending on the particular perspective of every single firm: an innovation can be considered competence-enhancing by one firm while, another firm, in another industry, considers it as competence-destroying.

- *Architectural Innovation vs. Component Innovation*

  The last dualism is referred to the entity of the variations from the point of view of the product, seen as a set of components or as an integrated system.

  On one hand, an innovation is considered "Architectural" when it necessitates the change of the whole design of the product or the ways components interact with each other. On the other hand, is defined Component (or Modular) that innovation which includes a change to one or more components but, unlike architectural innovations, doesn't affect the way these components interact.

  However, it is important to say that these innovations sometimes can occur both at the same time. Often, the majority of architectural innovations not only imply changes in the system but also in the components underlying this system.

In the automotive industry there are plenty of examples of each kind of these innovations. Perhaps the most important historical innovation in the automotive

industry is the adoption of the combustion engine (the famous "CicloOtto"[20]) in last few years of the 19th century. This important discovery changed a lot the concept of car. Previously cars were moved by a steam engine or by the first prototypes of electric motor. Often these cars were heavy, slow and disadvantageous from the point of view of consumptions. Starting from 1886, with the adoption of this new engine, cars became faster and cheaper (the petroleum, the fuel that allows the engine to run, was cheaper and more durable than the carbon fossil) and the entire design of the car was revolutionized becoming much more agile and, at the same time, structured.

Nowadays the electric engine can represent a comparable innovation: its functioning and configuration are completely different from the combustion engine and, nowadays, it is sharply more developed if compared with the first prototypes of the 19th century. The energy used to recharge the battery-packs is today more available (the user can recharge its vehicle at home in a short period of time) and cheaper. The engine is all in all more reliable and eco-friendly than in the past: it allows longer journeys with low rates of greenhouse gases emissions.

Therefore these innovations can be considered, looking at the classifications described above, radical and architectural. These important changes in the automotive world imply significant differences from previous adopted technologies and innovations both in the components and in the way they interact. However, there are also important changes from the point of view of the competences (combustion engines are very different from steam and electric engines in their manufacturing and functioning procedures), which allows to consider them competence-destroying innovations and product innovations.

Today most of the innovations are related to single components or to the whole vehicle's design and imply little changes for the functioning of the vehicle. Therefore they can be considered as component, competence-enhancing and incremental innovations.

Just think about the "IntelliSafe"[21] system developed by Volvo Cars. This system contributes to help the driver in dangerous situations such as the sudden and unexpected crossing of a pedestrian or the possibility to make a collision with another

[20] The nickname of this historical engine derives from the name of its inventor: the Deutschland engineer Nikolaus August Otto, who was the first to patent this discovery in 1876.

[21] http://www.volvocars.com/intl/about/our-innovation-brands/intellisafe

vehicle in a crossroad. It is a sort of autonomous driving technology powered by a series of radars, cameras, and laser sensors able to "read" the road ahead.

It constitutes an important innovation from the point of view of the product and it will increment the performances and the safe both of the car and the driver. It doesn't affect the overall design or functioning of the car (the mechanical parts are always the same) and can be considered an incremental evolution, an upgrading, of earlier security systems (seat belts, air bags, etc.).

Another fundamental issue to be explained when talking about innovation and automotive industry is related to the protection and, the eventual, diffusion of innovation. There are several ways through which an organization can protect its know-how and innovations. Securing returns on innovation depend, to a significant extent, on the ability of companies or individuals to protect it. For this reason the IP (Intellectual Property) legislation was established. However, recently, this is not completely true for all the companies. There are also some important and innovative firms that prefer the adoption of a more open approach to foster an easier and cheaper development of the technology, providing in this way competitive advantages for all the industry.

Among the most famous and adopted practices to protect something strategically critical for the competitiveness of the company can be found patens, trademarks, copyrights and industrial design rights.

Patents are one of the most widespread instruments to protect innovations and they consist in a form of right granted by the government to an inventor. This right exclude the others from using, selling, re-making, offering to sell and importing an invention for a limited period of time, in exchange of its public disclosure. Obviously, every country has its own law governing and regulating patent protections.

Trademarks, instead, may be used to prevent other from using a mark that could be as similar to be confused. This instrument, however, doesn't guarantee the protection against the production or from the sale of the same goods or services under a different mark.

Copyrights regard forms of protection granted to works of authorships for a limited period of time. Very important to underline is that this tool does not protect new ideas, knowledge or information, but it only covers the form in which they are expressed.

However, for obvious reasons, this form of protection is not so widespread in the automotive industry (there is little room for works of authorships).

A further instrument aimed at protecting new creations or innovation is called "industrial design right" and its role concerns the visual design of objects that are not purely utilitarian (creation of a shape, configuration of patterns or colours, etc.).

Another way to protect the know-how acquired by the company is the adoption of the Trade Secret. Inventors or firms often choose this form of protection instead of disclosing important information about a proprietary product or process in exchange of the grant of a patent. Moreover a trade secret comprehends information or important knowledge that belong to a business that is generally unknown to others. It is important to point out that information is suitable to be considered a trade secret if (1) it offers to the firm a significant competitive advantage in economic terms and (2) remains valuable only as long as it remains secret.

Even if it is not relevant for the automotive industry, Coca-Cola offers one of the most famous examples of trade secret: its formula for producing the famous beverage is still secret and unknown, after more than a hundred of years (from 1886).

These are, very briefly, the most famous and used forms of protection for an innovation or a new invention adopted in all the markets and not only in the automotive industry.

Skoda Auto constitutes an important example of innovation protection in the automotive industry. Thanks to an article published by the WIPO (World Intellectual Property Organization) Magazine, it is possible to understand the importance Intellectual Property (IP) rights have not only for the company itself but also for the whole automotive industry. In such an industry, where the products (cars) are made of high-tech components and produced using highly sophisticated processes, it is not enough for the firm to ordinarily administrate only the production phase and the sales process. The continuous development and introduction of innovations and, of course, their protection through IP rights are the pillars for a long-term success of the company.

Skoda Auto has established an Intellectual Property Department accountable for protecting and managing company's innovative discoveries and creations. This department is also responsible for maintaining relationships with patent and trademark's offices across the world.

Intellectual Property Department main tasks are, in summary, to evaluate and assess the most appropriate strategy to adopt in order to protect a new invention or innovation and to prepare and filing applications and the associated procedures aimed at obtaining patents, trademarks and all the protections indispensible.

Figure 3 - The Varioflex System
Source: www.skoda-auto.com

Skoda Auto is the owner of an extensive portfolio of trademarks. These protection tools are used in order to protect the multitude of model series and they include both the names of historical brands, no more in commerce, such as Popular, Felicia and Favorit and more recent models like Citigo, Octavia, Fabia, Yeti, etc. These words and their graphical form are all legally registered and have an important strategic meaning for the company: they are exploited for marketing strategies and for reputational purposes, as synonyms of high quality and high performance of the vehicles. The company spend a lot of time and makes a lot of efforts in order to produce attractive trademarks for the customer, who must perceive them as easy to pronounce, aesthetically pleasant and intuitive to memorize. Skoda not only chooses to register words inherent to the model series but it also registers trademarks that are important for the description of a certain product or component. For example, Twindoor® (**Figure 3**) is the name of a system developed by the company that allowed the customer to open the hatch both like a conventional trunk and, when necessary, like a rear hatch.

Another example is the Varioflex®: a new innovative solution for the back interior seats that increases the versatility and the comfort of the car.

Skoda also is the owner of a wide series of service marks (a particular type of trademark that protects services rather than physical products) that allows distinguishing sports variants of different models, types of engines and interior trims. Examples of service marks are: Skoda Service, GreenLine, Octavia Scout, Skoda Accessori Originali and others.

The large trademarks portfolio of Skoda is a fundamental pillar of the marketing strategy and, as previously said, plays an important role in constructing brand recognition and consumer confidence in the products.

Every company, in a period of rapid and frequent changes in the market like this, base its success on the ability to develop and therefore commercialize products able to overcome the competition in terms both of quality and technology. Today the most important factors that can determine the success or the failure of a product in the automotive industry are related mainly to the optimization of conventional drivetrains, the development of new types of engines, the improvement of the e-mobility, the infotainment, the expansion of connected cars, the planning of driverless cars and the design of new comfort functions.

Skoda non only possesses a large number of trademarks, but also has a wide range of patents. The company not only requests patents for the mechanical and technical parts of the car (engine, transmission, brake system, etc.) but it seek also to protect innovations related to the interiors which could an important element to improve the quality of the costumer experience (both of drivers and passengers).

Considering that the company has a strong international activity – it has manufacturing plants all around the world, from China to Europe, India and other important states, and exports to over 100 countries – the WIPO's Patent Cooperation Treaty (PCT)[22] plays an important role for its protection strategy. The PCT allows the company to protects its inventions all around the world saving costs and time. The majority of Skoda's patent applications are filed with the national IP office in Prague (Czech Republic, where it was founded).

The company also protect certain aesthetic features of the cars, including studies, concepts, visual chassis and lights. Nowadays, design is a fundamental factor for the commercial success of the cars making the driving experience more exciting, sleek and smooth. In this field Skoda takes advantage of the WIPO Hague System for the International Registration of Industrial Designs: a cost-effective and simplified method

[22] The Patent Cooperation Treaty (PCT) is an international treaty signed in 1970, in Washington, between more than 145 Contracting States. The PCT allows organizations or individuals to seek patent protection for an invention simultaneously in a large number of countries by filing a single "international" patent application.

to protect designs on an international base. The acquisition of legal rights over important design innovations plays a fundamental role in the battle against the production and sale of counterfeit and fake products.

Skoda IP Department is also responsible for managing the licensing agreements. Many times, instead of beginning an expensive legal battle against an illegal use of a particular innovation or invention that could end with an injunctive order demanding a license to be issued, the company prefers to establish a licensing agreement with the competitor willing to use and adopt that particular technology.

The company has concluded a wide range of licensing agreements with other actors of the market. These enable the company to take advantage by innovative technical solutions already protected by patents or utility models as well as licenses for trademarks, industrial designs and know-how. These licenses are exploited in a wide range of situations, including for reasons such as merchandising, financial services and car production (China, Russia and Ukraine).

To conclude, IP rights have always had and continue to play a significant role in the company main target of launching reliable high-performances vehicles, which continue to stimulate and conquer the mind of consumers. The cars manufactured by Skoda are becoming more and more smarter, and inevitably the management of all the IP assets is becoming increasingly complex and requires specific, qualified, knowledge.

The just discussed argument about the ways through which a company could protect its innovations refers directly to another important issue when talking about new knowledge and know-how: the convenience for an organization and its strategy to choose an open instead of a closed innovation system.

In the last few decades, thanks to the historic increase of the connectivity between people and organizations occurred starting from the third industrial revolution, can be registered a constant shift from a closed, vertical integrated, approach to innovation to a more open and less rigid one. This can be clearly observed especially when discussing about electric vehicles innovation. Many important companies, like Toyota, Daimler, Panasonic and Tesla (only to cite some of them), are now working together in order to increment this new technology, which can represent the future of the industry. This approach, as will be explained, brings some advantages both for companies, which can

save costs and time, and consumers, which can benefit from more reliable and performing products.

A closed innovation system, also called "wholly proprietary system", is based only on technologies strictly owned by the company and protected through the variety of instruments described above (patents, trademarks, copyrights, trade secrets, etc.). Usually, products developed with this kind of approach are not compatible with similar products commercialized by other manufacturers. The high degree of protection over developed and adopted technologies acts as a barrier for the competitors not allowing them to develop components or innovative technologies that could interact with the proprietary system. A crucial role in the closed innovation system is played by a centralized R&D function internal to the organization: it is the principal and most important driver of innovation and implies a strong vertical integration of the company. This approach obviously led to a severe protection of new knowledge and intellectual properties.

Open innovation system, at the opposite, can be assumed as the antithesis of the traditional vertical integration approach where internal R&D activities lead to internally developed products that are then distributed by the firm (Chesbrough, 2011).

In 2003 Chesbrough, a professor at the Hass Business School (UC Berkeley), defined the Open innovation as "*the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the market of external use of innovation, respectively*".

Open innovation system, also called by the experts "wholly open system", is also considered a more easy and profitable way to innovate. On one side it reduces costs and accelerates the time to market (a key factor for the competitiveness of the company); on the other side it constitutes an important strategy to increase the differentiation inside the market and creates new value opportunities for the company.

This system is considered open because, the technologies adopted to develop a product or a process, are not protected by patents or any other protection tool. The knowledge can be freely accessed, improved and distributed by anyone who is interested. If a number of firms are simultaneously producing, distributing and promoting the same technology, the technology's installed base may accumulate much more rapidly than if one firm is the only responsible for the development of such activities. The deriving competition among actors in the market can cause an important decrease of the price,

making it more attractive and purchasable for costumers. As a matter of fact one of the principal advantages of an open innovation system, as previously said, is the high rate of development of new technologies due also to a more rapid adoption.

However, in some cases technologies are neither wholly open nor wholly owned by the company: they can be considered partially open, utilizing varying degrees of control mechanisms to protect their technologies.

In the automotive industry the open innovation system has became the most adopted strategy to acquire important knowledge, also from other industries, and to develop new products and/or new services for the costumer. Tesla Motors constitute an important example of adoption of an open innovation system in the electric segment. In the following chapters will be analysed more in depth the strategy adopted by this important company and will be explained how it is contributing to the development of the electric "revolution". Here, instead, it is useful to discuss about an historical company of the automotive industry, which decided to shift from a closed innovation system to a more open and collaborative one.

Pininfarina, one of the most famous Italian designing companies, founded in 1930 in Turin, constitutes an important example of this strategy. It operates in a wide range of sectors but the bulk of its business derives from the automotive industry, as its core activities are to develop and produce chassis for niche vehicles.

The company has always tried to retain a leadership position inside its market, acting as a first mover and introducing important innovations related to the design and technologies before the principal competitors.

Until the 2007 the company was able to finance the whole R&D process thanks to its own liquid assets (for example, it built an innovative wind tunnel on a 1:1 scale which implies a yearly 2 million euros of investment). However a lot of collaboration relationships and partnerships were set with other strategic companies, with whom Pininfarina started some co-development projects with the objective of building prototypes based on new and innovative technologies. Furthermore, even the public financing played a crucial role in the planning and development these new projects.

In order to support the co-development mentioned above, in 2002 Pininfarina decided to build an important structure – the Engineering Centre in Cambiano (To)[23] – with the intent to give hospitality to the various partner's employees facilitating the exchange of knowledge and accelerating the jointly working process.

The process for the opening of innovation constitutes usually a critical and difficult passage for each company; it implies the combination of two, or more, different organizational cultures and expects company's employees to work in synergy with the partners' ones and vice-versa. Pininfarina, however, overcame this step brilliantly thanks to the development of IT interfaces through which both the company and the costumers can share projects and idea in a definitely secure way encouraging the spread of knowledge and core capabilities.

The whole development of the project is carried on with external specialized partners; this means that each one of them could provide the necessary and adequate technology competencies in order to the good success of the project itself. Pininfarina has had and still has now a lot of important and successful relationships with partners all around the world; among them it is worth mentioning: OSRAM, with whom Pininfarina developed the internal and external lightening system of the cars; NUVERA, a company leader in the fuel cell power and hydrogen supply fundamental in the development of the Pininfarina Sintesi[24]; and REICOM, that developed the vehicle to vehicle interfaces and interaction technologies. Another important initiative in this sense is the joint venture – Pininfarina Sverige AB - signed with Volvo Cars in 2003, and after definitively acquired by the same Swedish company in 2011, with the aim of developing and producing the new generation of Volvo cars such as the C70 model.

It is clear that the main goal for the company is to expand its own competence base and its technological know-how implementing a strategy strongly based on a constant comparison with external actors. In all this, the choice of the partners represents a crucial step and is usually induced by the possibility of acquiring new complementary competencies not already in the hands of the company.

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[23] http://www.pininfarinaextra.com/it/azienda/la_storia

[24] The Pininfarina Sintesi is a concept car developed and presented by Pininfarina in 2008. This concept model constitutes an example of safety, design, environmental sustainability, habitability and high performances.

The co-development strategy just described constitutes the practical example of this Open Innovation policy adopted by Pininfarina: the multitude of collaborations not only helped to acquire and implement new ideas and knowledge but also allowed the company to transfer owned knowledge, otherwise protected by IP rights. This means that there is a constant and equally distributed exchange of knowledge and information between all the actors involved.

However, it is also honest to point out that not always the collaborations with other companies were so profitable and successful. The collaboration between Pininfarina and Mitsubishi for the production of the Colt CZC model constitutes and example of this.

In 2010 the Japanese automaker was obliged by the International Chamber of Commerce's arbitration court of Paris to pay, after a strong legal battle, 19,2 million of euros to Pininfarina[25].

Some years before Mitsubishi signed an agreement with the Italian company about the development and production of 60.000 units of a small cabriolet named Colt CZC. However, between 2006 and 2008, were produced and assembled only 16.695 units.

Mitsubishi contested the work of Pininfarina impeaching the some delays in the production and some defects of quality and asking for 43,4 million of euros as a compensation for the damage; the Italian company, with an immediate reaction, asked 100 million of euros to the Japanese one as a reimbursement for the great amount of investments already done if compared with the effective production of vehicles.

The legals at the end accepted both the requests but, as previously said, combined a partial reimbursement in favour of Pininfarina.

This particular vicissitude demonstrates that, even if the theoretical premises of co-development are strategically and economically virtuous, sometimes the actors involved can fall into some misunderstandings prejudicing the good outcome of the relationship.

As just seen during this chapter, innovation and its development play a fundamental role in the automotive industry. The whole trend of the industry and the consequent costumers' product appreciation are strongly influenced by the development and marketing of new technologies, which can be able to guarantee improvements in the product performances and comforts.

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[25] http://europe.autonews.com/article/20100809/ANE/100809878/mitsubishi-told-to-compensate-pininfarina-over-production-dispute

In the history of the automotive industry there are plenty of examples regarding product innovations that were not able to definitely break through the market. The lacks in the development processes, or the deficiencies in the pre and post sales services to the costumer (communication, infrastructures, assistance, etc.), are among the most diffused reasons of the failure.

The hydrogen car is a clear example of this. Like the electric car is in these last few years, the hydrogen automobiles were considered the immediate future of the automotive industry. However, high development and maintenance costs and the lack of adequate investments and infrastructures immediately put aside this innovative idea. Hydrogen Fuel Cell cars were soon overcame by another, less disruptive, innovation: the hybrid electric car.

Thanks to the required know-how, similar to traditional cars, and to the joint efforts of some of the most important automakers of the world, this technology could surely be able to gain important market shares in the immediate future (more than 11 million vehicles sold until 2016). Toyota is one of the most involved companies in the production of hybrid vehicles: since the last years of the 20th century the company invests a lot in the development and diffusion of hybrid electric cars and made this strategy one of its strength points.

A different discussion must be done for the battery electric vehicles (BEV), also known as all-electric vehicles. The next chapters will explain that they represent a disruptive technology similar to hydrogen cars but, differently from the latter ones, they are a step forward thanks to the efforts made by bright entrepreneurs, like Elon Musk[26], and by important companies like Toyota and BMW. Although they are not already convenient, if compared with a traditional car, they could represent an important alternative in the future. Important efforts and investments are key factors in the development of this technology and are fundamental premises for the lowering of overall costs related to these electric automobiles and their complementary infrastructures.

[26] Elon Musk is an important American entrepreneur born in 1971 in Pretoria (RSA). He is the founder of numerous innovative projects and he is known specially for Space X (Space Exploration Technologies Corporation), Tesla Motors, Solar City and PayPal. He is also one of the richest men in the world following Forbes, with 12 billion of dollars.

Chapter 3 –The Electric Vehicles' Phenomenon

The main objective of this chapter is to describe and analyse from a economical and organizational point of view the electric vehicles phenomenon, a relatively new and interesting segment inside the automotive industry.

During the previous chapter has been explained that innovation plays a fundamental role both for each single company's competitiveness and the progress of the entire industry.

The open innovation paradigm constitutes one of the most important drivers for the evolution of innovation and, in this sense, gave an essential contribute to the development and diffusion of specific knowledge necessary to project and manufacture an electric vehicle.

Today there are plenty of examples of companies that are trying to develop and commercialize their own electric vehicles line. Among the most famous automakers that faced the challenge of the electric cars in the new millennium it is worth mentioning BMW (thanks to i3 and i8 models), Nissan (with its historical Leaf model) and Volkswagen, which it is starting to propose the hybrid variant of the historical Golf model. Tesla Motors and Toyota can surely find a place in this short list but, for this thesis, they constitute important and historical examples that will be discussed and analysed more deeply in a second moment.

In the first part of the chapter will be analysed the electric vehicles segment from an economical and historical point of view.

During this chapter will be also addressed all the technical differences that a consumer can encounter when discussing about electric powered cars. Essentially can be identified three different types of electric automobiles, depending on their degree of electrification: Hybrid Electric Vehicles (HEVs), Plug-In Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs).

There will be also space for a deep analysis of the sector from an economical and financial point of view. The last trends of the segment underline an important growth: electric vehicles are overcoming for the first time in history the amount of 1 million circulating vehicles. During the last few years the hierarchies inside the segment are profoundly changed, China has overcome after many years the United States and has become the most important market for electric vehicles of the world. Now Asiatic

countries, despite their lower experience in the automotive industry, are in a dominant position if compared to United States and to the most important countries of Europe.

The second part of the chapter will be, instead, more managerial and focused on organizational strategies. First of all will be investigated how consumers perceives the electric cars and how much they consider this innovation an important revolution for this sector. This study will be done through the investigation of market data acquired by previous researches, analysing the relative advantages and disadvantages inherent to the adoption of these kinds of vehicles and examining which factors can contribute to a much broaden diffusion of them.

A Well-to-Wheel analysis will help us to assess the real eco-sustainability of these automobiles and their costs of ownership if compared to traditional cars. During the analysis will be discovered that, despite their zero GHG emissions engines and their lower costs of refuelling, EVs have high purchasing and maintenance costs that function as barriers for the average costumer.

In the last part of the chapter will be described and analysed the changes that this electric "revolution" implies in the supply chain management and in the relationships with new specialized suppliers. The big automakers must be flexible enough and be able to exploit the capabilities of SMEs, previously not involved in the production of auto, but with a high level of specific knowledge in the field of electricity. Another crucial point is the required capacity of the traditional OEMs to conciliate both traditional cars production and electric vehicles production in an efficient and effective way: this will be an important challenge for the future developments of the segment at a large scale.

As a partial answer to the previous points will be studied some important partnerships. They are signed with the aim of further developing new technologies and components useful to the manufacturing of an efficient and reliable product. Thanks to this numerous partnerships many important automakers have been able to learn new core capabilities and to have access to innovative knowledge not properly characteristic of the automotive industry (i.e. battery technology).

3.1 Types of Electric Vehicles and their Characteristics.

The main characteristic of an electric car lies in its engine. Differently from traditional gasoline powered vehicles, an electric car adopts one or more electric engines fuelled thanks to rechargeable battery packs. These engines are very silent and what really difference them from traditional internal combustion engines are their consumptions: as we will se in the following pages, they are zero GHG emissions engines and their refuelling costs are sensibly lower if compared with gasoline or diesel ones.

Before discussing about the economical and managerial characteristics of this "revolution", it is worth to talk about some practical and technical aspects regarding these particular vehicles.

There are three main types of electric vehicle: Battery Electric Vehicles (BEV), Plug-in Hybrid Electric Vehicles (PHEV) and Hybrid Electric Vehicles (HEV).

3.1.1 Battery Electric Vehicles (BEVs)

Battery electric vehicle (BEV), also known as all-electric vehicle, represents the most simple and pure form of electric vehicle. It is completely different from a traditional conventional car: its main characteristic lies in the engine. This car is powered by a full electric motor and by a motor controller, instead of the traditional internal combustion engine (ICE). The electric motor runs thanks to the energy stored in rechargeable battery packs and, when this energy comes to an end, they can be simply recharged anywhere through a simple plug-in system. One of the most important elements of this car, in conjunction with the engine, is a sort of computer, the motor controller, which primary task is to control the engine and provide to the driver the best mix possible of performances and consumptions.

Electric vehicles on one side are extremely silent and produce zero emissions but, on the other side, their price today is quite high and their autonomy is not already comparable with the one of traditional powered cars. These drawbacks are still some of the causes of the slow adoption of this kind of vehicles.

Nissan Leaf, with more than 228.000 units sold, represents the most important and widespread BEV car in the world[27]. The recharge process takes about 30 minutes to

[27] http://nissannews.com/en-US/nissan/usa/releases/nissan-s-no-charge-to-charge-program-expands-to-10-new-markets?query=228%2C000

charge the batteries from 0 to the 80% and this could represent a discomfort when facing a long-range journey. Its important characteristic, however, stands in the price (around 20.000 euros) that is sensibly lower than the others all-electric vehicles.
Tesla Motors, instead, is the most famous and forefront examples of BEV cars producer and manufactures autos sold at more than hundred thousand of euros.

3.1.2 Hybrid Electric Vehicles (HEV)

Hybrid Electric Vehicles are powered both by an internal combustion engine (ICE) and by an electric engine. The electric energy required by the vehicle is produced by its own braking system and allows recharging the battery of the car. This specific system is called "regenerative braking": the electric motor contributed to the braking of the car and at the same time it uses the energy derived from this moment in order to re-charge the batteries.
HEVs usually employ the electric motor when they have to start or when the speed is low, while the internal combustion engine works only at high revs. The two different engines are controlled by an internal computer, which is programmed to ensure the best driving solution to the driver.
The Toyota Prius represents a famous example of Hybrid Electric Vehicles. This model, even if it was commercialized for the first time in 1997, is still the world's best selling hybrid car with more than 3,7 million units sold until 2016[28].

3.1.3 Plug-in Hybrid Electric Vehicles (PHEV)

A Plug-in Hybrid Electric Vehicles (PHEV) is a derivative model from the previous described Hybrid Electric Vehicle. In addition to the two different engines (an internal combustion engine and an electric one), it employs rechargeable batteries or others energy storage devices that can be easily recharged by plugging them into an external source of electric power (i.e. a simple home electric plug).
A PHEV vehicle shares the main features both of a traditional hybrid electric car, an electric motor assisted by a traditional one, and of a full electric car (the possibility to recharge the batteries also thanks to a simple plug system). This kind of vehicles is advantageous both for their low-emissions mobility and for their low operating costs, as

[28] http://newsroom.toyota.co.jp/en/detail/12077091/

the plug-in system (differently from a simple hybrid car) allows recharging the batteries at home and save some important fuel costs.

In the last few years these types of automobiles are becoming more and more popular. Almost all the most important automakers have decided to differentiate their product lines introducing a plug-in hybrid variant. BMW constitute an important example of this strategy: the company decided to produce and commercialize their most famous and appreciated cars (i.e. 2 Series, 3 Series, 7 Series, X5) also in an plug-in hybrid variant and develop "BMW iPerformance[29]", a special project entirely dedicated to the electric mobility and to make the consumer as aware as possible regarding this innovation.

3.2 Overview of the segment: actual trends.

The electric phenomenon has its roots in the 19th century, even before the development and commercialization of the car with internal combustion engine. In the far 1835 Christopher Becker actualized the project of the first electric car made by his Dutch professor, Sibrandus Stratingh. The technology, however, was already at its primordial stages and only after important studies on the functioning and duration of the batteries could be possible the real diffusion of the electric vehicles, which were much more competitive than steam engine and internal combustion engine vehicles.

France and Great Britain had important dominant positions in relation to the diffusion of these particular vehicles, but also the United States were very interested in this kind of automobiles.

In 1900 the 34% of the vehicles circulating in New York, Boston and Chicago, the three most important cities of the US, were electric powered.

However fuel powered vehicles, unlike the electric ones, improved significantly their performances and reliability thanks to the innovations of the second industrial revolution, gaining the today dominant position in the world market.

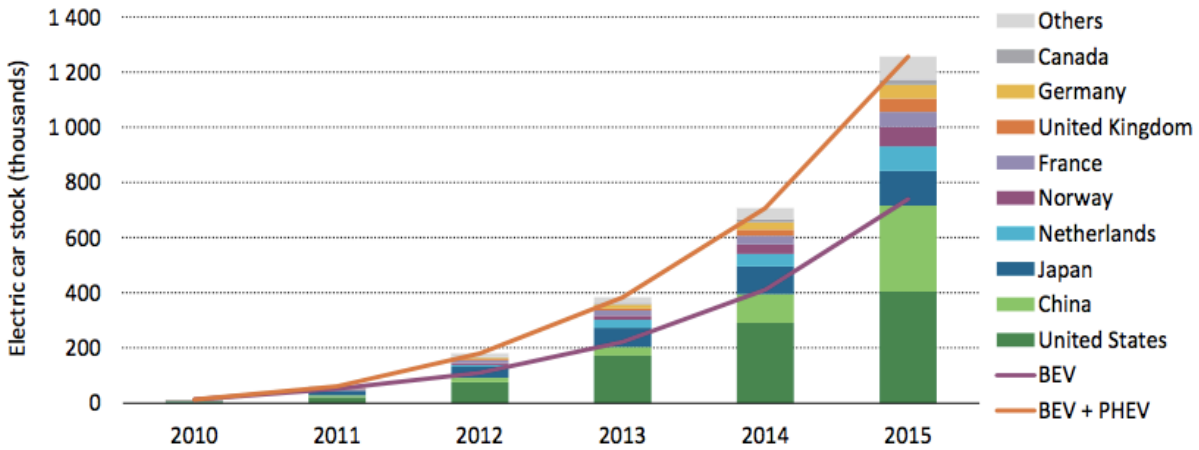
The discovery of new oil fields and the research progresses produced, at the same time, a decrease in the prices of the oil derivatives (like the gasoline) and shrank the drawbacks of the fossil fuels powered cars; while in that period the electric power was more expensive and not so diffused.

[29] http://www.bmw.com/com/en/insights/corporation/iperformance/index.html

The attention of the electric vehicles came back again in the '90s of the 20th century. The continuous crisis of the petrol market and the environmental damages caused by the greenhouse gases increasingly worried the entire public of the world and convinced the governments of the most important countries to publish dedicated measures.

However, the definitive consecration of the electric mobility occurred in the new millennium thanks to the new emerged technologies and to the birth and development of new important companies. In 2003, for example, was founded one of the most important companies in the actual world scenario: Tesla Motors.

Nevertheless, electric vehicles demonstrate still the unchanged lacks and have difficulties in competing with the traditional automobiles because of the higher costs and the inferior performances. The most important automakers of the world are nowadays engaged in research and development activities with the aim of overcoming the actual limits of this innovation: speed, autonomy, re-charging time, driving range and lack of adequate infrastructures. Special dedicated policies are of fundamental importance in order to accomplish these missions and foster the definitive diffusion of this type of vehicle with low maintenance and administration costs.



Note: the EV stock shown here is primarily estimated on the basis of cumulative sales since 2005.

Figure 4 - Evolution of the Global Electric Car Stock, 2010-15
Source: Global EV Outlook 2016-Beyond One Million Electric Cars; IEA

In 2015, as explained in a report made by the International Energy Agency (IEA), the electric vehicles market exceeded for the first time the global amount of 1 million of cars (**Figure 4**).

To be more precise, the stock reached 1.26 million of vehicles and it represents a significant growth if compared with the history of this segment.

An important contribution to this significant progress was provided by China, the Asiatic colossus: with more than 200 thousands of new registrations of vehicles (**Figure 5**), the Chinese electric vehicles market became the largest of the world overcoming at the first place the United States. Following the International Energy Agency the market share of these two economic powers in 2015 was respectively 0,7% for the United States and 1% for China.

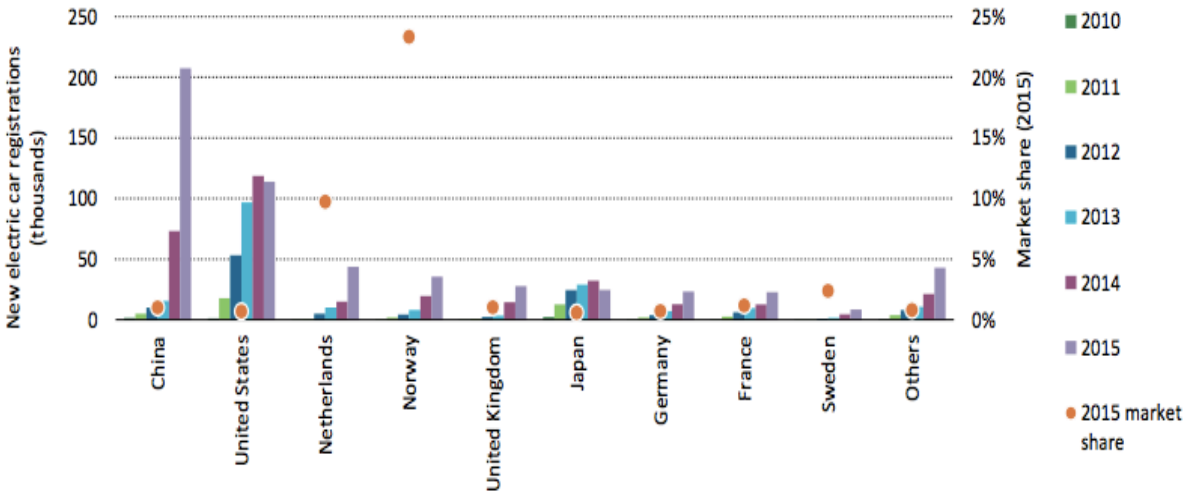


Figure 5 - EV sales and market share of selected countries in 2015
Source: Global EV Outlook 2016-Beyond One Million Electric Cars; IEA

Until 2014 the United State of America were the most important market, looking at the number of electric circulating vehicles, with more than 100 thousands of units compared to the few thousands of the Chinese market.

These two markets are now the most important and big ones in the entire world of the electric vehicles and contributed sensibly to the growth scored between 2014 and 2015: new registrations of electric cars (both BEV and PHEV) increased approximately of 70%, with more than 550 thousands vehicles being sold worldwide in 2015.

Looking back to the previous years can be appreciated that, starting from 2010, the growth was steady and significant. In 2010, in fact, the number of electric vehicles in the global market was very far from data registered today: the sum of Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV) did not exceed few thousands of units.

An important role in the development and diffusion of the electric cars was, and is still, played by financial incentives by the governments and the availability of charging infrastructures. There are plenty of measures than a government can implement to favour the adoption of electric vehicles. The most important and widely adopted are regulatory measures, such as tailpipe emissions regulations, fuel economy standards and credits to favour electric cars (e.g. mechanisms that allow increased weight for EVs when accounting for corporate average fuel economy standards); financial levers which can consist in a different vehicle taxation or based on fuel economy or GHG (Greenhouse Gases) emissions per kilometre; and other instruments like waivers on perking fees and tolls or relinquishments on urban access restrictions.

Norway represents an important example of "electric-friendly" market. It provides strong incentives in the form of registration tax reductions and, only for BEVs, the exemption from value added tax (VAT), waivers on road tolls and ferries, and access to bus lanes. This allowed the country to have, in 2015, the highest market share in the world (22,31%); sharply higher than Netherlands, the second market with 9,7% of market share, and the much bigger countries such as China and United States.

Another important element that, with the recent development of these years, favours a sharper diffusion of the electric and hybrid car across the world is the battery costs and efficiency (energy density). In the past few years the availability of new technologies, the increased importance of the R&D function, and the mass production led to a rapid decrease of the costs of this component and an improvement of the performances.

The United States Department of Energy (US DOE) affirmed that the PHEV battery costs had sensibly fallen down in the last decade: in 2008 the cost of a battery was about USD 1000/kWh, while in 2015 it reached USD 268/kWh; approximately a 73% reduction of the cost of a battery pack.

In expectation of 2022 the US DOE forecasts to achieve a further improvement in the competitiveness of the PHEV batteries in the United States in relation to other vehicles using conventional engines. The cost of a battery is expected to fall down at USD 125/kWh, implying more or less an additional 58% costs decrease in the next years.

The costs related to the batteries were not the only aspect that was developed but also were registered improvements in their energy density that allowed the production of

more performers vehicles and the consequent partial resolution of drawbacks typical of these kind of cars (i.e. the autonomy). The energy density of PHEV batteries in 2008 was at 60 Wh/Litre while in 2015 it reached 295 Wh/L: an improvement of about the 400% in seven years.

These developments in the battery costs and energy density are a partial explanation of the already described evolution and growth of this sector, which is now able to provide costumers with more autonomous and efficient products. However

3.3 How Costumers Perceive Electric Cars.

As we already seen in the previous lines, the alternative fuel vehicles' market and especially the electric segments (BEV, HEV and PHEV) are growing fast in these years and the core technologies are becoming more developed.

However, even if all the most important OEMs of the world are now developing and producing new passenger and commercial vehicles, the adoption of electric automobiles is already far from being at the level of traditional cars. Significant socio-technical barriers remain in the widespread adoption of these new kinds of vehicles and, despite the growth, they already represent only a small portion if compared to the totality of circulating vehicles (about 1 million of vehicles on a totality of 90 million of units).

One of the fundamental technological constraints to the commercialization of EVs is related to the energy storage. The battery technology, as previously explained, constitutes an important issue when discussing about electric powered vehicles and OEMs are facing important trade offs related to the power, energy, longevity, cost and safety of their new vehicles. The distance an electric automobile can travel is strongly influenced and limited by the duration of its all-electric range and of its single cycle charge. Battery Electric Vehicles, which are not so flexible as HEVs and PHEVs when talking about fuel and distance, need to be recharged en route during long journeys that exceed the whole duration of the batteries giving great importance to the range issue. Obviously easily available charging infrastructures during the trips play an important role in the diffusion of the electric vehicles. Battery costs therefore are a key determinant in the economic sustainability of the electric vehicles, especially when talking about pure electric vehicles and plug-in hybrid electric vehicles.

Electric vehicles not only have to face technological problems regarding battery duration and reliability but also social issues related to costumers' appreciation to achieve the definitive commercial success.

Usually consumers are quite sceptical about new technologies, considered unfamiliar and/or untested at a first impression. Some of the most important obstacles to a widespread acceptance of new technologies are recognized in the lack of an adequate specific knowledge by the potential adopters, high initial costs and a low predisposition to assume risks. Consumers' adoption of hybrid electric vehicles (HEVs), for example, is partially hindered by the risks involved in these new products and by the crucial trade-offs between vehicle fuel efficiency, size and price.

In terms of economic and financial benefits, individuals are more inclined to choose opportunities, which can maximize their utility, based on their personal preferences, knowledge of alternatives and budget. The initial cost of an EV is significantly higher if compared with to a traditional gasoline-powered car and this increases linearly with battery size and with the range allowed by the car. In an article made by M. Duvall (2002), of the Electric Power Research Institute, is enlightened that an electric car could cost between 2.500€ and 14.000€ more than a traditional car[30]. Due primarily to battery costs, electric vehicles, and especially BEVs and PHEVs, are significantly more expensive than conventional vehicles (CVs).

However there are also non-financial reasons that can influence the consumers' decisions in the purchase of an electric vehicle, especially those associated with energy and environment. Some costumers, for example, can be attracted by the capacity of the electric vehicles to create social benefits like the reduction of petroleum consumption and greenhouse gases emissions. Especially those costumers, which are strongly involved in actions to protect the environment, are more willing to buy an electric vehicle if compared to non-environmentalists and the choice of this type of cars can symbolize for them ideas related to one's individuality and can be used to communicate personal interests and values.

[30] Duvall, M., 2002, Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options for Compact Sedan and Sport Utility Vehicles. Electric Power Research Institute, Final Report.

Furthermore, historical trends concerning technology adoption indicate that while new technology is naturally attractive for few early adopters individuals, the majority of costumers will remain sceptical about the new technology: some individuals are less comfortable with technological changes and with uncertainty, and therefore are diffident regarding the acceptance of new innovations.

However, in recent times there are increasing reasons to buy an electric vehicle such as the rise and volatility of gasoline prices, the greenhouse gas emissions, the increased dependence on imported petroleum, and the high fuel economy of this kind of cars.

In a research made by some members of the Missouri University of Science and Technology, it is highlighted that the majority of people[31] (53%) had some experiences with alternative fuel vehicles (AFVs) and more or less the 47 per cent has no experience. Among the interviewed persons that have answered to have already some experience with non-conventional vehicles, the 38% had familiarity with hybrid electric vehicles (HEVs), the 17% of costumers affirmed to be practice with battery electric vehicles (BEVs), while only the 7% declared to be familiar with plug-in hybrid electric vehicles (PHEVs). Only the 18% answered to have with other vehicles different from the previous ones.

However, must be specified the degree of awareness regarding the various types of EVs shows that HEVs are the most well known vehicles, followed by PHEVs and finally by BEVs. These statistics fully reflects the tendencies of the market and the technology curve of these innovations. In fact, HEVs are the most widespread vehicles in the market after the traditional ones; PHEVs, which are not as widespread as HEVs, are more popular than BEVs are.

In the last few years the most important topics associated to electric vehicles are battery performance and charging, the impact on the environment, vehicle efficiency, high purchase costs, fossil fuels, alternative energy and the future in that order. Among the positive aspects associated to an EV there are: their impact on the environment (they are considered “green”, “zero emissions” and “environmental friendly” vehicles), their

[31] The research is made on a sample of 481 persons from all around the world. The 71% of them was male, while the remaining 29% were female. The majority (62%) of them were young people between the ages of 18 and 44. The majority of the sample (84%) is working towards or has completed an undergraduate degree or graduate degree.

role in the future of transportation ("the way of the future", "future of travel") and their efficiency in terms of fuel saving. Limited battery longevity and range, long recharging time, high purchasing costs and environmental impacts (increase of fossil fuels) of the power plants appointed to generate electricity for recharging EVs are, instead, among the negative considerations when analysing all the features of an electric vehicle.

In fact, as explained in the **Table 3**, EV battery range limitation was valuated as the biggest concern with the 33% of share, followed by high purchase and maintenance costs (27%) and by the lack of adequate charging infrastructures with the 17 per cent.

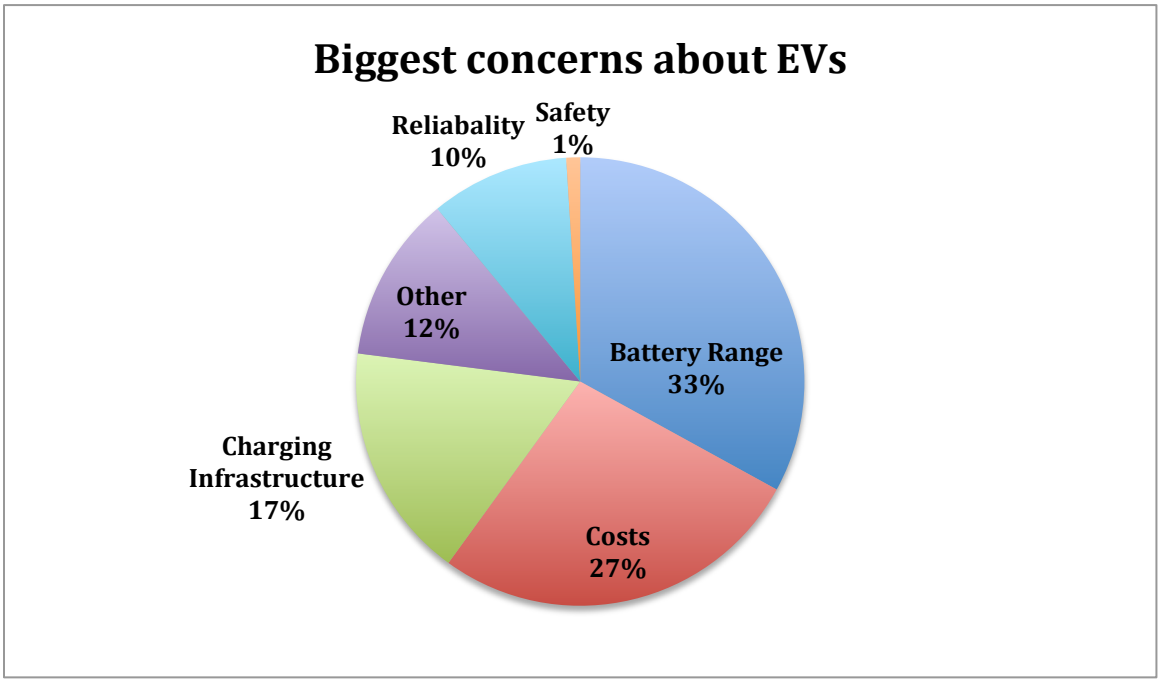


Table 3 – Biggest concerns about EVs
Source: Data from O. EGBUE, S. LONG; *Barriers to widespread adoption of electric vehicles: an analysis of consumer attitudes and perceptions*; 2012.

Reliability, safety and other concerns are considered of minor importance in the overall scenery of this kind of automobiles. Electric vehicles are considered by the majority of the sample as a safe mode of transportation. However must be appointed that the number of "unsure" about this argument is rather high, suggesting there might be a limited understanding of EVs' safety among the respondent willing to purchase these vehicles.

This research showed that, all in all, most of the people interviewed (49%) are strongly interested in purchasing an electric vehicle. Nevertheless, electric vehicles (especially BEVs) have two fundamental disadvantages in terms of fuel source and storage if

compared to ICE (Internal Combustion Engine) vehicles: battery packs are more expensive and bulky and the refuelling process is typically slower than the traditional one (approximately 1-20kW for electric versus 5000kW for gasoline). Of course this implies that pure electric vehicles, which are powered solely by on board battery packs, have less autonomy than traditional cars and the whole refuelling process is not as fast and simple as the one of gasoline powered cars. However, a particular kind of electric automobiles – the plug-in hybrid electric vehicle (PHEV) – is not involved in these types of problems because: it can be simply refuelled both with electricity and gasoline, abolishing the range problems and the reliability issues that affect electric cars.

Following the research of Egbue and Long (2012) can be noticed that the majority of the population interviewed drive on average 36 miles per day. This would means that electric vehicles (especially BEVs and PHEVs), which autonomy vary between 40 and 100 miles, are able to satisfy a large percentage of every day transportation needs, assuming their batteries are charged every day. Long travels, however, remain one of the main problems of these automobiles: a high mileage is not already possible without constantly recharging the batteries.

Therefore the battery range, as we already observed in the previous line, has a crucial role in the development and diffusion of these cars. Huge investment plans and developments in the battery field are necessary in order to gain a committed consent of the costumers. Only 32% of the sample of this research, in fact, is interested in a vehicle with a battery range between 0 and 100 miles, 23% is satisfied with a range between 100 and 200 miles, while the bulk of the population would seriously consider an investment on an electric vehicle only if it has an autonomy greater than 200 miles (to specify, the average minimum autonomy desired is 215 miles).

There is already a sensible gap between consumers' expectations of the driving autonomy of a full-electric vehicle and the real daily driving distance.

If battery performances continue to develop and growth at a steady rate, as in the last few years thanks to the numerous strategic alliances between important companies, then the most important challenge to be addressed is attracting an adequate market for EVs to support their limited range just in this period, before battery technology really improves and becomes tangible for the costumers. However many consumers of the

survey choose the battery range in relation to the recharging time: if the EV could be recharged quickly on the go they are, they would not expect the range to be as great.

The majority of the individuals interviewed (36%) are convinced that the refuelling process of an electric car is inconvenient. Only 32% of them, instead, consider it convenient if compared to the refuelling process of a gasoline-powered vehicle; the remaining 32% is already unsure about the two alternatives.

Since the distance an EV could make is rather short in the last few years, in order to solve this problem, also spread the idea that batteries employed by the car could be easily swapped. The battery swapping process refers to the quickly replacing of an exhausted battery with a fully charged one at an apposite battery swap station.

This solution, even if it could be a good answer, is still undeveloped and would imply the separation of battery ownership from the vehicle ownership: in this case the initial price of the car would decrease but, at the same time, consumers must spend ulterior money to cover the cost of battery ownership and the recharging and/or swapping of the battery. The majority of the interviewed (43%) is still unsure about this possible solution, while the 31% is willing to buy an electric vehicle if the battery and vehicle ownership are divided and if an adequate battery-swapping plan is available. The remaining 26%, instead, is completely against the notion of battery swapping.

Another important issue when talking about the automotive market, especially regarding the electric segment, is related to the sustainability of vehicles. The 79% of the consumers are more willing to buy a new vehicle if it is sustainable and eco-friendly.

Battery electric vehicles (BEVs) are evaluated as the most environmentally sustainable type of electric vehicles, followed by plug-in hybrid electric vehicles (PHEVs) and finally by simple hybrid electric vehicles (HEVs).

However, the results of this survey (**Table 4**) show that the majority of the respondents (more or less 43%) are unsure about the real eco-sustainability of the EVs if compared

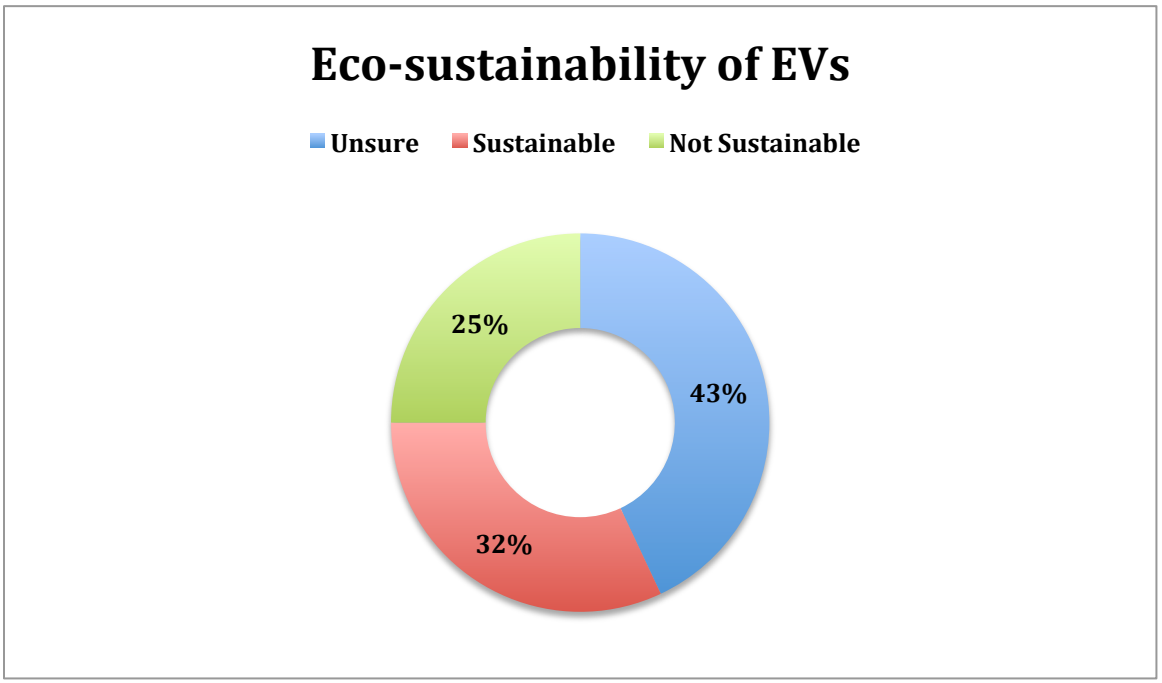


Table 4 - Eco-sustainability of EVs
Source: Data from O. EGBUE, S. LONG; *Barriers to widespread adoption of electric vehicles: an analysis of consumer attitudes and perceptions*; 2012.

to traditional gasoline-powered vehicles and to other alternatives. A scarce portion of the interviewed (32%) agrees with the sustainability of EVs, while 25% is already convinced that traditional vehicles are still, all included, more sustainable than EVs.

This uncertainty in relation to the real sustainability of electric-powered vehicles is confirmed also by some observations from respondents regarding the low environmental sustainability of the electric vehicles' production plants. It is of widespread opinion that while electric cars use zero fossil fuels if compared with traditional vehicles, at the same time, considering that a large amount of energy comes from coal plants, greenhouse gasses are transferred to the production plants.

These considerations constitute a potential barrier in the purchase of an electric vehicle: consumers with high environmental awareness can consider the purchase of an electric vehicle not in line with their ideals and not beneficial to the environment.

Nevertheless, individuals with high sustainability awareness remain more willing to adopt the EV technology sooner than consumers with low sustainability awareness.

The majority of the sample has questions about the battery technology, raw material supply, environmental impacts, appearance, operation and performance of EVs, cost, and how electric cars compare to conventional and other alternative fuel vehicles.

Potential consumers are interested in learning more about the mechanisms of charging, how the battery range limitation can be overcome and how to secure the mineral resources necessary for large-scale battery manufacturing.

Cost is the subject of several questions (17%); this includes the initial cost, maintenance cost and payback period of the investment. Other questions were about how electric vehicles could be made more economically competitive than traditional gasoline-powered vehicles.

To conclude, attitudes, knowledge and perceptions related to electric vehicles obviously differ across age, gender, and education groups. Moreover, this research shows that, although sustainability and environmental benefits regarding electric cars have an important role in the consumers' evaluation, as explained in the previous lines, they are ranked behind costs and performances.

Evidence provided in this research emphasizes the need to address important socio-technical barriers that contribute to obstacle a more widespread and definitive diffusion of the electric vehicles. Some of the most important challenges that electric vehicles' automakers must face are regarding batteries technology, batteries costs and adequate charging infrastructures. The uncertainty around these important factors, as already said, can constitute a potential and important barrier to a widespread adoption of the electric automobiles. This uncertainty can be attributed, on one side, to the unfamiliarity with the new technology provided by EVs but, on the other side, there is also a more technical factor that foster this sensation among consumers: several individuals, the most familiar and open to new innovations, are already not fully convinced about the convenience of electric vehicles if compared to traditional automobiles. The uncertainty manifested by some components of this segment of consumers about the sustainability and environmental performances of EVs compared to traditional ICE vehicles may mean that some individuals with high environmental awareness or values may not consider the purchase of an electric car as really eco-friendly.

Other instruments like subsidies on the cost of EVs, tax credits, incentives, fuel taxes exemptions are of low impact on the market if consumers have low confidence in EV

technology. However, some measures must be taken in order to increase the adoption of these vehicles. Among these measures can be mentioned a more complete education to this innovation, increased investments in the technologies and infrastructures surrounding the electric vehicles, the development of battery-swapping plans, the diffusion of strong warranties programs on EVs' batteries and, maybe, stronger tax policies to promote the cost of EVs.

Nowadays media and social networks, important marketing tools for every company, can constitute critical instruments for the rapid diffusion of information regarding EVs' technologies and polices increasing the familiarity and awareness with this kind of cars.

It is of clear evidence, looking at this research, that the opinions regarding electric vehicles are already very contrasting and uncertain. If, on one side, the public opinion actually is very excited and favourable to the adoption of this technology, almost all the most important car manufacturers are developing and producing their own electric lines; on the other side there is also a lack of specific knowledge regarding these vehicles and their real impact on the environment. As explained during this chapter, there are no apparent data that allow affirming that electric vehicles are, and will be, the immediate future of the automotive industry: a lot of costumers are already uncertain about some crucial aspects of electric cars such as the battery durability range, the high purchase and maintenance costs, the recharging system and real eco-sustainability of the vehicle itself and of its production plants.

In the next chapter will be analysed how much an electric car and all the activities surrounding it can consume and their impact on the world's environment. This will be done in order to further assess if electric vehicles are really more convenient and sustainably than traditional automobiles.

3.4 Electric Vehicles' "Well-to-Wheel" Analysis.

In order to assess if the electric "revolution" could represent a real opportunity for the development of the entire world mobility and the future of the automotive industry, it is of fundamental importance to conduct a "well-to-wheel" analysis related to the sustainability of these types of vehicles.

Before starting to implement this particular examination, it is useful to explain what really is and what comprehends a "well-to-wheel" analysis.

The "Well-To-Wheel" (WTW) is a particular kind of life-cycle analysis (LCA), a technique used to assess environmental impacts associated with all the stages of product's life. The primary objective of this tool is to compare different propulsion technologies and to estimate their overall energy and efficiency applied to different kind of automobiles.

The WTW analysis is composed by two different stages (**Figure 6**) that, put together, result in the overall vehicle efficiency: a first step, named "Well-To-Tank", and a second step also know as "Tank-To-Wheel". The first phase (WTT), refers to the stages from the extraction of feedstock until the delivery of fuel to the vehicle tank, while the latter phase (TTW) quantifies the performances of the drivetrain.

Efficiency of different propulsion technologies can be expressed either by CO_2 equivalent emissions per course unit (i.e. CO_2/km), by energy units (MJ/km), or simply by percentages looking at the energy transformed to motion.

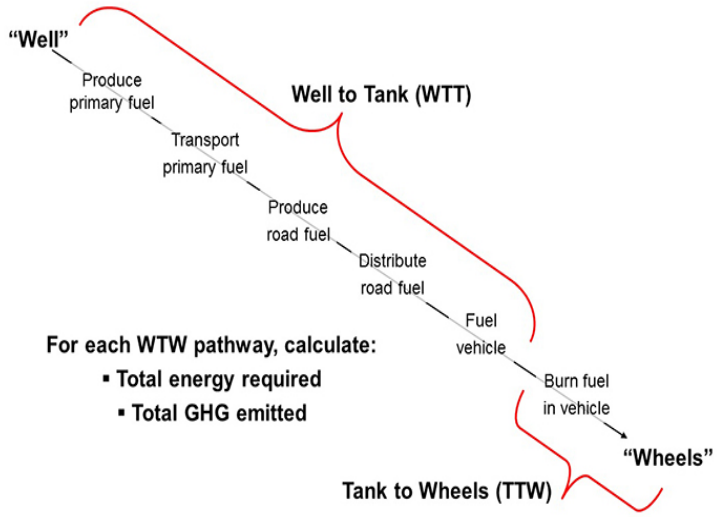


Figure 6 - Well-to-Wheels Pathway
Source: www.ec.europa.eu

Since petrol, diesel, LPG (propane and butane) as well as natural gas (methane) are all hydrocarbons and burn mainly CO_2 while releasing energy, the consumed energy and the CO_2 emissions are proportional. If, instead, WTW data are expressed in energy units or CO_2 emissions, they may allow assessing different technology alternatives at least within the ICE sector.

Nevertheless, comparing WTW data of traditional vehicles (ICEVs) with alternative fuel vehicles (AFVs) can be quite difficult because of the lack of data and testing schemes for the alternative technologies.

Fossil fuels and gasses power traditional internal-combustion engine vehicles: diesel, petrol, methane, propane or butane. However, these fossil hydrocarbons actually can be also substituted or exchanged with biofuels like bioethanol, biodiesel, or bio-methane.
Well-to-Tank (WTT) data for these kinds of fuels provisions reveal that up to 24% of the contained energy is already being consumed within the chain of production. For example, looking at the supply process of the methane, coming from Siberia to arrive in Europe trough up to 7000 km, there is a WTT loss of up to 35%. Also the Tank-to-Wheel efficiencies of ICEV are very low with 10% to 25% because 75% to 90% of the energy is lost as heat instead of propelling the car.
Despite these results, traditional ICE vehicles has been successful on the market for more than a century due also to the very high energy density (more or less 20 times higher than a Li-ion battery) of carbon-based fuels available worldwide for reasonable prices. With the development of hybrid ICE concepts, introduced for the first time in a large-scale production by Toyota in 1997, followed then by Honda in 1999, was experienced an efficiency jump; TTW's of hybrid ICE roughly doubled compared to that of ICEV without electric assistance. ICEV powered by gaseous hydrocarbons (methane, propane and butane), instead, are considered inefficient like petrol-powered cars.
WTW calculations reveal that, considering the entire ICE vehicles, during the operation of ICEV, between 68% and 90% of the entire energy is wasted.
However, today, powertrain electrification is considered more expensive, when compared with ICE technology, mainly due to the high cost of the batteries, with a price of 400-600€/kWh in 2010. This data is expected to decrease due to the mass production: the price per kWh of the batteries can fall between 25% and 65% in the next years.
Battery requirements, of course, vary depending on the vehicle architecture. A plug-in electric vehicle, for example, typically requires a battery capacity equal to 8-16 kWh for a 40-80 km range. An all-electric vehicle, instead, usually requires a battery capacity of 24 kWh in order to guarantee a 160 km range, already very far from the range of a traditional gasoline-powered car but sufficient enough to commute daily.
In terms of structure, ICEs and EVs are very similar and share parallel basis, such as chassis and the body. On the other hand, a battery electric vehicle doesn't require a fuel

tank, the exhaust system and catalyst, and the five or six speed gearbox is generally replaced by a single speed.

Several life cycle assessment studies enlighten that the environmental impacts of vehicles are dominated by the "operation phase" regardless of whether a gasoline fuelled ICEV or electricity fuelled BEV is used, being the gasoline vehicle the one with higher environmental burden.

Battery electric vehicles and traditional ones have a similar global warming potential during the manufacturing phase around 2.5 MT CO_{2e} (million tonnes of carbon dioxide equivalent), not considering the battery production. The share of the total environmental impact of electric mobility caused by the battery is 15%. The battery, as already explained, is among the most critical components, in terms of emissions, due to the necessary materials needed for the manufacturing, such as Lithium, Copper, and Aluminium. Depending on the manufacturing process of the Lithium-ion battery, the emissions could go from 1.7 MT CO_{2e} to 2.7 MT CO_{2e} per battery.

If we look at **Table 5** it is of clear evidence that, despite their high purchasing costs (even with the help of deductions) and their low range of autonomy (only 160 km), battery electric vehicles are the eco-friendly automobiles with zero GHG emission (in their TTW phase). They are followed by plug-in hybrid electric vehicles and by hybrid electric vehicles, respectively with 37 and 88 gCO_2/km. Obviously internal combustion engine vehicles are the most polluting kinds of cars: diesel-powered vehicles are responsible for emissions equal to 118 gCo_2/km, while gasoline-powered ones are even more polluting with 144 gCO_2/km.

	ICEVs		HEVs	PHEVs	BEVs
	Diesel	*Gasoline*			
Cost (€)	22.200	20.300	25.000	42.000	35.000
Deductions (€)	-	-	-	-	5.000
Emissions (gCO_2/km)	118	144	88	37	0
Consumption (l/100km)	4,2	6,2	3,8	6,4	0
Combustion Engine	1,6 l	1,4 l	1,8 l	1,4 l	0
Electric Motor (kW)	-	-	30	111	80
Battery Capacity (kWh)	-	-	13	16	24
Battery Weight (kg)	-	-	53,3	197	300
Battery Type	-	-	NiMH	Li-Ion	Li-Ion
Range (km)	700+	700+	700+	580 (80EV + 500 ER)	160
Curb weight (kg)	1.240	1.290	1.370	1.715	1.521

Table 5 - Costs and Consumptions characteristics of ICEVs and BEVs
Source: Data from Energy Conversion and Management, Elsevier.com.

In an electric vehicle the principal energy losses occur at three main subsystems.
At the Energy Storage System (ESS), the equivalent of a fuel tank in an EV; at the Powertrain (PT), the group of components that generate power and deliver it to the wheels; and at the Power Electronics Module (PEM), responsible for the motor control, charging and regenerative breaking.
The Energy Storage System is composed by batteries and by super-capacitors. Batteries are made of stacked cells where chemical energy is converted to electrical energy, while super-capacitors store the energy in the form of static electricity. Batteries are rated in terms of their energy and power capabilities. Other important characteristics of batteries are efficiency, life span (number of charge/discharge cycles), operating temperature, self-discharge rate, depth of discharge (minimum level of charge), and energy density.
The battery packs used to power an electric vehicle are “deep cycle batteries”, with an energy capacity normally in the range of 10-40 kWh and with efficiency between 70% and 95%.
Lithium-Ion batteries are the most common in EVs because they have a specific energy up to 300 Wh/Kg and a high specific power (up to 10 kW/Kg). For comparison, a Lead-

acid Battery, the one installed in a traditional car, has a specific energy density not superior to 30 Wh/Kg and a specific power up to 400 W/kg. An important disadvantage of the batteries is constituted by their internal resistance, which increases both with cycling and age. This factor usually causes a voltage drop under load and reduces the maximum current draw and affects the charge/discharge rate.

The Powertrain, instead, refers to a group of components that generate mechanical power and deliver it directly to the road. It includes the ICE or/and an electric motor, the transmission, the drive shaft, the differential and the drive wheels.

Regarding ICEVs, diesel engines are more common in Europe than gasoline ones, due to their higher fuel efficiency, and the most sophisticated ones achieves an efficiency of about 30-40%. Gasoline engines have an efficiency of 18-25%, meaning that more or less the 80% of available energy is lost as heat.

Talking about electric cars, the most common types of electric motors are permanent magnet motors and Alternate Current (AC) induction motors. When compared with internal combustion engines, the use of electric motors leads to an increase of efficiency: the efficiency rate can go from 85% to 95%, depending on the type of electric engine installed.

Finally, the last subsystem that can cause energy losses in an electric vehicle is the Power Electronics Module. This particular part of the vehicle has the control over motor torque, battery charging, regenerative braking, and it monitors things like the voltage delivered by the energy storage system, the speed of rotation of the motor, and the temperatures of the motor and power electronics. Another component to be taken into account, both for PHEVs and BEVs' efficiency, is the charger: this component typically has a loss of energy equivalent to the 6-9%.

To correctly assess the sustainability of an EV based mobility system, the way its fuel (electric energy) is generated constitutes an important factor. The process of generating electric energy can be achieved by several ways, each one with their own environmental impact depending from the energy source. Electricity generations based on renewable energy sources (RESs), such as hydro, sun or wind, have near zero green house gasses (GHG) emissions; while electricity generations based on fossil fuels sources (coals or fuel oils) have a sensibly high impact on the environment. However, even if electricity generation systems based on nuclear and/or RES do not cause any GHG emissions

during the operation phase (when the vehicle is running), they are not a zero emissions energy source.

GHG emissions, per unit of energy, by power plant energy source				
Fuel Type	Plant Efficiency (%)	Pollutant (g/kWh)		
		CO_2	***SO_2***	***NO_x***
Coal	37 (36-43)	916	9,3	3
Fuel Oil	37 (23-43)	777	3,1	2,1
Natural Gas (CCGT)	58 (55-60)	354	0	0,9
Hydro	87 (85-90)	12	0,04	0,04
Wind	37 (35-40)	10	0,02	0,02
PV	15 (12-18)	90	0,28	0,03

Table 6 - GHG emission, per unit of energy, by power plant energy source
Source: Data from Energy Conversion and Management, Elsevier.com.

The upstream supply stage, power plant construction and decommissioning require energy involving indirect emissions. For example, nuclear energy has estimated emissions of 10-130 gCO_{2e}/kWh, wind and hydro 10-25 gCO_{2e}/kWh, solar photovoltaic 30-100 gCO_{2e}/kWh, and fossil 600-1200 gCO_{2e}/kWh. Looking also at the **Table 6** can be observed that Hydro represents the most efficient and eco-friendly source of energy; it has an efficiency rate on average equal to 87% and its emission in terms of gCO_2/km are just 12. The opposite is represented, not surprising, by the Coal: the worst source of energy possible. It has a very high impact on the environment with 916 gCO_2/km and an efficiency rate among the lowest (37% on average), if compared with other energy sources. Natural gasses, even if they are sensibly more sustainable than coal and fuel oil, they are absolutely not comparable with other RESs: their efficiency rate is more or less 57% and their impact on the planet environment is equal to 354 gCO_2/km.
The increment in the use of renewable energy sources is seen as a key step in order to reduce the dependence from fossil fuels and their high level of GHG emissions. In 2020 is expected a 20% share of renewable energy, contributing, also with other measures such as the increasing of energy efficiency, to achieve a reduction of 20% of GHG emissions (compared with 1990 levels).
WTWs reported for BEVs are between 59% and 80%. This high level of efficiency is due

principally to the fact that only very little energy is wasted in the drivetrain (TTW phase). Altogether, BEVs represent the only credible alternative technology offering an efficiency improvement in individual mobility, consuming up to four times less energy than actual traditional cars. Although being much more efficient, as previously said, BEVs cannot cover all mobility needs due to range restrictions, so the other technologies (ICE and FCV) are still needed under sustainability-optimized conditions.

However, a further important issue in the sustainability evaluations of EVs concerns the displacement of the bulk of green house gasses emission from the streets to industrial areas, where automakers and/or their suppliers develop and assemble the whole product.

According to Bjorn Lomborg, a Danish environmentalist and writer of "*The Wall Street Journal*", electric vehicles are not completely zero-emission products, as the myriad of advertising campaigns and political declarations affirm. As explained in a research made by the Journal of Industrial Ecology in 2012, almost half of the lifetime green house gasses emissions (i.e. carbon dioxide) of an electric car come from the energy used to produce the same car, especially of its battery pack. The mining process to extract the Lithium, for example, is one of the most polluting activities of the whole production process. The production of energy represents another important issue when discussing about EVs: nowadays this process is considered one of the principal causes of global warming because of the employment of raw materials, such as lignite, coal or heavy oil combustion. Just to make a comparison, the whole manufacturing process of a gas-powered vehicle accounts for the 17% of its lifetime emissions.

The manufacturing impacts of EVs are greater than those of traditional cars, primarily because of battery production. These impacts need to be addressed through the use of greater material recycling and other eco-friendly measures.

The production process of an electric car, from the first development to the final assembly, is responsible for the production of 30.000 pounds of carbon-dioxide (CO_2) emissions; while the manufacturing of a traditional gasoline-powered car produces less than half of an electric vehicle (14.000 pounds).

In its whole life cycle (approximately 80.500 km), an electric car releases 8,7 tons of CO_2 lower than a traditional gasoline-powered car. However, assumed that every ton of carbon dioxide causes a social harm of approximately 5 dollars, the resulting total save

of battery electric vehicles is quantifiable in more or less 44 dollars per unit. These data clearly demonstrate that EVs are not so economically and environmentally advantageous in comparison of traditional gasoline-powered vehicles.
The electric car can surely become more developed and more performing in the future but, today, it doesn't represent a reliable way to tackle global warming. The real challenge towards a more widespread and sustainable diffusion of electric vehicles is increasingly investing in green research and development in order to exploit renewable resources also for the whole production process.

3.4.1 Costs of Ownership.

Another factor to be taken into account, when comparing EVs to traditional automobiles, is the ownership costs they imply. Looking at the **Table 7** it is of clear evidence that, on average, traditional vehicles (ICEVs) are already the most convenient, from an economic point of view, if compared to the actual of electric vehicles. Only if we look at possible future battery electric vehicles (Future BEVs) this gap with traditional cars can be filled.
Starting from the capital cost - the price consumers need to sustain in order to purchase the product - electric vehicles are on average more expensive than other kind of cars. Electricity-powered vehicles, in fact, could cost between 25.000€ of a hybrid electric vehicle and 42.000€ of a plug-in hybrid electric vehicle. A pure electric vehicle (BEV), even with contribute of incentives and deductions (more or less 5.000€), is not more convenient, assessing its total price around 30-35.000€.
Internal combustion engine vehicles, on their side, are more cheaper at a first impact on the budget of costumers: their range of price goes from about 22.000€ for diesel-powered vehicles to 20.300€ of vehicle fuelled by the gasoline.

	ICEVs		HEVs	PHEVs	BEVs	Future BEVs
	Diesel	*Gasoline*				
Capital Cost (€)	22.200	20.300	25.000	42.000	35.000	25.000
Deductions (€)	-	-	-	-	5.000	-
MRT (€/year)	500	500	500	350	300	300
Fuel (€/year)	850,5	1376	843	213,1	-	-
Electricity (€/year)	-	-	-	433,5	430,6	430,6
Ownership (€/year)	1.350	1.876	1.343	996,6	730,6	730,6
After 5 years						
Ownership (€)	7096	9861	7059	5239	3841	3841
Depreciation (€)	11.276	10.311	12.698	21.333	17.777	12.698
TCO (€)	18.372	20.172	19.757	26.572	21.618	16.539
After 10 years						
Ownership (€)	15.125	21.018	15.046	11.166	8.186	8.186
Depreciation (€)	15.749	14.402	17.735	29.796	24.830	17.735
TCO (€)	30.874	35.420	32.781	40.962	33.016	25.921

Table 7 - Costs of Ownership and Maintenance of ICEVs and EVs.
Source: Data from Energy Conversion and Management, Elsevier.com.

Despite these important initial costs manifested by electric vehicles, their total ownership costs per year result to be lower than the ones related to ICEVs. A gasoline-powered vehicle is the most expensive car to be maintained and cost to the costumers more or less 1.876€ per year, almost one thousand of euro more if compared to a battery electric vehicle (730,6€ per year).

This important difference between electric and non-electric vehicles is due principally to their different type of fuelling. Assuming that the cost of diesel and gasoline is respectively 1.35€ and 1.48€, an ICE vehicle fed with gasoline result to be the most expensive solution for the consumer (1.376€ per year only for refuelling; 73% of the total annual cost), followed by the diesel-powered engine with an annual cost equal roughly to 850,5€.

Battery electric vehicles, the only ones that can count exclusively on electric energy only, are sensibly cheaper from this point of view. Assuming that the cost of electricity is 0,16 €/kWh, they spend only 430,6€ per year in the refuelling phase, less than half of the total expenditures of fuel of a gasoline-powered car.

A separate discussion must be done regarding plug-in hybrid electric vehicles. As already explained they are powered both by an internal combustion engine and by an electric motor. This characteristic, on one side, allows them to save some fuel costs if compared to traditional cars (approximately 600€); but on the other side implies the use of some electricity to power the electric motor for a total cost of 433,5€.

Other factors that contribute, even in minor quantity, to the difference of ownership costs between these two kinds of vehicles are the insurance, maintenance, repairs and taxes costs (MRT). These costs amount to more or less 500€ for all the ICE vehicles and for hybrid electric vehicles; while, for that vehicles which use electricity, they are a little bit lower: 350€ per year for plug-in hybrid electric vehicles and 300€ for battery electric vehicles.

However an important issue, when discussing about vehicles and costs of ownerships, is represented by the depreciation. Analysing the trends over the horizon of respectively 5 and 10 years and considering a depreciation rate of 25% in the first year and 10% in the following years, was discovered that this element is by far the largest cost factor representing 50-61% for all the ICEVs, 64% for HEVs and 80-83% for PHEVs and BEVs.

Finally, looking at the total costs of ownerships (TCO) can be noticed that electric vehicles are not so convenient from the point of view of the costumers. The total cost of ownership of a plug-in hybrid electric vehicle after five years and then after ten years is respectively 26.572€ and 40.962€: the most expensive of the vehicles analysed.

Diesel-powered vehicles remain the most convenient with a TCO of 18.372€ after five years of ownership and of 30.874€ after ten years. Battery electric vehicles (BEVs), instead, are not particularly convenient: they are cheaper than PHEVs but, at the same time, more expensive if compared to ICEVs and HEVs. Their costs of ownership reach the amount of 21.618€ in five years and, after ten years, overcome 33.000€ per year all comprehended.

3.5 Supply Chain in the Electric Segment.

In the previous chapters, when discussing about the main features of the automotive industry, were also analysed all the organizational and managerial aspects related to the supply chain management.

The multitude of academic studies, regarding this argument, highlighted that the most important challenge for supply chain management is the strategic choice between outsourcing and insourcing. These two important approaches can be brought back to the traditional "Make or Buy" trade off, which contributes to determine the degree of vertical integration of the company.

In the last few years, as already seen, there was an important turnaround in the trends regarding these arguments. After the mass outsourcing phenomenon experienced during the years between the 20th and 21th century, now companies are more willing to reacquire and develop internally the specific knowledge useful to maintain the control over core and strategic phases of the production process.

The electric revolution that is happening in the automotive industry can surely play an important role in the dynamics related to the supply chain management. The integration of alternative power train concepts, like the electric engine, into traditional passenger cars will require completely new components and capabilities. Small and Medium Enterprises (SMEs), which are currently not present in the traditional automotive supply chain, and other important big suppliers involved in the electric segment will become particularly involved in the EV supply chain by developing and providing new automotive components and services. The supply chain designed to manufacture an electric vehicle differs considerably from that of a traditional vehicle; especially regarding the relationships with other industries such as energy suppliers and service providers. Many important components that are currently used in a traditional gasoline-powered vehicle will be no more useful in a total electric automobile and, maybe in the future, completely out-dated.

The electric vehicles revolution will imply new aspects and innovations related to the whole value chain development and they will transform the nature and level of logistics coordination across different plants: actors involved in this industry have to rethink the already existing plans related to inbound and outbound operations. Obviously the flow of materials from the supplier to the automaker's assembly plant and, then, to the final distributors is and will be considerably affected by the radically different production of electric vehicles. However, a great importance must be assigned also to the in-house flow of materials and components.

The almost complete elimination of traditional automotive components, the combustion engine and gearbox only to take some examples, merged with the simultaneous appearance of radically new car modules like battery packs, electric motors and transmissions can surely influence the innumerable relationships within the inbound supply chain. On the other side, other traditional components, like the air-conditioning system, water pumps, steering and brakes systems will have to be adapted.

As for a traditional car manufacturer, an important issue for future inbound logistics processes is the make or buy trade off of important modules like batteries, electric motors or power transmission. The powertrain is considered a part of strategic importance for the in-house development and production base of the most important automakers. Thanks to the advent of new electric technologies, vehicle manufacturers need to redefine their core competences: electrical components have not traditionally been a focus area for car manufacturers. However, the most important point of discussion might be which part of the value chain associated to the development and production of battery packs will take place in-house or in another specialized company.

Companies can face these difficult decisions following some different path. They can vertically integrate a battery producer; they can directly acquire it; the battery manufacturer can try to enter into the car production; or there can be the cooperation between the electric vehicle manufacturer and a local or foreign battery supplier on the development and production of this component.

In this scenario cell-manufacturers will have a fundamental role. They have significant R&D knowledge inherent to battery chemistries, which is difficult to transfer to leading car manufacturers, and they count for approximately the 50% of total manufacturing costs of a battery. These aspects give battery manufacturers a dominant position in the future value splitting of electric vehicle manufacturing. China, Japan and Korea already play a fundamental role in battery production and will increment their leading positions in the next future. Locations and total network structure of future electric car manufacturing will be strongly influenced by the amount of costs related to logistics and this will further contribute to focus future supply chains on Asian markets. As previously described, the incredible growth of the Chinese automotive market, recording also the highest level of automobile production and sales in the world, will set China in a favoured position and make it the centre of e-car manufacturing.

Wang and Kimble (2011)[32] affirmed that "*although the electric vehicle industry is in its early stages, thanks to its firm foundations in terms of key raw material extractions, battery production and infrastructure for vehicle manufacturing. China has the foundations to build a similar value chain for electric vehicles*."

One of the primary issues that have challenged the adoption of an electric vehicle up to now, and that continued to be the greatest barrier for a growing volume output, is the high purchase price of these kind of vehicles. Even the most important automakers are not been already able to commercialize reasonably priced e-cars, alternative to an internal combustion engine vehicle and with the same performances and driving range. Hitherto, electrified vehicles are clearly positioned in a niche market (i.e. sports cars or city vehicles) allowing only a small share of the costumers to buy them and delaying a more widespread diffusion of the underlying technology.

Besides these technical and market restrictions, political decisions to encourage "normal" consumers to acquire e-cars will have also a fundamental role in the future production volumes. As already explained, the availability of adequate infrastructures and services assisted by a serious plan of incentives by the governments are among the crucial points in order to foster an increment in the adoption rate.

Electric vehicles have some important differences if compared with traditional cars and their degree of differentiation is based on the design principle at the base of the same e-car. On one side there is the possibility to adopt a conversion design strategy, based on traditional car concepts. The traditional combustion engine is replaced by an electric motor while the whole architecture and components of the car remained the same. The major advantage of this design is that the mass-marked conventional vehicles can be exploited to promote economies of scale of e-cars in design and manufacturing.

On the other side can be followed a purpose design path. Thanks to this system, automakers can develop and construct a radical new vehicle, generating a car that is purpose-built to the needs of electro-mobility. This independence in designing the

[32] Wang, H. and Kimble, Ch. (2011), "Leapfrogging to electric vehicles: patterns and scenarios for China's automobile industry", *International Journal of Automotive Technology and Management*.

whole car allows the development of more radical innovations and offers new functionalities and possibilities.

However, arrived at this point, must be specified that there isn't a one best way in the production of electric vehicles. As for other important complex products, also electric vehicle production can be organized in different ways following the needs and the characteristics of the manufacturing company. In this thesis are considered four different paths that automakers can follow when deciding to develop a production process dedicated to electric vehicles: a fully integrated manufacturing system, a partially integrated approach, the contract manufacturing system and, finally, the parallel manufacturing of both traditional and electric vehicles.

In a fully integrated manufacturing system, all models of cars (both e-cars and non e-cars) are produced in the same place and on the same manufacturing line. Components and modules characteristic of each model can be manufactured in secondary lines, which are then all fed into the main line, to perform the mixed final vehicles manufacturing. The repetition of these processes over the time increases dramatically reducing, at the same time, manufacturing costs thanks to the exploitation of economies of scale. A crucial logistics goal, in terms of supply chain management, is to optimize the whole assembly process.

This production system is based on the conversion design notion. Traditional cars, which have proven to be well developed, reliable and successful on the market, can be merged with electric vehicles, based on the same conventional car concept. An important exploitation of the economies of scale in production is often combined with economies of scope in R&D and support functions. This system improves the availability of critical personnel and know-how, a more intensive knowledge exchange inside the company, and shortens delivery times between each car processing stage. However must be specified how this major efficiency is directly linked with higher cost flexibility. The almost complete integration of electric vehicles in a single assembly line produces a consequent increase in the volumes requirements regarding different components and therefore strongly influences the inventory policies of the principal manufacturers increasing the need of maintaining supply flexibility in order to remain competitive on the market.

In this particular model, the timely delivery of components is of strategic importance for the company and can decide the destiny of the entire vehicle assembly process. The sequenced in-line supply (SILS) puts evidence on the reliability (of the production and delivery) in such a way that temporal and spatial proximity between the supplier and the OEM becomes of strategic importance. Volvo (modularity), as already seen in the dedicate chapter, is a clearly example of this strategy: proximity enables low inventory, late configuration and also last-minute revisions in the sequencing to cope with planning failures.

A fully integrated manufacturing requires a modularised car architecture, like the one implemented by Volvo, based on the conversion design concept. Operations strongly related to the manufacturing of electric vehicles, in this situation, have to be fully integrated into the final assembly line. The final assembly of an electric vehicle comprehends operations like batteries' installation, charging and final control that are quite time-intensive and require an adequate level of attention. These technological and organizational limitations, on one side complicate the adoption of a fully integrated system, but, on the other side, favour the implementation of a more suited strategy.

The possible solution to the problems manifested by a fully integrated manufacturing system for the production of electric vehicles is a partially integrated bypass manufacturing approach. This system is characterised by splitting and emerging manufacturing operations and services for economic or technical reasons. Bypass manufacturing materialises in two phases: first of all it separates all the stages of production process and then recombines the most interested sequences in order to allow a partial parallel manufacturing. Electric vehicles developed with a modular design approach make possible the fragmentation of the whole production chain into autonomous sub-systems that can be also produced independently and partially in a parallel way. An important problem to face is related to e-cars and non e-cars modules: even if they are different form a technical and technological point of view, the interfaces must be standardized as much as possible in order to allow the right implementation of a modular strategy. Standardisation of components and connexions between them becomes therefore a critical issue for each company.

The matching and synchronization of the value creation process constitute another key factor for the success of the bypass manufacturing system: managing a synchronous

system like this one can result operationally and logistically difficult and demanding. The flow of raw materials and components must be synchronised in such a way that parts move in a strategic manner preventing local accumulation of inventory and creation of efficiency drops: the principal goal is the flows of material between the individual strands of the different models' value streams without interruptions through a highly organized process. In the automotive industry there is no space for inventory buffets to compensate possible delays, so it is of fundamental importance the volume and time coordination of the material flow. The "Takt"[33] time is an important index of this coordination, directly derived from the customer demand; it ensures that each operation performs equally and it is used to synchronize the pace of production with the rate of customer sales in an efficient way. Takt time between electric cars and traditional vehicles is very different and it reflects the differences in production volume between these two different automobile models.

A mixed production system is the right instrument to adjust surplus capacity and refuse useless stocks that characterizes a stable manufacturing process. This synchronous manufacturing process necessitates an effective management inherent to the flow of materials, a reliable communications systems and highly specialized production technologies.

A further possible method for the production of electric vehicles is the contract manufacturing. Contract manufacturing is usually implemented when the expected level of output of electric vehicles doesn't meet the requirements for the integration in one's own manufacturing process and the degree of electric vehicles' differentiation in relation to traditional cars is rather high.

Contract manufacturers (Little OEMs) usually produce a low-volume of products and develop specialised car models, such as electric cars, for and under the brand name of already established automakers: usually these companies decide to exploit their engineering know-how to become mainly niche car manufacturers. Due to their flexibility and highly specialised know-how they can manufacture at this low level more cost-effectively the then traditional big vehicle manufacturers. This production type implies a number of logistics requirements for the contract manufacturers: they have to

[33] "Takt" is a term derived from the German vocabulary and means rhythm or meter.

deal with different OEMs, each one with its own logistic systems, and a high number of different models (both e-cars and non e-cars). They have to manage many suppliers, part numbers, containers and packaging instructions, which leads to higher material flow complexity. Nevertheless, also contract manufacturers must try to standardize their logistics processes in order to respect the cost structure and their balance sheet parameters.

The last possible production strategy is the parallel manufacturing. This production type is the only one based on a purpose design concept, which develops and assembles a totally new vehicle. This radical innovation implies the creation of new specific components and modules with as much new dedicated operations in manufacturing and logistics.

The parallel manufacturing separates operations exclusively dedicated to electric vehicles from the ones related to traditional cars; this in order to avoid interferences between operations that can utilise shared resources thus causing value streams queuing up. However, a totally fragmented manufacturing system where assembly, painting, and body shop is separated between e-cars and non e-cars is, according to the already low volume of e-cars, unlikely to be implemented. As long as electric vehicles remain a niche market with low volumes of production, high investment in body and paint shop lead to parallel manufacturing only in the assembly plant. In this case EVs assembly lines are separated and totally focused on technologies regarding the electric mobility. Investing in a separate assembly line, also with independent supply processes, implies high investments simultaneously combined with a higher risk of capacity utilisation.

However, electric cars manufacturing has also some outbound implications that must be explained and analysed. Outbound driven aspects comprehend the need to set up a adequate network to recharge or exchange the batteries and to install an electronic billing system.

Huge investments are required especially for implementing the planned recharging strategies – installation of charging infrastructures for supplying electric vehicles with power – and the metering infrastructures necessary to guarantee a dedicated billing.

The feasible change of technology from internal combustion engines to the electric mobility will further have a high impact on the whole automotive aftermarket. The new

components brought with the advent of all-electric vehicles will change the after sales logistics significantly: automotive manufacturers and suppliers, which have traditional core competencies in engines, clutches and gearboxes, have to realign their strategies and identify new business opportunities.

The most important drivers that contribute to the change are a decreasing share of mechanical and moving parts, long service intervals, an immature battery technology, less additional units and limited opportunities for self-service.

With the advent of electric vehicles, all the most important automakers will face important and radical changes in their sales and distribution strategies. Dealers and service networks, on their side, must have the adequate skills and be ready to deal with the necessities of a broader product portfolio.

Finally, as we have seen during this chapter, can be said that electric vehicles constitute an innovation, not only from a technical and technological point of view. Strong organizational and coordination capabilities are asked to the principal OEMs in order to develop and implement the right strategic supply and delivery solutions aimed at producing and commercializing efficiently both of electric and internal combustion engine vehicles.

3.6 Partnerships and Joint Ventures in the Electric Vehicles' Segment

A great importance in the whole automotive industry and especially in a highly technological segment, like the one of the electric vehicles, is played by the numerous partnerships and joint ventures between companies. They can foster a better and more rapid development and diffusion of new innovations and competencies inside the companies involved and through all the value chains

On one side can be defined as a partnership "*the type of business organization in which two or more individuals pool money, skills and other resources, and share profits and loss in accordance with terms of the partnership agreement.*"[34]

On the other side, a join venture (JV) is described as a business arrangement in which two or more parties agree to pool their resources for the purpose of accomplishing a new project or any other business activity. From a juridical point of view it is considered

[34] http://www.businessdictionary.com/definition/partnership.html

an independent entity (not connected with the two or more parties) and allows the partners to separate a specific project from their other business interests. When signing a JV, each of the participants becomes responsible for profits, losses and costs deriving from it. Companies typically pursue joint ventures mainly for the following four reasons: first of all, to gain a faster entry into a new market; second, to acquire more expertise; third, to increase production scale, efficiencies, or coverage; or, finally, to expand its business development by gaining access to distributor networks.

As already described, the manufacturing of an electric automobile comprehends completely new components and services provided by suppliers previously unrelated with the automotive industry. There are plenty of examples of components that are impossible to be developed and manufactured by traditional automakers alone: we can talk about the battery packs, the engine controller, the regenerative breaking systems, the 220V re-charging system and so on. The big OEMs are not already able to develop such components and services, which have to be highly efficient and well performing, because of the huge costs this would imply.

The types of strategic agreements, which can be found also in the EV, are mainly of three different types depending on their step in the whole value chain of the leading automaker:

- *Agreements in the upstream area*: usually made to foster the diffusion of industrial standards or R&D investments, by large consortia or through public R&D projects; sometimes the open innovation approach is involved in these types of agreements.
- *Agreements in the core business of the EV industry*: the goals of these type of agreements is usually to produce or develop new components for the EV, such as batteries, electric motors, electronic control units, software, cooling systems and so on.
- *Agreements in the downstream area*: these arrangements are not related to the internal components of the EV but, rather, to the other services and infrastructures EVs needed, such as new recharging infrastructures and standards, financial services for billing the use of an EV, smart grids to increase the supply of electric power and so on.

In the automotive industry there are plenty of examples regarding strategic alliances and joint ventures between important companies of the sector.

One of the most important and recent partnerships regarding the electric vehicles and its core business is the one engaged between Aston Martin and LeEco[35] at the beginning of 2016.

One of the leading companies regarding the technology sector, LeEco, and one of the most famous luxury sports car brands, Aston Martin, decided to sign a Memorandum of Understanding in order to plan the formation of a partnership with the aim of allowing the development and the real production of the Aston Martin RapidE, an electric vehicle concept presented in 2015 and planned for 2018.

LeEco is an important group of Chinese companies founded by Jia Yueting, the principal financier of Faraday Future (an American technology start-up focused on the development of intelligent electric vehicles). The partnership, in fact, will see the two companies working together in order to develop and manufacture a completely new vehicle, with potential for adding a range of next-generation connected electric vehicles on behalf of Aston Martin, LeEco and Faraday Future.

The agreement focused mainly on the development of low-emission vehicle technologies and will lead to the launch of new range of electric vehicles, RapidE excluded, starting from 2020. Exactly the RapidE will be the first car developed thanks to this partnership and the first Aston Martin electric model. This concept model was established to explore how the company can exploit the already existing production vehicle lines in for the production of an all-electric sports sedan.

Aston Martin and Letv.com, one of the companies involved in LeEco group, are strongly collaborating for the development and implementation of technology solutions for battery systems and powertrain.

Both companies are now focused on bringing the RapidE to market in 2018 utilising the best technologies from the companies' portfolios.

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35 https://www.astonmartin.com/en/media-centre/press-releases/2016/02/17/aston-martin-and-leeco-partner-to-co-develop-electric-vehicle

Mr Ding Lei (**Figure 7**), co-founder and global vice chairman of SEE Plan, affirmed that this partnership contributes to the beginning of a new step of the collaboration and that the company, LeEco, will be strongly involved to build electric, smart, connected and socialized cars. Strengthening collaborations with Aston Martin, LeEco future models will provide premium qualities and delicate arts and crafts as good as those of a traditional Aston Martin.

Figure 7 - Aston Martin & LeEco
Source: www.astonmartin.com

The main goal of Aston Martin, as affirmed by Andy Palmer (CEO of the company), is to develop a range of sports vehicles with low emission technologies. In this project LeEco constitutes an important partner: the capabilities and technological knowledge supplied by the partner encouraged the British company to implement its idea and to schedule a full market production. Commercializing the RapidE in the market starting from 2018 could constitute an important milestone for both companies and will underline, one more time, the growing importance that Asiatic partners have in the development and production of new electric technologies.

Another important partnership is the one that will be signed by Volkswagen AG and JAC (Anhui Jianghuai Automobile Co.) Motors. The most important car manufacturer of the world, strongly involved in the development and production of electric vehicles, announced in a memorandum of understanding released in September 2016 that it is intentioned to joint the forces with JAC Motors, the mid-size Chinese state owned automobile and commercial manufacturers. JAC's main products include: heavy, medium, light and miniature trucks, multi-functions commercial vehicles, SUVs, sedans, buses, and core components like chassis, gearboxes, engines and axle assemblies. JAC delivered 333.639 vehicles and chassis in the first six months of 2016 with new energy vehicle sales increased massively compared with last year (+261%), while SUV sales maintained stable growth (+30%).

The intention of the two companies is to achieve a long-term cooperation in order to develop new all-electric vehicles for the Chinese market. As already described in the

previous paragraph, the Chinese market is experiencing a huge growth in the last years and almost all the most important automakers are interested in investing in the Asiatic continent and collaborating with the principal local players.

For the German company, the possible agreement with JAC Motors can constitute a further improvement in the development of its own electric vehicle and an additional step to strengthen the presence of the brand in China. Volkswagen, in fact, has already signed, in the past, two important partnerships with Chinese automakers. The first was signed in the far 1985 with SAIC Motor (a Chinese state-owned automotive design and manufacturing company) in order to produce cars under Volkswagen and Skoda brands; the second, instead, was approved in 1991 by Volkswagen Group and FAW Group (one of the "Big Four" Chinese automakers with SAIC Motor) for the production of Volkswagen models and, specially, Audi cars to be commercialized in the Chinese market.

The memorandum of understanding calls for setting up a 50-50 joint venture to build and sell electric vehicles in the Asiatic market as well as to develop parts that would increase fuel efficiency. The two parts are discussing some important details such as investment amounts and plant size, hoping to reach a final and definitive agreement within five months.

Matthias Müller, Chairman of the Board of Management of Volkswagen AG, affirmed that the company is looking forward to explore all options in order to set up a close and mutually beneficial partnership with JAC, believing that this cooperation would be not only a value added for the two organizations but would be also of great value for the customers, the environment and the Chinese society in general.

These are only tow of the myriad of partnerships and joint ventures that are signed in the automotive industry and, in particular, in the electric segment. These two partnerships were chosen with the purpose of underlining, once again, the growing role of the Asiatic continent in the development and production of new eco-friendly technology. As demonstrated by market data, the Asiatic countries, China over all, are seriously threatening the leading role of the United States in the whole automotive market. In the next chapter, however, will be analysed one of the most important companies when talking about electric mobility. Tesla Motors, one of the most innovative companies of the world, represents the principal American antagonist to the

big Asiatic companies (i.e. Nissan, Toyota, etc.) regarding electric vehicles. European automakers, instead, are trying to solve this competitive problem with the help of strategic alliances and the development of hybrid electric car of already existing models.

Chapter 4 – Different Approaches to The Electric Vehicles Revolution

In the previous chapters were analysed the main characteristics and economical trends of the whole automotive industry and, later, was explored in detail the electric vehicles segment. In the last few years the automotive industry experienced a constant recovery after the economic and financial crisis that involved it in the years between 2008 and 2010. Thanks to this there is the appearance of new innovations and new technologies related both to comfort aspects and to new alternative fuelled mobility ways.

The electric vehicles in 2015 showed an important increase in the production and sales: for the first time in history the segment overcame the symbolic amount of one million circulating vehicles. This number is already paltry if compared to the totality of the vehicles in commerce (90,7 million of units) but, however, puts evidence to the fact that something is changing. One of the most important barriers to a widespread adoption of electric vehicles is constituted, as explained, by their high initial price.

4.1 Tesla Motors Case Study

Tesla Motors constitutes one of the most important examples when discussing about electric vehicles. Even if it is a relatively young company (just 13 years of history), Tesla Motors is now considered one of the most important players in the whole automotive industry thanks to its innovative contribution and also thank to the revolutionary thinking and reputation of its CEO and founders, Elon Musk. In this chapter will be discussed and analysed the key episodes regarding the history, the products and the organizational innovations that characterized this company and could contribute to the development and widespread diffusion of the electric mobility all around the world.

4.1.1 History

Tesla Motors was founded in 2003 near San Carlos (California), in the Silicon Valley, by a group of experienced engineers (among them Martin Eberhard and Marc Tarpenning) guided by Elon Musk, the actual Chief Executive Officer and majority shareholder. The name of the company was chosen in honour of Nikola Tesla, the famous electric inventor and engineer.

Actually the headquarter of Tesla Motors is situated in Palo Alto, California, where a lot of other important innovative companies have theirs head office. Elon Musk was

immediately an important resource for the company since he was directly involved in the designing and financing research processes needed in order to reach the primary purpose of the company: the development and production of an all-electric car.

The first product entirely developed and manufactured by Tesla Motors, the Roadster model, was firstly presented in July 2006 during a special event dedicated to only 350 guests and then showed to the rest of the world at the "San Francisco International Auto Show"

Thanks to the effort of Elon Musk, the company could raise more than 180 million of dollars in less than five years. He was the first to believe in this project and directly financed it with 13 millions. Among other investors there are prominent figures like Larry Page and Sergey Brin (Google founders), Jeff Skoll (eBay president), Hyatt Heir, Nick Pritzker, Fisher Jurvestone, Capricorn Management and The Bay Area Equity Fund (owned by JPMorgan Chase). In the first part of 2009 the project received an important financial help (50 millions) from Daimler in exchange for the 10% of the company's capital. Just in this moment, the destiny of the company started to change in a positive way. In June of the same year the US Government accorded to Tesla an important subsidized investment for the amount of 500 million of dollars: an indispensable financing in order to start the development and production of the Tesla Model S.

One year later, on 29th June 2010, the company decided to make its debut on Wall Street raising in a short time more than 200 millions of dollars. Before Tesla Motors, only Ford Motor Company was a public listed company in this industry thanks to the subscription of its IPO (Initial Public Offering) in the 1956.

In the same year, Elon Musk decided to sign an important partnership with Toyota, which acquired actions for a total amount of 50 million of dollars. The two companies worked together to develop and produce electric vehicles, components, and new production and design systems. Toyota RAV 4 EV (electric) constitute the first product of this partnership

In 2013, despite a decrease in the price of its actions due to some reliability problems of the cars, Tesla Motors won the award of best index of NASDAQ 100. Just to look at some financial data, when Tesla Motors decided to make the debut at the Wall Street stock market on 29th June 2010 its shares price was 19 USD per stock. Six years later, at the opening of the markets on 29th June 2016, this price was sensibly higher and one stock

was sold for 205,13 USD: an incredible increment of about the 979% testifying the significant growth both from a financial and from an organizational point of view that contributed to make this company one of the most important and innovative of the whole automotive industry. Recently, on 30th December 2016, the price is still growing reaching 216,30$ for each share[36].

In order to further demonstrate the actual importance of the company, it is worth mentioning the huge growth of its revenues experienced in the last few years. Looking at **Table 8** can be seen that Tesla Motors, in the years between 2012 and 2015, almost incremented sensibly the quantity of its revenues. If in 2012 the total amount of revenues was 413,26 million of dollars; three years later, at the end of 2015, this number grew up in an incredible way reaching the total amount of 4.046,03 million of dollars: more or less one million per year since 2012.

This significant growth can be credited principally to the quality and reliability of its new vehicles, and all the services connected to them, that will be described and analysed in the following pages.

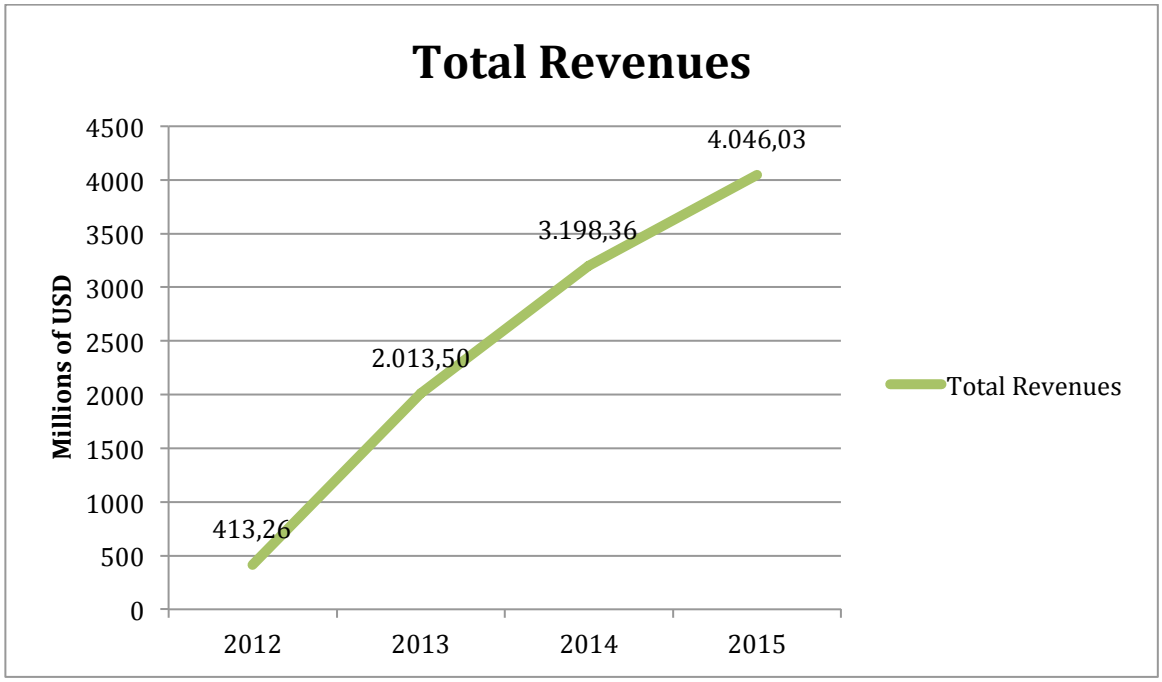

Table 8 - Tesla Motors' Total Revenues
Source: Data from https://www.google.com/finance.

[36] https://www.google.com/finance

4.1.2 Products

Today Tesla Motors has three main products (Model S, Model X and Model 3) but, however, before talking about these actual vehicles, it is important to introduce the product that allowed the company to enter in the electric vehicles' market and start what is called the "Electric Vehicles Revolution": the Tesla Roadster.

Tesla Roaster model was the first product produced by the company and it was a fast and powerful car, contrarily to what were the tendencies of the electric cars. The first version of the Roadster was officialised and commercialized for the first time in 2008; while, the last version of this model was produced in 2012. In approximately four years were sold more than 2500 units in 31 different countries with a price that started from 100.000€ and could rise depending of the addition of some optional components.

The Tesla Roadster was the first car, at that time, to adopt Lithium-ion batteries and able to travel for more than 300 kilometres with a single cycle of charge. Other important characteristics that made this auto a success were its performances like the ones of a supercar: from 0 to 100 km/h in less than four seconds and a maximum speed equal to 200 km/h. This vehicles is one of the first to be assembled with electric-regeneration brakes and it chassis made in carbon fibre was developed with help of Lotus Cars, in fact can be noticed particular similarities with some Lotus models (i.e. Lotus Elite).

Starting from 2012, with the simultaneous stop in the production of the Roadster model, Tesla Motors decided to improve the quality, comfort and technology of its vehicles and started to produce the Tesla Model S (**Figure 8**). It was already presented in 2009 at the International Motor Show Germany (IAA) in Frankfurt and it was the first entirely electric car with five doors.

Figure 8 - Tesla Model S
Source: www.tesla.com

The Tesla Model S, "*Whitestar*" the name of the original project, was designed and partially developed by Franz Von Holzhausen, the actual responsible of the design inside Tesla Motors and in the past designer also for Mazda and Volkswagen. The first mass production started in 2012 in the plant near Fremont (California) and the first deliveries

were all destined to the United States of America. Despite the production started about one year earlier, the Model S arrived in Europe only towards the middle of the 2013 and principally in the most eco-friendly countries of that time (i.e. Norway, Netherlands and Switzerland).

This model won a lot of awards in the world of innovations and automotive. Just to mention some of them, it won the "Time Magazine Best 25 Inventions of the Year" in 2012, the "World Green Car of the Year", the "Motor Trend Car of the Year" and the "Automobile Magazine's Car of the Year" all in 2013.

In 2015 Elon Musk announced that, all the circulating vehicles comprehended, the Model S has travelled more than 1,5 billion of kilometres (like the Chevrolet Volt and more than Nissan Leaf) and that the global sales of this model exceeded the amount of 100.000 units. According to Tesla Motors, the majority of the vehicles were sold in America (68%) while the remaining part has to be divided between Europe (25%) and Asia (7%), which was not already in the vanguard regarding electric mobility at that time, as already explained in the second chapter of this thesis.

In the beginning of 2016, Tesla Motors decided to make a restyling of the Model S introducing some new elements, like the new integral front bumper and the new full LED adaptive headlights, and other technical improvements (i.e. a more efficient battery charger and a powerful powertrain). This new version is equipped also with an innovative "Auto Pilot" that is able, thanks to the employment of some radars, sensors and camcorders to drive autonomously the car without the necessity of any human actions. This system, even if it is still in the development stage, represents an important innovation for the whole automotive industry and not only for the electric segment: other important companies (i.e. Google) are trying to implement their personal self-driving car, not without encountering some important difficulties especially form the point of view of security and drive precision.

Looking in particular at the technical characteristics, the Model S has taken much from its ancestor, the Roadster: it is always considered a sport car. Usually the electric engine is assembled in the backside of the car and can furnish to the vehicle a maximum power of 387 CV with a maximum torque equal to 440 Nm. This model can be found in two different versions: the first with a battery pack able to supply 60 kWh and the second with a battery power of 75kWh. The first version is able to guarantee an autonomy

range of approximately 375 km (New European Driving Cycle) and an acceleration from 0 to 100 km/h in just 5,6 seconds; the second, instead, can travel for more than 400 kilometres without being recharged and has a maximum speed of 225 km/h.

However there are other two possibilities in the configuration of the car. The first possibility is a Model S with double engine traction – one on the backside and one on the front of the car – and assembled with battery packs of 60, 70 and 90 kWh. This configuration, especially with a battery pack 90 kWh, is one of the most efficient Tesla's models: it can reach the maximum speed of 250 km/h and an autonomy range near to 530 km. The second possibility, however, is absolutely the most performing electric vehicle of the world. It is named "Model S Performance" and is equipped with a double engine powered by battery packs at 90 kWh or 100 kWh: it can reach the speed of 100 km/h in only 2,7 seconds with a maximum speed of 250 km/h and a maximum autonomy range calculated in 613 km. This data confirm the absolute quality of this luxury sedan vehicle comparing it with the most famous and renowned sports cars.

The Model S is sold starting from 85.000€ for the most standard version (Model S 60) while the price sensibly increases (157.000€) if the costumer pretends to have the most powerful and comfortable car possible (Model S P100D).

Starting with the Model S, Tesla Motors decided to implement its own recharging system, also known as "Tesla Supercharger", and to diffuse it firstly in the most important and strategic cities of America and, then, through Europe and Asia.

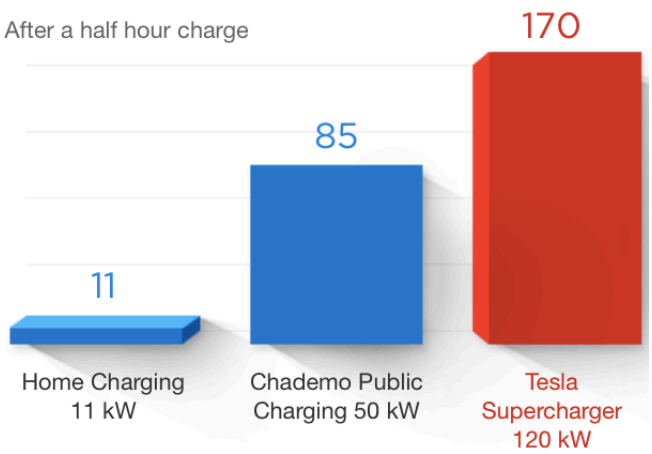

Figure 9 - Autonomy Range after 30 min of charge.
Source: www.tesla.com

Tesla's cars adopt their on-board charger to convert the alternate current (AC) coming from the principal charger in direct current (DC) useful for the battery packs. Many chargers that work in parallel compose the "Superchargers", transmitting up to 120 kW of direct current to the battery assembled inside the vehicle. This fast-recharging system is able restore autonomy equal to 270 km

(80% of the battery) in only 30 minutes and the totality of the battery (100%) in approximately 75 minutes (**Figure 9**). These data are subject to variations depending on different factors such as the environmental temperature, limitations regarding the use of the electricity or the number of simultaneous recharging processes. However, Tesla Model S can be recharged also with the "home charging" (11 kW), which implies longer times and is able to guarantee only 11 kilometres of autonomy after 30 minutes, or with the "CHAdeMO Public Charging" (50 kW) that can guarantee in the same time 85 kilometres of autonomy.

The Supercharger system is not only compatible with the Model S, but also with other subsequent models like the Model X and the Model 3.

After the success of the Model S and the widespread diffusion and customers' appreciation of SUVs in the whole automotive industry, Tesla Motors decided to develop its own crossover and present the first concepts of the Model X (**Figure 10**) on 9th February 2012 at its Tesla Design Studios. However, the official production started in 2015 in the plant near Fremont, California (the same of the Model S). The real start of the production was expected at the beginning of 2014 but, because of some organizational problems, was firstly postponed at the end of 2014 and then further delayed to the third quarter of 2015. Considering that Tesla Motors concluded the third quarter of the 2016 with the record in the global matriculations (24.500 units, +70%) and considering that, after only one year, 8.700 of them are Model X[37], can be affirmed that this model has been successful among Tesla's fans. Especially in Norway the Model X reached a particular success: in 2016 it was the second most sold car all around the country (behind only Volkswagen Golf) and by far the most sold electric car with 601 vehicles before BMW i3 and Nissan Leaf[38].

Figure 10 - Tesla Model X
Source: www.tesla.com

[37] Data from www.ilsole24ore.com
[38] http://www.motorionline.com/2016/10/06/tesla-model-x-e-la-seconda-auto-piu-venduta-in-norvegia/?refresh_ce

The company considers the Model X the most capacious (7 seats), faster and safer SUV of the history. This car can transport up to seven passengers with their luggage and, thanks to the assembly of the battery pack on the loader of the vehicle, the centre of gravity is contributing to improve the safety of the whole car.

Differently from the Model S, are commercialized only three different versions of the Model X. The first version is assembled with a double engine with a 75 kWh battery pack and can reach an autonomy range approximately of 400 km with a maximum speed of 225 km/h. The final price, incentives included, is 101.300 € with a saving on the fuel calculated in 3800€ (on the base of five years). The other two versions (Model X 90D and Model X P100D) are more powerful and performing: they have respectively a 90 kWh and 100 kWh batteries pack and an autonomy range of 489 km and 542 km. Their maximum speed is more or less 250 km/h – in particular, the P100D model is able to from 0 to 100 km/h in only 3,1 seconds – and their price can vary from 112.000€ to 156.800€ (incentives and fuel saving included).

The last battery electric vehicle developed by the company of Elon Musk is called Model 3 (**Figure 11**). This model was officially presented on 26th March 2016 during an exclusive event in Hawthorne (California) for only 800 invited and was transmitted in streaming on the website of the company.

Figure 11 - Tesla Model 3
Source: www.tesla.com

Tesla Model 3 production is not yet started but, however, it has already more than 400.000 reservations and the company expects to deliver all the vehicles within the end of 2017 in US and for the beginning of 2018 in Europe. The production of this model will be initially implemented in the main plant of Fremont, as for the Model S and the Model X.

Its main characteristic and the main source of its great success, differently from previous ones models, is represented by the price. The Model 3, in fact, is considered the first electric vehicles for the mass market developed by Tesla Motors.

If compared with the previous vehicles, this model is slightly less performing but it still can assure high standards of safety, speed and autonomy range. It will cost more or less 35.000 USD (incentives excluded), will ensure to the costumer an autonomy for approximately 345 km with an acceleration from 0 to 100 km/h in less than 6 seconds and will be already assembled with the Tesla Autopilot and the Supercharger system. At the beginning the Model 3 will be assembled with a single electric engine positioned on the backside but, in the future, it is expected a version with a four-wheel drive.

An important novelty in the production of the Model 3 is the exploitation of the "Gigafactory", the new gigantic plant for the production of energy and Lithium-ion batteries necessary to feed all the Tesla's vehicles.

4.1.3 Tesla Gigafactory

One of the most important goals in the mind of Elon Musk, the founder of Tesla Motors, is a still wider diffusion of electric mobility and the dejection of organizational and purchasing costs. To do this, the company decided to collaborate with some important battery-manufacturing partners and planned to build a large-scale and innovative factory in order to exploit economies of scale, reduce logistics waste and minimize the costs of production.

In 2014 Tesla Motors and Panasonic signed an agreement about their cooperation for the construction of this large battery-manufacturing plant near Sparks, Nevada. The company and its partners are intentioned to invest more or less 4-5 billion of USD in this project through 2020: 1,5 – 2 billion directly from Panasonic.

In 2018 Gigafactory is expected to reach the full capacity with a total production of Lithium-ion batteries that will overcome the whole world batteries production rate registered in 2013.

In collaboration with Panasonic, and other strategic partners, the Gigafactory will produce cheaper battery packs thanks to an innovative production system, the waste reduction, the exploitation of economies of scale and a huge optimization of all the phases of the production system through vertical integration under the same roof. Tesla Motors supposes to reduce the costs of battery production of the 30% and lower the

price of lithium-ion batteries from 190$ per kWh in 2016 to 130$ per kWh when the Gigafactory will be completely operative.[39]

The Gigafactory is planned to produce 35 GWh (billions watt per hour) of cells and 50 GWh of packs per year by 2020 and, following the plans of the company, it will employ 20.000 people when it will be completed (today it employs approximately 6500 workers). It is considered, only after the monumental plant of Everett where are manufactured Boeing's airplanes, the second most extended plant in the world (approximately as 100 football fields) and it is powered only by renewable energies with the aim of reaching a net zero energy.

In October 2016 Tesla Motors announced that, besides the manufacturing of batteries and battery packs, it will produce also its own powertrains and drive units.

The realization of this project could be of fundamental importance for the destiny of the whole electric segment. As already established, two of the most important barriers in the adoption of electric vehicles are made up by their high ownership costs and by the lower autonomy range in comparison to a traditional ICE car. Company's effort in the creation and exploitation of economies of scale in the production of components for the electric segment is also a serious attempt to accelerate the world's transition to sustainable energy.

Tesla Motors represents the only company that was able to create a set of complementary products and services able to foster a widespread and diffusion electric vehicles. Next to the production of electric vehicles, the company administered by Elon Musk has been able to develop its own forefront production plant (the Gigafactory), its own recharging system (the Superchargers) and an important ecosystem to promote and increase an efficient employment of renewable resources both for privates and business (the Powerwall and Powerpack[40]).

[39] https://techcrunch.com/2016/11/06/what-teslas-new-gigafactory-means-for-electric-vehicles/
[40] https://www.tesla.com/en_GB/energy

4.2 BMW Case Study

The second case study concerns BMW, an historical German company and one of the most important original equipment manufacturers (OEMs) in the world. It is an interesting example because the German group has a different structure and a different approach to the electric revolution if compared to the Tesla Motors. The core activities of BMW regard the development and production of traditional vehicles powered by an internal combustion engine. BMW has in its "line-up" nine different models, each one with its own characteristics (i.e. suv, coupe, cabrio, sedan) and possibilities to be customized (comforts, engines, etc.). In 2013 the company decided to start the production of its own electric mobility project (BMWi) and to strongly invest its organizational and financial resources in the electric market. Besides the commercialization of traditional models, in fact, BMW decided to produce two electric vehicles (BMW i3 and i8) and to develop some plug-in hybrid electric vehicles of already existing models (i.e. BMW Serie 3 Plug-in Hybrid).

4.2.1 History

BMW (Bayerische Motoren Werke) was officially founded in 1917 and at the beginning its core business was the production of airplanes' engines for the planning of the world war. After the tragic end (for Germany) of the First World War and the following exclusion from the production of air engines, the company was forced to find good alternatives to survive. At first BMW decided to produce engine for motorcycling and boating, but starting from 1928, it enter into the automobiles market with the BMW 3/15. During the Second World War it was delegated for the mass production of military vehicles and airplanes and it became one of the most important company of the whole Nazi Germany. After the end of the war begun the most difficult years of BMW's history: the American invasion contributed to reduce and readdress the production in order to avoid military rearmament.

In 1950 the production was moved from Eisenach to Munich, still today the headquarter of the company, and towards the end of the decade, thanks to the financial help of Herbert Quandt (the main shareholder), the company started a slow but stable recovery process. The turning point was the 1966, when BMW decided to acquire Glas, an important German company that was involved in the production of low and midrange

vehicles. Despite this BMW-Glas models were not so successful in the market and BMW was obliged to review its plans: it eliminated the Glas brand, dismantled the principal plant of Dingolfing and restored the whole production process following the needs of BMW.

Starting from the '70s BMW experienced a huge growth and became one of the most important automakers in the world. In this period were developed two of the most important models of the company: the BMW Serie 3 and BMW Serie 5. In 1994 the Bavarian company decided to acquire the Rover Group and from 2000 it decided to sell all the brands (Land Rover, MG Rover, etc.) except for Mini, of which held the whole control. This acquisition allowed BMW to gain important specific knowledge to produce a range of four-wheel drive vehicles (i.e. BMW X3 and X5) and, starting from 2003, the BMW Group started to produce another important British luxury brand (Rolls Royce) after an agreement with Volkswagen group.

Today BMW represents one of the most important and powerful automotive and motorcycle groups of the world. Following Statista, BMW in 2015 was the 9th automakers of the world; before it there are only the most historic and financially powerful manufacturers, among which Toyota, Volkswagen Group, General Motors, Daimler and Ford. Looking at **Table 9**, in the same year (2015) the total revenues of the company overcomes 90 billion of euros and confirmed a very positive trend in the years between 2011 and 2015 (+31,1%). Only in 2013 has been registered a slightly decrease in the total revenues: from 76,8 to 76,1 billion of euros (-0,01%).

Despite this, the company fully reflects the trends of the whole automotive industry that, as explained in the previous chapters, after the economic crisis, experienced a constant and convincing recovery.

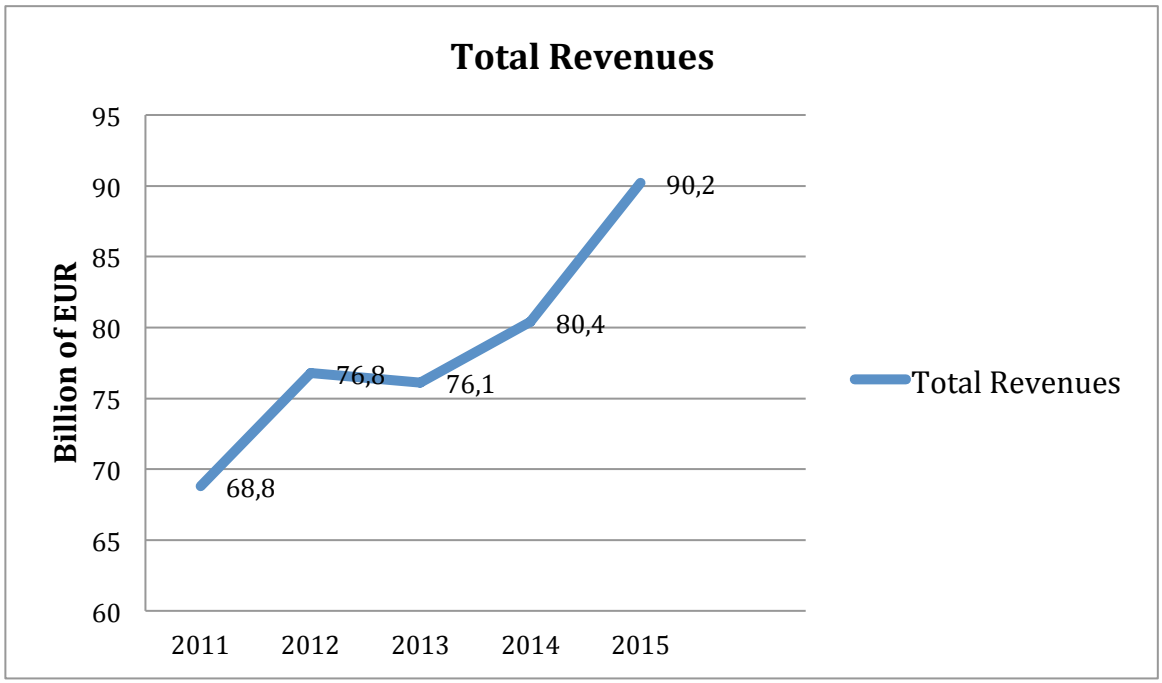

Table 9 - BMW's Total Revenues
Source: Data from www.bmwgroup.com.

4.2.2 Products

In 2011 BMW decided to develop, following the strategic choices of its main competitors (Toyota, Volkswagen Group, Daimler, etc.) and the success of Tesla Motors, its own line of electric vehicles. BMWi represents an important and revolutionary project to diffuse an increasingly sustainable mobility all around the world. This model isn't just a concept about electric vehicles but it is a wider plan that involves a set of complementary services and a focus on sustainability through the entire value chain. At the beginning the company planned to release two kinds of vehicles (BMW i3 and BMW i8) and their concepts were presented in 2009 during the Frankfurt Motor Show.

The official mass-production of these vehicles started respectively at the end of 2013 and in June 2014 and until the beginning of 2016 total BMWi sales reached approximately 50.000 units.

The BMW i3 (**Figure 12**) is a battery electric vehicle (BEV), the first zero-emissions car produced by Bavarian company. The electric propeller "BMW eDrive" powers this electric car and, thanks to a power equal to 125 kW (170 CV) and a maximum torque of 250 Nm, it is able to provide the costumers with an immediate responsiveness and respectable performances. Differently from traditional vehicles, which have to change

gear during their acceleration phase, the electric BMW i3 can go from 0 to 100 km/h in only 7,3 seconds without interruptions. Through December 2016, the BMW i3 has been the third most sold electric car in the world (only after the Tesla Model S and the Nissan Leaf), with more or less 65.500 units delivered in 49 countries, and its top selling markets of are United States (about 23.950 units sold), Norway (8.000 new units registered), Germany (approximately 7.493 new cars) and UK, with more or less 6000 i3s sold. Actually it is commercialized in two possible variants: the basic version and a more performing and sportive one.

The first version is assembled with a battery pack able to supply 60 ampere per hour (Ah) with a consumption of 12,9 kWh every 100 km. Its autonomy can reach approximately 130 km and, when the level of charge is quite low, the battery pack can be simply recharged at home or, when during a journey, thanks to the "ChargeNow" mobility service: using the traditional 230 volt socket, the vehicle will recharge the 80% of its batteries in less than 8 hours.

Figure 12 - BMW i3
Source: www.bmw.com

The second version of the BMW i3 is manufactured with a more performing battery, which is able to guarantee 94 ampere per hour (Ah) and a consumption of 12,6 kWh (more or less 3,5 euro every 100 km). This model was made to increase the performances and the comfort of the drivers: the BMW i3 (94 Ah) has an autonomy range approximately equal to 200 km depending also on external conditions.

However, in order to increase the performances of the BMWi, the company decided to offer a Range Extender (REx) option. It is essentially a 647 cc two-cylinder gasoline engine, very silent and with a 9L fuel tank, which is collocated on the backside of the car near the electric engine. This gasoline engine activates automatically when the level of charge is low and powers an electricity generator, which in turn maintains constant the charge of the high voltage battery. The Range Extender allows to extend the autonomy range of the BMWi respectively to 270 km (for the 60 Ah version) and to 330 km (for the 94 Ah model).

The final price of the BMW i3 (all the variants comprised) can vary from 36.500€ to 42.350€, excluding all the optional and comforts available. This price level places the BMW i3 in a medium-high range of expense and make it compete directly with the future Tesla Model 3.

The second electric model developed and produced by BMW is the BMW i8 (**Figure 13**). This vehicle is considered a supercar, as its performances demonstrate, but, differently from the i3 model, it is not an all-electric vehicle. It is rather a plug-in hybrid electric car, which is powered both by an electric engine and by a traditional internal combustion engine. On one side, the electric motor is located on the front axle and has a power equivalent to 96 kW, more or less 131 CV. On the other side, a powerful BMW TwinPower Turbo 1.5-litre 3-cylinder petrol engine contributed to power the rear axle with 170 kW (231 CV) and a maximum torque of 320 Nm. These two drive systems are combined together in order to offer the costumer a sensational driving experience: the BMW i8 can reach 100 km/h in less than 4,4 seconds and a maximum speed of 250 km/h with a fuel consumption approximately of 2,1 L per 100 km and CO_2 emissions of 49 g/km (depending also on external conditions). Regarding the autonomy range, even if it depends on variety of factors (i.e. personal driving behaviours, wheatear conditions, selected route, etc.), the i8 can reach 37 km only with the power of the electric motor and a maximum total range of 440 km. When the autonomy of the vehicle is reaching its limit, the car can be easily recharged at home through the BMWi Wallbox reaching the 80% of its full autonomy in less than two hours or using the public recharging system (ChargeNow) or, finally, directly exploiting the energy recovery in thrust and brake phases. The final price of the BMW i8 starts from 139.650€ and this made the i8 one of the most expensive electric car in the whole world scenario, even more than Tesla Model X.

Figure 13 - BMW i8
Source: www.bmw.com

At the end of 2015, BMW i8 has sold more or less 7.200 vehicles all around the world since when it is in commerce: 1.741 units in 2014 and 5.456 in 2015[41]. The United States are the most important market for the i8, as for the i3 model, followed by UK and Germany. Since its appearance on the market, in the mid-2014, BMW has sold more than 10.000 i8 models all around the world making it the first among electrified sports cars.

4.2.3 Complementary Products and Services

Beside the development and production of electric and hybrid vehicles, BMW decide also to provide its costumers with complementary products and services that can facilitate the use of principal products and can result of strategic importance for the company in comparison to its competitors. As already seen in Tesla Motors case study, the most important complementary product/service when discussing about electric vehicles is represented by the recharging system.

BMW decided to develop and commercialize its own recharging system, named "BWM Wallbox". This recharging station is commercialized in two different versions (Wallbox Pure and Wallbox Pro), can be easily installed at home and allows the costumer to improve recharging performances and to reduce the whole charging time. Compared to traditional recharging systems, such as the standard cables supplied with the car, the Wallbox can shorten the whole recharging process of about 30% but has a cost approximately of 900€ (installation costs excluded).

This special charging station has a power equal to 4,6 kW and allows to recharge the 80% of the whole BMW i3 battery in less than five hours; while the more performing Wallbox Pro can recharge the 80% of a BMW i8 in less than two hours (depending also on the electricity infrastructure available).

As for the Tesla Supercharger, this device can also exploit home-generated electricity (i.e. photovoltaic energy) and can be easily incorporated into local energy management and smart home systems. These highly technological recharging systems can be of fundamental importance for costumers' satisfaction and, as a consequence, for the future diffusion of all electric vehicles.

[41] https://www.press.bmwgroup.com/global/article/detail/T0249765EN/bmw-group-achieves-fifth-consecutive-record-sales-year

4.3 FCA Case Study

FCA (Fiat-Chrysler Automobiles) represents the third and last example of this thesis about electric mobility. This company is very interesting because it has a completely different approach to electric vehicle revolution in comparison to the previous analysed companies. If Tesla Motors and BMW decided to bet in electric vehicles without particular hesitations, FCA is still quite sceptical about this technology and, as we will see, it decided to strongly invest in another mobility innovation: the self-driving car.

However, despite the scepticism of its CEO Sergio Marchionne, starting from the end of 2016 the company seriously considered the possibility to add to its "line-up" some 100% electric vehicles.

4.3.1 History

Fiat Chrysler Automobiles is an important automotive group born from the fusion of the Italian company, FIAT S.p.A., and the American one, Chrysler Group.

The history of this group started unofficially in January 2009 when Fiat announced a preliminary and non-binding agreement to acquire the 35% of the American, which was encountering some financial difficulties almost since many years. At that time, Daimler and Cerberus (an American fund) owned respectively the 19,9% and the 80,1% of Chrysler Group. In June 2009, after Marchionne became the CEO of Chrysler and a piloted bankruptcy of the American group, Fiat acquired officially the 20% of the company and Robert Kidder was named president.

In April 2010, after many years and the supervision of Fiat, the finances of Chrysler returned in positive sign with an operating profit of 143 million dollar and a positive cash flow of 1,5 billion of USD. In the same month, Sergio Marchionne announced the first vehicle under the Fiat administration: the new Jeep Grand Cherokee.

At the beginning of 2011 the share ownership of Fiat grew from 20% to 25% and six months later, after having paid all the debts towards Canadian and US governments for a total amount of 7,6 billion of USD, acquired the quotes of ownership of the respective states and reached the 53,5% of the total Chrysler's ownership.

In January 2014, Fiat reach an agreement to buy all remaining shares of Chrysler from Veba fund for a total price of 3,6 billion dollars. On 29 January of the same year, during

the presentation of data on financial statements, it is also announced the new company name after the fusion (Fiat Chrysler Automobiles) and the new logo (FCA).

The effective merger between Fiat S.p.A. and Fiat Investments N.V. (a Dutch based company controlled directly by Fiat) was ratified on 12 October 2014 and Fiat Chrysler Automobiles (FCA) became officially the holding company of the entire group. The day after FCA made also its debut on Wall Street and on Milan stock exchange.

In the same year it was furthermore announced the separation from Ferrari N.V.; however, this agreement became effective only at the beginning of 2016 when Ferrari went directly under the control of Exor (already the major shareholder of FCA).

Today FCA represents the 7th automakers in the whole automotive industry, before some other important groups like BMW, Renault and Nissan, and it is actually the owner of many important automotive brands, such as Alfa Romeo, Jeep, Lancia, Maserati, Dodge and Abarth.

At the end of 2015 Fiat Chrysler Automobiles (FCA) total revenues, excluding Ferrari, reached approximately the amount of 110 billion of euro (**Table 10**). An increase of 18%, if compared to the year 2014, when total revenues were about 93,6 billion. However must be said that the group has always performed well, even in 2011 and 2012 when the total revenues cannot be imputed yet to FCA because they are still of Fiat Group financial statements.

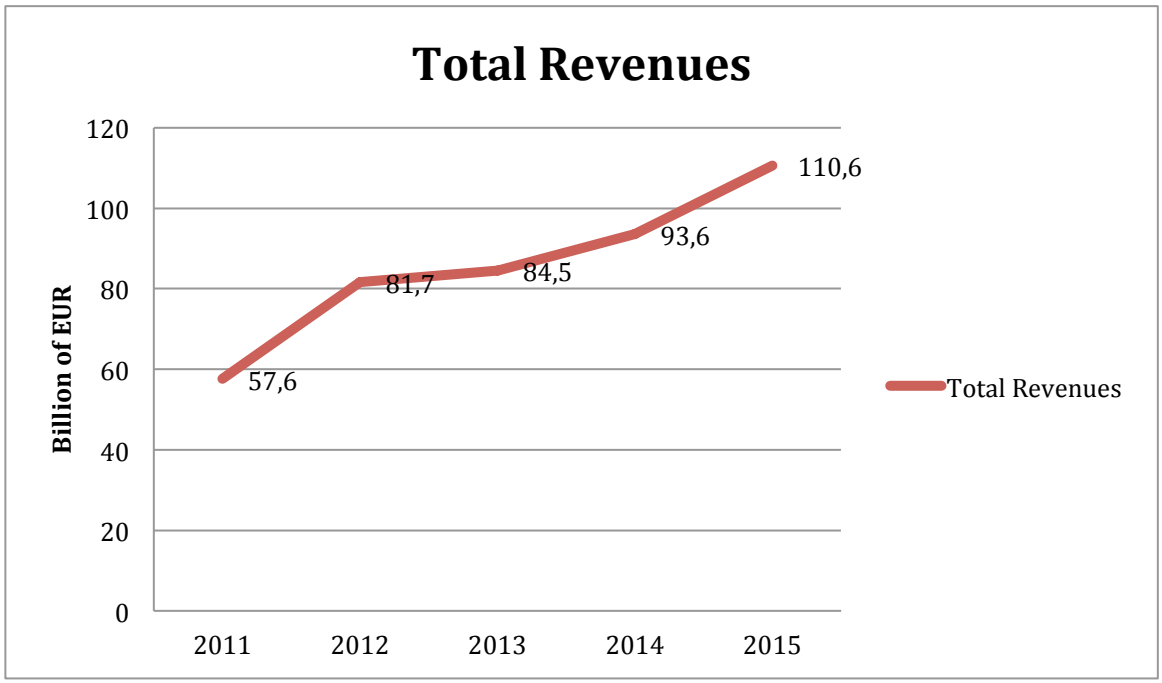

Table 10 - FCA Total Revenues
Source: Data from FCA 2015 Annual Report.

4.3.2 Products

Fiat Chrysler Automobiles, as already said, is not so favourable to the development and production of electric vehicles. Its CEO, Sergio Marchionne, is steadily convinced that producing electric cars is uneconomic. Today the company is strongly involved in improving the performances and efficiency of internal combustion engines (ICEs)

The Italian-American group, in fact, still does not produce an all-electric range of vehicles at a worldwide level. However, mostly because of some environmental sustainability laws, it is obliged to commercialize in California an electric version of the famous Fiat 500.

The Fiat 500e is a battery electric vehicle developed, produced and commercialized exclusively for the Californian market. It is composed essentially by three components: a high voltage lithium-ion battery pack, a high-power electric-drive engine and a power inverter module to help manage the power flow. Fiat 500e has an electric motor with a power of 83 kW that delivers 111 CV to the front axle and a maximum torque approximately of 200 Nm. It is assembled with a battery pack, placed in the bottom part of the vehicle, which has a consumption of 24 kWh and is provided with a particular

system that actively heats and cool the battery in order to maintain its optimal operating temperature. Fiat 500e has an autonomy range more or less equal to 84 km (depending also on external conditions) and can go from 0 to 60 km/h in 9.1 seconds. There are two possible system through which 500e can be recharged: a Level 1 charger, which has a power of 120 Volt and it is standard with the vehicle, and a Level 2 charger that can be installed also at home and, with a power of 240 Volt, can charge the whole car in less than 4 hours. Since it is sold only in California, the company has not developed a worldwide set of complementary products and services (like have done Tesla Motors and BMW) but, nevertheless, it has implemented a broad network of charging stations all around the country (more than 1.000 public charging stations).

As can be easily noticed, this car has sensibly lower performance if compares to a Tesla or a BMW and this contributed to keep down also the final price. Fiat 500e starts from a price of 31.800 dollars but thanks to a series of incentives, for a total amount of maximum 14.000$, the final price of this car fall to only 17.800 dollars: sharply more affordable than a Tesla Model S or a BMW i3.

A partial turnaround in the strategies of FCA towards the electric revolution could be represented by a plug-in hybrid electric version of the Chrysler Pacifica. This the first hybrid model commercialized by FCA and represents also the first hybrid multi-purpose vehicle (MPV) in the whole global market.

The Chrysler Pacifica Plug-in Hybrid version (**Figure 14**) can travel for more or less 53 kilometres as an all-electric vehicle, until the battery pack is completely discharged and the gasoline engine started to work, and in its conventional hybrid mode has a total autonomy range equal to 910 km (566 miles).

Figure 14 - Chrysler Pacifica PHEV; **Source:** www.chrysler.com

The Pacifica is assembled with a 3.6 litres Pentastar V-6 engine, a 16 kWh battery pack and a twin electric motor able to produce a power of 260 CV, a maximum torque of 355 Nm and to deliver 80 MPGe (Miles per gallon gasoline equivalent) when travelling in the city. The battery pack is located in the backside of the car, under the second-row floor,

and, according to Chrysler, it can be completely recharged in just two hours with a 240-volt electric charger.

The hybrid system of this vehicle is composed by a Chrysler-designed dual motor transmission, which incorporates two electric engines that can be used both for the front wheels and to recharge the battery pack through the exploitation of the regenerative brake.

Chrysler Pacific is sold in the United States starting from 41.995$ (more or less 39.400€) for both the "Premium" and the "Platinum" versions that can be reduced to 34.495$ thanks to some special federal American incentives and to some particular local concessions.

As a further demonstration that something is changing in FCA strategies, it is worth mentioning the presentation of a new concept vehicle: the Chrysler Portal. This prototype was presented at the beginning of January 2017 at CES in Las Vegas but, anyway, it is still unknown when and if the mass-production will start. In the development and design of this vehicle, FCA was also helped by the collaboration of some of the most important companies of the world like Samsung, Panasonic and Magneti Marelli.

The Chrysler Portal is conceived to be a minivan with six seats, a 100 kWh battery pack with an estimated autonomy range of 400 km, and a rapid recharging system that is able to allow an autonomy of approximately 250 km in only twenty minutes. This model will have a level 3 of drive autonomy, which means that, in certain situations, it can drive itself thanks to special cameras, radars and ultrasonic sensors. The Portal, according to FCA, was designed thinking to the "millennials", especially those who will have large families, and is full comforts and technological components like, for example, the facial-recognition system and a vehicle-to-vehicle (V2V) communication system.

Nevertheless, must be underlined once again that FCA is not yet convinced about the economic sustainability of electric vehicles and it still the less exposed automotive group in the field of electric mobility. The Italian-American company, as already said, relies heavily on other mobility innovations and, especially, on the implementation of the self-driving system.

Conclusions

The aim of this thesis was to describe and analyse the electric vehicles phenomenon from a technology and innovation management perspective and to assess the possibility that this innovation could represent the near future of the automotive industry and a possible solution for the future lack of oil, as it is not an infinite source.

The dissertation started with a general overview of the most important theoretical aspects underlying an efficient and effective management of new technologies and innovations. There are some critical variables and strategic assessments to be considered from an organizational point of view when an innovation, like the electric vehicles, appears for the first time in the market. As we have seen, being a pioneer in the market or in a specific segment implies some advantages but also some disadvantages: the first mover is the principal responsible of the development of completely new technologies and, as a consequence, must be able to withstand all the costs related to a total reorganization of the whole value chain. Along with the necessity of developing and reorganizing an efficient production process, that companies who are intentioned to enter in a new market must have also the know-how and the adequate resources to produce all the complementary products and the enabling technologies useful for an easier and widespread diffusion of the main product.

After the economic and financial crisis crossed in the years between 2008 and 2010, the automotive industry is now growing steadily both in production and sales; costumers' needs and expectations are also changing fast providing new important challenges for automakers. Today this industry, as we have seen, represents one of the most influent industries in the whole world economy and innovation and technology management plays a fundamental role in the competitiveness of each company.

Being competitive in such an industry, and especially in the electric segment, is not a simple task and requires the investment of important financial resources and the possession of strong organizational capabilities. Adapting the whole production process to the electric revolution is not an easy task and not all companies have the willing, the resources and capabilities to face such a challenge. However, the electric segment recorded an important growth in the last few years, overcoming the symbolic amount of 1 million of circulating units and emphasizing the growing role of Asiatic continent (especially China) not only in the electric segment but also in the whole automotive

industry. The majority of the automakers decided to propose their own versions of electric vehicles, whether they are BEVs, HEVs or PHEVs, and new players, like Tesla Motors, emerged in the market in order to foster this opportunity.

Electric vehicles are born in an attempt to satisfy mainly two necessities. On one side it was manifested the short-term want to lower the total GHG (Green House Gasses) emissions and to pay much more attention to the environmental sustainability for the improvement of life quality. On the other side, there is the need to think in a long-term perspective and to find a plausible alternative for when the global oil reserves will end. However, here it was put more evidence on the question regarding emissions and environmental properties of electric vehicles.

An important step in the evaluation of electric vehicles' performances and consumptions is made during the third chapter. The analysis of fuels consumptions and emissions, both of electric vehicles and traditional cars, were investigated thanks to a well-to-wheel (WTW) analysis and the emerging data clearly showed that electricity-powered vehicles are not so much more eco-friendly and convenient if compared to traditional cars. The bulk of the emissions have moved from the Tank-to-Wheel (TTW) phase to the Well-to-Tank (WTT) stage, de facto only displacing the pollution problem from cities to industrial areas without any big progress for the global environment.

A further confirmation that electric vehicles are not as much convenient as the majority of people believe is given by the analysis of the total costs of ownership. Examining and calculating all the costs related to the purchasing and maintenance of an electric car (initial price, possible incentives and exemptions, depreciation, fuel expenses, assurances, etc.) can be noticed that they are on average more expensive than traditional cars and, as long as their initial price will not decrease, they will have less chances to reach a diffusion rate and an appreciation like the ones of gasoline-powered cars.

This analysis allowed also to observe different approaches to the electric revolution and to underline their main characteristics. Here were considered three different organizational strategies (Tesla Motors, BMW Group and FCA Group) and their resulting visions about the future of the electric vehicles.

On one side we have Tesla Motors. Tesla's strategy seems very clear and defined: the future of the automotive industry will be the electrification of the vehicles and the

diffusion of a complete sustainable mobility. Its core business, in fact, is the exclusive production of pure electric vehicles with the aim of lowering and, in the future, reset the entire green house gases emissions (GHG). Starting from 2014, the American company decided also to revolutionize the production process of its plants starting the Gigafactory project. Tesla Motors represent, without any doubts, the most positive and interesting case study to demonstrate that electric vehicles could really characterise the future of the automotive industry and could contribute to spread a more sustainable mobility.

A further approach is, instead, represented by BMW. Differently from the American company, BMW is not a new entrant in the automotive industry and, as a consequence, has an already reliable and clear structure both from an organizational and a financial perspective. Along with traditional gasoline-powered vehicles, except for the pure electric version of BMW i3, the German group decided to develop and commercialize a wide range of hybrid and plug-in hybrid electric vehicles. This particular approach to the electric revolution can be considered a temporary solution while waiting for further developments regarding complementary technologies and for new market opportunities. BMW, as Tesla, offers to its costumers a set of complementary product and services (i.e. the Wallbox) in order to ease the adoption of the technology and favour the success of its products. However, differently from the American company, it doesn't aim to reach a growing exploitation of renewable resources and, as a consequence, a complete sustainability of the whole production process. BMW doesn't eliminate the environmental problem highlighted by the Well-to-Wheel analysis, but only postpone it to an indeterminate future.

Finally, Fiat Chrysler Automobiles provides a third different strategy and a further hint regarding the future of electric vehicles. The Italian-American group represents an interesting example because it's the only company, among the most important automakers of the world, to be so reluctant about the development and production of electric vehicles and the future diffusion of this technology. As explained many times by its CEO, Sergio Marchionne, the mass-production of electric vehicles is not yet sustainable from an organizational and financial point of view and, for this reason, the company decided to put all its efforts on another technology: the self-driving car. At the

beginning of 2016, just to demonstrate it, was signed an agreement between FCA and Google Inc. to join the forces under the development of this new mobility innovation.

As we have seen, despite its sceptical vision, FCA decided - and, in some cases, was forced - to produce specific pure electric and hybrid models for the American market only. Clear examples of that are the Fiat 500e and the Chrysler Pacifica, which are produced and sold exclusively in California and Oregon. The view of the company remains anyway against the production of both pure-electric and hybrid electric vehicles and in a certain sense quite critical about Tesla Motors' business model. The crux of the matter is that, today, is not yet possible to start a mass production of electric vehicles without raising the final price of the product and losing out financial resources. Tesla Motors, according to Marchionne, is able to sustain its production process thanks principally to its higher prices (more than 100.000€) and also to its lower products' demand, if compared to traditional vehicles. However, if in the future there will be enough margins to make profits from the electric revolution, FCA assures to have the necessary know-how and the adequate organizational structures to compete with the most important companies of the segment.

To conclude, on the basis of all the various documents and examples analysed, can be affirmed that the electric revolution is still far from being the immediate future of the automotive industry. There is no clear evidence about the possibility that, in the following years, the electric car will undermine the predominance of gasoline-powered cars. At the moment, even if they have a good reputation, electric vehicles are disadvantageous both from organizational and costumers' perspective. On one side, from a costumer point of view, the high prices of these vehicles, the lower autonomy range, the lack of adequate infrastructures (i.e. recharging stations) and a refuelling process, which is sensibly slower and more uncomfortable than a traditional car, act as important barriers for a widespread diffusion on the market. On the other side, looking at the company perspective, electric vehicles are very demanding (economically speaking), they require an almost complete reorganization of the value chain (from the suppliers to the providers of complementary services) and they relocate all the green house gasses emissions from the vehicle to the production process, circumventing but not eliminating the environmental problem.

However nobody can exactly predict the long-term future of the world and nor the one of the automotive industry. There will be, without any doubts, some opportunities for the electric vehicles to improve their performances and eliminate their drawbacks. Maybe, in a remote future, when the core technology will be in a more advanced stage and when companies will find a reliable and efficient way to exploit the renewable resources also for the whole production process, our roads will be populated for the most part by electric vehicles. However, now, it is not yet that moment.

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