LUISS Guido Carli
LIBERA UNIVERSITA' INTERNAZIONALE DEGLI STUDI SOCIALI

DIPARTIMENTO DI IMPRESA E MANAGEMENT

CATTEDRA DI ECONOMIA E GESTIONE DELL'INNOVAZIONE AZIENDALE

The Open Innovation Paradigm in Electric Vehicle Industry: A case study of Tesla Motors

RELATORE

Prof.ssa Angela Sansonetti

CANDIDATO

Marco Purificato
MATR. 167171

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List of Abbreviations

IPR: Intellectual Property Right

R&D: Research and Development

IP: Intellectual Property

EPA: Environment Protection Agency

EV: Electric Vehicle

ICE: Internal Combustion Engine

DOE: Department of Energy

ZEV: Zero Emission Vehicle

NiMH: Nickel Metal Hydride

MOU: Memorandum of Understand

BEV: Battery Electric Vehicle

PHEV: Plug-In Hybrid Electric Vehicle

HEV: Hybrid Electric Vehicle

DC: Direct Current

AC: Alternate Current

Introduction

In today's rapidly changing business environment, companies realize that innovation process becomes increasingly important to survive in this environment and to develop competitive advantage. Following the internet revolution and the raise of new technologies and markets, global economy has known a shift from a relatively closed model to a more open one. In this environment, companies seek new ways for value creation in order to unlock new sources of competitive advantage. These circumstances led the current environment of business rapidly to change from an industrial based economy to a knowledge-based economy. Knowledge-based economy places a great importance on the diffusion and use of knowledge, as well as its creation. Knowledge, in all its forms, plays an important role in economy, and innovation becomes the application and transfer of knowledge from research to development and the related adoptions of new applications. However, in today globalized world, companies cannot rely on internal knowledge anymore, but they need to collaborate with actors from the external environment. Thus, "*firms with more knowledge systematically outperform those with less*" (Oslo Manual, 2005), and firms cannot survive anymore only by relying on their own R&D.

According to this background, this thesis examines the topic of Open Innovation, introduced by Henry William Chesbrough, specifically applied to the electric vehicle industry. This paper aims to analyse the forms of collaboration among the players of the industry, in order to understand how these aspects influenced the industry development until now. In addition, though the analysis of Tesla Motors, this thesis aims to understand how the new business models introduced by the American company, which has used an approach based on Open Innovation since its early stages, may influence the future development of the industry.

The first chapter of this work will focus on Open Innovation Paradigm and the differences between this model and Closed Innovation, which influenced firms' strategies and behaviours in the last decades. An analysis of the role of Intellectual Property Rights in Open Innovation Paradigm will be introduced to understand the most recent strategies applied by Tesla Motors.

The second chapter of this work will focus on the electric vehicle industry. Within this chapter, the state of the art in the electric vehicle industry, the main players in the industry and the challenges and opportunities that will determinate the electric vehicle outlook, will be analysed in order to understand the industry. In addition, an introduction of North American policies for the electric vehicle industry that influenced the development of the industry in the last decades will be provided. In order to understand the electric vehicle industry, an analysis through Porter’s Five Forces Model will be used as well.

Chapter 3 will implement the first Chapter with the second Chapter. Within this Chapter, we will provide an analysis of the relationships between the main players in the industry, in order to understand how partnerships and collaborative networks are spread in the electric vehicle value chain and how these aspects influenced the industry until now, concluding the first part of this research.

Chapter 4 is a case study of Tesla Motors, introducing the second part of this thesis. After an introduction of the American company and its products, strategies and partnerships, the focus will shift to the company’s decision to share Tesla’s patents, in order to understand how a nondefense use of patents in an Open Innovation environment can be the key element to create a stronger ecosystem through competition and collaboration.

A presentation of conclusions, achieved in this work, about the future of electric vehicle industry and the strategies used by Tesla Motors to develop a better ecosystem to support electric vehicles will conclude this thesis.

Chapter 1: The Open Innovation background

1.1 From Closed Innovation to Open Innovation models: key elements and differences

Being innovative is a key issue in the process of value creation and growth of firms. Innovation supports companies to stay ahead of their competitors and achieve competitive advantage. Innovative companies are more inclined to discover new opportunities and anticipate future trends, products or services that allows them to meet the future demand of consumers. In the traditional model of value creation, consumers are outside the firm while value is created inside the firm. Essentially, the market is defined as an aggregation of consumers and it is just a target for the firm's offering (Prahalad and Ramaswamy, 2003)[1]. Furthermore, in the period between the end of World War II and the mid-1980s, the setup of internal R&D was perceived as a strong barrier for potential new competitors: the result was a golden age for internal R&D with huge investments in order to create economies of scale in R&D[2]. The logic underlying this approach to innovation was one of closed, centralized and internal R&D that implies a deep vertical integration. Henry Chesbrough called this approach "Closed Innovation". In certain industries, this approach produces results yet, especially under an intense protection of intellectual properties. However, in many other industries, this approach has become obsolete. According to Henry Chesbrough, the Closed Innovation Paradigm has eroded due to the following factors: the increasing availability and mobility of skilled workers, the venture capital market, external options for unused technologies and the increasing capability of external suppliers.

[1] C.K. Prahalad and Venkat Ramaswamy; *"Co-Creation Experiences: The Next Practice in Value Creation";* Wiley Periodicals; deepblue.lib.umich.edu; 2004.
The Term "offering" was used by Prahald and Ramaswamy to denote products and services.
[2] Henry Chesbrough, *Open Innovation: the new imperative for Creating and Profiting from Technology,* Harvard Business Review Press,2003

These elements introduced a shift from Closed Innovation to a new paradigm introduced by Chesbrough[3], called “Open Innovation Paradigm”.

Open Innovation can be defined as:

“*The use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology*” (Chesbrough,Vanhaverbeke,West;2006).

According to Chesbrough (2003), the idea behind Open Innovation is that “*not all smart people work for you, in a world of abundant knowledge*”. Companies have to create networks with the outside in order to have an access to the abundance of knowledge that is created and made available in the environment. Open Innovation can be understood as the antithesis of the traditional vertical integration approach.

One of the greatest drivers of scientific innovation and technological innovation has been the historic increase in connectivity, which allowed people and organizations to exchange ideas and knowledge to turn them into something new (Steven Johnson; 2011[4]). Indeed, Open Innovation assumes that firm should use external ideas as well as internal ideas to advance their technologies, which is possible through new approaches to intellectual property management, spin-offs, licensing and other methods that may absorb external ideas into the company. For business, Open Innovation is a more profitable way to innovate: it can reduce costs, accelerate time to market, increase the differentiation into the market and create new value streams for the company[5]. In addition, Open Innovation emphasizes the importance of business models. Companies should look for ideas and technologies that fit with their business model while internal ideas and technologies that do not fit should go to the outside[5]. Differently, the Closed

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[3] Henry Chesbrough, *Open Innovation: the new imperative for Creating and Profiting from Technology,* Harvard Business Review Press,2003

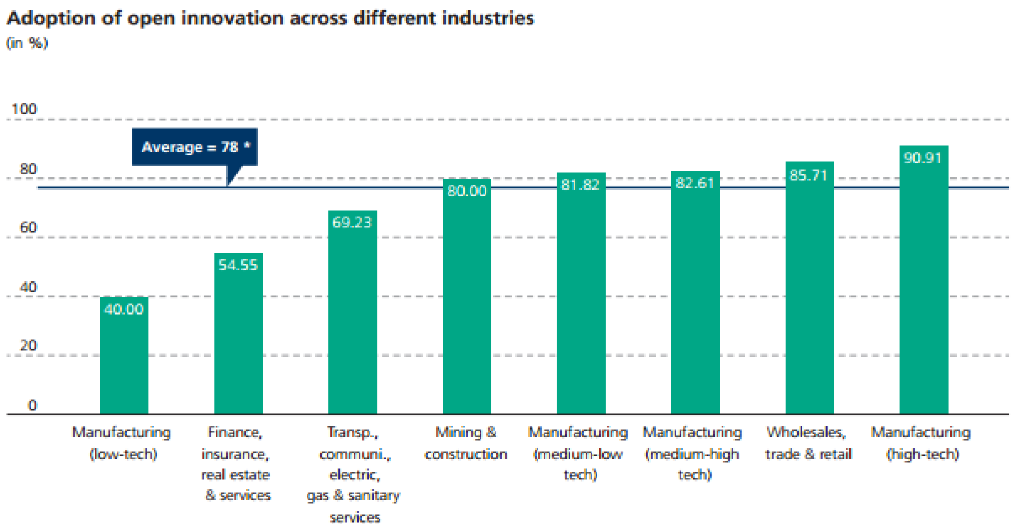
[4] Steven Johnson; *“Where good ideas come from”; Riverheadbooks; Youtube.com; 2010*

[5] Henry Chesbrough; “*Everything you need to know about Open Innovation”;* Forbes; forbes.com; 2011

Innovation Paradigm emphasizes the importance behind the first-move advantage while the best ideas in the industry provide competitive advantage. The role of Intellectual Property Rights in the Open Innovation Paradigm will be introduced in paragraph 1.3. In addition, this thesis will not focus on the partnership between universities and firms.

1.2 The adoption of Open Innovation across different industries

A closer look into different industries indicates that open innovation is most widely adopted in hi-tech sectors, whereas low-tech manufacturing sectors show the lowest rate of adoption.



Source: Fraunhofer & UC Berkeley; *"Open Innovation Executive Survey";* Fraunhofer IAO; openinnovation.berkeley.edu; 2013

Indeed, companies that attempt to apply Open Innovation face three fundamental challenges (West and Gallagher, 2006): *maximization* of the returns to the internal innovation, *incorporation* of the relevant knowledge into the innovation activity and *motivation* of the outsiders to supply an ongoing stream of external innovations.[6] In order to face these challenges, companies have to explore the environment, scan it and develop absorptive capacity of the external knowledge, but at the same time, companies have to share or give away IP to maximize the return from entire innovation portfolio and provide rewards and structures for contributions. High-tech manufacturing industry appear to be more suitable to these principles than low-tech manufacturing despite the adoption of Open Innovation is at an early stage in many industries as Chesbrough evidenced in "Beyond high tech: early adopters of open innovation in other industries" (2006) and as the image above illustrate.

However, Open Innovation is now playing a crucial role in electric vehicle industry as a variety of innovators and companies work to develop the industry, which is considered a niche industry yet. Some industry players have adopted Open Innovation and are already benefiting from it, while more players are creating collaborative networks and new business models. Indeed, the electric vehicle industry is still in its infancy and Open Innovation finds a greater application in an industry with such a high amount of knowledge available outside. Companies that operate in EV market have to face major challenges and barriers. The industry requires an ecosystem to support the shift from standard mobility systems to electric vehicles, and companies cannot rely on their own efforts to develop it. According to this background, the average number of collaborations between firms is increasing year by year. In addition, the industry forces contacts between companies that operate in different industry: battery manufactures, automotive manufacturers, providers of charging infrastructures, software producers and more. Companies seem to benefit from the creation of collaborative networks, partnerships and joint ventures to combine different expertise in one product.

In Chapter 3, this thesis analyses in-depth the adoption of Open Innovation in electric vehicle industry.

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[6] Henry Chesbrough, Wim Vanhaverbeke, Joel West; *Open Innovation: Researching a New Paradigm;* Oxford University Press, 2006.

1.3 The role of Intellectual Property Rights in Open Innovation

Intellectual Property Rights (IPRs) legally allow creators or owners of patents, copyrights and trademarks to benefit from their own work or investment in creation. Intellectual property was recognized at least at 1867 with the founding of North German Confederation whose constitution granted legislative protection of intellectual property but it was completely recognized in the Paris Convention for the Protection of Industrial Property back in the 1883. Today, the World Intellectual Property Organization (WIPO) is an international organization dedicated to ensure that the rights of intellectual property owners are protected worldwide. The legal protection of Intellectual Property Rights encourages the commitment, investments and the creation of new works in the technology and culture fields and drives the economic growth creating new jobs and industries. Indeed, the main goal of intellectual property protection is to create incentives that maximize the difference between the value of IP that is created and used, and the social cost of its creation (Besen and Raskind, 1991).

According to Open Innovation, firms can and should use external ideas as well as internal ideas. IPRs are not perceived as an impediment to Open Innovation, but rather it allows a stronger collaboration that can lead into a better innovation process. As has already been said, companies cannot rely on internal knowledge anymore and cannot invent everything in-house. Cooperation and sharing are the key points to face the economic and technological challenges of the global economy. Besides that, Open Innovation cannot be totally associated with open source referring to the solidarity economy. Therefore, Open Innovation must be viewed as a controlled opening: knowledge and information have a value; IPRs sharing is not about authorize others to profit off your work, it is a about a different management of the IPRs to build a specific strategy with precise results. There is no inherent value in a technology per se; the business model used to bring it to the market determines the value (Chesbrough, 2003) and managing IPRs under an Open Innovation approach is a different way to capture value from IPRs in order to redefine the business model of a firm.

Chesbrough explained the management of IPRs under Open Innovation as:

"Instead of managing intellectual property (IP) as a way to exclude anyone else from using your technology, you manage IP to advance your own business model and to profit from your rival's use. […] The Open Innovation paradigm assumes that the firm should be an active buyer and seller of IP". (Chesbrough, 2003).

According to Chesbrough, companies have to change their approach to the management of IPRs: it is not a defensive use of IPRs in order to exclude competitors from "*your technology*", but it is a proactive behaviour to profit from their use. However, this approach may be in conflict with the standard definition of IPRs. As has already been said, the purpose of IPRs is to protect inventors or their owners against free riding behaviours and reward their investments in innovation. Joel West analysed this concept between 2003 and 2007. According to West, motivating individuals to generate and contribute with their IPRs in absence of a direct financial return is a significant challenge but it is still economically rational under a condition of co-opetition.[7] A different approach to the management of IPRs under this paradigm can still lead to the growth of an industry and firms still benefit from an overall growth of their industry: firms compete in dividing markets but they still collaborate to create and grow markets (Brandenburger & Nalebuff, 1996). In addition, the management of IPRs under Open Innovation can lead to specific strategies and results. Therefore, we can still expect some kind of free ride behaviours, but the overall system under Open Innovation is still economically rational.

[7] Joel West; Scott Gallagher; *"Key Challenges of Open Innovation: Lessons from Open Source Software"; cob.sjsu.edu; 2004*

Chapter 2: Electric vehicle industry

2.1 Understanding the importance of Electric Vehicles: benefits and macroeconomic impacts

Global warming and Greenhouse Effect are becoming topics of interest and climate change poses risks for human and natural systems. In many regions, climate changes are altering hydrological systems while glaciers continue to melt. Many terrestrial and marine species had to move from their habitats and recent climate-related extremes such as floods, cyclones and heat waves are exposing ecosystems and human systems and economies to current climate variability[8]. Governments are introducing policies to limit the emissions of Greenhouse gases such as water vapour, carbon dioxide, methane and ozone, which are contributing to the Greenhouse Effect. Despite the Kyoto Protocol aimed at reducing greenhouse gas emissions, the situation has not changed considerably. Air pollution in urban areas is contributing to the Greenhouse Effect and it is a significant risk factor for a number of health conditions. It has been demonstrated that the major source of air pollution in urban areas are cars and trucks, being responsible for more than 50% of hydrocarbon, carbon monoxide and dioxide, and nitrogen oxide emissions in the air[9]. The process of releasing energy from the fuel alters the atmosphere, and from an environmental point of view, the transportation system has to be re-thought. According to these circumstances, the automotive industry has launched many R&D projects to reduce automotive emissions. However, even if the environmental issue is one of the most important reasons to find new mobility systems, it is not the only reason. Indeed, world today is dependent on oil. Most of the world's petroleum reserves are located in politically unstable countries, making the countries'

[8] IPCC WGII AR5 Summary for Policymakers; *"Climate Change 2014: Impacts, Adaptation, and Vulnerability: Summery for Policy Makers";* ipcc-wg2.gov; 2014

[9] Innovation Energy Environment; *"Greenhouse gas emissions and the transport sector";* Panorama; ifpenergiesnouvelles.com; 2009

economies vulnerable to price spikes. Since the actual transportation sector relies on these issues, companies need to consider them when they promote innovations in their industries. Car manufacturers have to re-think the product life circle from its conception until its dismantlement and recycle. The use of electric vehicles could significantly reduce the petroleum consumptions worldwide with positive impacts on the environment. Differently from gasoline-powered vehicles, electric vehicles produce almost half of Greenhouse Gas emissions and do not rely directly on petroleum. In addition, the electric vehicle industry may create up to 200.000 jobs by 2020[10] worldwide.

According to this background, companies that work in the automotive market are now increasing their efforts to develop alternative automotive systems like electric vehicles.

However, this work focuses on the electric vehicle industry in the United States. According to that, we will now introduce potential benefits and macroeconomic impacts behind the development of the American electric vehicle industry. In 2012, United States imported about 40% of its petroleum consumptions and transport industry was responsible for nearly 27% of these consumptions[11]. The development and the introduction in the market of innovative automotive systems, like EVs, could support the United States to reduce its reliance on imported petroleum and reduce the emissions of cars and trucks. According to the Centre for Entrepreneurship and Technology at the University Of California[12], the development of electric vehicles could imply a reduction of U.S. oil imports up to 38% by 2030. The Environment Protection Agency (EPA) is working to stabilize the carbon monoxide emissions by 2050. According to EPA, if 30 percent of the cars on the road between 2025-2050 are PHEV, carbon dioxide emissions from the entire transportation sector (including airplanes, trains etc.) will be reduced enough to meet 25 percent of the EPA's goals. According to University of California, EV industry could create a net

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[10] BlueGreenAlliance & American Council for an Energy-Efficient Economy; "*Gearing up: Smart Standards Create Jobs Building Cleaner Cars*"; drivinggrowth.org; June 2012

[11] U.S. Department of Energy; *"Alternative Fuels Data Center"*; afdc.energy.gov; 2013

[12] Center for Entreprenership & Technology (CET); *"Electric Vehicles in the United States: A new Model with Forecasts to 2030"*; University of California, Berkeley; funginistitute.berkeley.edy; 2009

employment gain around 130.000 and 350.000 more jobs by 2030 in the United States. In addition, the reduction of Greenhouse Gas emissions (20-69% by 2030) could save health care costs up to $210 billion in the United States.

EVs provide an evident number of general benefits as well: they are safer to drive since, in case of accident, the current flow from the battery to the engine is interrupted reducing the risk of fire, and EVs can be fuelled for cheaper prices than gasoline-powered vehicles. Beyond the fuel-saving benefits, electric vehicles have lower maintenance costs. Indeed, electric vehicles do not use oil to lubricate the engine; this means no oil change while pads do normally last longer compared to gasoline-powered pads. Electric vehicles are not only cheaper to operate but also to buy through federal income tax credits. Unfortunately, there are disadvantages as well. One of the major disadvantages is the time required to recharge batteries that is normally up to several hours. In addition, EVs are normally more expensive than traditional cars and electric engines have a limited range due to limited battery life.

2.2 The North American policies in Electric Vehicle Industry

In 2011, President Barack Obama announced the target for the U.S. to become the first country to have 1 million electric vehicles on the road by 2015.

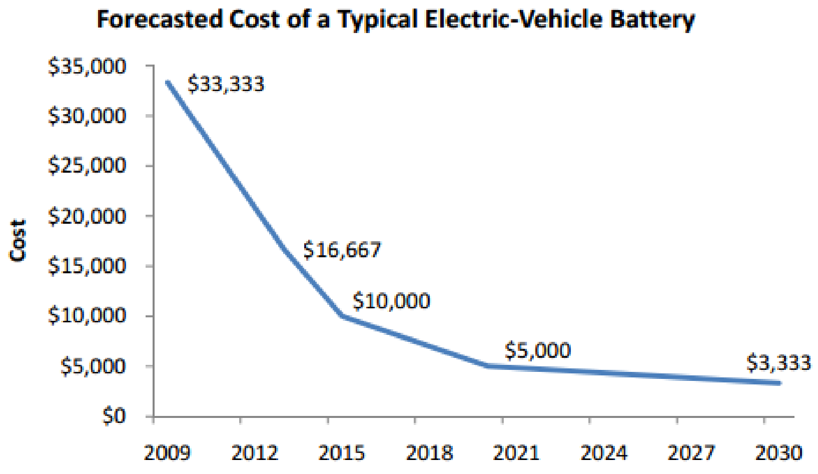
"We can break our dependence on oil… and become the first country to have one million electric vehicles on the road by 2015". (President Barack Obama, 2011).

However, several experts sustained that related to the actual sales, the target announced by President Barack Obama cannot be reached. In the last years, a number of Federal and State policy initiatives encouraged the introduction and sales of EVs. The incentives for production include grants to companies that manufacture batteries and other components of electric vehicles. In order to incentivize the EV industry, the U.S. Federal Government created specific financial instruments like investment tax credits (ITC) aimed to the establishment and the extensions of new facilities. The U.S. Department of Energy (DOE) supports the development and the deployment of advancements in electric vehicles, engine efficiency and lightweight materials. The office of

Energy Efficiency and Renewable Energy (EERE) aims to strengthen the environment quality and economic vitality in public-private partnerships. This work focuses on the new U.S. policies to support the EVs industry, especially in California, where Tesla Motors has its headquarter.

2.2.1 Recovery Act (2009)

Through the Recovery Act, the United States made an important investment to build and develop the domestic manufacturing capacity and secure its position as a global leader in lithium-ion battery technology. The Act included $4 billion to support the development of advanced vehicles and clean fuel technology. Furthermore, the Recovery Act included at total of $2.4 billion for advanced vehicles technology projects divided into: $1.5 billion in funding to accelerate the manufacturing and the development of batteries technologies, $500 million in funding to electric-drive components manufacturing, $400 million in funding to transportation electrification. By the end of 2015, Recovery Act investments may reduce the costs of electric vehicle batteries by nearly 70%, making EVs more affordable.



Source: U.S. DOE Vehicle technologies program.

2.2.2 CARB Zero-Emissions Vehicle

California's Zero-Emissions Vehicle (ZEV) program demands auto companies to produce a certain percentage of ZEVs. The California Air Resources Board is in charge of the ZEV program and updates it every three years[13]. In 1990, CARB announced in its program that 2% of the vehicles produced had to be ZEVs by 1998; it increased this target to 5% in 2001 and 10% in 2003. In February 2013, California Governor Jerry Brown's Office and state agencies released a ZEV Action Plan, which aimed to enable 1.5 million ZEVs on California roadways by 2025[14]. A Low-Emission Vehicle Program is currently under revision to define ZEVs regulations for 2015 models.

2.2.3 Incentives

Tax incentives and other financial instruments have been effective in providing the additional boost needed for consumers to choose EVs[15]. The Recovery Act created federal income tax credits for people who purchase EVs; the size of the incentive depends on the capacity of the vehicle's battery. The credits start at $2500 for an electric vehicle with a 4 KWh battery up to $7500 for a vehicle with a 16 KWh or larger battery (it increases by $417 for every additional KWh). The tax credit is subtracted from the amount of federal income taxes that the buyer owes. The current tax credits apply to the first 200.000 EVs sold by each manufacturer in the United States. The tax credits for electric vehicles have a budgetary cost of $1.5 billion, since it is up to $7500 for 200.000 vehicles, for each manufacturer. [16]

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[13] Union of Concerned Scientists; *"History of California's Zero Emission Vehicle (ZEV) Program";* Union of Concerned Scientists; ucsusa.org; 2012

[14] Green Car Congress; *"California Governor's Office releases 2013 ZEV action plan; 1.5M ZEVs on CA roadways by 2025";* Green Car Congress; 2013

[15] Department of Energy; *"One Million Electric Vehicles by 2015";* Department of Energy Reports; eere.energy.gov; 2011

[16] Congress of the United States, Congressional Budget Office (CBO): "*Effects of Federal Tax Credits for the Purchase of Electric Vehicles"*; cbo.gov; 2012

The “Electric Drive Vehicle Battery and Component Manufacturing Initiative” includes grants to manufacturers of batteries and other parts of electric vehicles; providing $2 billion in funding from the DOE. According to this initiative, $1.5 billion went to battery producers, recyclers and intermediate suppliers while $500 million went to manufacturers of components for EVs and intermediate suppliers. The “Transportation Electrification Initiative” includes $400 million in grants for demonstration, deployment and education projects that involves EVs, in order to accelerate the introduction of electric vehicles. The “Advanced Technology Vehicles Manufacturing Program” includes up to $25 billion to manufacturers of vehicles to promote the production of high-fuel-efficiency vehicles, including EVs. In California, the “Clean Vehicle Rebate Project” (CVRP) includes rebates up to $20.000 for a specific list of eligible vehicles, including the Tesla Motors Model S.

2.3 Main types of electric vehicles

In order to understand paragraph 2.4, where an analysis of the state of the art in the EV industry will be provided, this paragraph introduces a brief explanation of three main types of electric vehicles, which will be analysed in-depth in paragraph 2.4.

2.3.1 Battery electric vehicles (BEV)

A Battery electric vehicle (BEV) is powered only by an electric motor and has no internal combustion engine (ICE). BEVs tend to be equipped with powerful lithium-ion batteries since the battery is the only power source, and they are becoming more attractive with the advancement of battery technology. The grid charges the batteries. Some examples of BEVs are the Nissan Leaf, Renault Twizy, Tesla Roadster, Tesla Model S and the Mitsubishi I-MIEV.

2.3.2 Hybrid Electric Vehicles (HEV)

A Hybrid Electric Vehicle (HEV) combines a conventional internal combustion engine (ICE) with an electric propulsion system. It has a battery that is charged by the ICE and by regenerative braking, which converts the vehicle's kinetic energy into electric energy. Some examples of HEVs are the Toyota Prius, Honda CR-Z, Ford Fusion Hybrid and the BMW 5 Series Active Hybrid.

2.3.3 Plug-in hybrid electric vehicles (PHEV)

A Plug-in hybrid electric vehicle (PHEV) is equipped with an ICE and a lithium-ion battery that could be charged by either the ICE or a grid. A PHEV shares the characteristics of both conventional hybrid electric vehicles, having an electric motor and an ICE, and BEV, having a plug to connect the grid. Some examples of the PHEV are the Chevrolet Volt, a 2009 version of the Toyota Prius and the BMW i8 plug-in hybrid.

2.4 State of the art in electric vehicle industry

In previous paragraphs, we introduced the background of EVs. In this paragraph, this work will introduce the technological aspects of EVs in order to understand the state of the art in the industry.

An electric vehicle uses one or more electric motors, powered by rechargeable battery packs, rather than a gasoline engine. In addition, the main differences between an electric vehicle and a gasoline-powered vehicle are the presence of an electric motor, a controller and rechargeable batteries. The controller takes power from the battery and delivers it to the motor. Potentiometers, connected to the acceleration pedal, provide a signal to the controller in order to manage the power delivered to the engine. Modern controllers adjust speed and acceleration through a "pulse modulation": it rapidly switches a device to interrupt the electricity flow to the motor and turns it on again when the acceleration pedal is pushed; in this way, high speed and acceleration are achieved automatically and in short intervals. Most of the vehicles nowadays, have regenerative braking that recharge the batteries when the vehicle is slowing down.

2.4.1 Batteries

Batteries supply power to the starter and ignition system in order to start the engine and supply the extra power necessary. In addition, a car battery prevents voltage spikes from damaging other components in the electric system. Briefly, a battery produces voltage through the chemical reaction produced when two materials, like positive and negative plates, are immersed in electrolyte, which prevents the materials to connect directly. There are three main types of rechargeable batteries suitable with electric vehicles.

Lead-acid batteries are cheap “wet-cell batteries” that usually contain a mild solution of sulphuric acid. The name of these batteries comes from the combination of lead electrodes and acid used to generate electricity. Lead-acid batteries constantly produce a chemical process of charge and discharge: when they are connected to something that needs electricity, the battery emits a current flow. In this case, the battery begins to discharge. Differently, the battery is charged when the current flow restores the chemical difference between the plates. Lead-acid batteries have been used for more than 140 years and provide the longest life cycle and the best price per KW/h. In addition, 90% of these batteries can be recycled and reused. Despite that, lead-acid batteries have disadvantages. They are heavier than other types of batteries, and there is a small risk of explosion under certain conditions, which requires continuous maintenance to prevent sulfation. However, Lead-acid batteries currently are the most used batteries in EV industry, especially the 12 volt used for starting lighting and ignition functions while a higher voltage battery is used to power up the motor and other basic functions.

Nickel-metal hydride batteries (NiMH) use a hydrogen-absorbing compound for the negative electrode while the positive electrode is nickel oxyhydroxide. Its chemical reactions are similar to nickel-cadmium cells used in other industries but, as has been said, the positive electrode uses a hydrogen-absorbing compound instead of cadmium. NiMH batteries became commercially available in 1989. However, NiMH batteries are now considered mature and found a greater use in high voltage automotive applications. As Lead-acid batteries, NiHM batteries have advantages and disadvantages. These batteries provide high energy density and long life cycles; they have fast recharging times, and they can operate in wide temperature ranges. Despite that, the discharge of NiMH batteries is faster than other batteries, and their costs are higher compared to other batteries. However, considering their long life cycles, their high energy density and their fast charging time, NiHM batteries are appropriate for EVs and found great application in this industry, as has been said. Despite that, Lithium-ion batteries found a greater application in the EV industry.

Lithium-ion batteries are growing as the most popular batteries in the EV industry. Lithium-ion batteries have a negative electrode and a positive electrode: when the battery is discharged, lithium ions are connected to the positive electrode since they lack of electrons; during the recharging process, electrons are provided to the lithium ions that will naturally dissociate from the positive electrode moving back to the negative electrode. In this case, the battery is charged. The positive electrode is made of lithium cobalt oxide, while the negative electrode is made of carbon. The movement of these lithium ions produces a higher voltage compared to other batteries. Defining the reasons to explain this massive growth of the Lithium-ion batteries is simple: they are generally much lighter, lithium is a highly reactive element providing these batteries a high energy density (twice as NiHM for kilogram), their charge lasts longer than other batteries and there is no need to discharge these batteries completely before the recharging process. Despite that, disadvantages exist for Lithium-ion batteries as well: degrading process is faster than other kind of batteries; they are sensitive to high temperatures forcing these batteries to have a temperature measurement system inside, a complete discharge can ruin the battery and the cost is higher than other batteries. Besides that, their higher energy density is going to make them the best candidate to power EVs in the future.

Battery manufacturers pushing to find new solutions in order to evolve their technologies. Power Japan Plus, for example, announced “the Ryden”[17], a dual carbon battery with a carbon anode and cathode that may allow these batteries to recharge 20 times faster than Lithium-ion batteries, and discharge completely without damaging the battery. This new technology may change the whole EV industry. Indeed, many prototypes are being developed recently and it is a period of great research in the battery industry in order to find a final solution especially to fit the smartphone industry. However, Lithium-ion batteries and Lead-acid batteries are the best candidate to fit the EV industry, but consumers demand stronger performance from their EVs and mainly they are looking for a “definite solution”. Indeed, consumers face the risk that new battery technologies may reduce the value of their old vehicles. Battery technology is going to influence the industry in the years to come, and it is a major challenge that companies working in this industry have to face.

2.4.2 Controller

The controller is considered the “brain” of electric vehicles. Indeed, the controller takes power from the batteries and delivers it to the electric motor. Through the potentiometers, which are connected to the acceleration pedal, the controller receives a signal that it uses to manage the power delivered to the engine. As we will see in the next paragraph, the controller acts differently according to the type of electric motor used in the vehicle. Controllers mainly pulse the power from the battery, according to the movements of the acceleration pedal: by switching on and off the power supply, the controller reacts to the accelerator pedal managing the power provided to the vehicle. For example, when the pedal is halfway pushed, the controller switches the power on and off in order to have it on half the time and off half the time[18]. This is possible through very large transistors that rapidly turn the batteries’ voltage on and off. The system explained may change according to the electric motor used, as has been

[17] Yahoo Finance; *“Power Japan Plus Reveals New Ryden Dual Carbon Battery”;* finance.yahoo.com ; 2014

[18] Marshall Brain; *“How Electric Cars Work”;* howstuffworks; auto.howstuffworks.com; 2011

said, but the basic principle is the one explained. Despite that, we can recognize two kind of controllers: the Alternating Current (AC) or Direct Current (DC). The DC controller sends pulses to the motor up to 15.000 times per second. The AC controller uses three pseudo-sine waves to pulse on and off the Direct Current voltage. In this way, the AC controller reverses the polarity of the Direct Current voltage 60 times per second. The AC controller is normally more expensive and complex but the motor of controlled vehicles can reach over 200 volts. The DC controller is cheaper and simpler but the controlled motor can reach a power from 96 to 195 volts.

2.4.3 Electric motors

Electric motors are connected to the wheels: the battery provides the energy to the controller that manages the voltage and delivers it to the motors, which will move the wheels. As has been said, there is a strong connection between controllers and electric motors. Indeed, we can recognize two main types of electric motors: Alternating Current (AC) and Direct Current (DC), which can be divided in more categorizes but according to the purpose of this work, only a brief introduction of electric motors will be provided. The most used motor in EVs is the AC motor. As has been said in the previous paragraph, it can achieve better performances than DC motors. AC motors operates with AC controllers: the controller provides alternating current to the Stator, a stationary part equipped with magnets, which generate a magnetic field that changes their polarity continuously. Inside the electric motor there is a Rotor, a moving part equipped with other magnets that interact with the magnetic field, which moves constantly. Electric motors are very efficient compared to standard engines, but it seems like there is room for improvement. The main challenge for engineers and manufactures is the reduction of electric motors and the enchantment of their performances and efficiency. Mitsubishi Electric recently developed a new electric motor with an integrated silicon carbine and improved cooling: this new motor is smaller providing more space for batteries inside the vehicle, but at the same time, it can achieve the same performances of standard electric vehicles with a better cooling system[19]. C-Motive technologies, an UW-Madison spinoff, is developing a new concept of electric motor that uses electric fields rather than magnetic fields. The use of electrostatic force in electric motors is not entirely new but recent technologies allow this motor to save weight, materials and costs while providing a better efficiency[20].

2.4.4 Range limitations and charging time

Range limitations and charging times are probably the main issues in the electric vehicle industry. According to a Deloitte report[21], despite almost the totality of the drivers surveyed drive less than 80 kilometres per day, consumers' expectations are considerably higher. Although lithium-ion batteries offer the highest energy density power relative to the size, it is still the main limiting factor for EVs' range. Most of the consumers also expect their electric vehicle to recharge in less than two hours, which is not possible with the current technology capabilities except for specific super chargers supplied by private manufacturer or EV manufacturers.

Indeed, according to most recent reports, Tesla Model S is currently the pure electric vehicle with the highest range performances: 500km between charges. Model S is considered one the best electric vehicles available and the charging infrastructure made available by Tesla Motors allows its consumers to charge their vehicle by half in only 20 minutes through their supercharges. Model S is clearly an exception, unfortunately, other EV manufacturers cannot achieve such technologies or they are not investing enough in the industry. Indeed, most of the electric vehicles available now, barely achieve a range of 160km between charges. In addition, most of the vehicles take up from 1.5 hours to 7 hours for a full charge. BMW i3 can actually achieve a full charge in 30 minutes, faster than Tesla Model S but the battery can achieve half the range of Tesla's model. As

[19] Antony Ingram; *"Mitsubishi's Mini-Motor for Electric Cars Integrates….Well, A Lot"*; Green Car Reports, greencarreports.com; 2014

[20] David Tenenbaum; *"New Motor Under Development by UW-Madison Spinoff";* University of Wisconsin-Madison News; news.wisc.edu; 2014

[21] Deloitte; *Unplugged: Electric Vehicle Realities versus consumer expectations;* Deloitte Global Services Limited; 2011

has been said in the previous paragraphs, companies and engineers are working on smaller motors and batteries: Audi is working on a new electric vehicle that may achieve a range of 450km, while General Motors is working with LG to develop a battery with a capacity of 350km. However, the biggest challenge right now is the “1000miles race”: manufacturers are working to achieve in the next years a battery capacity of 1000 miles (more than 1600km). The Israeli firm Phinergy is developing with the American company Alcoa an Aluminium Air Battery which is far more energy dense than lithium-ion batteries[22]. This battery is not rechargeable and uses oxygen from the air to form the battery’s cathode, unlike traditional batteries, and according to recent demonstrations it should allow EVs to achieve the astonish result of 1000 miles. As we will see in the next paragraphs and chapters, players in the electric vehicle industry are mainly dividing into two categories: some are working on a faster and better charging infrastructure while others are mainly working on better battery technologies.

2.4.5 Regenerative braking

The battery is not the only element that influences the range: today’s companies putting their efforts into regenerative braking technologies. Regenerative braking captures the kinetic energy and turns it into electricity that recharges the battery by producing a small voltage. Indeed, when the controller is “turned off” and it does not deliver battery’s current to the motor, the vehicle reduces its speed since the current is not delivered to the motor; however, its kinetic energy can be captured to recharge the battery (as we know from physics, energy cannot be destroyed). When the vehicle slows down, the system that drives the vehicle does the majority of the braking work, while the motor runs in reverse mode slowing the car wheels, but it also acts like an electric generator that produces voltage for the battery. Once again, Tesla’s technology is ahead of its competitors. Tesla model S offers two re-gen settings: Normal and Low. When it is set in low, the car slowly brakes providing voltage that recharge the battery. When set in normal, the car slows down more aggressively providing a greater recharge of

[22] Angus MacKenzie; *“Electric test car with aluminium-air battery takes to the track”;* Gizmag; gizmag.com; 2014

the battery, which is able to capture as much as 70 percent of the energy that would otherwise have been lost. In this way, the driver can choose the speed reduction when he push the brake pedal or release the acceleration pedal and according to it, the energy restored. Volkswagen recently added this technology to its electric vehicles.

2.5 Main players in the U.S. electric vehicle market

In the next paragraphs, major players in the U.S. electric vehicle market will be introduced. In this chapter, the focus will be on the players, their investments and shares in the EV industry, and their plans after an introduction of their main products and technology. In chapter 3 an in depth analysis of the relationships between those players and their suppliers will be provided. A brief introduction of battery manufacturers and charging stations providers will be introduced as well. All the data related to sale volumes are taken from Wikipedia or from official sales reports provided online.

2.5.1 Toyota Motors U.S.A.

Toyota Motor Corporation is a major Japanese automotive manufacturer. Its subsidiary, Toyota Motors U.S.A., operates in the U.S. market since 1957. Its current headquarters are in California as many other automotive companies in U.S., but Toyota is now moving its subsidiary to Dallas, in Texas. Toyota Motor is one of the major manufacturers in the EV industry: it is the world-leading selling of hybrids with a. market share of over 1 million units for the whole Prius family since 2000; however, in 2013, over 23.000 units were sold in U.S. making Toyota the third major player in the industry. As has been said, the Toyota Prius is the most famous hybrid vehicle sold by Toyota Motors, announced back in December 1997, which received continuous upgrades with other versions released during the last decade. Toyota Motors developed a new system called Toyota Hybrid System (THS), which is equipped on the Prius family. THS is a series of parallel hybrid systems: both the gasoline-powered engine and the electric motor drive the wheels while the driver can switch between the two sources and, for example, uses the electric motor as a generator to charge the battery and drives the vehicle through the engine or directly through the current from the battery. In THS, a device divides the power in two paths: in one path, the power from the engine drives the vehicle's wheels while in the other path, which is electrical, a generator converts the power from the engine into electricity to charge the battery. Through this system, Prius can achieve fuel efficiency and high power performances. Most recent innovations from Toyota Motors brought to THS II. According to THS II, the system has two power sources: a gasoline engine and a magnet AC motor connected through the controller to a NiMH battery. When the vehicle starts moving, the vehicle runs on the electric motor; under normal conditions, a device divides the power in two paths turning on a generator, which drives the motor and the wheels directly. When the acceleration pedal is pushed, the extra power is supplied from the battery while the engine and the electric motor provides the acceleration. Briefly, THS II adopts high-voltage power circuits and a NiMH battery; the motor's power and engine's power provide a more powerful performance by diving the power to the wheels and a generator, which drives the motor and recharge the battery.

Toyota developed more technologies, which drove the innovation through the hybrid vehicles industry and allowed this company to be one of the main players in the worldwide EV industry. Toyota Motors developed also an all-electric SUV: the Toyota RAV4 EV. This vehicle will be analysed in the Tesla Motors study case since it is the result of a collaboration between the two companies. Besides that, the first generation of this vehicle became available in 1997 for limited basis, while a major access to this vehicle was allowed only in 2001. It uses NiMH batteries with a range of 240 km. The RAV4 EV is comparable to a standard engine vehicle, except for the fact that it uses a power electric source.

Toyota Motors is actually reducing its efforts in the EV industry: according to recent statements[23], Toyota is working on Fuel Cell Vehicles (FCV): a vehicle that uses hydrogen and oxygen as fuels collected from the natural environment.

[23] Marco della Cava; *"Toyota quietly rolls 2015 fuel cell car into town"; USA Today; usatoday.com; 2014*

According to Toyota Motors, battery technologies and charging times need a better development to promote a real success of the EV industry.

2.5.2 General Motors

General Motors Corporation is one of the main players in the automotive industry, producing vehicles under brands like Chevrolet, Opel, Cadillac, Holden etc. General Motors had a huge presence in the hybrid EV industry with the Saturn Vue Green Line, which uses the Belt Alternator Starter (BAS) technology. According to this system, an electric motor is connected to a modified automatic transmission, which stops the engine when the vehicle stops and restarts it when the vehicle moves again, while the electric motor assists the vehicle launch and acceleration. The battery was a 36-volt NiMH able to store the energy from the regenerative braking. The Green line was available to the market in 2006. Following the demise of the Saturn brand in 2009, after a second generation released in 2008, this vehicle was discontinued. Besides that, General Motors was the first company, in the modern era, to release an all-electric vehicle: the EV1 back in 1996. EV1 featured an aluminium frame and body panel made of plastic rather than metal, making this vehicle more lightweight than competitors ones up to 40%. EV1 also used an AC electric motor and acid-lead batteries provided by Panasonic rather than standard NiMH used at that time. According to the fact that EV1 was a 1996 EV model, it had the most advanced technologies available at the time, making it one of the best EVs ever produced. Despite that, EV1 was retired from the market in 2002. The reasons behind this choice are controversial: according to a documentary called "Who killed the Electric Car?"[24] the oil industry, automotive manufacturers and U.S. government limited the development of this technology, while technology limitations caused by battery technologies and hybrid's threats were only a second reason that forced General Motors to take EV1 away from the market. General Motors responded to this documentary with a blog post[25], back in 2006.

[24] Chris Paine; *"Who Killed the Electric Car?";* Electric Entertainment; Documentary Films; 2006

[25] General Motors blog post; *"Who Ignored the Facts About the Electric Car";* altfuels.org; 2006

According to General Motors, the EV1 was far from a viable commercial success since the support from suppliers was inadequate and the consumer demand was poor.

Besides that, General Motors efforts toward the EV industry are clear. Chevrolet Volt is a 2010 PHEV produced by General Motors. Chevrolet Volt sold over 63.000 units worldwide since 2010 making General Motor the major player in worldwide EV industry and in the U.S. industry , according to the total sales of Chevrolet Volt (over 28000 units) in 2013. Chevrolet Volt uses a pure electric system until its full battery capacity is used. From there, the vehicle uses an internal combustion engine that powers a generator to extend the vehicle range. The Volt uses lithium-ion batteries able to achieve a range of 60km up to 610 km with the gasoline engine, but the 2015 model will be provided with an extended range and will be able to fully recharge its battery in 4 hours through a 240V charging station.

2.5.3 Nissan Motor

Nissan Motor Corporation is a major Japanese player in the automotive industry and the second major player in the U.S. EV industry with its Nissan Leaf, which sold over 58.000 units since its release but with the highest market share in 2013 according to the total number of sales (over 47000 units). Nissan Leaf is a pure electric vehicle powered only by electricity able to reach a range of 160km with one charge through its lithium-ion batteries. In addition, Nissan Leaf uses a Synchronous motor: an AC motor, which contain electromagnets on a stator that rotate the rotor through a magnetic field produced by current provided by the battery. As has been said, one of main problems for the consumers is the battery. When the consumers buy an electric vehicle, they are exposed to the risk that the technology development in the battery's industry will reduce the value of their vehicles. In order to face this issue, in 2013, Nissan announced a battery replacement program, which went into effect in 2014[26]. According to this

[26] Nissan News; *"Nissan Announces Battery Replacement Program For Leaf"; nissannews.com; 2013*

program, Leaf's owners can get a new battery pack with the latest technology available by paying a fee of $100 each month. This policy increasing the amount of Leafs sold each year. The Leaf can be charged through a standard connector or a high-voltage connector able to achieve faster charging times (about 30 minutes for 80% capacity of the battery). Nissan involvement in the EV industry grew over the time: the alliance with Renault and NEC Corporation have the ambition to push into constant innovation to develop new batteries' technologies and quality standards as we will see in chapter 3.

2.5.4 Mitsubishi Group

Mitsubishi group is a group of Japanese multinational companies focused in the automotive industry, which shares the Mitsubishi brand. The most famous electric car produced by the Mitsubishi Group is the Mitsubishi i-MiEV but according to recent reports, only about 1800 units were sold in the U.S. market providing Mitsubishi Group only about 1% of market share. U.S. sales began in 2011 after the Japan lunch back in 2009, but additional features were provided to the U.S. consumers to fit the U.S. policies. I-MiEV uses lithium-ion batteries able to reach a range of 100km with one charge for the U.S. version, but it was recently upgraded after a partnership with Toshiba. The new battery made with Lithium Titanate has a longer charge and discharge cycle and can be recharged in less time (30 minutes from a high voltage charging station, according to Toshiba). The engine is a synchronous electric motor: an AC motor that acts as standard AC engines explained in the previous paragraphs, but the motor rotates in exact synchronism with the current frequency and it is water-cooled. The low range and speed make the Mitsubishi i-MiEV a city-car. In 2015 Mitsubishi group will lunch in the U.S. market the Mitsubishi Outlander P-HEV, a crossover SUV. It uses a lithium-ion battery able to achieve a range of 60km. The technology used is derived from the i-MiEV series.

2.5.5 Ford Motors

Ford Motors interests in the EV industry grew with U.S. policies focused on the development of the fuel economy and its technologies. Ford Motors is in the top ten EV automakers with its Ford C-Max Energi, Ford Fusion Energi and Ford Focus Electric. The Ford C-Max Energi is a five-door MPV (multi-purpose vehicle) and it is the plug-in hybrid version of the Ford C-Max. It uses a four-cylinder gasoline engine and an electric motor powered by lithium-ion batteries. The driver can switch between the standard mode using the gasoline engine and the EV mode. It can reach a range of 100km through the lithium-ion batteries with one charge, up to 960km using the gasoline engine. There is also a third mode available to the driver: an automatic setting that switch between the two engines according to the driving conditions. The Ford C-Max Energi sold over 7000 units in 2013 for a 3% of the U.S. EV market share.

The Ford Fusion Energi is a mid-size gasoline-electric hybrid powered version of the Ford Fusion launched to the U.S. market in 2009. The Ford Fusion Energi can run by using the engine, the batteries or a combination of both. It uses a four-cylinder Atkinson Cycle engine and an electric motor supplied by the Japanese company Sanyo, connected to a NiMH battery with a recharging time of 2.5 hours from a level two charger (middle voltage charger). The Ford Fusion Energi has an electric range of 30km up to 960km through the gasoline engine: the driver can switch between the two modes. Ford Motors sold over 6000 units of this vehicle up to 3% of the U.S. EV market share.

The Ford Focus Electric, at the very end, is a five-door hatchback electric car lunched to the U.S. market in 2011. It uses a lithium-ion battery pack supplied by LG Cherm with a specific active liquid cooling system to keep it at low temperatures in every driving conditions, and it is able to achieve a range of 122km rechargeable in four hours with a level 2 charger. The vehicle can be charged and controlled remotely through an application powered by Microsoft that will be analysed in chapter 3. The first production of the vehicle was delivered to Google back in 2011[27]. Ford Motors sold over 1800 units in 2013 of the Ford Focus Electric, up to 1% of the U.S. EV market share.

Ford Motors is currently developing a full electric version of the C-Max and Fusion models and it expects EV sales to raise up to 30 percent of all their sales in the next ten years. Ford Motors is also working on a new C-Max concept, which uses a sun-powered system to avoid the dependence from the electric grid. They are also working with General Electric to build a charging infrastructure in the United States and Canada, as we will see in chapter 3. Ford Motors expects to be a major player in the EV industry through continuous partnerships and investments in R&D.

2.5.6 BMW

BMW public interest in the EV industry began with the "Project i" featuring a sub-brand of the BMW founded in 2011, the BMW i, containing the initial lunch of the i3 all-electric car and the i8 plug-in hybrid. The BMW i3 is a five-door urban electric car made of carbon-fibre plastic powered by a lithium-ion battery pack able to achieve a range of 160km with one charge and rechargeable in 30 minutes with a level 3 charger (high voltage charger) up to eight hours with a level 1 charger (low voltage charger). The BMW i3 can also uses two conservation mode called Eco Pro and Eco Pro+ able to achieve a range up to 200km at lower performances. The technology behind BMW i3 allows achieving higher acceleration up to 100km/h in 7 seconds. Through a Park Assistant software, BMW i3 is able to finish the parking manoeuvre all by itself. BMW i3 sold over 700 units in U.S. BMW offers a gasoline engine as an option extender up to 320Km.

The BMW i8 is a plug-in hybrid sports car lunched to the U.S. market in 2013 after 2 concepts and a prototype showed between 2011 and 2013. It uses a lithium-ion battery able to achieve a total range of 37km up to 530km through the three-cylinder gasoline engine. BMW interests in the design part of the

[27] Michael Gorman; *"First Ford Focus Electric rolls off the production line into Google's open arms";* Endadget.com (AOL); 2012

vehicle led to a futuristic look with the chassis built in carbon and aluminium. In addition, the software allows the driver to control remotely functions like the radio or the air conditioning through the smartphone. The BMW i8 is considered one the most technology advanced plug-in hybrid. The comfort mode provided allows the driver to use only the electric motor without producing any noise with an increment in efficiency. In addition, there is a display on the windshield, providing all the information needed like the vehicle's speed, battery energy and more. BMW entered in the EV industry only recently but with the "Project i" BMW is going to be a major player in this industry with a total investment in the project of $2.7 billion[28].

2.5.7 Tesla Motors

Tesla Motors will be studied in-depth in chapter 4. However, the company was founded in 2003 and since then, produced two models with another two coming in the next years. Their first product, the Tesla Roadster, is a sport EV car, able to achieve high performances but coming at high costs. Their second vehicle, the Model S, is a luxury sedan EV, able to achieve the highest performances in the industry and coming at mid-high price. The company built its strategies on collaborations with the other players in the industry and is now looking for ambitious projects coming between 2015 and 2020.

2.5.8 Battery Manufacturers

Similar to any consumer product, a number of raw materials are needed to manufacture an electric car battery. As has been said in paragraph 2.4.1, lithium-ion batteries are expected to be the most used batteries in the years to come for the industry under analysis. The global demand for lithium has been minor in the last decades, but the recent growth of the electric devices industry has caused an increase of the demand for lithium. An electric car battery requires much more lithium than an electric device battery, influencing and producing major effects

[28] Reuters UK; *"BMW's i3 hatchback is mark of electric car confidence" ;* uk.reuters.com; 2013

on the global demand for this material. Most of the reserves of lithium are located respectively in Bolivia, Chile, Argentina, United States and Afghanistan. The "Sociedad Quìmica y Minera de Chile" is the major lithium company, which supplies the major battery manufacturers in Asia. Indeed, Asian companies are the major manufacturers of batteries for electric cars. LG Chem, the famous South Korean company, provides its batteries to General Motors and Renault. For example, the Volt runs on a battery supplied by Compact Power, a subsidiary of LG Cherm. Panasonic Corporation provides batteries to Tesla Motors and is now working to build a Gigafactory in the U.S. as we will in chapter 3 and 4. Another major Japanese player is Sanyo Electric Co., which supplies its batteries to Daimler and Ford. The U.S. government through the Recovery Act (2009) provided a huge boost to the U.S. battery market. A123Systems provides batteries to over 10 EV manufacturers like General Motors, Daimler, BMW and Mercedes-Benz. Despite that, the real value of a battery is inside its technology. Asian players are providing the highest level of technology at the current state while through huge investments in R&D they are preparing new technologies as we have seen in paragraph 2.4.1.

2.6 Electric vehicles charging infrastructure

Charging infrastructure is probably a key point of the electric vehicle industry. Consumers need an effective charging infrastructure in their territory, but the industry have to answer to three main questions. Who will own and operate the charging facilities? Who will provide the power? What is the overall cost to the consumers? Answers to these questions are not clear yet but we will try to understand the infrastructure to find a connecting point between these three questions and the issue. The main problem companies and consumers face is related to the absence of an extended charging infrastructure: consumers are hesitant to buy EVs as long there is not an effective charging structure, but companies are hesitant to build it as long there is a lack of demand. In 2013, many companies started to invest in the charging infrastructure through collaborations, joint ventures and partnerships, as we will analyse in chapter 3. However, a unique business model is not clear yet. The first element to point out is the Home charging. It is obviously the way to achieve lower costs to the consumer especially in the nigh time. Consumers need to be educated about home charging while the charging provider need to manage the installation and the costs. Power providers offer already a number of discounts for night charging and it is a benefit for the consumer. We can define three kind of charging stations. Level 1 charger provides a charging power of 120 volts, it does not require a specific equipment and it is the slowest to recharge the battery of an EV (approximately 8-12 hours); the average price of this charger is $0-$200. Level 2 charger provides a charging power of 240 volts and it requires a special equipment while the total recharge time is approximately 4-6 hours; the average price of this charger is $2000-$2500. At the very end, Level 3 charger is the faster charger and it provides a charging power up to 500 volts, but it requires special equipment while the total recharge time is approximately 30 minutes – 1 hour. The average price of this charger is $30.000-$50.000.

Most consumers may charge their EVs at home through a level 1-2 charger. As has been said the price of this kinds of chargers fluctuate between $0 and $2500. As has been said, the costs of the power reduce during the night, but we still think the EV manufacturers should provide at least the installation free.

However, the main issue is related to the charging on the road. As of March 2013, 5,678 public charging stations existed across the United States with 16,256 public charging points[29]. Level 3 charger are the chargers that should be provided publicly in order to increase the overall efficiency of the infrastructure and reduce the time drivers spend to recharge their vehicles, while level 1 chargers can easily be provided as home chargers. Level 2 chargers are mid-efficiency and should be provided in stop spots where the driver usually takes a break. As we will see in chapter 4, Tesla Motors is building the most ambitious EV charging infrastructure worldwide. However, we can still analyse the infrastructure according the most recent data, while the charging infrastructure provided through collaborations between the main players in the EV industry will be analyse in chapter 3. Austin Energy is a major player in the electric utility industry with over 400.000 customers and provides a subscription-based service

[29] U.S. Department of Energy; *"Alternative Fueling Station Counts by State";* Alternative Fuels Data Center (AFDC); afdc.energy.gov; 2013

to EV's owners for about $80 a month. Drivers can use the 186 public charging stations provided by Austin Energy by paying the subscription fee. Austin Energy provides also home charging stations and their installations to consumers. CarbonDay Automotive is another major player providing over 600 charging stations in the U.S. Many of these stations can be used for free while the others requests the payment of a subscription fee; the company also provides a software installable on the EVs or usable on their website to find the stations near the driver. Coulomb Technologies, an American charging infrastructure company provides over 18000 charging stations in the U.S[30]. The driver can buy a card to use at the charging point to recharge its vehicle while the company provides all the information needed through a smartphone app. Siemens Energy does also provides stations in the U.S. where drivers can access to some for free and through a specific consuming payment for the others.

We can define many other companies that provides those charging services but this will be done in-depth in chapter 3, we want to point out a trend now to understand the industry. Until 2011, many companies were providing the charging service autonomously especially after the incentives provided by the government in 2009 through the Recovery Act. Indeed, the government is putting its efforts in the development of an effective and efficient charging infrastructure but the trend is changing in the last years. EV manufactures wants to have a stronger control over the charging stations to provide the best services to their consumer but also to provide a unique service. Indeed, we can notice that in the last years there is a rise of collaborations or joint ventures between charging stations providers and automotive companies and most often the service provided is unique and usable only by a specific vehicle through different connectors. We can also notice a huge amount of public charging stations available to everyone through a subscription fee or a unique payment related to consumes, but automotive companies are increasing their presence in the industry. We can now try to give an answer to the questions defined at the beginning of the chapter. Charging facilities are most often operated by private companies not related to the automotive industry but mainly operating in the electric industry. The overall cost to the consumer depends on the single stations.

[30] You may notice a discrepancy in numbers. The Data provided about the companies is updated to 2014, while the total count of stations provided is dated in 2013.

Many EV manufacturers provide the access to the public charging station free, through collaborations with the owner of the facility, while the public charging stations operated by private electric companies are offered under the payment of a fee, a unique price or even free through collaborations with the public authority.

2.7 Today's EV Industry overview

2.7.1 Introduction

In 2010, there were about 750 million passenger vehicles in the world, but emerging markets such as China and India will increase world demand for passenger vehicles. By 2030, this number is predicted to grow to 1.1 billion and by 2050, it could reach 1.5 billion[31]. The EV market is in its early stages yet. According to a 2014 report of Navigant Research[32], Clean Diesel Vehicles are the most used vehicles globally, with an estimated $239.5 billion in revenue in 2013. Despite that, a considerable growth came in EVs, PHEVs specifically, from $1.9 billion in 2011 to $6.9 billion in 2013 (271% growth). According to Polk Vehicle Registration Data, electric and hybrid sales reached 70.000 units sold in 2013 with a 0.62% market share. Electric car sales were expected to triple in the U.S. each year from 20.000 in 2011, 60.000 in 2012 to 180.000 in 2013 but the mark in 2013 was not achieved by a wide margin. Ernst & Young reported that in 2010, EV's led investments attracting in venture capital funding for $1.5 billion. In addition, approximately 60% of Americans drive fewer than 40 miles per day, making EV's viable. As of June 2014, U.S. is the world's leader in PHEVs sales with a 45% share of global sales, followed by Japan, China and Netherlands. California has the largest number of public charging stations, due to incentives aimed at promoting emission-free traffic. Several industry forecasts

[31] Clean Energy Ministerial, Electric Vehicles Initiative, Internation Energy Agency (IEG); *Global EV outlook: Understanding the Electric Vehicle Landscape to 2020"; iea.org;* Report 2013
[32] Nivigant Research; *Advanced Energy Now 2014 Market Report: Global and U.S. Markets by Revenue 2011-2013 and Key Trends in Advanced Energy Growth";* Advanced Energy Economy; puc.hawaii.gov; Report 2014

agree that plug-in hybrids will continue to outsell pure electric cars in the U.S. at least until 2020.

2.7.2 Porter's Five Forces Model

Porter's five forces model is a framework to evaluate and define a firm's strategic position. It also describes how these five forces determine the profitability of an industry.

- *Bargaining Power of Suppliers*

Just as growing demand for EVs is creating new manufacturers, it is also providing a great opportunity to suppliers. Electric vehicles and conventional vehicles share some of the same component parts (which this work will not focus on), but there are new systems used specifically for EVs like battery packs, cell components, charger and more. Battery cells are mostly imported by Asia, in countries like Japan, Korea and China but U.S. federal government is supporting domestic battery makers. Vertical integration in the battery manufacturing fall off in the last years with the increasing outsourcing but automakers are deeply involved in the design and the production of batteries for their vehicles. Through partnerships (Nissan and NEC, LG and Renault, Panasonic and Tesla etc.) and joint ventures (Panasonic and Toyota in Primearth EV Energy Co. etc.), automakers and batteries manufacturers are increasing their interdependence and sharing their power. These accommodations may benefit the battery manufacturers by permitting large-volume productions and strong connections, but at the same time, it may also tie the future of a single battery manufacturer to the success of a single vehicle manufacturer. This industry is also creating some very dominant players. Suppliers like AC Propulsion, Continental, Valeo and A123Systems are building relationships and networks with the most important automakers in the scene, supplying advanced technologies, chargers, batteries and controllers.

- *Bargaining power of Buyers*

According to a Deloitte's survey[33], between 2010 and 2011, the average electric vehicle consumer and first mover profile and can be summarize in this features: generally well educated who tends to live in urban areas, more likely to be a male of middle-upper class, environmentally conscious, tech savvy, politically active and sensitive to government incentives and vehicle's features. This means that highly profitable buyers are generally less price sensitive. On the other hand, for buyers, one of the key concerns about electric cars is their limited range together with their charge time. Once more, according to Deloitte survey, no more than 2 to 4 percent of the population in any country have their expectation about range and charge time met today. Another key concern for buyers is the future value of their vehicle. With technology growing at such a fast rate, consumers wonder what will happen to it when more durable and better batteries will be released.

All of that seems to suggest that the power of buyers is increasing and highly influencing automakers strategies. The globalized consumer is less willing to deviate from their expectations and only a small niche of today's consumers find current technology acceptable. This is forcing automakers to make strong investments in R&D to come out with a more acceptable technology. Consumers are just likely to abandon their interest in EVs if the fuel efficiency of ICEs continues to improve.

The buying power of retailers is determined by the same rules of the traditional automotive industry.

- *Threat of Substitutes*

The main threat to EVs is obviously the ICEs industry. As has been said, ICEs do actually fit better consumer's expectations especially if fuel efficiency of

[33] Deloitte; *"Unplugged: Electric Vehicle realities versus consumer expectations";* Deloitte Global Services Limited; deloitte.com; 2011

ICEs continues to improve. In addition, the cost advantage of EVs increases as gasoline costs rise and decreases as they fall, increasing the relationship between EVs and uncertain factors out from the control of the automakers (positively and negatively). Consumers of products that have network externalities also place value on the number of other adopters of these products; electric vehicle industry needs to build a whole ecosystem while ICEs already have one.

Today, there are also several kinds of energy sources that can be used in vehicles. A hydrogen car is a vehicle that uses hydrogen as its primary source of power. The hydrogen is turned into electricity through fuel cells that powers electric motors. A small number of prototype hydrogen cars currently exist especially made by BMW, Honda and General Motors[34], but the industry is still under a significant amount of research to make the technology viable. A solar car is an electric vehicle powered by solar energy obtained from specific panels on the car. Today, solar panels cannot be used directly to supply a car but they can be used to extend the range of EVs. Biofuels as bio alcohol, ethanol and biogas are also used to fuel vehicles. Besides that, threat of substitutes does not appear to be too high in EVs industry: most of the alternative fuel sources are still under development and research, and most of the competition is played on the field of traditional vehicles.

- *Threat of New Entrants*

The growth potential of the EV industry will likely attract potential investors and venture capital but it is also true that EVs will sell at low volumes for a long time without a massive policy action or major disruptive changes. Most of the biggest players of the traditional automotive industry, like BMW, General Motors, Chrysler, Nissan and Toyota, are already into the industry although often only with prototypes or projects. Despite that, the actors on the EV industry are not so numerous until now. The main threat may come from China and India markets: most of China consumers are first-time car buyers and seem relatively

[34] Travis Hoium; *"Why Hydrogen Cars May be Stranded Before they even hit the Road";* The Motley Fool; fool.com; 2014

open to EVs. A recent McKinsey & Co. study[35] estimates the Chinese electric vehicle market could be worth up to $220 billion by 2030. EV market in India is at an early stage but the government launched a $3.5 billion plan with an ambition target of 6 million EVs on the road by 2020.

In the future, more players may enter into the industry especially as a result of a contingent policy action or following the development of a more suitable ecosystem. Until then, new entrants are not considered as a real threat, also because the development of the EV infrastructure and market requests more players and consideration.

- *Rivalry Among Existing Competitors*

As has been said, companies can no longer rely on in-house innovation; this is even truer in a developing industry. In "Open Innovation", firms recognize that all the innovation cannot come from the inside organization but they can accelerate the process and researches by acquiring technology externally, especially through co-operation and collaboration. For corporation in the EV market, as well as those planning to enter, forming partnerships will be the key to success in a market with major obstacles. Many important partnerships are already in place, especially between suppliers and automakers, but in many cases, these relationships may not continue in the future. The EV market now is all about technology, this means that the corporation or the strategic alliance that can prove the value of their technology will most likely increase its positioning into the landscape. This uncertainty together with the fast rate of the technological change will lead to a breach of many partnerships and will increase the competition into the market especially after the development of the industry.

[35]Paul Gao, Arthur Wang, August Wu; *"China Charges up: The Electric Vehicle Opportunity";* McKinsey&Company Reports; mckinsey.it; 2008

2.8 Challenges and Opportunities: electric vehicle industry outlook

Despite the growth of electric vehicle industry in the last decade, there are still major barriers that prevent a greater adoption of EVs. The main barrier comes from technological aspects. Prices per usable KW/h of a lithium-ion battery ranges between $500 and 650$ which represent a huge part of EV's costs. Most EVs will remain more expensive than their equivalent ICEs even with the government incentives. Furthermore, consumers perceive range limitations as a major obstacle; one survey of American consumers[36] found that 75% of respondents considered range to be the major disadvantage of EVs even if in the U.S. the average daily vehicle distance travelled is 46 Km. Despite that, there is still a major gap between consumers' expectations and EVs state of the art. Many reports addressed that battery failures, recalls and degradations have raised doubts about EV technology. It actually appears that consumers have quite high expectations about EVs.

The most urgent need in EV markets is in financing charging infrastructure. According to International Energy Agency, companies need to identify a sustainable business model to best match charging infrastructure supply and demand. Nevertheless, how public and private need to manage this issue? Pricing and operating models depends on the ultimate owner of the charging station: the cost of a charging station can be between $5000 and $15000 and calculating the ROI is an issue when demand data is uncertain. National governments have most probably to support R&D and the first development of the industry until private companies can consider real investments. Furthermore, few automakers offering no-fees charging stations to their customers discouraging other private's investments. Consumers need to be well informed of EVs' benefits to better realize the total lower cost of EVs.

However, the use of electric vehicles is on the rise globally. According to a PWC report[37], a significant rise in the number of grid-enabled vehicles is expected by 2020, but industry experts agree that China will surpass U.S. as the most

[36] Drew Kodjak; *"Consumer Acceptance of Electric Vehicles in the US";* International Council on Clean Trasportation; epa.gov; 2012
[37] PWC; "*Adopting Electric Vehicles: The Role of Technology and investment";* PriceWaterHouseCoopers; pwc.in; 2009

important player in both manufacture and sales. A number of governments are promoting initiatives to develop the EV industry, automakers and consumers are embracing this technological shift consequently. Furthermore, according to the PWC report, by 2023, the average mileage per year of EVs will reach the current average mileage for ICEs, due to technological development in the next ten years and an average efficiency increase of 5% can be expected every five years. The current goal of U.S. government is to reach 5.9 million annual sales of EVs in 2020; this requests a growth of 72% each year until 2020 (according to the 45.000 units sold in 2011). By 2020, U.S. is targeting the deployment of over 22.000 chargers, including 350 fast chargers by the end of 2014.

Chapter 3: The role of Open Innovation in Electric Vehicle industry

3.1 Collaborative Networks, Partnership and Alliances

With collaborative networks, partnerships and alliances, companies agree to collaborate in order to achieve a common goal by remaining independent and autonomous. In the EV industry, the technological development is a main issue that companies have to face. As has been said, electric vehicles have different parts like the electric motor, the battery, the software but also the charging stations. All this elements need to be developed in order to achieve better technological standards to fit the consumers' need. An organization cannot rely on its own innovation and develop all this technologies by itself. Developing the industry is the main goal for those companies; it is not only about the shares when you can increase the overall market size. An industry growth can benefit standard EV producers but also their suppliers and many other organizations related with this industry. This is the main reason that can explain why there is such a huge amount of collaboration in this industry.

First, a brief explanation of the differences between these three forms of networks will be provided. Collaborative networks stand for a set of relationship between independent and autonomous organizations both horizontal and vertical, while strategic alliances are agreements between companies to achieve a common goal, often through mergers and acquisitions. Gulati (1995) defines strategic alliances as "*any independently initiated inter-firm link that involves exchange, sharing or co-development. A strategic partnership define an alliance between companies normally formalized by a business contract*".

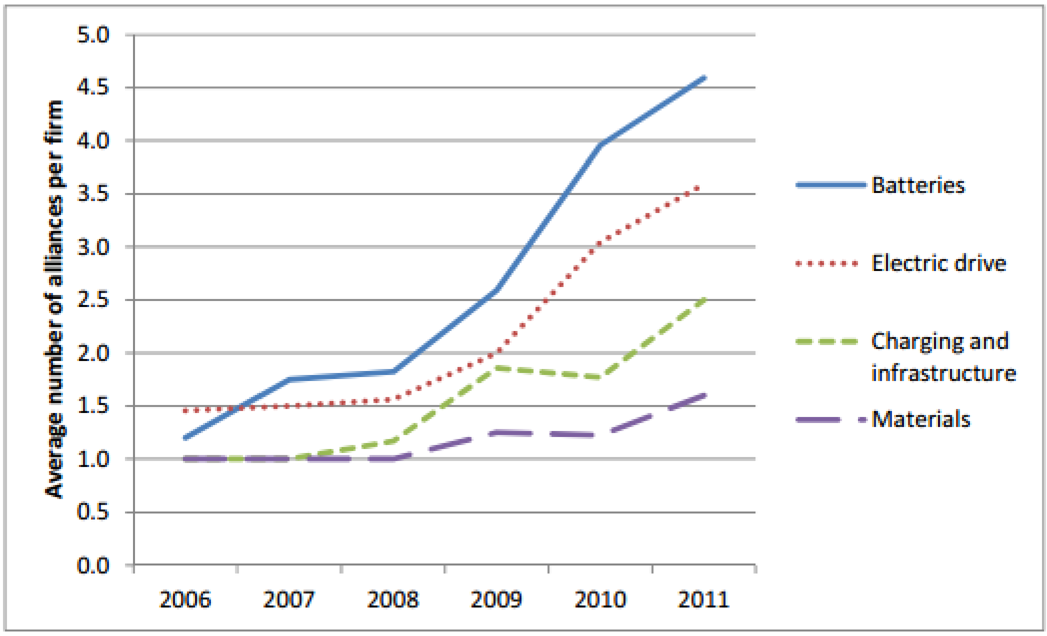


Figure 3: Average number of alliances per firm in key knowledge areas

Source: "Alliance Formation in the Electric Vehicle Industry during an era of Ferment"; William Sierzchila, Sjoerd Bakker, Kees Maat.

The image above is updated to 2011, but the trend is easily understandable. With the technological development of the industry and with more companies interested in EVs, the average number of alliance per firm is increasing year by year.

The biggest networks are created in the batteries industry. Automakers cannot develop the batteries internally without huge investments in R&D and expertise. Mainly, automakers prefer to build networks and alliances with batteries manufacturers in order to access the best technologies available and increase the range of their vehicles since, as has been said, it is a main issue for consumers. In 2007, after the concept of Chevrolet Volt, General Motors was looking for a partner to build the Volt's batteries. Compact Power, a subsidiary of LG Chemical and Continental Automotive Systems was choose to develop this technology. LG Chemical is now the main partner of General Motors in the development of the batteries for the Chevrolet Volt, especially after that LG Chem and Compact Power, with an investment of $300 million, built a factory to produce batteries for 200.000 vehicles. In addition, General Motors had a partnership both financially and technologically with Better Place to develop batteries' technologies but Better Place was liquidated after a bankrupt in 2013. A123Systems produces the monophosphate lithium-ion battery pack for the Chevrolet Spark EV and Chrysler. Ford Motors teamed up with Compact Power for the production of the lithium-ion batteries for its Ford Focus Electric while Sanyo Electric provides NiHM batteries for Ford's hybrid vehicles. Samsung SDI have a partnership with BMW Group for the supplement of its batteries to models i3 and i8 since 2009 and in 2014, after a Memorandum of Understanding (MOU), Samsung SDI and BMW Group agreed to increase the overall supplement of batteries after the growth of i3 and i8 sales. Since batteries are a main issue for automakers, many producers built joint ventures with the main batteries manufacturers, as we will see in the next paragraph.

Developing the overall industry is another big step and an important issue for companies operating in the EV industry. Companies collaborating to develop new technologies or share the R&D investments to develop the industry and its infrastructure. The Nissan-Renault alliance for the Zero-emission vehicle is an example of this case. The Alliance cover multiple elements and joint ventures, as we will see in the next paragraph. However, the Alliance has created partnerships with more than 100 public and private organizations to create consumer buying incentives and EV infrastructure investment. Nissan covered the battery production for the Alliance, but it is now considering a collaboration with LG Chem for the production of the batteries since they seem unable to achieve the same technological level of the Korean company. Nissan wants to keep the production of the batteries in-house developing a new generation of batteries but in-depth information are not provided yet. Renault and Nissan sold more than 120.000 electric cars over the past five years and if we consider the Alliance as one player, it is the major player in the global industry. The Leaf was the first EV produced by the Alliance. In 2015, the Alliance will supply EVs to Orange, one of the world's largest telecommunication operators, mostly for car-sharing purpose. The Alliance is achieving important results and collaborations: with Daimler, a new plant is going to be built in Mexico with an investment of $1 billion for each company, able to produce 300.000 vehicles each year and employ 5700 workers[38]. Joint ventures and efforts to build a charging

[38] William Boston; *"Daimler, Nissan to share New Production in Mexico";* The Wall Street Journal; online.wsj.com; 2014

infrastructure, coming up from this alliance, will be analysed in the next paragraphs.

Software is another notable part of the EV industry. With the raise and growth of smartphone industry and electric devices but also with incoming efforts in the “internet of the things”, connecting the car to the smartphone and providing a valuable software within the vehicle is becoming an important technological part of the electric vehicle. In order to develop a good software product, companies need to collaborate with major players of the software industry. Ford Sync is the software used in the Ford’s EVs. It runs on a small computer designed with the collaboration of Continental AG, a Germany automotive company. The software allows the driver to make hands-free telephone calls, control the music through voice or the smartphone and other “standard” functions as traffic information and vehicle’s data. The software also allows controlling remotely a computer through a software provided by Sprint, a United States telecommunication company. The first versions of Ford Sync were provided by Microsoft through an agreement between the two companies expired in 2008. Today, the software is developed in-house from Ford Motors but it runs on an operating system provided by Microsoft called Windows Embedded Automotive. Toyota’s EVs run Toyota Entune, a telematics system providing general information related to the vehicle but also subscription based services as weather, sports scores and more. The software is provided by a collaboration with Sirius XM Holdings, an American broadcasting company, which is connected with Bing and Pandora. OnStar Corporation, a subsidiary of General Motors, provides the software service on General Motors EVs. The company was formed in 1995 as a collaboration between General Motors and two American companies: Electronic Data Systems and Direct TV. The software provides general information like traffic, vehicle’s data etc. but after a collaboration with Verizon, an American telecommunication company, the software is able to use wireless communications to contact emergency centres during an emergency through the Advanced Automatic Collision Notification, a program developed by Centre of Disease and Control after a partnership with General Motors. In this way, the driver can have a faster assistance in case of accident. In addition, the software can help to recover a stolen vehicle through the GPS and wireless services. This led to partnerships between General Motors and major insurance companies. Nissan provided its Leafs with a software developed in-house running on Microsoft Windows Embedded Automotive technology. The software is called CarWings providing support and information like the identification and mapping of charging stations. The Software runs on a computer developed by Sanyo. iDrive is the software used on BMW i vehicles. The software was developed by Microsoft and running on Microsoft Windows Embedded. Now it is developed in-house by BMW but Google provides its services on the software after a collaboration between the two companies. iDrive provides standard information, entertainment services and music control. Through the Google collaboration, iDrive is able to use major apps working on Android systems. Anyway, as has been said, the software is a major part of the EV. Drivers need to easily access to major information during the drive session but they also need to control the battery life and charging stations available around them. Most of the services run on the Microsoft operating system but the major telecommunication companies develop the services provided by the software.

3.2 Joint Ventures

A joint venture is an agreement between two parties to achieve a common goal by creating a new business activity with contributing equity. As has been said in the previous paragraphs, companies in the EV industry are concerned about the importance regarding the development of the industry, and they also understand how important is to have an access to the best technologies available, which requests huge investments in R&D in order to resolve the main issues related to the industry. The purpose of this paragraph is the understanding of joint ventures in the industry and how the companies collaborate in this way to achieve new results and competitive advantage. Once again, the greatest number of joint ventures can be found between automakers and batteries manufacturers. Primearth EV Energy (PEVE) is a joint venture between Toyota, which detains 40.5% of the equity, and Panasonic, which detains 60% of the equity. PEVE was formed in 1996 and supplies the NiMH battery packs to Toyota’s hybrids. As has been said in the previous paragraph, Nissan covers the batteries production for the Alliance. It does actually happen through a Joint Venture with NEC Corporation, a Japanese multinational that works in the IT services and products industry. The project led to a Joint Venture called Automotive Energy Supply Corporation (AESC) established in 2007. Nissan owns 51% of the equity while NEC Corporation owns 42% of the equity and NEC Tokin owns the 7% providing electronic raw materials. As has been said, the joint venture led to good results but not strong enough to deal with LG Chem technologies; the Alliance is considering then to collaborate directly with LG Chem. BMW takes its battery from Samsung SDI but it happens through a joint venture between Samsung SDI and Robert Bosch GmbH, a German electronics company. Lithium Energy and Power GmbH is a joint venture established in 2013 between Mitsubishi Corporation, GS Yuasa International, a Japanese company that develops lead acid batteries, and Robert Bosch GmbH. Mitsubishi and GS Yuasa holds 25% of the joint venture while Bosch holds 50% of the equity. The idea behind this joint venture is to develop a new generation of lithium-ion batteries with Bosch providing the electronic raw materials, while GS Yuasa shares its knowledge in the battery industry and Mitsubishi provides all the support to integrate the batteries in the EVs.

However, we can totally define a trend in the last decade, which led to a shift in the collaboration between the automotive companies and the batteries manufacturers. Back in the early ’90s, most of the battery manufacturers had joint ventures with other battery manufacturers to develop new technologies. In the last decades, most of these joint ventures ended up while many joint ventures, but mainly collaboration networks, born between automotive companies and battery manufacturers. Looking at the overall industry, suppliers seem to prefer a direct connection with automotive companies to build a factory by sharing the costs and the investments to develop better technologies and directly connect them with the EVs. SBLiMotive was a joint venture between Samsung SDI and Bosch with each of those companies owning 50% of the equity. The purpose of the joint venture was the development of lithium-ion technologies to use in EVs. The Joint venture was ended in 2012 after an agreement between the two companies to have a mutual access to the patents. After that, both companies joined collaborations or joint ventures directly with automotive companies. Indeed, EVs manufacturers prefer to have a stronger control over their suppliers and their technologies, especially since the battery is most probably the main issue of EVs. This may explain the reason behind recent dismiss of many joint ventures between the battery manufacturers and an overall increase of joint ventures or collaborations between EVs manufacturers and battery manufacturers. For example, Johnson Controls and Saft Groupe S.A., a French battery manufacturer, had a joint venture, ended in 2011, called Johnson Controls-Saft Advanced Power Solutions (JCS). The joint venture produced the cells for the batteries in French, while through a collaboration with VARTA, a German battery manufacturer, the batteries were assembled in Germany. After the dissolution, as has been said, Johnson Controls made a collaboration with Ford while VARTA built a joint venture with Volkswagen.

The development of new markets like China, India and Russia, are gathering the interest of EVs manufacturers, especially to fit the government requests in term of market electrification. In order to enter those markets, companies prefer to build joint ventures with companies that are already into the market. The Alliance have a joint venture with AvtoVAZ, a major Russian automotive company, with the Alliance owning the 67% of the equity. With this joint venture, the Alliance is increasing its chances to enter the Russian market. However, as has been said, the Chinese market is the most interesting one. Daimler for example, is creating a joint venture with BYD Co. Ltd a major player of the Chinese EV industry. Nissan have a joint venture with Dongfeng Motor Corporation, called Dongfeng Motor Company Limited. Nissan owns 50% of the equity while Dongfeng Motor owns the other 50%; Nissan produces passenger car under its brand while Dongfeng produces commercial vehicles under its brand.

We can define more joint ventures in the EV industry, especially considering all the joint ventures in the overall value chain. Anyway, the purpose of this paragraph has been reached. Considering the battery side of EVs, as has been said, we can define a trend. EVs manufacturers trying to have more power over their suppliers while battery manufacturers prefer to directly connect to an automotive industry to share the risks and the investments in the R&D. We can expect more joint ventures to born in the next years, especially considering the overall outlook of the EV industry and the development of new markets.

Companies cannot rely on their own technologies in such a technology-based industry. Collaboration, alliances and joint ventures is the best way to achieve stronger results and share the risks behind such an uncertain market. However, it is not over yet. The Charging infrastructure is another main issue of the EV industry. As we will see in the next paragraph, building a charging infrastructure to cover the overall territory requests an extraordinary effort where companies have to collaborate to promote a valid offer to the customers.

3.3 Charging Infrastructure: a key point

In paragraph 2.6, we introduced the charging infrastructure industry pointing out the major players and their services. In addition, we introduced a trend in the industry where many collaborations and joint ventures are coming out: in this way, the charging station operator reduces his risks by sharing them with the EV manufacturer while the latter increase his presence in the industry and offer a unique service to the consumer. As has been said, the technological side of EV is a major issue in the industry but the consumers define their preferences also by the presence of an effective charging infrastructure. In this paragraph, the major collaborations in the charging infrastructure industry will be analysed.

AeroVironment Inc. is an American technology company involved in energy systems. Nissan chose AeroVironment for the home charging of its Nissan Leaf, after a partnership between the two companies. Indeed, AeroVironment provides the level 2 home charger to Nissan Leaf consumers and its installation. Leaf owners can request a visit from an AeroVironment operator who will provide a quote with all the information and costs of the installation. As most of the home charging stations, the price of the installation and of the station is up to the consumer but Nissan and Aerovironment provide a special warranty. BetterPlace had a partnership with Renault-Nissan Alliance to provide the public charging stations for their EVs under a special fee reduction. After the bankruptcy of BetterPlace Nissan developed a new project called EZ charge: under this program, Nissan created a network with major charging stations providers like AeroVironment, Blink, CarCharging, ChargePoint, Greenlots and NRG eVgo. Owners of Nissan EVs can use the public stations of those operators freely for two years. Nissan is also building its own charging infrastructure with level 3 chargers. Nissan is also participating with U.S. Department of Energy and General Motors in the development of an ambitious program called "The EV Project" started in 2009[39]. The project aims to provide a free home-station and installation to consumers who qualify (according to their home electrical power capabilities). The consumer have to provide in exchange his vehicle and charge information. The project allows also the consumer to recharge their vehicles at Blink stations freely. In this way, Nissan and General Motors are collecting a huge amount of data about their vehicles usage and other information and it is boosting the sales of Leaf as Brendan Jones, director of Nissan Electric vehicles sales, stated. The EV project provided over 8000 home chargers and over 1000 public chargers.

ChargePoint America[40] is a program sponsored by Coulomb Technologies in collaboration with General Motors, Ford and Smart USA. Under this program, 4600 public charging stations have been installed in ten selected regions in the U.S. through a collaboration with the U.S. Department of Energy after the Recovery Act (2009). General Motors does also collaborate with Nissan, Google, Ford, Siemens and Tesla in the Workplace Charging Challenge launched by the U.S. government to offer a workplace in their charging stations to a number of citizen. The project aims to increase tenfold the number of U.S. employers in the charging infrastructure. General Motors owns also 400 charging stations.

Ford Motors have a collaboration with Leviton Manufacturing Company, the largest American manufacturer of electrical equipment, to provide the home-charging station to its consumer. Costs associated to the station and its installation are up to the consumer but Leviton offers a ten-year warranty to Ford EV owners instead of the standard 3 years warranty. Ford is also building its own public charging infrastructure in collaboration with General Motors[41]: Ford Motors will own and operate the facility but owners of a General Motors' EV will be able to use the charging station as well.

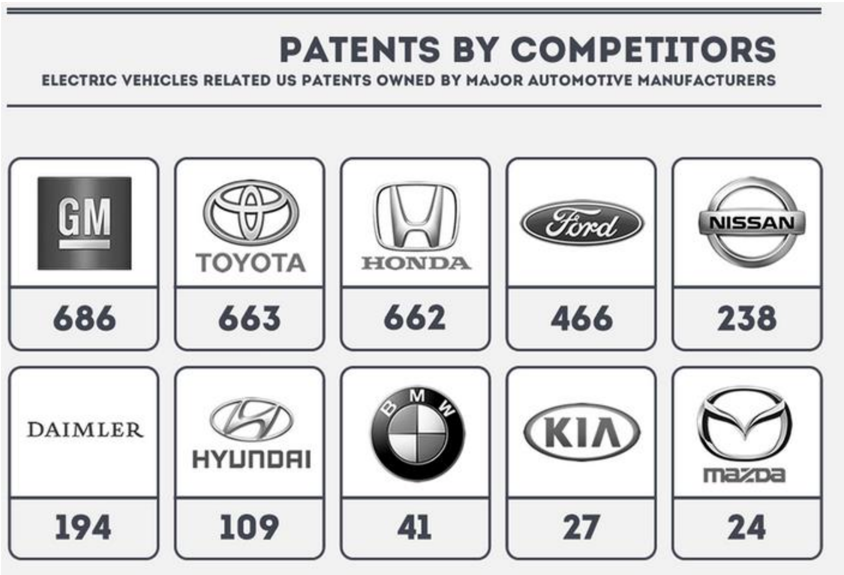
[39] www.theevproject.com
[40] www.chargepoint.com
[41] Jay Cole; *"GM and BMW Join Forces To Complete Testing on DC "Combo" Fast Charge Stations";* InsideEVs; inseevs.com; 2013

BMW have a partnership with Bosch Automotive Service Solution to provide a home-charging station to its consumers. The quote and assistance are provided for free while the charging station costs are up to the consumer. However, BMW provides special offers and price reductions through its Financial Service and they also provide an extra 3 years warranty over the 3 years warranty provided by Bosch. BMW also built its own chargers provided through a collaboration with NRG EVgo for free.

We can define collaborations also between companies outside of the automotive industry. For example, Siemens and Columbus Technologies have a collaboration to provide Samsung charging stations with Coulumb Technologies' ChargePoint Network allowing consumers to control remotely the charging status and information related the state of the vehicle and the charging process. We can also define a number of collaboration between payment services providers and charging infrastructure to provide flexible billing methods but the purpose of this paragraph has been reached. We can surely identify a high number of collaboration in the charging infrastructure. Automotive companies prefer to offer to their consumer the most efficient charging system by providing often free or fee-reduced public charging services and flexible home charging stations. In this way, consumer can access to charging networks provided by any private charging company but with special offers related to the vehicle they own. We can also notice that many EV manufacturers are increasing their efforts in the development of their own charging stations in order to cover the territory with unique offers.

3.4 Intellectual Property Rights in the Electric vehicle industry

As has been said in chapter 1, IPRs allow their owners to benefit from an innovation and protect themselves from free-riding behaviours. IPRs does also provide incentives to boost the innovation process in a country. In paragraph 1.3, we introduced the role of IPRs in the Open Innovation paradigm in order to understand how a different management of IPRs can lead to specific results and strategies to grow an industry since companies "*collaborate in growing an* *industry and compete in sharing the market*". As we made clear in chapter 3, the EV industry is still in its early days and much have to be done to promote EVs and create a better ecosystem. A different approach to IPRs management can lead to those results as we will see in chapter 4 through the Tesla Motors case study and its decision to share all of its patents. However, in this paragraph we want to understand how the IPRs are managed in the EV industry. Indeed, Tesla Motors is not the first company to share its patents but it is the first to share all of its patents. In this chapter, we pointed out how strong is the collaboration between the companies to grow the industry and build an ecosystem to the EVs but not much has been done in this industry on the IPR side.



Source: Infographic provided by DeltaSigh.com and Envisionip.com

As we can see in the above infographic, all of the major automotive companies built a significant patent portfolio related to their EVs' technologies after well-established R&D programs.

However, most of those companies did not share their patents or technologies in the EV industry. Indeed, patent sharing is not new in the automotive industry. General Motors, back in 1970, shared its R&D results in developing the catalytic converter while Ford Motors shared some of its patents with small suppliers. However, we cannot really define a trend until now in the EV industry. Indeed, in this industry, the use of patents and IPRs is always been in a defensive way: companies protect their technologies to achieve better results in competitive advantage. Tesla seems to be really the first player to introduce such a massive model in the industry. In many other industries, we can define this kind of behaviour like the Software industry or the old textile industry. Nevertheless, until now, we cannot find any decision of this kind from other players in this industry. Despite that, Tesla Motors seems to be introducing a brand new trend in the industry: as we will see in chapter 4, companies like BMW and Nissan are collaborating with Tesla and are taking benefits from the patent sharing of Tesla. In addition, BMW seems to be ready to share part of its patent portfolio after Tesla's decision. The use of patents in a defensive way does not really seem to benefit the industry: as long as the industry is small and need to build a whole ecosystem (from standard technologies to an effective charging infrastructure and consumers' education), the growth of the industry should be a major focus for the players operating in EVs. General Motors and Honda built a well-established portfolio and they seem to prefer to use their own technologies without any collaboration in patents, with other players in the industry, even after the Tesla's decision. General Motors seems to be looking at the competition as major point of its EV strategy development by using its patents in a defensive way, indeed, as the image above shows, General Motors detains the biggest patent portfolio in the industry and their strategies still focus on major cross-industry collaborations.

Chapter 4: Tesla Motors: a case study

4.1 Background

Tesla Motors Inc. is an American company founded in 2003 by a group of Silicon Valley engineers until the involvement of Elon Musk, currently CEO of Tesla Motors, who shook up the organization and the industry. The organization was named after electric engineer Nikola Tesla who invented the induction motor and AC power transmission, making the EV industry possible. The company aims to accelerate the advent of sustainable transports through the commercialization of electric vehicles and new technologies related to the EV industry. The company moved fast in the last decade with over 6000 employers, becoming a major player in the industry with ambitious programs. Tesla headquarter is located in Palo Alto, California, and it now operates globally with strong ambitions in the emergent markets. In 2008, Tesla gained widespread attention with the release of the Tesla Roadster, a BEV sports car with major performances and technologies, which sold thousands of units by the end of 2012 when the vehicle was taken off from the market. The Roadster proved worldwide that there was space for electric vehicles in the market. Tesla has expanded its business to the luxury sedan market with its Model S providing the highest performances on the market and drawing the attention to the industry once more. Model S proved that electric vehicles could reach high performances and compete with gasoline-powered vehicles. Tesla aims to accelerate the world transition from gasoline-powered vehicles to electric mobility and it is being achieved through interesting strategies and investments to develop the overall industry. Through collaborations and partnerships Tesla is developing the major charging infrastructure available made by an automotive company and the

Gigafactory, a factory plant that should be able to produce enough batteries to manufacture 500.000 Tesla cars per year by 2020 with a price reduction of 30%[42]. Unfortunately, Tesla past and future was not and will not be downhill. The EV industry is still at its early days and it requests huge investments to be developed. In 2008, Tesla Motors began to have financial troubles forcing the company to cut off 25% of its workforce, postponing the production of its Model S and creating collaborations with major players like Daimler after a reintegration of the capital from the founders. Another crisis showed up during 2012 and part of 2013 and the company still has low revenues in 2014. The future does not seem bright neither, the company needs huge investments to develop the industry and continue its strategy. However, Tesla Motors is receiving support from the Government according to its electrification program, and is developing important collaborations with the major players in the industry. Tesla plans are huge and their vision will play an important role in the development of the industry aiming to become a key player in the years to come.

4.2 The man behind Tesla: Elon Musk

"If you go back a few hundred years, what we take for granted today would seem like magic - being able to talk to people over long distances, to transmit images, flying, accessing vast amounts of data like an oracle. These are all things that would have been considered magic a few hundred years ago." (Elon Musk)

Elon Musk is an innovator, inventor and an entrepreneur who is revolutionizing three industry with its vision of the future. In 1995, Elon Musk at the age of 24, dropped the University to start his first company, called Zip2 Corporation, an online city guide that provided contents for major newspapers and then acquired by Compaq Computer Corporation in 1999. In the same year, Musk founded X.com, a money transfer system, which uses e-mail addresses to cover the transactions. X.com bought a company called Confinity in 2000, which had a subsidiary known as PayPal. Musk quickly understood the prospective of PayPal putting all its efforts into this company. He started to revolutionize the online transferring money industry. In 2002, Elon Musk started a new company called

[42] Tim Worstall; *"The Economics of Tesla's Gigafactory Battery Plan";* Forbes; forbes.com; 2014

Space Exploration Technologies (SpaceX) that develops and manufactures space launch vehicles with a huge vision: the advancement of the state of rocket technology to bring the man on Mars. The company launched two space vehicles and drew the attention of NASA. In 2004, Elon Musk cofounded Tesla Motors to accelerate the world's transition from gasoline-powered vehicles to electric mobility. Musk believes EVs will be the future of the mobility worldwide and he is putting strong efforts to make it possible.

"When Henry Ford made cheap, reliable cars people said, 'Nah, what's wrong with a horse?'. That was a huge bet he made, and it worked" (Elon Musk)

In 2006, Elon Musk became the chairman of SolarCity, a company founded by his cousin, which is now the largest provider of solar power in the United States. Elon Musk tried to revolutionize three industries with his vision of the future and he is often compared to Tony Stark, the main character of Iron Man franchise. Musk is now putting all its efforts in SpaceX and Tesla Motors to achieve his vision: in 2008 after the first financial troubles of Tesla, he used most of the moneys received through the sale of PayPal and Zip2Corporation to restore the financial conditions of his company, and in 2014 he shared all Tesla's patents to the industry.

Elon Musk is a visionary who wants to shape the future according to his vision by bringing a colony of people to Mars, by shaking up the automotive industry and the energy industry. Peoples who worked with him describe Musk as a good communicator, perseverant and always ready to listen everyone. He has no fear of challengers and taking risks, as Musk said, "*If things are not failing, you are not innovating enough".* We cannot know where Musk will get, if he will able to achieve his vision or not. However, he will be a key person in the future technological progress.

4.3 Core Products

Tesla Motors developed mainly three car models: Tesla Roadster, Model S and Model X. The company started with sports cars, the Roadster excels in performances and technologies and it is oriented to innovators. Indeed, Tesla Roadster had higher performances compared to the competition but it also had a higher price. Roadster aimed to give modern electric vehicles a new reputation. Model S is a luxury sedan vehicle with the highest performances on the industry and it aimed to provide a real electric vehicle that could totally substitute gasoline-powered vehicles. Model X Is a full-size crossover utility vehicle expected to be delivered to customers in the second quarter of 2015. The Model X aims to the draw the attentions of early adopters with a vehicle able to achieve high performance at a low price. Model III will be the first economy car produced by Tesla Motors targeted toward the mass-market. The starting price will be of $35.000[43] providing the first high performances EV oriented to a larger market. The original name of Model III was Model E but Ford had already a trademark over that name forcing Tesla to switch the name to Model III. Since not much has been said over Model III yet, only a brief introduction of this vehicle will be provided. However, it helps to understand the business development of Tesla Motors: starting with a sports car, Tesla aimed to introduce the EV potentials to the market, aiming after that to early adopters through Model S and X and looking now for a massive expansion of EVs through economy cars.

[43] Steve Fowler; *"Tesla Model III to challenge BMW 3 Series – World Exclusive";* Auto Express; autoexpress.co.uk; 2014

4.3.1 Tesla Roadster

The Tesla Roadster is a battery electric vehicle produced by Tesla Motors between 2008 and 2012. The Roadster was the first automobile to use lithium-ion batteries able to achieve a total range of 320km per charge and it was the first BEV to reach such a range with one charge. The Tesla's vehicle proved worldwide the potentials of the electric vehicles being the first car with those performances usable both as a sport car and as a daily driver vehicle. With that range capability, drivers could use the car without recharge it daily and a spacious legroom makes it very comfortable for long trips. As has been said, the Roadster uses a battery pack coming from 20 years of research in Lithium-ion cell technology providing the highest energy density in the industry available at that time (almost the double of the Nissan Leaf). The battery uses 6.831 cells with a total battery weight of 450kg (about 1/3 of the most common vehicles of the competition), reducing the total weight of the car to provide stronger performances and acceleration. The cooling system keeps the battery always at the perfect temperatures in any condition increasing the battery life. The electric motor uses AC power switched from the DC provided by the battery through a switch called IGBT. The switch allows more currency from the battery to the motor reducing the time needed to accelerate. The Roadster runs on a firmware developed in-house by Tesla Motors providing all the standard information, a remote diagnostic made by Tesla and information related to the battery status. Therefore, Tesla Roadster, was one of the most advanced vehicles available at the time but there is a specific strategy behind that. Tesla Motors was coming out with its first vehicle in a small market with many troubles and hurdles. Tesla had to convince its potential customers and drivers worldwide that there was space in the market for electric vehicles. They had to disclose a high performance vehicle, different from the competition and their limitations, and it obviously aimed to catch the innovators and early adopters attention. However, Tesla Roadster had some major limitation. That technology level had a cost, higher than the competition's one. Indeed, Tesla Roadster had a base price of $109.000 in the United States up to $130.000 for the full version. A car with that price, even with good performances but far from ICEs ones, could not catch the attention of the mass-market. Besides that, we think that the mission of Tesla Motors have been reached: 2400 Roadsters were sold by the end of 2012 and it proved that the electric vehicles could reach high performances and there were enough interest in the market. When, back in 2011, the supplement of Lotus gliders expired, Tesla Motors stopped taking orders for the Roadster in the U.S., even if a new model is expected to be introduced by 2018. The challenge then, was to provide a vehicle with high performances but at lower price, with a desirable design able to reach a bigger audience. As we pointed out in chapter 2, the technology development in the industry was going on making this challenge accomplishable.

4.4.2 Tesla Model S: a revolution

After the Roadster success, Tesla was looking for a high performance car sold for half of the Roadster's price able to catch the attention of its premium segment. In 2012, Tesla Motors started the production of its Model S, a full-sized electric five-door luxury sedan vehicle. Tesla Model S is fully designed and manufactured by Tesla with a special goal: produce a desirable vehicle, with standards curves but fully designed to maximize the performances and the efficiency. The body and the waist are shaped to not produce an excessive mass, only 2100 kg for the whole car, even the door handles are aerodynamic receding flush into the body to increase the vehicle range. The power train is one of the smallest available on the market and it is inserted next to the wheels so there is no need for a drive shaft. This design left a lot of free space to use as trunk or to add additional seats up to seven passengers. The front of the car is empty since there is no need of standard ICEs technologies, becoming an additional trunk showed as promotional element in the marketing campaign of the company. Technology speaking, Model S is the most advanced vehicle available on the market. It uses lithium-ion battery pack able to achieve a range up to 510km (426 according to EPA) with 7104 cells made of nickel-cobalt aluminium cathodes produced by Panasonic, guaranteed for eight years. The use of more cells than normal was a precise strategic choice[44]: Tesla Motors could use a simpler pack with less but bigger cells as other EV manufacturers but it would set a problem. Bigger cells provide less technological complexity but they require a safety system in each cell to prevent fire in case of accident. This makes the cells more expensive and companies to avoid a price increase of their vehicles normally reduce the battery density in order to decrease the risk of fire, which unfortunately reduce the vehicle range as well. Tesla's solution, increase the complexity of the battery but reduces the risk of fire in case of accident, reducing the costs of safety systems guarantying a safe product (Tesla Model S is marked as the most safe car in the market[45]) without reducing the density of the batteries, which accordingly increase the maximum range of the vehicle. As we will see later in this work, the Panasonic solution boosts this aspect. The temperature is a controlled by a computer-system and the vehicle presents radiators, which are not so common in EVs, in order to keep the batteries' temperatures as low as possible to increase their lifetime. The vehicle is designed to allow a fast battery swapping according to Tesla's strategy to deploy battery-swapping stations. The powertrain of Tesla Model S is the result of years spent in R&D to bring the best electric motor on the market. The motor consists of two parts, as many other electric motors seen in chapter 2, the rotor and the stator. Three materials were used to build the powertrain: aluminium on the exteriors, copper and steel inside. It is an AC motor put at 290 KW and it is a brushless electric motor. According

[44] Thomas Fisher; *"What Goes into A Tesla Model S Battery, And What It May Cost";* Green Car Reports; greencarreports.com; 2013
[45] Betsy Isaacson; *"Tesla's Model S Sedan Named Safer Car In The History of Cars";* Huffington Post; huffigtonpost.com; 2013

to this technology, the electric motor is driven by an electric input and it does not need brushes to work, increasing the life of the motor, reducing the overall size of the powertrain without reducing the power. Indeed, Tesla Model S can hit 0-100km/h in 4.7sec and 0-160km/h in 12.1 seconds: the highest performance in the industry. The powertrain is inserted close to the wheels to not waste power. The use of more compact technologies allows Model S to have lot of free space inside the car. We can definitely say that Model S represents the state of the art in the industry. On the dash of the car, a 17-inch touchscreen display works as a console control. The software running on this screen is produced in-house by Tesla Motors, providing information as the speed, charge level, estimated range but also apps as Google Maps, music etc. It uses chips produced by NVIDIA (NVIDIA Tegra) running eight processors and a GPU. The software is often updated by the company: the last version takes traffic information from other Model S to create a precise traffic-based navigation map, connects the smartphone to the computer in order to visualize all the information needed as the calendar with meeting schedules etc. and a remote control from the smartphone. Model S won awards such as Car of Year 2013 (by Automobile Magazine's) and best Innovation of the year 2012 (Time Magazine).

With Model S, Tesla Motors tried to offer the most advanced electric vehicle in the market. However, the price is not as low as Tesla wished. In 2012, Model S was priced at $95.400 up to $105.400. In 2014, it starts at $69.900 up to $93.400. Besides that, Tesla accomplished its mission. Tesla Model S provided a huge media and market attention toward the EVs industry and over 30.000 units were sold in the U.S. with over 40.000 units sold worldwide. Model S proved the world that the interest in EVs is rising and the main challenge is to accomplish the development of the whole ecosystem. However, after Model S there was another challenge to overcome: a product designed for everyone, with a low price that could definitely open the mass-market to Tesla Motors.

4.4.3 Model X and Model III

With the Model S satisficing the premium segment of Tesla Motors and its expansion toward the mass market, Tesla was looking for a brand-new vehicle to fully achieve the attention of the mass market. A family-friendly vehicle and an economic car had to be produced in order to accomplish this mission. Model X is the third vehicle produced by Tesla Motors, unveiled in 2012, which is expected to be derived for customers in 2015. It is a crossover utility vehicle (CUV) designed to be a SUV with minivan qualities. The idea behind Model X is the production of a family-friendly vehicle with the performances of a sport car. In order to do that, about 60% of the Model X is taken from the Model S to keep the design and the style of the luxury sedan vehicle produced by the company. The gull-wing doors provide a better access to the seven seats available in the car and a clear style to the vehicle. Tesla Model X takes the best from the Model S: a lithium-ion battery pack provided by the partnership with Panasonic and a double powertrain inserted between the front wheels and the back wheels. Using the same technology of the Model S in a bigger vehicle provide more space than ever with a more sporty interior compared to the Model S. The vehicle is expected to reach a range of 480km with one charge and over 15.000 units have been reserved.

Model III will be the fourth EV produced by Tesla Motors and its first economic car. With the Model X targeted to the last part of the market not yet satisfied by the Model S, the Model III aims to achieve the attention of the mass market. Not much has been said about this vehicle, but it will be most likely launched in 2017. With the technology development in the industry, there is now space to produce a vehicle with high performances but at lower price: Model III is expected to reach a range of 320km with one charge and the starting price will be most probably between $30.000 and $35.000.

4.4 Business Strategies

The key elements behinds the success of Tesla Motors are its precise business strategies. Tesla Motors built strong collaborations with most of the players in the industry to develop the best technologies and to learn as much as possible from the external environment. Its products followed a precise strategy: the Roadster was a high price vehicle to introduce EVs potential into the market, selling at low volumes. The Model S is a mid-high price vehicle selling at middle volumes with the Model X, a mid-price car, in order to increase the interest towards EVs and provide open solution to new customers. The Model III will be a low price vehicle selling at high volumes aimed towards mass-market to introduce a real daily substitute of gasoline-powered vehicles. However, it is not only about that. The business model of Tesla Motors is all about innovation, from its production methods to its products to reach that futuristic vision of an environmentally friendly mobility. In order to reduce the costs behind the production of Tesla's products, the company's factory is equipped with over 160 advanced robotic technologies. The Tesla Factory was formally known as NUMMI, a joint venture between General Motors and Toyota, acquired by Tesla Motors in 2010 after a partnership with Toyota. The robotic technologies are controlled by the employers and build the vehicle from the raw materials until the assembly phase. The factory can produce about 20.000 vehicles a year. However, the selling strategy of Tesla Motors is another interesting aspect. Tesla Motors started to sell its Roadster back in 2008 and they removed it from the market in 2012. Between the retirement of Roadster from the market and the release of the Model S, Tesla Motors had no real revenues. They started to sell the Model S before it was produced; this strategy is still active now. Tesla Motors takes reservations for its vehicles and requests a fee to be paid when the reservation is taken. This strategy provides revenues before the actual release of their products to be invested directly in the production of the vehicles. Besides that, this strategy was not enough to make real revenues especially during the global crisis of the last years, indeed, as has been said in paragraph 4.1, Tesla

Motors had real financial troubles in this period. In order to get out of that, Tesla Motors started to out licensing its technologies and sold part of its emission credits. Almost 10% of total revenues of Tesla Motors came from technology licensing while 7% came from emission credits: almost 20% of total revenues of Tesla Motors were not coming directly from its products. In addition, Tesla Motors does not sell its vehicles through common stores: Tesla vehicles can only be purchased by their website while they set up showrooms in the major malls. However, after the success of Tesla Model S, the main problems about the revenues were solved and the company had to face another major challenge: the development of the industry. As has been said, collaboration is the key point of this part of their strategy. Tesla Motors created partnerships with the major players in the industry from Panasonic to Daimler to build cross-industry relationships and boost the technological progress of EVs. The constant interest besides the design of its products, the luxury style of its vehicles, the rejection of selling its products through standard retailers, reminds to Apple Computer's strategy. In the last three years, Tesla Motors started to open its own Stores which are more likely showrooms since the potential customers are then directed to make their reservation online; each store have an unique design to fit the location where it is located. Tesla Motors acts as a first mover, constantly facing the industry challenges, who tries to set the standard in the industry through disruptive innovations but a real interesting point of their strategy, have been reached in 2014. Tesla Motors built strong networks, introduced fascinating products, developed advanced technologies to make EVs a reality but the development of the industry was not as fast as Tesla expected. In June 2014, Elon Musk opened all its patents to the rivals in order to boost the technological progress of its rivals to create a real competition, as we will analyse in-depth in paragraph 4.6. After that, Tesla had to build a strong network of chargers worldwide, introducing one of the biggest charging infrastructure ever made by an automotive company. Those ambitious programs provided Tesla Motors the attention needed to increase the interest towards the EV industry. However, there was still a main issue in the firm: increase the amount of vehicles produced per year while reducing the total costs of its production. This issue led to the project of the Gigafactory with the participation of Panasonic: a lithium-ion battery factory that can achieve a minimum cost reduction of 30% and supply the manufacture of 500.000 Tesla vehicles per year.

4.5 Partnership and collaborative networks

As has been said, Tesla Motors' strategy focus on collaborative networks and partnerships. Since its early days, Tesla always worked with other companies in the industry, licensed out its technologies in order to develop its competitive advantage and the overall industry. When companies collaborate and build networks, they try to learn as much as possible from their partners but it does not mean that they, equivalently, are willing to share as much of their knowledge. As we will see in the next paragraphs, Tesla's collaboration are somehow different from this "standard" concept. Tesla always tried to learn as much as possible through collaborations but they also shared as much knowledge to their partners. Indeed, Tesla always tried to be a leader of its industry, gaining competitive advantages through its strategy and more; but they also tried to develop the industry in the meanwhile by making its competitors stronger in order to increase the competition in the market. We will now cover the main partnerships built by Tesla Motors, chronologically, in order to understand how the company moved to reach its current points and how the collaboration strategies changed during the years.

4.5.1 The partnership with Lotus Cars

Back in 2005, Tesla Motors was still a "small" company trying to make its way through the EV industry where major players were developing prototypes, concepts and some early products. Tesla had to develop its first vehicle, the Roadster, but the company had no internal expertise in the production of the body and the chassis design of the vehicle. In addition, Tesla could not afford a real factory plant to produce its new vehicle. The company, mainly to break down its firm-specific barriers, started to look for another company to collaborate. Tesla set up a design competition to find a team to collaborate in the production design of its new vehicle's concept. The Lotus design team won. The collaboration between the two companies started with the design concept of the new Roadster. Lotus took almost 6% from its Lotus Elise: the aluminium frame, the windshield, mirrors, suspensions and the style of the roof. The reminder of the car like the frame, the powertrain or the technology, were unique to the Roadster designed by the Lotus team. Besides that, the Tesla's vehicle design still reminds to the Lotus Elise in most of its part. Indeed, Lotus is a well-known company in the sport-car industry and since the Roadster concept was a sport-car EV, Tesla could benefit from the safety systems and some of the technologies provided by Lotus. Many of those were unique elements that only Lotus could benefit through partnerships with its suppliers. Tesla had a huge benefit from this partnership, allowing them to build such an advanced vehicle in their early years. However, Tesla had another issue to face. The company did not have a real factory plant to produce enough chassis for its Roadster. Tesla Motors started to think about acquiring a new plant, but it was an huge investment for a new company especially considering that the market was not that big to provide high revenues or forecasts about sales. However, Lotus had a plant in UK that could fit the production rate of Tesla Roadsters and after an agreement, Lotus accepted to manufacture the chassis on a contract basis. In addition, Tesla Motors could benefit from the Lotus' supply chain. However, some controversies showed up. In 2009, almost 350 Roadster had to be retired from the market because there were some major technical problems in the chassis of the vehicle[46]. In addition, Lotus was clearly the stronger company in the partnership requesting major benefits in the agreement. Furthermore, Lotus started to collaborate with other major players in the industry to develop a new vehicle able to compete with the Roadster. In 2011, when the agreements between the two companies expired, Tesla Motors had enough knowledge and affluence to walk on its own: the agreements was not renewed.

Thus far, the collaboration could appear to have been successful mainly for Tesla. Actually, Lotus had interesting benefits from this partnership as well. The British company could access to the advanced technologies built by Tesla especially on the powertrain and could increase its credibility in the EV market. Indeed, Lotus is now collaborating with major players in the industry to develop new sport-car EVs. Besides that, Lotus had manufacturing capacity unused: by

[46] Jay Yarow; *"Tesla Recalls more than 75% of its Roadsters";* Business Insider; businessinsider.com; 2009

manufacturing the chassis for the Roadster, the company could retain part of the revenues from the Tesla's vehicle sales.

The partnership with Lotus was the first step of Tesla's collaborative strategy. The new company learned a lot and developed enough expertise to build the Model S. Besides that, Tesla was able to produce its own powertrain technology in Taiwan, one of the most advanced powertrain but there were major issue yet. Tesla's production costs were still too high to pierce the mass-market and constants production and delivery delays were spoiling the company's reputation. Tesla had to look at another partner to solve those issues.

4.5.2 Daimler

Tesla Motors had one of the most technology advanced powertrain and battery systems in the market but they had to produce a more affordable and open vehicle at lower costs. Daimler was looking for advanced technologies for its new EV products like the Smart EVs and Mercedes Benz E-Cell while Tesla was looking for more expertise to include in its new vehicle. Daimler and Tesla have been in talk since 2007 and only in 2009, the partnership was formally announced with the German manufacturer taking 10% stake in the American company. According to this partnership, Tesla became a real supplier to Daimler providing the powertrain for its Mercedes Benz E-Cell in 2010 and the battery packs with chargers for its Smart EVs. While helping Daimler to enter in the nascent industry, Tesla was guaranteeing itself a stronger position in the market: it was a strategic partnership. In the meanwhile, Tesla had the access to the technologies of Daimler, especially about brakes, suspensions and safety systems, but another key point for Tesla were Daimler's battery technologies. Indeed, even if Tesla was able to provide high-density batteries at lower weights, the battery is the main issue in the industry, as has been said. Daimler had a joint venture with Evonik, a leading German chemical company, and they were building a new battery technology that could be even better than Tesla's one. The project between the two companies was far from its completeness; this explains the reason behind Daimler choice to work with Tesla for its Smart EV's batteries. Besides that, Tesla could learn a lot from the German automotive company about this new technology. Both companies were benefiting from each other's know-how, while Tesla was increasing its credibility after the delivery and production delays and then improve its position in the market. In addition, Daimler working with its Mercedes vehicles had a lot of expertise in luxury sedan vehicles, which was obviously helpful to Tesla for its new Model S. Furthermore, the Daimler investment helped Tesla to get out from its financial troubles back in 2008; Elon Musk often claimed that the credit for saving Tesla should go to Daimler[47]. The partnership is still operative nowadays: Tesla provides its powertrains and batteries to Daimler EVs especially for the Smart brand, while Daimler owns 4.3% stake in Tesla.

4.5.3 Toyota

As has been said in chapter 2, Toyota is a leader in the EV industry with its hybrid model, the Toyota Prius, overselling every hybrid in the industry. Toyota production systems and engineering are famous worldwide: the Japanese company is one of the most innovative organization and one of the most interesting player in the automotive industry. Tesla Motors strategy is based on collaborations to take as much knowledge as possible from the outside, while Toyota was rapidly moving from its hybrid vehicles to EVs. Both companies could benefit from a collaboration. In 2010, Tesla Motors and Toyota announced a partnership and it is still one of the most significant collaborations of the American company. The partnership started with Toyota acquiring 3% stake in Tesla Motors. In mid-2010, Tesla Motors acquired part of NUMMI, a factory plant coming from a joint venture between Toyota and General Motors to solve its production issues. In June 2010, the partnership led to an agreement between the two parties to collaborate in the second generation of a SUV branded under Toyota Motors. The RAV4 EV is an electric SUV produced by Toyota in collaboration with Tesla Motors: Tesla provided the powertrain, the battery technologies, the software and the design of the technology arrangement into the chassis while Toyota built the remainder of the vehicle. The powertrain is an AC induction motor while the battery pack supplied by Tesla, is a lithium-ion battery pack with 4500 cells able to reach a range of 182Km. Tesla is famous to design its vehicles' chassis to leave as much free space as possible. The battery pack of

[47] Sebastian Bianco; *"Elon Musk: 'The Credit for Saving Tesla should go to Daimler'";* Autoblog; autoblog.com; 2012

the RAV4 EV is located in the lowest part of the vehicle where the lower centre of gravity provide a better roadworthiness. In addition, the powertrain technology provided by Tesla, allows the RAV4 EV to run in a “Sport Mode” with higher speed performances. The partnership allowed the Japanese company to enter strongly into the full-electric vehicle industry with advanced technologies while learning how to be flexible as Tesla. The American company, instead, had the access to a new production plant while learning the engineering of Toyota, their production systems, and it also became a real supplier for Toyota increasing its credibility and position in the market. Toyota was an important partner to Tesla, who made the Model S possible. As has been said, Tesla needed to decrease its production costs and increase its expertise: the new production plant and systems provided by Toyota allowed the American company to reach those results. Besides that, RAV4 EV sales were not high as expected while Tesla Motors was working in its new vehicle catalysing the media attention. In addition, some major clashes started to happen between the engineering teams of the two companies. However, the partnership is still active and Elon Musk often argued that he would love to continue the partnership with Toyota in the years to come[48]. Toyota is actually looking for new battery technologies in order to decrease the costs of its full electric vehicles; at the beginning, this could lead to a break in the partnership but the new ambitious program started by Tesla and Panasonic may be the key to provide new fuel in the partnership between Toyota and Tesla Motors.

4.5.4 Panasonic

In 2010, Tesla Motors had enough knowledge and capabilities to produce its Model S and deliver it to its consumers. The partnerships with Lotus, Daimler and Toyota provided Tesla all the expertise needed to become a major player in the industry and achieve lower costs to sell its vehicle for a more affordable price. Panasonic was a supplier to Tesla since 2009, providing its leading batteries’ technologies to the American company. However, Tesla was looking around to find a new technology to increase the maximum range achievable by EVs while reducing the overall cost, which is one of the higher in the production

[48] Bloomberg TV; *“Elon Musk: Tesla May Work With Toyota Again”;* Bloomberg; Bloomberg.com; 2014

of an EV. In 2010, Panasonic and Tesla formally announced their partnership with a Panasonic investment of $30 million in the American company. As has been said, Tesla wanted to boost the technology behind the battery pack provided by Panasonic to insert it in the Model S. In 2011, the two companies agreed in a R&D collaboration to develop a next-generation of battery cells. Indeed, Tesla was taking cells from multiple suppliers while Panasonic was the supplier of the lithium-ion cells. Meanwhile, Tesla was providing its expertise in battery packaging and technologies to other automotive companies as Toyota and Daimler, as has already been said. However, Tesla wanted a new technology to be incorporated in its Model S. Meanwhile, Panasonic developed special cells for EVs and Tesla could provide them enough expertise about the EV industry. Panasonic became the only supplier of cells for Tesla. The R&D agreement resulted in a nickel-type cathode technology optimized for EVs, which provided the highest energy density and the maximum range available in the industry, as we analysed in paragraph 4.4.2. In addition, the new cathode metal enables higher capacity without affecting the current charge voltage and it is not influenced by the fluctuations of the price of cobalt, normally used in the previous battery technologies, and the technology safety system inside the battery reduce the risk of fire. The agreement provided Tesla enough cells to build over 80.000 Model S in four years[49].

However, the partnership with Panasonic was beneficial for both companies and the Model S launch was a success. In 2013, the two companies continued this partnership achieving a new agreement: Panasonic expanded its supply to Tesla Motors providing 2 billion cells for the Model S and the Model X. The partnership between the two companies is actually the most important collaboration for the American company: as we will see later in this work, Panasonic and Tesla are working in the Gigafactory project to build a battery factory plant.

[49] Panasonic Official Announcement; *"Panasonic Enters Into Supply Agreement with Tesla Motors to Supply Automotive-Grade Battery Cell";* Panasonic official website; Panasonic.com

4.6 "All our patent are belong to you"

Nowadays, Tesla Motors appears as a major player in the industry. The Model S sales are increasing, its vehicles cover an important part of the most advanced technologies in the industry and its collaboration network is expanding day by day. Besides that, the vision of Elon Musk looks far yet. The industry is still small, considered as a niche and there is a full ecosystem to develop. In mid-2014, the company argued that the sales of its Model S were high and were increasing but still far from the expectations. Tesla is covering enough supplement to build over 500.000 vehicles but the demand does not surpass the 50.000 vehicles. A major shock was needed. In June 2014, Elon Musk announced on Tesla Motors' blog a new astonish decision to move a big step in the industry[50].

"Tesla Motors was created to accelerate the advent of sustainable transport. If we clear a path to the creation of compelling electric vehicles, but then lay intellectual property landmines behind us to inhibit others, we are acting in a manner contrary to that goal. Tesla will not initiate patent lawsuits against anyone who, in good faith, wants to use our technology." (Elon Musk, 2014)

According to this decision, Tesla Motors was opening all of its patents to the competitors. Orly Lobel, an author and University of San Diego law professor, analysed the patents opened by Tesla finding that the American company shared not only its patents about design, chassis and more, but everything about its technologies like the battery packages and the powertrain[51]. This is not a very new move. As we introduced in paragraph 3.5, this kind of behaviour was already used in the past by early day's industries to create more competition and develop the overall industry. However, this could be a smart move strategically but also a brilliant PR (Public Relations) move.

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[50] Elon Musk; *"All our Patent are Belong to you";* Tesla Official Blog; TeslaMotors.com; 2014
[51] Harvard Business Review; *"#HBRLive: Is Tesla's Patent Sharing a Good Idea?";* Harvard Business Review YouTube; *youtube.com; 2014*

4.6.1 Reasons behind this choice

*"Technology leadership is not defined by patents, which history has repeatedly shown to be small protection indeed against a determined competitor, but rather by the ability of a company to attract and motivate the world's most talented engineers. We believe that applying the open source philosophy to our patents will strengthen rather than diminish Tesla's position in this regard." (*Elon Musk, 2014*)*

The strategy of Tesla Motors about opening its patents may appear controversial, especially referring to the words used by Elon Musk in 2012, when he claimed *"Our business will be adversely affected if we are unable to protect our Intellectual Property Rights from unauthorized use or infringement by third parties".* Indeed, as has been said, a big part of the revenues produced by Tesla Motors came from the licensing technologies especially until 2013. In addition, the company always argued that their design, technologies and engineering capabilities, have enabled them to overcome the elements that normally limited the adoption of EVs. However, the vision on which the company is founded is far from the reality. Sales were not high as expected and the overall interest toward the industry is scarce yet. In addition, Elon Musk explained in his blog, his growing detachment from the patent system. According to the CEO of Tesla, the current status of patents involves complex legal systems and lawsuits with high costs that are barely affordable by a "small company". Furthermore, other companies can develop similar technologies independently and circumvent their patents. In today's world, where the economic progress is achieved through rapid innovations, and companies often innovate faster than what patents can cover, patents seem to only limit this process: the value to innovator of patents is decreasing over time. This argument is obviously not valid in every industry (pharmaceutical, for example), but it can clearly explain what is happening in many industries (especially IT).

The main point to understand, is that Tesla Motors is not competing with other electric vehicles manufacturers but with gasoline-powered vehicles. When you are at that point of an industry, in its early days, you have to look at cooperation with other manufacturers to set new standards, develop new technologies, reduce the overall costs behind the industry and develop the whole ecosystem with its infrastructure. At this point of an industry, there is only a little penalty, economically, on sharing technologies and not profiting from it, because the competition is not directly in your industry. The use of patents defensively to exclude your competitors, simply, does not make sense at this point. In addition, Tesla hopes to attract the best engineers into the industry and create a strong relationship between the company and other manufacturers. Indeed, Tesla will be the connection player between its patents and the real product; this may lead to create more collaborative networks, which are one of the strongest elements in the company's strategy. Furthermore, if other companies will use Tesla's technologies and knowledge, the company will set its own standards to the industry. Tesla seems to benefit way more from all the effects that its sharing patent strategy may create than a defensive use of its patents could have created. However, we can explain this strategy as a way to transform Tesla's weakness, mainly related to the overall industry, into strengths.

4.6.2 A different approach is possible

Estimating the results of this new Tesla's strategy can be complicated at this point, since it is a recent strategy. However, we can definitely understand how this approach may change the EV field. Other automotive manufacturers, right now, does not seem to be much interested in the EV industry: by sharing its patents, Tesla hopes that other manufacturers will increase their investments toward the industry, accelerating the innovation progress and reducing the major costs behind an EV, especially the batteries' costs. Tesla tried to design its vehicles to allow a fast changing of its batteries in order not to force its consumers to recharge it and increase the range of its vehicles. However, with the current costs behind a battery pack, this idea is not that applicable yet. In addition, Tesla is looking to create a collaborative network to accelerate the development of the industry. How this patent sharing strategy will influence the EV industry? BMW recently announced that they are opening up their patents related to battery cell technology developed in collaboration with Samsung

SDI[52]. According to BMW, the company hopes that more manufacturers will use their cells reducing the costs of the batteries; meanwhile, Samsung SDI hopes to increase its position in the automotive industry. Nissan was interested in the patent sharing of Tesla as well. According to the Japanese company, Nissan wants to participate[53] in the ambitious charging infrastructure project promoted by Tesla, which we will introduce in the next paragraph, but the companies use different charging connectors and technologies, especially on region-basis, while not all the EVs are compatible with the voltage of the superchargers that Tesla is building. Tesla and Nissan entered in talk with BMW to promote a technology compatible with all their EVs. Tesla seems to be setting the standard, as we introduced in the previous paragraph. Contrary to that[54], Honda argued that their technologies are ahead of Tesla's ones and there is no interest from them about the American company's portfolio. General Motors argued that they are not interested in the patents themselves, but mainly on the business model adopted by Tesla Motors to understand how it may influence the industry. As has been said, the decision adopted by the American company is too recent to find some results, but we consider the interest of Nissan and BMW, especially the last one who is considered a main rival to Tesla, as a first sign of the effects produced by the patents sharing. BMW is trying to collaborate and share its cells patents to reduce the costs of the batteries and create economy of scale, while Nissan is collaborating with Tesla to set a new standard. In addition, the whole matter is obviously providing a lot of visibility to the Model S manufacturer.

4.7 Charging infrastructure: a worldwide ambition

Tesla Motors perfectly knows that is not all about its products, but they have offer some high-quality services to its consumer to let them feel the presence of an ecosystem that can somehow support their choice to move from a gasoline-powered vehicle to an electric vehicle. In addition, its model S is designed to allow a fast battery swapping and this obviously need an infrastructure to allow

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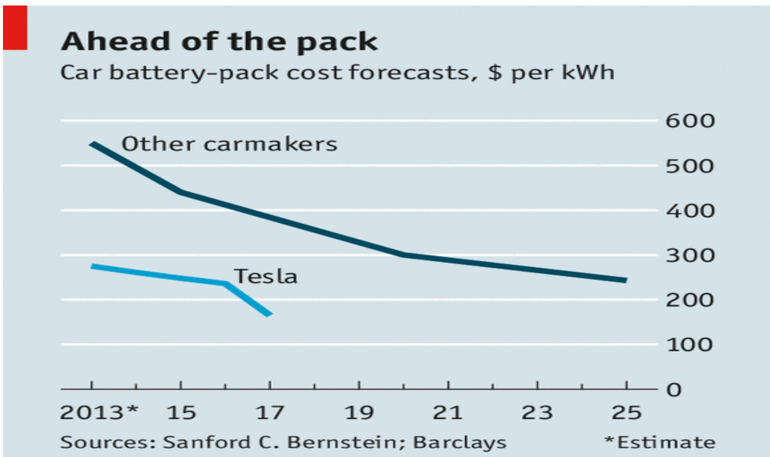
[52] Luca Ciferri; "*BMW Open to sharing battery technology with rivals";* Automotive News; autonews.com; 2014
[53] Trevor Collett; *"Nissan and BMW interested in Tesla's Patent-Sharing Invitation:Report";* The Motor Report; themorreport.com; 2014
[54] Sebastian Bianco; "*Automaker interest in open Tesla EV patents is decidedly lukewarm";* Autobloggreen; green.autoblog.com; 2014

that. Back in 2013, Tesla Motors planned a massive project to build a charging infrastructure worldwide by 2015[55]. According to this project, Tesla will cover 98% of U.S. population by 2015, a good part of Europe and the main cities of Asia. Today, 115 stations have been opened in North America, 71 stations in Europa and 23 in Asia. The stations will be equipped with superchargers able to recharge Tesla's batteries by 70% in less than 30 min (to not overload the cells the last 30% would take longer), while only a few are now equipped to allow a battery swapping. The superchargers provided by Tesla can recharge the vehicle faster than any other charger provided publicly by delivering DC power directly to the battery through special cables compatible with Tesla's models. The recharging service is free for Tesla's consumers while the battery swapping comes at a cost. The superchargers take energy through a solar panel provided by the Musk's company SolarCity. The project is also receiving public investments according to the energy policies in the U.S. One again, Tesla's technologies represent the state of the art in the industry, with the fastest technologies available publicly and with a massive coverage. However, Tesla's superchargers use a special connector compatible only with the Tesla Models. Tesla could probably profit by providing its recharging service to users who does not own a Tesla's vehicle under a small fee, but as we introduced in the previous paragraph, BMW, Nissan and Tesla entered in talk to build the charging infrastructure together and create a standard in the cables and the connectors. Nissan claimed that they welcomes any initiative to expand the volumes of the electric vehicles, while BMW argued that they are interested in the Tesla's commitment to the success of EVs and they would like to work together to make it a reality. This collaboration will probably be a crucial step to the vision of Elon Musk: BMW, Nissan and Tesla covers almost 80% of the EV market sales and the American company rapidly became the fourth player in the industry. We still do not know if recharging stations will be a field where the companies will compete, or where they will collaborate. However, building an ecosystem around the EVs will probably be the main challenge between the EV manufacturers, even before the competition, and the recent talks may be a sign that the companies are moving in this direction.

[55] http://www.teslamotors.com/supercharger

4.8 Tesla Gigafactory: an important step for the electric vehicle industry

At this point of this work, we moved through the history of Tesla Motors, from its first products, its collaborative networks and partnerships until its future projects. The company firstly tried to provide the best products in the industry to achieve the consumers' attention and now is rapidly moving to develop a whole ecosystem. In 2014, Tesla announced in collaboration with Panasonic, the construction of a battery factory, called Tesla Gigafactory, in Nevada, able to produce enough cells to supply 500.000 electric vehicles, and create 22.000 jobs with 6500 employees under an investment of $5 billion provided by Tesla, Panasonic and the public authorities. The factory will be powered completely by renewable energies with a surplus of 20%. Through economies of scale, Tesla expects to reduce the cost per-kilowatt of the lithium-ion car batteries by 30% in 2017 in order to reduce the price of batteries which is, as has been said, one of the highest behind the production of an electric vehicle. By 2020, the Gigafactory should produce more lithium-ion batteries in one year than the ones produced worldwide in 2013. This may help the battery swapping strategy that Tesla is trying to provide worldwide. In addition, as has been said, the Tesla's battery pack is based on enormous amount of cells compared to other EV manufacturers: an economy of scale on cells may help Tesla to provide the best technologies at lower prices. Tesla is already producing its batteries with Panasonic at a lower cost compared to other manufacturers, but this plant is expected to increase this gap.



Source: Sanford C. Bernstein; Barclays; image taken from an Economist Article; "Assault on Batteries"; economist.com; June 2014

As we introduced in chapter 2, most of the batteries are produced in Asia. The Gigafactory is not only a Tesla's project to achieve competitive advantage and build an ecosystem around EVs, but this is a macroeconomic shift bringing the highest volumes of batteries production in North America. Indeed, the project is expected to have an economic impact of approximately $100 billion over 20 years. We cannot know if these expectations will be attained but other companies will have to react somehow to this project. A massive switch of production is happening influencing not only the electric vehicle market but also the battery industry. Other battery manufacturers may try to jump aboard, but the other EV manufacturers will have to reduce their battery costs as well. With the Gigafactory, Tesla will be finally able to produce its electric vehicles for the mass-market by reducing the price without reducing the performances.

Conclusions

In this thesis, we tried to analyse the role of Open Innovation in the electric vehicle industry, through a general analysis of the collaborations and partnership in the industries and through a case study of the American company Tesla Motors. The electric vehicles industry is considered a niche industry yet, but the major global policies for the environment are providing an important boost to the attention that major automotive players are addressing toward this industry. We introduced an analysis about the whole EV industry, but we also addressed most of this work toward the American electric vehicle industry. In the first part of this thesis, we pointed out how a major shift is happening in the industry. In the last decade, the attention toward the EV industry is increasing year by year and companies are rapidly changing their business strategies. At the beginning, major players of this industry were mainly focusing on the development of the best technologies to satisfy the consumer's demand but also gain competitive advantage. However, we pointed out how companies are increasing their collaborative networks to introduce more advanced technologies in the industry. Indeed, the industry does not only need products with higher performances but also a whole ecosystem able to support the consumer in this shift from a standard mobility system to a new one. In addition, we pointed out how companies realizing that their major competition is not in the electric vehicle industry but in the gasoline-powered vehicle industry. With this background, this work can provide an answer to the questions introduced at the beginning of this work: how an Open Innovation approach influenced the industry until now and how it may influence the development of this industry? In chapter 3, we introduced some examples of collaborations, technology licensing, partnership and alliances in the industry. We found out that companies are increasing these of collaborations because they understood the importance behind the development of the whole ecosystem. The battery pack, which is the most important technology behind an electric vehicle and its costs, is one of the main issue that companies have to face. Indeed, the most important collaborative networks are created between the EV industry players and the battery industry players. Developing battery internally requests huge investments in R&D and expertise; consequently, companies prefer to create partnerships with the major players of this industry, especially to develop the best technologies in order to increase the range of their vehicles, which is one of the main issues for the consumers. We also introduced how companies are rapidly moving from NiMH batteries to lithium-ion batteries, able to provide a higher energy density and more security. Companies that provide lithium-ion batteries are benefiting from these collaborations and this shift by increasing their production volumes and their position in this industry. However, companies have to face another major issue, which is the charging infrastructure. In this paper, we pointed out how EV manufacturers are increasing their collaborations on this side of the industry to cover most of the territory. Building a charging infrastructure all by themselves can be a major investment and it is difficult to forecast the return of this investment in a developing industry. Companies prefer to share those risks with other players in order to provide the best service to their consumers. Within Chapter 3, we understood how an approach based on Open Innovation paradigm influenced the industry until now and how it is going to influence it in the future. Companies keep realizing year by year the importance of collaborations in a small industry that request such efforts to be developed, and we noticed that forms of collaboration almost doubled in the last ten years. Besides that, we could notice that companies does not seem open to share their patents or use them in a different way from a standard defensive application. At least, until Tesla Motors' decision to share its patents. In Chapter 4, we tried to bring a more empirical case to this study, introducing the American company Tesla Motors that based most of its development through a collaborative approach. With Tesla Motors, we tried to provide a better answer to the second part of our question, in order to understand how an approach based on Tesla Motors' strategies can influence the industry in the future. We found that the company, founded only in 2003, used a collaborative approach to develop the industry. The CEO of Tesla Motors, Elon Musk, realized the importance behind the development of the industry, and set up the company's business model not only to gain competitive advantage but also to achieve this goal. Sharing all the patents of Tesla Motors was a decision aimed not only to develop the industry by increasing the competition but also an attempt to bring other manufacturers to do the same thing. We pointed out how Nissan and BMW are now following this path. In addition, Tesla Motors is using collaborations with Panasonic and SolarCity to develop the Gigafactory, which will be able to reduce the costs behind a battery pack by 30% in the next years, and a worldwide charging infrastructure to cover the consumer's demand and allow the shift from a standard mobility through gasoline-powered vehicles to electric vehicles. According to this background, we think that the trend in the industry should be clear. Companies tried to gain competitive advantage in the industry through the standard business models used in the automotive industry, but in the last decade, they realized the importance behind the development of the whole ecosystem. Companies are increasing their collaborations to achieve this goal and we think this behaviour will increase in the next year, at least until the industry will be enough developed to recreate the standard models of a mature-stage industry.

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