THESIS WORK

Jorge A. Reyes A.

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Auto Industry’s Disruption and the Climate Change Issue:
How Electric & Traditional Vehicle Manufacturers are responding

Jorge A. Reyes A.
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Thesis Supervisor: András Tetenyi
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<table>
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<tr>
<th>ABBREVIATION</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>ADV</td>
<td>Autonomous Driving Vehicles</td>
</tr>
<tr>
<td>BEV</td>
<td>Battery Electric Vehicle</td>
</tr>
<tr>
<td>CCS</td>
<td>Carbon Capture &amp; Storage</td>
</tr>
<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>CL</td>
<td>Climate Change</td>
</tr>
<tr>
<td>CLI</td>
<td>Climate Change Issue</td>
</tr>
<tr>
<td>CO2</td>
<td>Carbon Dioxide</td>
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<tr>
<td>E2E</td>
<td>Everyone to Everyone Connectivity</td>
</tr>
<tr>
<td>E-Hailing</td>
<td>Electronic Hailing</td>
</tr>
<tr>
<td>E-Mobility</td>
<td>Electrified Mobility</td>
</tr>
<tr>
<td>EV</td>
<td>Electric Vehicle</td>
</tr>
<tr>
<td>EVM</td>
<td>Electric Vehicle Manufacturer</td>
</tr>
<tr>
<td>gCO2-eq/km</td>
<td>grams of equivalent Carbon Dioxide per kilometer</td>
</tr>
<tr>
<td>GHG</td>
<td>Green House Gas</td>
</tr>
<tr>
<td>GM</td>
<td>General Motors (US Auto maker)</td>
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<tr>
<td>GW</td>
<td>Global Warming</td>
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<tr>
<td>HEV</td>
<td>Hybrid Electric Vehicle</td>
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<tr>
<td>ICE</td>
<td>Internal Combustion Engine</td>
</tr>
<tr>
<td>ICEV</td>
<td>Internal Combustion Engine Vehicle</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel On Climate Change</td>
</tr>
<tr>
<td>kg</td>
<td>Kilo gram</td>
</tr>
<tr>
<td>km</td>
<td>Kilo meter</td>
</tr>
<tr>
<td>kWh</td>
<td>Kilo watt-Hour</td>
</tr>
<tr>
<td>LDV</td>
<td>Light Duty Vehicle</td>
</tr>
<tr>
<td>PHEV</td>
<td>Plug-in Hybrid Electric Vehicle</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>TTW</td>
<td>Tank-to-Wheels</td>
</tr>
<tr>
<td>TV</td>
<td>Traditional Vehicle</td>
</tr>
<tr>
<td>TVM</td>
<td>Traditional Vehicle Manufacturer</td>
</tr>
<tr>
<td>US</td>
<td>United States of America</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollar</td>
</tr>
<tr>
<td>WTT</td>
<td>Well-to-Tank</td>
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<tr>
<td>WTW</td>
<td>Well-to-Wheels</td>
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1. INTRODUCTION

The transport sector, specifically in this dissertation the automotive industry, has a significant potential to impact every aspect of human life. On the one hand, it helps humans to move from one location to another in a daily basis, whether it is local or international, and by any means of transport. Hence, there are incentives to improve this industry. This can be done by embracing Key Driving Forces (KDFs) that are currently increasing its efficiency and increasing the value added to users (McKinsey & Company, 2016). On the other hand, because of an increasing population and unsustainable lifestyles, the environment’s equilibrium has been affected and it will intensify even more in the future, which is the Climate Change issue (Azar, 2009; Stern, 2006). Therefore, these potential positive and negative impacts increase pressure to analyze and to commit to direct the industry towards a better system and reduced environmental impacts. This dissertation proposes a new way to perform this analysis by creating a framework and then by using it to evaluate relevant players in the industry.

In regards of the Climate Change Issue, it needs changes in the transport sector and its automotive industry. In particular, this industry has a great potential to reduce or to increase climate change through the level of emissions of Greenhouse Gases (GHG) (Azar, 2009; IPCC, 2014, Chapter 8; US EPA, 2017a). It depends of how the industry responds to outer stimulus. For example, new consumer preferences and the opportunity to integrate new and cleaner technologies in their propulsion and other systems. It has to be emphasized that the increasing population and economic growth increase concerns because it will translate to further GHG emissions due to new vehicles sold (Greene, Baker, & Plotkin, 2011). Hence, changes in the demand and supply side in the automotive industry are required as soon as possible to avoid climate change by reducing GHG emissions.

Moreover, the Climate Change Issue has been extensively studied from many years ago, with majority of scientific institutions, as for example the North American Space Station (NASA) and the Japanese Meteorological Agency, supporting it as imminent. Even more, it is said that 97% or more of active publishing scientist authors agree that the climate change is extremely likely to be caused by human activities (Cook et al., 2016; NASA, 2017). Furthermore, nowadays, there is real evidence of it as for example rising
sea levels, droughts, floods and Arctic sea loss (Stern, 2006). Therefore, there is a huge pressure like never before to set the “right” direction towards avoiding climate change. It is worth to mention that this pressure is one of the reasons of why this dissertation was done. High sense of social responsibility from the dissertation’s author to create awareness in readers and to guide them to explore some available options to reduce environmental impacts.

In regards of the Key Driving Forces that are shaping the automotive industry, they have been studied by many consultancy agencies, such as McKinsey & Company and KPMG, researchers and international institutions to determine the possible disruptions in the industry. The KDFs discussed in this dissertation are mainly new mobility business models, digitalization and connectivity, electrification or e-mobility and autonomous driving vehicle. Others are mentioned but the main research was done on these after an extensive selection process which is explained in Section 3.1.

The KDFs can be briefly summarized as, for example, the new mobility business models includes schemes like car or ride sharing which tends to lower car ownership but that helps to increase mobility in cities (Bouton, Knupfer, Mihov, & Swartz, 2015). Digitalization and connectivity of the car is creating a new form of adding value to users and increasing the possible revenues by using data and digital services (Beiker, Hansson, Suneson, & Uhl, 2016; Viereckl et al., 2016). Electrification or e-mobility, which are Electric Vehicles (EVs), are gaining consumer acceptance and is a viable option to reduce GHG emissions by replacing fossil fuels vehicles (Dijk, Orsato, & Kemp, 2013). Finally, the autonomous driving vehicle sets a major disruption by exerting more pressure to shift the paradigm from a product-based to a service-based mobility, in which vehicles drive themselves while they provide users the services they like (KPMG, 2016).

Regarding of what the automotive industry is doing, the focus is centered on the Traditional Vehicle Manufacturers (TVMs) and the Electric Vehicle Manufacturers (EVMs). As was said, EVs are currently taken as the most viable option to replace Traditional Vehicles (TVs) for the sake of lowering GHG emissions. The automotive industry has currently a 14% share of global emissions with some countries like the United States more than 25% of their total GHG emissions. These emissions are expected to grow significantly proportional to the increase of population (IPCC, 2014; US EPA, 2017a). Moreover, due to the fact that VMs create different business models depending
on their strategies and their reaction to implement services or products related to the KDF varies with the purchasing power of users (Bohnsack, Pinkse, & Kolk, 2014), then the luxury passenger vehicle segment of the industry was selected. The relevant VMs were BMW and Tesla Inc. which were carefully selected and is explained in Section 3.2.

Next, the research scope was delimited as follows. The transport sector consists of different modes of transport, but this dissertation analyzed the road mode of transport and specifically the luxury passenger segment of Light Duty Vehicles (LDV) of the global automotive industry addressing Electric and Traditional Manufacturers. Other options to choose from were aircraft, water ships and so on, but it was chosen this topic and scope because of the personal interest and professional experience in the automotive field by the dissertation’s author.

This dissertation seeks to address the following question: Are relevant EVMs in comparison with relevant TVMs, in the luxury segment, addressing better the Climate Change Issue through their responses to the main key driving forces that are changing the passenger segment of Light Duty Vehicles in the global automotive industry?. In order to answer this research question, facts were gathered about the Climate Change Issue, the KDFs and the VMs. These facts were analyzed and their relationships were established and then they were an input for the creation of a comprehensive framework which consists of a diagram block and a points-based system. This framework was then used to evaluate the current and potential responses of the chosen TVM and EVM to the KDFs that affect the Climate Change in order to establish which is performing better.

The research showed that there was not a direct link between KDFs, Climate Change impacts and VMs. Other studies were focused on the KDFs, others on Climate Change and others in sustainable business models. Nonetheless, the construction of the proposed framework was developed based on the material reviewed and some insights from the dissertation’s author. The framework is the gap which this dissertation is filling. It creates a powerful resource that can be used by companies in the industry to create dashboards and address weaknesses or strengthen their unique capabilities. It can also be used by policymakers to establish new standards or promote a particularly system or technology. Ultimately, the purpose of this study is to determine if TVMs lack commitment to accept change introduced by the KDFs and more importantly to avoid Climate Change based on the results obtained.
The research methodology is basically qualitative desk research from reliable online and offline sources in the academic field and technical field; from independent researchers, newspapers, relevant technology blogs and consultancy agencies. Research is done with a limited budget which is a limitation to get access to recent and reliable data. The detailed methodology is explained in Section 2.5.

This dissertation is divided into three main sections. The first section is the theoretical background which starts with the context in the Climate Change Issue and in technical matters in order to understand the research problem. Then, further background about differences between EVs and TVs. At last, a literature review in business models and strategies to provide for the VMs selection subsection. The second section is the central topic which is divided into four subsections. Firstly and secondly, the selection of the KDFs and of the key players. Thirdly, the creation of the framework. Fourthly and fifthly, the findings of the created framework and its evaluation of VMs are shown, then they are discussed. The third and last section are the conclusions and recommendations. After this, the appendix and references can be found.
2. THEORETICAL BACKGROUND

2.1. CLIMATE CHANGE

In the past few years the Climate Change Issue has become very relevant and it can be easily evidenced around the world. To begin, it can be mentioned the abnormal sea surface temperatures higher than average up to +5 °C in the Arctic in 2014 (NSIDC, 2014), big chunks of ice coming off in the Antarctica caused by warm ocean waters (Palazzo, 2017; University of East Anglia, 2017), abnormal droughts and floods reported around the world and several other issues like this can be listed. Recently, just at the end of 2016 it was reported that the current Carbon Dioxide (CO2) greenhouse gas level in the atmosphere measured by then marked a “new era” in the world’s changing climate (McGrath, 2016).

In order to continue, this dissertation answers first the question: from when became CO2 the cause of the Climate Change Issue and what is the relationship with the automotive industry? There is the need to explain climate change’s root causes and the relationship with evidence found so far. Only then the relationship with the automotive industry is given in the end of this sub-section (Section 2.1.3).

Two key definitions have to be understood: global warming and climate change. The first one, as defined by EPA (United States Environmental Protection Agency) it is the current increase of global average temperature on Earth’s surface which is produced by GHG gases in the atmosphere. This warming is causing the global climate to change. However, global warming is only considered one aspect of the Climate Change Issue (US EPA, 2017b). The important new point here is to highlight that the global warming is only one part of climate change’s issue. There is the common belief that the global warming is the main issue but it is not.

On the second definition, a definition of Climate Change is given also by EPA, which refers to “any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer” (US EPA, 2017b). Altogether, it has to be said that the climate is the sum of complex ongoing processes like ocean temperature, ground temperature, moisture, and
other key variables. In particular, again, GHG emissions in the atmosphere are responsible for increasing the global average temperature.

Still, the question made about the role of CO2 in Climate Change has not been answered. If history is reviewed, there are crucial evidences that in the past there were changes in climate induced by greenhouse gases. For instance, there is several experimental data connecting climate change with the accumulation of greenhouse gases. There is evidence using indirect methods which is used by scientists in Antarctica in which they drill into the ice to get the concentration of carbon dioxide (CO2) in the bubbles found in the ice. The result was that 10.000 years ago the concentration was 280 parts per million (ppm) until the industrial revolution in the first half of the 19th century, from which the levels started to rise significantly with others greenhouse gases like methane and nitrous oxide (Azar, 2009). This is also evidenced by different sources as for example the North American Space Agency (NASA) which reported that in the past ice ages the CO2 concentration was approximately 200 ppm and during warm cycles it fluctuated around 280 ppm (see Figure 5-1), and that recently in 2013 it peaked more than 400 ppm which demonstrates the capacity of human effects to modify the Earth’s climate (National Oceanic and Atmospheric Administration as cited by NASA, 2013). The latter value was only measured at some point in Hawaii for a brief time. However, it was until the 2015 that the average global concentration surpassed the 400 ppm. Then, in 2016 it “surged to new records” and in early 2017 the year 2016 was confirmed to be the hottest year on record with 1.1 °C above the pre-industrial era (BBC News, 2015; WMO, 2016, 2017). Therefore, there is a connection between greenhouse gases increase, specifically CO2, and global average surface temperature increase.

2.1.1. THE BRIEF DESCRIPTION OF THE PROBLEM

In this subsection, it is explain why the atmosphere is so important and why the greenhouse gases are so important to maintain life on earth through the natural greenhouse effect and finally the connection between climate change and the automotive industry.

The atmosphere traps the energy provided by the sun of our solar system. This method is one of the important mechanisms to trap the incoming energy. It is the natural greenhouse effect. The way it works is that the sun emits vast amounts of energy in all
directions. It is said to be a million times the yearly power consumption of the United States per second (Cox, B. as cited by Kendall, 2010). Moreover, it is said that from that energy only a fraction reaches the Earth and from that approximately 30% is reflected outwards back into space by clouds, ice and deserts and the rest is the amount which warms its surface, oceans and atmosphere. Furthermore, in the 19th century the greenhouse effect was discovered and had water vapor and carbon dioxide as the most important (Azar, 2009). Here, it is important to highlight the importance of the greenhouse gases in the atmosphere because they maintain warm the planet. If temperature was critically low, there would not be life on the Earth; if critically high, no life again. Hence, the so-called natural greenhouse effect helps to create the conditions to keep life on the Earth. The Climate Change Issue arises when their concentrations are high.

In terms of the problem of “too much” greenhouse gases, the basis is that in addition to the natural greenhouse effect there is a human effect which is increasing significantly to critical levels. Therefore, this human effect is affecting balance of the natural effect and is the root cause of climate change. In other words, NASA said that the planet is on a transition to a new geologic era which it is called the “Anthropocene”; in which the current and future climate cannot be predicted from what was learned in the past and it is caused by greenhouse gases due to human activity (NASA, 2013; Salawitch, Bennett, Hope, Tribett, & Canty, 2017).

Although there are others greenhouse gases which are listed later, CO2 nowadays poses the biggest threat. The problem is that levels of CO2 are increasing in the atmosphere partly because of the use of fossil fuels (e.g. coal, oil and natural gas). In 2009, the levels of CO2 were 385 ppm which was 35% higher than before the industrial revolution 280 ppm (Azar, 2009). Now, as was previously said, in 2016 the global average CO2 concentration was the highest above 400 ppm.

To illustrate it, an amount of 385ppm found in 2009 levels, “it corresponds to roughly 6 kilograms of CO2 on top of every square meter of the surface of the Earth” or in other terms if the CO2 gas were at surface pressure it corresponds to a 3 meter thick layer wrapping the Earth (Azar, 2009, p. 4). In other words, the term parts per million or ppm is simply, without involving chemistry terms, the relationship of CO2 molecules with the molecules found in the atmosphere. At the current levels, it is 400 CO2’s molecules in
every million molecules found in the atmosphere (McGrath, 2016; NOAA, 2009). Then the term ppm is a concentration measurement, and it indicates the amount of CO2 in the atmosphere. The more of it in the atmosphere, the more heat is trapped on the Earth.

Among the most important greenhouse gases it is found, in order of importance, the water vapor, CO2, methane, nitrous oxide and ozone. These help to trap heat as was already mentioned. They have increased as shown in Figure 5-2 (IPCC, 2014; Salawitch et al., 2017). They are produced/absorbed naturally and also produced by human activities (US EPA, 2017a), but nowadays the balance has been broken and anthropogenic emissions, i.e. emissions produced by human activities, have surpassed the natural capacity to regulate GHG to “normal” levels (Salawitch et al., 2017). Nevertheless, oceans and lands (terrestrial ecosystems) are absorbing human emissions but its efficiency is decreasing (Salawitch et al., 2017). Moreover, others argue that in the future terrestrial ecosystems will emit more than all the carbon emitted by the most relevant countries combined (Hadley centre study as cited by Azar, 2009). Hence, anthropogenic emissions needs to be reduced.

2.1.2. POTENTIAL CONSEQUENCES

After understanding the greenhouse gases effects on climate change there are ongoing and potential consequences. They are for sure not good for any living being on the Earth, indeed. The Earth is facing multiple changes. For instance, sea level rose 17 cm last century and is currently rising at nearly double the rate of the last century. Global temperature is rising as was already mentioned and is more than 1°C above pre-industrial average value. Oceans are warming because have absorbed the increase in temperature. Shrinking ice sheets where severe ice loss in many glaciers is evidenced. Decreasing Artic sea ice, which as a personal experience, the author evidenced this change while flying over the heavily fractured Artic ice sheets from New York to Shanghai in 2014 and later realized that during that time the Artic sea ice reached a minimum extent and there were higher than normal sea surface temperatures as reported by NSIDC (National Snow & Ice Data Center) (NSIDC, 2014). Glacial retreats almost anywhere in the world and decreased snow cover. Extreme events as droughts and floods. Finally, ocean acidification is due to the absorption of CO2 and its acidity has increased compared with pre-industrial
revolution levels. All these consequences have been reported and have evidence of their existence (Balog, 2014; NASA, 2011; NSIDC, 2014).

In addition, more problems can come through, the heating of oceans will occur more rapidly when the sea ice melts because ocean will be exposed to sun light and later the oceans will heat the atmosphere; this is what is called the *polar amplification* which states that 2°C increase in global average temperature could result in 4 to 5°C increase over the Artic (Azar, 2009).

In order conclude this subsection of climate change there is a final definition which is climate sensitivity. Climate models are very complex and are still to be refined. These are used to calculate climate sensitivity, which states the amount of increase in average surface temperature by doubling the CO2 concentration in the atmosphere. If low (+1.5°C) it is possible to stabilize CO2 below 600 ppm and if high (+4.5°C) there is the need to decrease CO2 levels to 350 ppm or below this value (Caldeira, Ken, et al as cited by Azar, 2009). The main challenge here is that population is increasing and therefore energy demand is increasing and there is the need to cut emissions (Azar, 2009).

### 2.1.3. CLIMATE CHANGE AND THIS DISSERTATION

This dissertation creates the link between the Key Driving Forces that are disrupting the climate change, the actions of VMs and the Climate Change Issue. The research shows that the link emerges from the greenhouse gases emitted by the automotive industry. Hence, the task of this dissertation is to determine how the emissions can be impacted through the KDFs. So that the Climate Change Issue is solved.

It is worth mentioning, that this link continues to aggravate because the rate of growth of these emissions is really high. For example, in the terms of global GHG emissions for 2010 the IPCC reported a value of 14% of the total value (IPCC, 2014; US EPA, 2017a). Meanwhile, in the United States the GHG emissions for 2014 was 26% of the total value in the country (US EPA, 2017c). With this it is shown the potential of reducing GHG if mitigation measures are set in the industry, for now this is sufficient evidence to prove relevance.
2.2. GREEN HOUSE GASES MITIGATION AND VEHICLES

2.2.1. ENERGY PRIMER

It is important to realize how the energy supply is generated, whether it is Traditional Vehicles (TVs) or Electric Vehicles (EVs). The importance of energy systems is that they are the biggest contributor in GHG. It is said that in 2010 the energy supply was the largest contributor of anthropogenic emissions globally with a value corresponding to approximately 35% of the total global value by. This energy supply, as given by the IPCC report, consists of energy extraction, conversion, storage, transmission and distribution processes until it gets to end-users. It is said that this emissions were caused by a rapid economic growth and an increase in the use of coal as fuel (IPCC, 2014, Chapter 7). Furthermore, it is also important to mention that there is a significant amount of energy wasted in the processes of generation, transmission and distribution of electricity; in which, for instance, the electricity generation stage can waste 62% of the primary input energy in modern thermal power stations (Azar, 2012). The key points to remember in this topic is that there is a big opportunity in increasing efficiency in electricity generation which would reduce the energy consumption and therefore the GHG emissions. Moreover, if economic growth continue to increase the demand for energy will also increase, and more fossil fuels are going to be needed at least in the short-term(IPCC, 2014, Chapter 7).

2.2.2. GHG IN TRANSPORT SECTOR AND ROAD VEHICLES

On the transport sector, the GHG emissions are said to have doubled since 1970 and have the fastest rate than any other energy end-use sector; approximately 80% of this increase comes from road vehicles ; and again there is the issue of efficiency in which the final value from fuel to kinetic energy is 32% for freight and passengers with heat losses the largest of total losses (IPCC, 2014, Chapter 8). Similarly, another source states that due to the high auto sales there will be also high GHG emissions concentrated largely in the developing world. It also adds that world’s auto fleet went from 50 million vehicles in 1950 to 580 million vehicles in 1997 which is said to be 5 times faster than the growth in population. It also gives the example of China that went from 700,000 vehicles sold in 2001 to be the largest in domestic sales with 13 million sales per year in 2010 (Barker, et
al. and BBC News as cited by Greene et al., 2011). Moreover, other authors take China as a factor that will change the automotive industry because of the volume of vehicles sales (cars & trucks) would reach 30 million vehicles sold in China per year by 2020 (IHS Automotive as cited by Paul Gao, Russell Hensley, & Andreas Zielke, 2014). In addition, Vanek et al. states that in 2005 passenger cars were the largest in GHG emissions in the United States (Vanek, Angenent, Banks, Daziano, & Turnquist, 2014). Hence, one can see the great concern about the potential negative effects of this industry. It has been a problem in the past, but it is expected to aggravate in the future.

2.2.3. HISTORY OF TRADITIONAL AND ELECTRIC VEHICLES MANUFACTURERS

It is difficult for the recent generations to establish which technology was first, was it the Electric Vehicles (EVs)? Or the Traditional vehicles (TVs) named also the Internal Combustion Engine (ICE) vehicles? To be able to answer this question there is the need to look back in history and see what actually happened. This research on the history gives understanding about what happened then and what applies for today’s technological change from TVs to EVs.

For an average tech-savvy person, there might be the misbelief that ICE vehicles were first and the EVs are only a recent trend that is taking force. In fact, when reviewing the history, it is found that EVs came first and then the TVs or ICE vehicles (gasoline) came later. EVs were born from two major inventions. It is said that first the invention of the battery by Volta in 1800 and then the discovery of Faraday’s law in early 1830s gave a big push to invent applications for the electric motor. Moreover, there are several theories about who made the first experiment, it is told not to be clear. However it is indicated that a monk named Jedlik Ányos of Hungary created in 1828 an electric motor and afterwards a model electric vehicle which it is said to be operated. Other experiments are said to come later in different countries including Scotland, the Netherlands and the United States. (Morimoto, 2015, pp. 31–33).

Further development of EVs started with the invention of the rechargeable lead battery in 1859 by Gaston Plante of France and later with the improvements made by Camille Alphonse Faure in 1881. The latter is said to be the practical lead battery which led to the
practical EV. It was in the same year, 1881, when the first chargeable electric vehicle was shown made by Gustave Trouvé of France. And later, in 1882, William Ayrton and John Perry of England created the first “true electric car” with a top speed of 9 miles per hour and electric range of 10 miles to 25 miles (Morimoto, 2015, p. 33).

In contrast, the first gasoline-fueled ICE was built in 1876, then Carl Benz began the commercial production of ICE vehicles in 1886 and by the 1890s they were significant developed as comparable for modern level of development (Melosi, 2004).

The last decade of the 19th century and the beginning decade of the 20th century were a battleground of transportation technologies for the establishment as the standard technology. Many authors tells about this and make their statements about why the EVs failed to establish as the standard technology.

For instance, David Kirsch tells that during the major developments of the ICE vehicle, EVs lacked the needed developments to establish as the standard. It is said that there was a decade of delay and that it was possible to have a different story nowadays if promotion agencies like the Electric Vehicle Association of the Americas (EVAA) were created in 1898 instead of 1908 (Kirsch, 1997).

Authors tell that in 1900 to 1910 there were thousands of electric vehicles in London and the United States, but later were displaced by the gasoline-powered ICE vehicles for numerous reasons collected from other authors as for example the superior range and power by the ICE vehicles and from the EVs the technical problems of electric engines, their low energy density, higher manufacturing costs, lack of charging infrastructure and their relatively short range (Ivory & Genus, 2010; Kirsch, 1997; Melosi, 2004). Moreover, it is said that the emerging car culture benefited demand for ICE vehicles and affected negatively the EVs. The ongoing car culture of the time had the cars as a means of travel for pleasure, object of class distinction, masculinity and as an adventure machine. Finally, it is concluded that EVs were a symbol of modernity, practicality, rationalism and wealth but lack the masculinity which left it out from the ongoing consumption preferences (Ivory & Genus, 2010).


2.2.4. CLASSIFICATION OF TRADITIONAL AND NEWEST VEHICLES

Before the reader goes further into this dissertation it is necessary to get into the EVs and TVs topic. It is of high importance to know the terms used in the industry. To be clear enough, as Vanek et al. defines it, in transport or transportation systems the objective is to provide a transport service which is to move people or goods and it has building blocks as vehicles, infrastructure, equipment, power systems, fuel supply systems and control systems. Also important for this dissertation is to understand the ways of categorizing it by function (passenger or freight), modes (road, rail, water, air or pipeline) and ownership (private or commercial) (Vanek et al., 2014). In the latter, as has been said before, this dissertation will focus in passenger, road and both private and commercial in the LDVs, respectively.

When starting to talk about electric vehicles (EVs), at the moment of writing this part of the dissertation, there are many nomenclatures to the type of vehicles. Here it is stated the one used on this document based on the more relevant, reliable sources which agree with the experience of the dissertation’s author. EVs are those which have in their electric powertrain drive (i.e. components from the source of power until it is delivered to the road) an electric motor.

EVs are categorized as Hybrid Electric Vehicle (HEV), Plug-in Hybrid Electric Vehicle (PHEV) and Battery Electric Vehicles (BEV). HEV includes an Internal Combustion Engine (ICE) and an electric motor, but the main is the ICE and the battery for the electric motor is small and cannot be charged from exterior. PHEV or Extended Range Electric Vehicle (EREV as GM calls the Chevy Volt 2010), also has an ICE engine and an electric motor but this time the ICE has smaller power output than in HEV and the electric range is superior and can be plugged into an exterior electric power source. Battery Electric Vehicles (BEV) or All-Electric Vehicles (AEV), have a large battery capacity that feeds the motor and batteries and are charged by plugging it into an exterior power source (Hao, Wang, Zhou, Wang, & Ouyang, 2015; US Department of Energy, 2016).

2.2.5. THE VEHICULAR EMISSIONS PROBLEM

There is a major discussion about whether which type of vehicles are better in terms of the environmental impacts and this is analyzed using a powerful known tool called the
Life Cycle Analysis (LCA). This tool can be used to determine the environmental impacts from the production of the vehicle, energy used, sources of fuels until the disposal of the vehicle. This could include not only GHG emissions but other variables like energy used, other pollutants and other impacts.

The LCA is better diagramed as shown in the Figure 5-3. It shows six stages or phases in which environmental impacts are assessed. Firstly, is the well-to-tank (WTT), used in the fossil fuels propelled vehicles or in EVs if electricity supply comes from fossil fuels. Secondly, the production or manufacturing, used by any vehicle. Thirdly, the maintenance and infrastructure, used by any vehicle e.g. charging stations or supply of fossil fuels. Fifthly, the use of vehicle or tank-to-wheels (TTW), which is associated to the direct emissions of the vehicle. It is worth mentioning that in this stage EVs are nearly-zero or zero GHG emissions. Sixthly and lastly, the disposal or end-of-life, that includes all types of activities as recycling, etc. (Messagie, Macharis, & Mierlo, 2013). This is a powerful tool but it is a very sensitive one that can lead to very different results, as it will be discussed next.

There are different approaches, assumptions, goals and scopes that lead to different results in LCA. Some LCA studies are reported to have a spread in their results that are said to be explained by uncertainty in the source of the energy supply, the energy consumption, the production of the battery and the vehicle (Messagie et al., 2013; Tagliaferri et al., 2016). For example, very few studies are detailed and account the entire life cycle of vehicles (Notter et al. & Hawkins et al. as cited by Tagliaferri et al., 2016) and others do not provide detailed description or focus only in some stages of the life cycle. There is also a consensus on the literature review that the true potential of BEV is shown when energy supply comes from renewable sources, but if it comes from coal or inefficient plants it could be worse than TVs (Azar, 2009; Helmers & Marx, 2012; Messagie et al., 2013; Tagliaferri et al., 2016).

Prior to the literature review it was the belief of the dissertation’s author that EVs were far better or at least the same level of emissions of TVs in the manufacturing or production phase. Instead, the literature review has shown that although BEVs are near-zero GHG emissions in the use stage, the manufacturing stage actually is a weakness in comparison with TVs. In particular, it is said that BEVs’ manufacturing phase is almost double that
of the TVs. This weakness is in part from the battery manufacturing process and its complex powertrain system. Nevertheless, the BEVs were found to be the best option to reduce emissions where electricity supply mixture was cleaner and efficient (Helmers & Marx, 2012; Messagie et al., 2013; Tagliaferri et al., 2016).

2.3. COMPARISON OF EVMS AND TVMS

This section will give further understanding about how the EVs and TVs stands in GHG emissions, primary energy supply problem, infrastructure and fuel energy density, that will expand the technical challenges of each one.

2.3.1. GHG EMISSIONS IN EVS AND TVS

It is worth to emphasize that in regards of GHG emissions one may be careful when comparing values obtained from different sources because they differ in the assumptions, methods or conditions to calculate or measure the results. For instance, it is said that once, a particular study put emissions from diesel vehicles 10% to 27% lower than gasoline vehicles but when analyzing the study its model used to calculate emissions did not use the actual vehicle size preferred and extensively used by consumers (Sullivan et al. as cited in Helmers & Marx, 2012). The latter is an example how the available data can be misleading. Moreover, another concern is that TVMs can manipulate emissions measurements by introducing software developments which improve emissions performance temporarily during measurements giving a better-than-actual emission levels. For instance, the Volkswagen scandal in 2015 (NYTIMES, 2015).

In order to get a specific perception of the levels of CO2 emissions, one can review an interesting academic article which dealt not only with CO2 emissions but with other environmental impacts that are not under scope of this dissertation. In this article, with the vehicles used and its assumptions, the emissions for the vehicle production phase were estimated. CO2 emissions for EVs were 87 to 95 gCO2-eq/km, with battery production accounting 35 to 41%, electric motor 7 to 8% and other passive battery cooling systems made of aluminum 16 to 18%. For TVs CO2 emissions were 43 gCO2-eq/km. Next, for calculating the Total life cycle potential emissions, the emissions of the vehicle use phase were trickier to review because of the electricity source mix in energy supply; this is the
sources shares in production of electricity, which is discussed in section 2.3.2. In the end, it is told that for EVs depending on the used Lithium-ion battery technology and assuming same life time as TVs, the total life cycle emissions could be between 197 to 206 gCO2-eq/km and for TVs would be 20 to 24% more using the electricity European mixture (Hawkins, Singh, Majeau-Bettez, & Strømman, 2013).

2.3.2. PRIMARY ENERGY SUPPLY MIXTURE

The GHG emissions depends on what primary sources are used specifically for EVs is how the electricity is produced. For EVs the more renewable sources are used, the better. By primary energy supply, it is clearly diagramed by the IPCC as can be found in Figure 5-4, where the sources are crude oil, coal, natural gas, nuclear energy, hydro power, geothermal energy, wind energy, solar energy and bioenergy. Moreover, one may not confuse energy supply with electricity supply. Electricity, as a secondary supply, has its inputs from the primary sources that has just been mentioned and it is produced by electric power stations, nuclear power plants, hydro power plants, geothermal power plants, wind energy conversion, solar power plant and bio energy power station (IPCC, 2014, Chapter 7).

In these spirits, in order to see that the benefits of EVs are expected to increase in the future, one can review trends in statistics referred to total energy supply and electricity production. For example, the International Energy Agency (IEA), in its key world energy statistics report 2016 (IEA, 2016) summarized in Table 5-1, shows that from 1973 to 2014 there was a decrease in the use of fossil fuels in the total energy supply and, more importantly, in the electricity generation. In total energy supply it decreased from around 86% to 81% and in the electricity supply it suffered a greater drop from 75% to 66%. This electricity supply trend aids the EVs to increase their benefits because fossil fuels has been displaced by renewable sources, nuclear and hydro power. Nuclear and hydro power, although they are not considered a renewable source due to its externalities, e.g nuclear waste and ecology impacts, respectively, they can also benefit the EVs. Altogether, there is the concern about how these shares in the total energy and electricity supply will behave in the future for fossil fuels and renewable energies. This issue is discussed below.
In regards of fossil fuels, its share in the energy supply is expected to decline. The so-called “peak oil” from conventional fossil fuels denotes scarcity given the current rate of consumption and its reserves (estimated proven quantities). This scarcity is putting pressure to look for new sources in order to increase energy security (Vanek, Louis D. Albright, & Largus T. Angenent, 2016). Some argue that the peak has been passed, it is imminent or should happen after two decades (Hook et al., Owen et al., Sorrell et al., IEA, Sorrell et al. as cited by IPCC, 2014). Similarly, others also tell that conventional oil reserves are running low and it is said that there is an ongoing oil transition. For current transport, there is the need for liquid fuels. In order to continue its supply other fossil fuels as unconventional oil, which are fossil-based liquid hydrocarbons, are being used. The latter are called unconventional petroleum. These are the result of production, as for example, from heavy oil or tar sands; synthetic crude oil extracted from oil shale; and synthetic liquid fuels, which are typically produced from natural gas or coal. There are currently reserves and a large amount of resources (estimated quantity yet to be proven) which are larger than the resources of conventional oil. To extract these more investment and more energy input is required and therefore will induced more negative impacts for the climate change (Azar, 2009; Farrell & Brandt, 2006; IPCC, 2014, Chapter 7; Vanek et al., 2016). Hence, this create incentives to switch from TVs to EVs as soon as possible.

In regards of renewable sources of energy, its share in the energy supply is expected to grow in the upcoming years. The IPCC concludes that the aggregated global technical potential for renewable energies is far above the global energy demands; which basically indicates that use of these sources is feasible based on their limitations as its system performance, land use, or any environmental constraint. It is also said that there are other problems besides technical issues that can affect the deployment like economic factors, public acceptance, environmental concerns and system integration (IPCC, 2014). Nevertheless, there is consensus that in order to mitigate climate change, the electricity sector must decarbonize electricity generation, let use the fossil fuel directly by end-users (buildings, industry and transport fuels partially) and reduce energy demand using technology (efficiency)(Azar, 2009; IPCC, 2014). Others add that, regardless of local impacts, fossil fuels can use Carbon Capture and Storage (CCS) techniques to make them cleaner in the future (Vanek et al., 2016). Altogether, for EVs
the best scenario is one that increases the share of low-emissions sources (Azar, 2009; Hawkins et al., 2013; Helmers & Marx, 2012; Messagie et al., 2013) and I strongly support this scenario because the long term risk of CCS are unknown as they are simply putting the GHG in emptied oil wells that can easily get to the atmosphere.

To sum, on the one hand, the fossil fuel industry is extending their business to new and unconventional fossil fuels, which would be in the end worse, but on the other hand there are new technologies which are from renewable sources that are clean with their own challenges. Nevertheless, despite the benefits of EVs and a cleaner electricity supply trend. Fossil fuels will continue to have a relatively larger share than renewable and low-energy sources. This transition cannot happen suddenly. For instance, a relevant report from the U.S. Energy Information Administration indicates that by 2040 shares for coal, natural gas and renewable sources would be around 28-29% of world’s total net electricity generation (U.S. Energy Information Administration, 2016).

2.3.3. INFRASTRUCTURE

There is the need to understand that both technologies of EVs and TVs are different. On the one hand, EVs are charged and require infrastructure which needs distributed chargers so that vehicles can use it throughout urban and rural areas. On the other hand, TVs have experimented a century of development and therefore there is a fuel station almost everywhere as the reader may have already noticed. Undoubtedly, this represents a challenge for EVs. Nonetheless, many EVMs have started efforts to create standards for the chargers and moreover to extend the number of chargers in urban and rural areas. For instance, Tesla, a popular EVM, had introduced and is working on its superchargers network which are carefully located upon customer needs with 828 stations with 5339 superchargers globally (Tesla, 2017j).

2.3.4. ENERGY DENSITY OF FUELS AND BATTERIES

TVs have the advantage that fossil fuels have more energy density than its counterpart the batteries from the EVs. Energy density means more stored energy per weight or per volume of the fuel or battery. In units, that is kilowatt-hour (kWh) per kg or per cubic meter, respectively (Vanek et al., 2014). In other words, a practical example can be used to understand what this means using approximate weights of storage systems. A compact
TV in 2011 could travel around 500 km (on specific conditions as fuel consumption, hilly or flat roads, etc) with an approximately 40 kg and more than 300 kWh tank full of gasoline, which corresponds to 12.5 km per kg or 7.5 kWh per kg. Whereas the Chevy Volt 2010, an PHEV (or EREV by GM), could only travel nearly 60 km with a “T” shape, 200 kg and 16kWh battery which took up a large space leaving space for only two passengers in the back seat; which corresponds to 0.3 km per kg or 0.08 kWh per kg.

Nevertheless, despite the low energy density, the urban performance of the Chevy Volt was excellent due to there was no need to use the ICE due to the fact that commutation workplace-home-workplace was less than 60 km and for longer distances the ICE activated to feed the main electric motor through a generator, as experimented by the author of this dissertation in a former job as a Validation Engineer. In regards of EVs in general, nowadays, energy density of batteries has improved but it is worth to express that further developments are needed for the EVs to displace TVs for long distance traveling.

The battery is one of the critical components of the EVs; without it there would be no energy available to create movement. It was already mentioned in the history of EVs and TVs (Section 2.2.3) that batteries were originally born in the mid-to-late 19th century. Multiple battery technologies have been developed, but due to the success of TVs, there were no significant efforts or incentives for the automotive industry to increase the energy storage capacity of the batteries. Batteries in vehicles were assigned to the task of supply energy to the starting motor of the ICEs. However, since the late 1990s EVs have taken real strength and need for higher capacity has been included again as a priority. Nowadays, there are several types of batteries as lead-acid (very heavy and most used for starting ICEs), Nickel-zinc, lithium-ion and lithium polymer (Van Themsche, 2016). In EVs, the lithium batteries are commonly used. Lastly, apart from the technical constraints mentioned and others like the maximum number of charge/discharge cycles, charging time and life span, there is also the high cost that avoids the deployment of them in markets, which is said to be between $200 to $333 USD per kWh (Van Themsche, 2016) and others add that in the early days it was $2000 per kWh and now it is $200 USD per kWh (Botsford & Edwards, 2015). Accordingly, there are expectations that cost will drop further because batteries’ capacity have doubled every 3 years and this trend would continue so that by 2025 a current Nissan Leaf’s equivalent battery will cost less than
$1800 making its powertrain (battery and motor) cheaper than an ICE (Van Themsche, 2016).

2.4. BUSINESS STRATEGY AND BUSINESS MODELS

There are multiple definitions of business strategy and business models. Hence, in order to understand VMs decisions, there is the need to review definitions so that it could enhance comprehension during this dissertation. Moreover, there was also the need of differentiating what strategy and what business models are and their interdependence.

To begin with strategy, Michael Porter, a known academic by his theories in business and economics, said that main focus in operational effectiveness, such as productivity, quality and speed, is not sufficient to maintain firms’ competitiveness and instead a strategic positioning is needed (Porter, 1996). It is important to highlight this because, although this article is from 1996, it was already facing the globalization consequences of having a connected world. Nowadays, this is more truth than before because the world has developed not only better physical connections but also a nearly real-time connections through high-speed internet that makes information spread faster. It is easier for firms to imitate other firms. Hence, strategy is really important so that companies can maintain competitive. They cannot fully rely in operational matters anymore.

Strategy definition is taken from different perspectives by different authors. For instance, M. Porter defined it as “Strategy is the creation of a unique and valuable position, involving a different set of activities” (Porter, 1996, p. 68). This definition comes from the strategic positioning that can be originated from focusing on the product or service, customers’ needs, ways to access the customers or a combination of these. He also mentioned his generic strategies framework, in which firms choose to establish cost leadership, differentiation, and cost or differentiation focus in a niche market. For instance, Ikea, a furniture retailer, is cost-focused based on the needs of a customer group; in other words, customers that accept less services to pay lower prices. Finally, he tells that the strategic positioning rise from having activities that differ from rivals and needs to be sustainable by imposing trade-offs that avoids competition to imitate.

Moreover, other authors as Rumelt (2011) defined strategy as a “coherent action backed by an argument”. To put it more simply, there is a strategist who has the role of identifying...
the critical challenges or factors in a situation and then devise how to coordinate and focus actions to overcome them.

Furthermore, other authors defined it like “the long-term direction of an organization” (Johnson, Whittington, & Angwin, 2014). They said that long-term can be taken as decades or more and it is emphasized by the thee-horizons framework. This framework points out that organizations should think in three horizons in time. The first horizon are the current core activities which are defended and extended now, but eventually are expected to decline in their value in the future. The second horizon, relates to build emerging businesses that can provide profits in the future. The third and last horizon, are to create possibilities for the future which have high uncertainty now but can be viable in the future, such as Research and Development (R&D). To sum up, the main message of the framework is that organizations should extent the first horizon while dealing with the second and third horizons. They also said that strategies are guided by a long-term direction. For instance, long-term objectives as profit maximization, increasing market share or simply brand recognition. Finally, they said that organizations are taken as internal and external stakeholders with complex relationships.

To partially conclude, the strategy definition helps to understand how organizations are dealing with current and future challenges. Hence, strategies of VMs can shed light to determine how they are addressing both, the KDFs and the Climate Change Issue.

In regards of business models, it is said that they are the bridge between the organization’s strategy and its business processes. It is an abstract representation of an organization that defines all the interactions of its business, such as value proposition, value architecture, value network and value finance, in order to achieve its strategic goals and objectives (Al-Debei, El-Haddadeh, & Avison, 2008). Moreover, other authors said that “A business model describes the rationale of how an organization creates, delivers, and captures value” (Osterwalder & Pigneur, 2010, p. 14). They also developed a framework which cover main areas which are customers, offer, infrastructure and financial viability. In these main areas they said that 9 buildings blocks fit in that describe how the business works. These are: customer segments, value proposition, channels to deliver, customer relationship, revenue streams, key resources, key activities, key partnerships and cost structure.
To conclude, organizations business models and their strategies can give further insights to analyze the actions made by them. In particular, VMs can be analyzed to establish determine how they are dealing with the KDFs and Climate Change Issue.

2.5. METHODOLOGY

The automotive industry in this dissertation play an important role in the abatement of GHG emissions as was previously discussed. Currently, there are ongoing Key Driving Forces (KDFs) that are changing the industry and there is the Climate Change Issue that is taking place. The main objective of this dissertation is to merge these three complex topics: the changing automotive industry, the KDF and the Climate Change Issue. Although many literature studies addressed only one or two topics, there was not a single study which explicitly linked these three topics.

In order to answer the research question of this dissertation a qualitative desk research was done. It involved reliable online and offline sources in the academic field and technical field as the Corvinus University of Budapest library through its access to academic journals as Elsevier and EBSCO Host, and the theory learnt during the Master of Arts in International Economy and Business degree program; specifically in courses like transnational corporations, international financial management, international business economics and international business strategy.

Other courses created insights but the latter were the main ones. Furthermore, relevant material regarding the Climate Change Issue was initially taken from a former Master program course named Global Energy Challenges from the Chalmers University of Sweden completed by the dissertation’s author in previous years. It was then complemented with more recent data found during the research.

Moreover, a content analysis of websites related to technology and the automotive industry was made, for instance Automotive News and the Institute of Electrical and Electronics Engineers (IEEE). In regards of the VMs, content analysis of the websites from Tesla Inc. and BMW and their official reports and vehicles specification were analyzed. Other sources included the BBC news, The Guardian and Bloomberg which are recognized online newspapers and provide updated information.
Finally, a keyword research was made in the mentioned academic journals and websites of major consulting firms such as McKinsey & Company, KPMG, BCG, Navigant Research, PwC and among others which can be seen in the references. Keywords used involved a combination of words related to the main topics: KDFs, Climate Change and VMs.

In regards of the research methodology it was briefly described in the introduction but is expanded here. First, facts and theory regarding the Climate Change Issue was gathered and related to the automotive industry. Second, the KDFs of the automotive industry were analyzed and selected as per relevance with the Climate Change Issue. Third, the selection and profile analysis of the key players in Electrical and Traditional VMs was performed. The chosen VMs were BMW as a TVM and Tesla Inc. as an EVM. Fourth, the research done provided material to be analyzed so that patterns and relationships were established and were the input to create the framework. The created framework consists of a diagram block and a points-based system. The diagram block gave insights to establish relationships among the players of the supply and demand side of products and services in the automotive industry which can be reviewed in the Figure 3-1. Then, the points-based system (Section 5.6.2) summarizes the relevant impacts to the climate change in each category of the KDF, which were found from the research and analysis done of the KDF, Climate Change Issue and VMs. Points were assigned the same weight of one unit.

Next, the framework enabled the analysis of the responses of the chosen VMs to the KDFs and their impacts on the Climate Change Issue. The results are shown in the findings section. Finally, the findings are discussed focusing on the differences between their responses and of course the potential effects to the climate change.

It is worth mentioning that this research is done with a limited budget which is a limitation to get access to recent and reliable data.
3. CENTRAL TOPIC

In this section the research question is addressed sequentially in its main parts. They have already been described. The order in which it is addressed is done in five subsections. First, the KDFs changing the automotive industry are explored and the relevant to the Climate Change are selected. Second, Electrical and Traditional Vehicle Manufacturers (VMs) are also selected. Third, the framework involving all parts is created. Fourth, the evaluation of VMs and its findings are shown. Fifth and last, the findings are discussed.

3.1. SELECTION OF KEY DRIVING FORCES

The selection of the KDFs consist of the review of the KDFs from many sources and its analysis. After this, they were summarized in order to gain insights and finally they were selected based on the relevance with the Climate Change Issue.

3.1.1. KEY DRIVING FORCES IN THE AUTOMOTIVE INDUSTRY

The vehicle industry has been present since the mid to late 19th century. It has evolved and established very strong. Series of improvements throughout its history related to safety, performance and efficiency of the Internal Combustion Engine (ICE) (Greene et al., 2011). However, currently there are major forces around the world that have changed other industries and the automotive is not an exception. These are basically related to digitalization, technology, social behavior and new business models proven to be effective. Driving forces are firstly introduced using a report from McKinsey & Company which is a global management consulting firm with specialists in many industries including the automotive sector and after this the topic is explored in detail. Then, in a following subsection the KDFs are selected based on literature relevance, the dissertation’s author experience and the relevance for climate change.

The McKinsey & Company’s forecast report was made in collaboration with the Stanford University. It involved researching, interviewing and discussing with experts from different countries. It indicates that there are four ongoing disruptive technology trends which are electrification, autonomous driving, diverse mobility and connectivity. Moreover, it mentions 8 key perspectives based on high and low disruption scenarios.
which are categorized in four groups: 1) shifting markets and revenue pools, 2) changes in mobility behavior, 3) diffusion of advanced technology and 4) new competition and cooperation (McKinsey & Company, 2016).

As a brief description, the first one estimates that revenue pools could increase up to 30% by 2030 compared to 2015 boosted by recurring revenues obtained from on-demand mobility services and data-driven services. Accelerating the automotive industry growth to 4.4% from 3.6% in 2010-2015 period. In addition, it mentions that mobility will become a shared mobility, but vehicle sales will continue to grow at a lower rate; from 3.6% in the last five years to ~2% in 2030 (McKinsey & Company, 2016).

The second, mentions that due to technology, regulations and consumer preferences are generating pressure to have a shift from individual to shared mobility. It is said that the importance of private car ownership is decreasing, for instance, the number of car sharing member has increased in a 30% annually-basis in the last five years. Moreover, it emphasizes the city type segmentation; if cities are high income level and density then shared mobility will be useful and for rural areas private cars (McKinsey & Company, 2016).

The third, basically indicates that 15% of new cars sold in 2030 could be completely autonomous and that EVs will be adopted depending on local preferences and regulations. With respect to Autonomous Vehicles (AV) tech players and startups are said to play an important role. Moreover, regulation and consumer acceptance are the main barriers for full AV. And for EVs the main important variables are emission regulations, battery cost, charging stations and consumer acceptance which are told to back electrified vehicles (PHEV, Hybrid Vehicles, BEV and fuel cells) so that in 2030 could be between 10 to 50% of new vehicle sales (McKinsey & Company, 2016).

The fourth and last, mentions that automakers need to see mobility as a service, compete and cooperate in a new battleground of multiple market fronts like software (features and services), e-hailing, (order any kind of transport online), car sharing and others. Furthermore, due to the latter new entrants can come. For instance, Tesla, Google, Apple, Baidu and Uber are taken at first glance but others may come. They may expand their share in the value chain, turning competition fierce (McKinsey & Company, 2016).
The dissertation’s author believes that this article has pinpointed correctly several of the important trends in the industry and therefore that is the reason why it was summarized in detail to be used as an introduction of the KDFs. Nevertheless, this topic will be further analyzed below.

Another source is a survey reported by KPMG, named Global Automotive Executive Survey (KPMG, 2016), which had as respondents 800 senior executives from automakers, suppliers, dealers, financial services firms, rental firms, mobility companies, technology firms and 2100 consumers across the world. This survey agrees with the trends given by McKinsey & Company. However, it reported that there are more expectations for disruption from the connectivity and digitalization with 50.1% of executive respondents rated the trend as extremely important. It is worth to mention that it is shown as the most important, but other trends are shown just slightly behind as for example in the second place the HEVs (49.5%), third place the BEVs (46.5%), sixth place the mobility as a service and ninth place the autonomous driving vehicle (37.6%) and in the tenth place the downsizing and optimization of ICE (36.8%). Altogether, what was noticed in this report is that there is not a unique single important key trend that can create disruption. There are many going on which were fully analyzed, categorized and explored below using many sources and own arguments.

The KDFs of the automotive sector are not only trends or something that came out of nothing. These are said to be due to a technical and social transition (Dijk et al., 2013). Moreover, from the literature reviewed in the theoretical background about the history of the EVMs and TVMs, it was noticed by the dissertation’s author that the automotive industry is currently living the same situation. Preferences from society are creating new forces that are putting pressures on VMs to develop new business models and alternative technologies for powertrain. For example, in the late 19th century EVs were displaced by TVs because of the emerging car culture of the time which had the cars as a means of travel for pleasure (sense of freedom), object of class distinction, masculinity and as an adventure machine (Ivory & Genus, 2010). Now, it is more accentuated as discussed next.

In fact, nowadays consumer movements are stronger because consumers are said to be more informed and they value their time, money and quality of life (KPMG, 2016). Hence, due to the current technology and this changes in social behavior a new transition has begun and is favoring EVs.
3.1.2. ANALYSIS OF THE KEY DRIVING FORCES

A discussion of all the KDFs are shown below as follows: new mobility business models, digitalization, connectivity, electrification or e-mobility (electrified-mobility) and autonomous driving or self-driving vehicle.

In regards of new mobility business models, due to the fact that there is an ongoing urbanization process, cities are denser in population with traffic jams and consequently a shared economy or, more precisely, a shared mobility has appeared to solve this. It is said that by 2030 one of every 10 cars will be a shared vehicle (Dijk et al., 2013; Kley, Lerch, & Dallinger, 2011; KPMG, 2016; McKinsey & Company, 2016; Viereckl et al., 2016). Therefore, customers face a big decision: choose between vehicle ownership or on-demand mobility where vehicle is fit for purpose (KPMG, 2016; McKinsey & Company, 2016). Although KPMG (2016) said that total cost ownership is and will play the most relevant role in customer’s decision, whether is owning a vehicle or getting involved in mobility services. It is the dissertation’s author opinion that this is not totally true in the present and depends on the region being analyzed, e.g. in his home country having a vehicle is symbol of power and success and therefore sharing a vehicle would be nonsense for the average people.

Moreover, China’s middle class is rising and is desiring to buy vehicles, whereas the US urban citizens are more oriented towards the sharing economy (Viereckl et al., 2016). Hence, EVs are indirectly positively affected by this. Customers find EVs expensive and therefore it is better to spread the initial investments with other customers in car sharing schemes or pay for mobility services. This new schemes are very beneficial for fleet operators due to the fact that EVs, although their high initial cost, their operation and maintenance cost is low in comparison with ICEVs. They have higher utilization rates and better performance in cities (Kley et al., 2011). Consequently, shared mobility initiatives, as car sharing, car-pooling or e-hailing, can be beneficial for EVs if their advantages are exploited in cities (short distances).

In regards of digitalization it is worth mentioning that it also comes with connectivity, although they were discussed separately in this subsection. The automotive industry have had new entrants which are in this case technology firms, start-ups and emerging automakers (Beiker et al., 2016). Various authors agree on this. For instance, as
previously said, by 2030 it is said that revenues will shift to services as shared mobility, connectivity and feature upgrades (McKinsey & Company, 2016). Another author indicated that new entrants like tech players are already developing autonomous driving systems, others are developing new business models in mobility services and others developing infotainment systems (Beiker et al., 2016). Another author said that the relationship with customers is shifting from product-oriented to service-oriented and data-driven powered not only by software or digitalization but by connectivity (KPMG, 2016).

In addition, it is worth to mention that these new entrants pose a big threat to the traditional automakers because they bring innovation and speed up product development cycle (Viereckl et al., 2016) and they have better financial flexibility and higher valuation and are also willing to take more risks, value innovation by disrupting services or software, whereas automakers minimize risk and value consistency (Beiker et al., 2016). No wonder why it has been questioned if automakers could be contractors of technology firms in the future (KPMG, 2016). With respect of these two topics, digitalization and connectivity, the dissertation’s author hereby claimed that these are the most fascinating and are the enablers for any kind of service that can contribute to further and meaningful customer experience. For example, think about the infinite applications that are found in mobile phones online. As told by KPMG (2016) cars will transform in “mobile data rooms”.

In regards of the connectivity driving force, as was mentioned in digitalization, these work together but connectivity is the enabler for other trends like car sharing, e-hailing, and even autonomous driving. It offers the opportunity for new entrants to come in (KPMG, 2016; McKinsey & Company, 2016). Both driving forces can shift the revenues and profits shift from hardware to software (Viereckl et al., 2016). Consequently, it is important to mention that the automotive industry will have to have different product development cycles in order to succeed. For instance, it is said that Research & Development (R&D) activities should focus in hardware which has a long lifecycle and software which has a shorter lifecycle (McKinsey & Company, 2016). Similarly but more elaborated, KPMG tells that there should be three minimum cycles: long term (3 to 5 years) for vehicle development, mid-term (1 to 2 years) for software/exchangeable components and short-term for (1 month to 1 year) release on demand based. In these
spirits, the vehicle becomes not only to be a means of transport but a platform to provide on-demand services.

In regards of electrification or e-mobility, which consists of all electrified vehicles discussed before and its infrastructure, it is said that has benefited by government incentives and support policies, developments of battery storage, charging infrastructure, investors willing to take part in clean technologies and automakers initiating diversification in powertrains. Moreover, it is said that to continue its development more charging infrastructure is needed, developments in mobility like car sharing, developments in manufacturing, energy prices should be favorable due to the increased price in oil (use of unconventional oil), development of the electricity sector towards renewable energies and finally climate policies and public opinion (Dijk et al., 2013). In addition, battery developments are expected for the next decade with battery prices potentially decreasing to $150 to $200 USD per kWh which will enable the cost competitiveness of EVs relatively to TVs (McKinsey & Company, 2016). After all, the electrification is going on and more EVs are seen on the streets supported by an expanding infrastructure and expecting the electricity generation to become cleaner soon to maximize its benefits towards the Climate Change Issue.

Last but not least, is the key driving force of Autonomous Driving Vehicles (ADV). This technology is also an enabler for further disruption in the automotive industry. Currently, there are different levels of this technology such as the Advanced Driver Assistance Systems (ADAS), conditionally autonomous car (level 3 according to the National Highway Traffic Safety Administration (NHTSA)) and fully autonomous car (level 4 NHTSA) (McKinsey & Company, 2016). For the future, ADVs are said to be up to 15% of the new vehicles sold in 2030 (McKinsey & Company, 2016). They can change the way the passengers spent their time by using it efficiently and opens the doors to enjoy more services.

Moreover, it is said that due to the product and technology-based nature of ADVs, automakers are the ones that should develop it and technology firms only observed and wait for the precise moment to take the human machine interface (KPMG, 2016). The dissertation’s author argued that KPMG is mistaken in this statement. Technology firms have the capabilities to develop this technology and should get involve on its development process. Technology firms have incentives due to large revenues in the future through
online services and therefore they are benefited if this technology is developed at earliest. For instance, such an efforts can be seen by Intel Corp., the microchip manufacturer, which acquired recently Mobileye one of the most important developer company for this technology (Reuters, 2017). Moreover, it is worth evidencing that automakers lack the software engineers workforce of the technology firms (Beiker et al., 2016). In conclusion, ADVs with digitalization and connectivity creates the scenario for a shift in mobility. Further applications can be developed to add value to all passengers within the vehicle.

### 3.1.3. BRIEF DESCRIPTION OF KEY DRIVING FORCES

In order to find the relevance of each of the KDFs, for the sake of clarity, were enlisted with a brief description so that it could create further insights. The Table 3-1 do this. Then, in the next subsection they were analyzed and discussed about their relevance to the climate change.

<table>
<thead>
<tr>
<th>Key Driving Forces</th>
<th>Brief Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New mobility business models</strong></td>
<td>The mobility is changing from a product based perspective to a service perspective. New initiatives as car sharing, e-hailing, carpooling, and other mobility services in which there is a more efficient use of the vehicles. This trend has started because of society’s current needs that make them think about owning or engaging in mobility services, and the development of technology (digital and connectivity).</td>
</tr>
<tr>
<td><strong>Digitalization</strong></td>
<td>Vehicles are evolving from being hardware-based to be software-based. They already have several lines of code to make them work and increase performance but trends are focusing on new ways to add value to users. Levels of digital intensity are going up and with connectivity even more.</td>
</tr>
<tr>
<td><strong>Connectivity</strong></td>
<td>Vehicles will increase their connectivity to the world: this can be from vehicle to vehicle and vehicle to everything. Furthermore, there is also the Internet of Things (Khare, Stewart, &amp; Schatz, 2017) that will also bring more disruption. To sum, connectivity is the enabler which unlocks new services</td>
</tr>
</tbody>
</table>
Key Driving Forces | Brief Summary
--- | ---
in the car. Incoming 5G technology in the upcoming years will strengthen this trend (McKinsey & Company, 2016).

Electrification (e-mobility) | Automakers are using more and more electric powertrains in their produced vehicles. For instance, HEV, PHEV, FCV and BEV.

Autonomous Driving Vehicle | Although this is a feature from the vehicle, it adds value to customers by letting customers use their time efficiently while traveling or commuting. Moreover, this enables the car to be a platform for users to be connected and automakers and technology firms to offer more and new digital services.

Table 3-1 List of Key Driving Forces changing the automotive industry.
Based on research done in Sections 3.1.1 & 3.1.2.

3.1.1. RELEVANCE AND RELATIONSHIP WITH CLIMATE CHANGE

The link to the climate change was done analyzing each key driving force. A research was conducted to find the ways this KDFs are and could impact the climate change. In this subsection, only the general relationships are listed. Later, in the chapter which creates the framework, it is further analyzed. Consider this an incremental analysis to get to the framework.

During the literature review of the theoretical background section, the consensus was that GHG emissions needed to be lowered so that the Carbon Dioxide (CO2) concentration in the atmosphere could stabilize and eventually decrease. The critical values were less than 600 ppm being very optimistic or less than 350 ppm being precautious (Caldeira, Ken, et al as cited by Azar, 2009). However, current levels are at more than 400 ppm as was previously said. In order to achieve this stabilization the consensus, as analyzed by the dissertation’s author from the research done, was that it can be done in different ways but they can be grouped in two categories. It can be done through increasing efficiency and reducing CO2 emissions. These two categories are going to be the focus on how the links or relationships are established between the KDFs and climate change. When analyzing efficiency it can be taken from an energy perspective, i.e. the use of energy (in any form fuel or electricity) is optimized, or from a
usage rate or system perspective, in which the usage rate or the system efficiency is improved i.e. resources (vehicles) are effectively and efficiently used.

As an example of energy or performance efficiency one can take the classical example of increasing the fossil fuel economy of vehicles, so that less fuel used means less GHG emissions to the atmosphere. As an example of usage rate or system efficiency it can be said that the more the fossil-powered vehicle moves in a traffic jam, the more efficient it is, because it does not waste energy while idling.

To conclude, the selection of the KDFs was done and basically they all stay present in the construction of the framework, however digitalization and connectivity are grouped together. The rationale behind this was that the dissertation’s authors believes that this dissertation will be used by others as a tool to see opportunities of what can be done to improve impacts to deal with the Climate Change Issue. The following analysis of the KDFs was done with this in mind and remember that the objective of this section is to identify relationships and later to build the framework in Section 3.3.

### 3.1.1.1 New Mobility Business Models

New mobility business models can potentially reduce GHG emissions and in particularly CO2 emissions due to the fact that it can impact both efficiencies: performance and usage rate (system efficiency). This is discussed in the end of this subsection but before that some facts are analyzed.

There are two main causes related to consumer preferences that have stimulate the creation of these new mobility business models; it was an opportunity and some firms are taking advantage of it. First, there is an increasingly new trend of awareness about environmental issues which is taken as shift towards post-materialism which mainly happens in industrialized societies (Mikler, 2009). This trend is also taken as a change in public opinion that can influence policy makers so that a climate policy is established in some countries (Azar, 2009). This creates a positively impact to the climate change because new business models in mobility emerge that help to mitigate GHG emissions by commitment to improve corporate image towards the environment in order to capitalize this “green market”.
Second, there is, as was already said, an increasing population worldwide and also an urbanization trend in all types of countries; i.e. advanced, emerging or low income economies (Bouton et al., 2015; Greene et al., 2011; McKinsey & Company, 2016). It is said that by 2030 60% of the global population will live in cities which is 50% more when comparing with the current level. In addition to this, the problem gets bigger when predictions show that more than two billion of the population are possibly entering the middle class with the majority living in China which will likely double the global vehicle fleet (Bouton et al., 2015). Hence, more cars means more pollution.

Fortunately, due to the fact that more people living in cities means more congestion, smog, increasing cost of living, wasted time and in general a decrease in their quality of life, citizens are opting to support this new business models (shared economy) that have appeared because they fit their needs. For instance, it is said that the generation Y ("millenials") are more interested in mobility rather than vehicle ownership (Bohnsack et al., 2014). There is plenty of literature about this topic but it is beyond the scope of this dissertation to analyze the causes of why urban and commercial consumers supports shared economy.

After all, these two causes have generated a shift from product-based to service-based perspective in the way that mobility business models are created. Consequently, the customer relationship has been changed and now it is call an individual-centered economy in which value is added by improving the customer experience; and is expected to turn into a everyone to everyone economy which is discussed in the subsection of digital and connectivity KDF (Berman & Others, 2013). It is in these new mobility business models where shared economy appears. It is said that shared economy in these new mobility business models can be categorized as individual or grouped, it consists of car sharing, e-hailing and others (Bouton et al., 2015). For better understanding the Figure 5-5 can be reviewed. For example, it has been discussed that ownership of private vehicles have decreased in some countries. For instance, even in USA, a known passionate country for cars, vehicle ownership rate has decreased and less distance travelled, which is in part because car sharing, e-hailing and other new services have come into the mobility market (Bouton et al., 2015).

Next, it is now discussed the link between new mobility business models and the Climate Change Issue. As it was said before, it can be through reducing CO2 emissions,
which can be done by decarbonizing the transport system or the energy supply to it. Moreover, it can also be through increasing efficiency which can be related to performance or usage rate or system efficiency. From an economics perspective, it can be said by the dissertation’s author, that the mobility service is placed on a market place where consumers and suppliers interact. The traditional way of interaction occurred in isolation where there were difficulties to access data or information about which was the most convenient, cost-beneficial, best service or the fastest but right now due to the new mobility business models and the platform behind the market place is practically virtual. As said by an author there is more transparency to choose the best and therefore the mobility is more efficient (Bouton et al., 2015).

Another concern for the Climate Change Issue is the global population growth, as was mentioned before. It has to be over-emphasized due to the fact that it is a critical issue. In China and India, it is said that less than the 5% of their population own a vehicle and the road infrastructure is already with heavy traffic (Matus & Heck, 2015). Fortunately, this supports the reduction of GHG emissions due to the fact that it is not incentivizing ownership of new cars. Having an ownership business model is not sustainable in any aspect and the solution is to look for the new business models.

For instance, a study made in New York city in USA shows that car sharing has the potential to meet the mobility requirements of all with 80% less vehicles (Claudel & Ratti, 2015). Remember that less vehicles used means less GHG emissions. Moreover, when using a car sharing scheme users can fit their trip or purpose to the proper vehicle (Dijk et al., 2013). This means that usage rate or system efficiency can be enhanced. A basic example could be the bad use of a Sport Utility Vehicle (SUV) to go to work while being alone i.e. waste of space and energy and higher GHG emissions in comparison with a compact efficient car or much more if compared with an EV. With car sharing they can select a compact and efficient car, or also there is the option of using any other share economy business model as ride sharing and it would be even better. With ride sharing the overall usage rate efficiency of the vehicle improves (more passengers per vehicle). Furthermore, if there are less cars on the streets and roads an indirect impact is that less energy is used and less pollution is emitted from building and the maintenance of the infrastructure (Claudel & Ratti, 2015), which is another incentive to use this new mobility business models.
There is another trend that can increase the overall system efficiency by using different modes and means (vehicles) of transport in a complementary way. This trend is called the multimodal approach in which there is an increasing integration between all the main components of urban mobility (Bouton et al., 2015; Kley et al., 2011) which can be seen in the Figure 5-6. This figure is related to the segmentation of cities, or in other words, the types of cities depending in population density and the quality of public transport. It is said by Bouton et al. (2015) that depending on these characteristics the components that deliver mobility are going to develop further, decrease or be stable. In short, they also forecast that vehicle’s ownership is expected to fall in every type of city at different rates, new mobility services will increase with the same behavior and public transport will remain stable in advanced economies and established megacities, but will increase in rising megacities and mature cities. Altogether, in order to impact positively the climate change issue the idea is to have different modes and means of transport so that they can be used by citizens to increase efficiency and reduce GHG emissions and the energy used. Longer trips can be made in public transport, as for example in metro, and then use any vehicle to complete the journey.

It is worth to mention that there is a mutual reinforcement between all the KDFs. For instance, this new mobility business models needs the development of digital and connectivity in order to function properly. For example, car sharing depends on connectivity and a digital system (app) to match the user who wants a mobility service and the other user who offers it. More importantly, when comparing TVs and EVs, this new mobility services are favoring EVs because car sharing enables the high initial cost to be spread on the members of the group or fleet operator and then operation and maintenance is comparatively much lower (Kley et al., 2011). Finally, although the autonomous driving vehicle KDF is not fully developed, it shows a significant potential to increase efficiency and enable new different services in the shared economy and more (Viereckl et al., 2016).

3.1.1.2. Digitalization and Connectivity

The digitalization and connectivity KDF is the enabler for other KDFs like new mobility business models and autonomous driving vehicle. For instance, new mobility business models need connectivity to be able to reach users with their digital services and
vehicles that are driving autonomously need feedback to update any danger on roads. Nowadays, users are already connected to the internet through their mobile phones, computers and even refrigerators and the time has arrived to connect the car.

The technology trends are placing a new relationship with customers through software, as has been emphasized by the literature review in this dissertation. The reason for this is not only the already told shifting revenues but also as a way to solve the mobility problem of a growing population. This solution can be summarized by Claudel & Ratti (2015) when they indicated that “global mobility challenges will be met by silicon not asphalt”, with silicon they mean software. Moreover, more technology developments are expected to come in the connectivity KDF. For instance, mobile networks are currently using 4G technology but 5G is expected to come by 2020 (McKinsey & Company, 2016). There are new architectures and technologies improving networks in vehicles and automakers and third parties are giving connectivity features (Roland Berger, 2016). Altogether, the trend is moving towards to have real time access to information (Claudel & Ratti, 2015), opportunity to use analytics (Big Data) and having everyone connected to everyone (E2E) (Berman & Others, 2013), efficient mobility services (Bouton et al., 2015) and also that vehicles could use more optimally the roads and energy (Matus & Heck, 2015).

As there is an increasing pressure for firms in the automotive to go digital there is also the pressure for having connected the car as soon as possible. It is said by Roland Berger that there is a shortcut to do this that is being already implemented. Third party firms are developing retrofit solutions to connect the car and be able to provide digital services and get access to data. This solution has been implemented through various means from using mobile phone for basic services to creating specific USB dongles which connect to the On Board Diagnostic (OBD - II) port to interact with the vehicle’s network (Roland Berger, 2016). Using this technology users are already being offered digital services. For instance, the type of digital services can be Business to Business (B2B) or Business to Consumers (B2C) and could be remote diagnostic, fleet management, car sharing and other shown on the Figure 5-7. There is also a fierce competition in who owns this interface with the user. It is said that there is an improvement opportunity for VMs. Their solutions are too complex and expensive, range of €2000-3000 EUR, in comparison with the third-party retrofit solutions, €60-300 EUR (Roland Berger, 2016). Moreover, another challenge is to increase security and bandwidth in the networks of vehicles.
The link between the climate change issue and the digital and connectivity KDF is that these digital services and connectivity offer an opportunity to increase the performance and usage rate efficiency of vehicles and mobility in general, and also increase awareness of users of the Climate Change Issue and their emissions. Which can reduce the energy demanded and the GHG emissions. Consequently, creating a positive impact on the climate change issue. For example, congestion or traffic jams can be reduced or eliminated which increases the system efficiency performance and also using navigation services the route is the most optimal and therefore less energy used traduces in less GHG emissions (Claudel & Ratti, 2015). Digital services as pay-by-how-you-drive (Roland Berger, 2016), can be used to incentivize and create awareness in users to improve their driving habits so that the vehicle’s performance is increase. This can be done by avoiding sudden high positive and negative accelerations so that less energy is wasted as heat. Statistics services (Roland Berger, 2016), as proposed by the dissertation’s author, can be used to monitor GHG emissions in real time and having accurate global emissions measurements. Maintenance and remote diagnostics (Roland Berger, 2016), can be used to indicate the user a malfunction and therefore after a maintenance the efficiency of the vehicle should be increased. Moreover, there are plenty of many other “car packages” and consumer services that can be offered as shown in the Figure 5-8.

For the future, new technology will for sure arrive as the 5G mobile network technology and automotive networks will improve to suit users’ needs. In addition, there are other technologies which are also creating new trends, these are named but are not under scope of this dissertation such as artificial intelligence, big data, cybersecurity, internet of things (IoT) and industry 4.0. To conclude this subsection, as told before, revenues will shift to a service-oriented based using software i.e. digital services. Hence, automakers need to enhance their capabilities and response time to be able to compete in these new marketplace. Moreover, as reviewed there are means to counter act climate change through this KDF.

3.1.1.3. Electrification (E-mobility)

TVMs and EVMs are now competing in the e-mobility market. Because of the maturity of the TV, EVs have been experimenting a long and no that successful penetration to the market. Nevertheless, it is worth noting that this has happened in all technological
changes in normal life. There is always the need of change of paradigm. Specifically for this issue is a paradigm shift from the VMs and users. EVs have started the market penetration since the high sales of the HEV from Toyota Prius, which from 1997 to 2005 had more than 1 million global sales. Despite its hybrid nature which have an ICE engine, it helped developed the technology needed for fully electric vehicles (Dijk et al., 2013).

The key point to highlight is that EVMs and TVMs have developed different business models to obtain market penetration. EVMs have used a services-based system that later was copied by TVMs and both types of VMs have used their previous capabilities. Moreover, it is said that the business models have pointed towards different segments, such as luxury and economy, implementing vehicles with a specific or multi-purpose. However, as of 2014 it seemed a slight convergence towards the economy multi-purpose vehicle (Bohnsack et al., 2014). Electrification of vehicles is an ongoing process and there is a consensus that due to the distance range limitation and the lack of charging stations it is better to deploy EVs in an urban environment.

The link to the climate change issue lays in the fact that in overall the GHG emissions from manufacturing, operating and disposing EVs are lower than TVs under the condition of having an efficient or clean energy source for generating electricity (Hawkins et al., 2013). But because renewable energies are being used more, the benefits of EVs are increasing. EVs offer not only low GHG emissions but also low costs during operation and maintenance. Furthermore, EVs have a higher performance efficiency than TVs (Bouton et al., 2015) and can also have a higher usage rate if they are set to interact with smart grids so that while they are parked they can storage energy (Kley et al., 2011).

For the future it seems that at least in the short term the EVs will be successful in cities. The new mobility business models and a cleaner production of electricity are supporting also their success. Just remember that battery technology needs to be improved.

3.1.1.4. Autonomous Driving Vehicles

Autonomous driving vehicles are being developed and although some VMs tell that they are close to have this technology ready for development before 2020, it can be noticed that there are still huge challenges to overcome. Some accidents have been reported last and current year from the leading companies which are developing this
technology. What is important to remark is that the transition to autonomous driving vehicle will be gradual (Claudel & Ratti, 2015). In regards of having ready the fully autonomous vehicle some argue they can have it ready by 2018 as Tesla and Google, others in 2020 as Mercedes Benz, Audi, Nissan and BMW (Van Thamesche, 2016). But the dissertation’s author agree that this kind of technology needs to be deployed gradually. It is very complex with many unpredictable inputs and scenarios that at current level of development cannot be deployed in markets; other technologies as artificial intelligence and big data can come into and help to solve this. However, current level of development, i.e. level three which is conditional autonomous driving (McKinsey & Company, 2016), can continue to be enhanced by experimenting real scenarios and real drivers, but the Advanced Driver Assistance Systems (ADAS), such as lane change assistance and collision warnings, offer more control over risk and can also make further developments.

The link with the climate change issue is basically similar to the digitalization and connectivity KDF. In theory, one may argue that this is a software application and not a KDF. However, the dissertation’s author agree that this technology is more than a mere software application because it has the potential to change the paradigm of how mobility and vehicles are taken. It has the potential to unlock more digital services (Viereckl et al., 2016) and with it more revenues (Matus & Heck, 2015; McKinsey & Company, 2016; Roland Berger, 2016; Viereckl et al., 2016). Moreover, the most important point towards the climate change issue is that autonomous driving vehicles will displaced eventually humans and therefore their mistakes. These vehicles are said to be able to select optimal navigation routes and driving patterns, and also can reduce number of cars which traduces to less energy used and less GHG emissions and besides less space used (Claudel & Ratti, 2015).

The future for this KDF brings impressive changes to the automotive sector but that will take some time. Some authors tell that sales of fully autonomous vehicles can reach 21 million globally by 2035 (IHS, 2016) and others tell that by 2030 they can reach up to 15% of the passenger segment (McKinsey & Company, 2016). To conclude this subsection, this KDF have the power to optimize efficiencies of performance and usage rate (system efficiency) and therefore GHG emission will also decrease.
3.2. SELECTION OF KEY PLAYERS

The selection of the key players, one EVM and one TVM, is done based on the brand recognition, technological relevance and targeting the same vehicle segment. As discussed in the methodology section of this dissertation document, these key players are analyzed using the framework made in the next section (Section 3.3) and subsequently determine which is addressing better the Climate Change Issue through their responses to the KDFs.

The initial pool of VMs included all vehicle segments such as BMW (Bayerische Motoren Werke AG), Volkswagen, Chevrolet (GM), Renault-Nissan, Tesla Inc. and BYD, but the research done showed that different business models has been developed by different VMs and are still evolving, and that their target vehicle segment can differ (Bohnsack et al., 2014). Therefore, in order to make an accurate comparison the research was delimited to the luxury segment which are the VMs which have the capabilities, finance support, technological advantage, brand recognition and more importantly the purchasing power of their targeted users in the market to respond quickly to the KDF (Bohnsack et al., 2014). Nonetheless, the framework can also be used to determine the opportunities of others VMs. In addition, the framework can be expanded in the future by researchers who would be interested to continue to analyze the automotive industry and their impacts to the climate change.

Finally, the selected VMs to be analyzed were Tesla Inc. as the EVM and BMW as the TVM. These were the more relevant that complied with the requirements proposed since the beginning. Next, the selection process is discussed and later the strategies of each VM are analyzed so that their priorities are known which shed light about where they are heading.

3.2.1. TRADITIONAL VEHICLE MANUFACTURER: BMW

BMW is a worldwide recognized traditional vehicle manufacturer. There is no doubt of this. It is part of the BMW group which has other premium brands as Mini, Rolls-Royce Motor Cars Limited and BMW Motorrad. Particularly, the BMW vehicle manufacturer is focused in the luxury segment and has a considerable portfolio offering diverse products from sport performance M-performance series to recently the i-
performance series which are EVs. It was observed that BMW’s 2016 and current strategy document (BMW, 2016e) address all of the KDFs. Clearly, BMW is aware of the KDFs mentioned in this dissertation. Moreover, its vision “We are number one. We inspire people on the move: we shape tomorrow’s individual premium mobility” gives the idea that they continue to stay in the individual premium mobility, but it is fair to mention that they have mobility services as the DriveNow or ReachNow which are a car and ride sharing system so that they have willingness to deviate by some degree with its vision.

A detailed description of the BMW strategy is that it focus on technological innovation and technological improvements categories which is diagramed in the Figure 5-9. On the first category, it includes programs like electric mobility or electrification which includes a set of EVs as BEV, PHEV and FCV. It also has automated driving and are developing its basic technologies such as sensor systems, artificial intelligence and map technology. Digitalization and connectivity is already on ongoing process like programs like DriveNow, ParkNow and ChargeNow which are digital mobility services. On the second category, they seek to increase efficiency of the ICE of their core products; operational efficiency in their production; and enhance the customer relationship (BMW, 2016c, 2016e).

BMW is also recognized by the reliability and the state-of-art technology of its products. Recently, BMW and Toyota were selected, by the surveyed executives in the already mentioned recent global survey, as the two traditional automakers which are set to have market success and technological advancements (KPMG, 2016).

3.2.2. ELECTRIC VEHICLE MANUFACTURER: TESLA INC.

Tesla Inc. was founded in 2003 by some engineers in Silicon Valley, in the US. In that time it was named Tesla Motors. These engineers first designed a car using an induction motor invented in 1888 by Nikola Tesla, whose surname became the company’s name. Later, in 2008 the first product was launched and it was a roadster (i.e. two-seat vehicle with a sporting look). It is said that “Each new generation would be increasingly affordable, helping the company work towards its mission: to accelerate the world’s transition to sustainable energy.” (Tesla, 2017a). From these words, it can be noticed that there is a successive plan to the get to the point of using only sustainable energy, which in other words means not using fossil fuels.
This successive plan can be evidenced by how Tesla Inc.’s CEO, Elon Musk, has communicated it. First, in 2006 the plan was named the “Master Plan” and it consisted of four stages which were: create a low volume vehicle, create a medium volume vehicle, create an affordable or mass-market vehicle, and lastly provide solar power. The goal in terms of the vehicles mentioned was to lower their prices with each model produced and in terms of solar power it was basically to install solar panels, from a partner company called SolarCity, on roofs to be able to charge their vehicles (Tesla, 2006). Second, in 2016 the plan evolved to be the “Master Plan, Part Deux”. In which the goals are to integrate energy generation with storage, expand EVs in portfolio to address all major segments, develop the autonomous driving technology to be ten times safer than humans and lastly get involved in the car sharing scheme (Tesla, 2016a).

These plans are what Tesla Inc. has published on its website but also scholars tell it in another way that agrees with what the plans were established and what the outcome of the business model analysis was. For instance, it is mentioned that Tesla’s business models used the EVs advantages in the high-performance luxury segment (Kley et al., 2011) and found customers with purchasing power to purchase these vehicles with a premium (Bohnsack et al., 2014). Hence, Tesla Inc.’s plan are being successful and they have been elaborated to sequentially lower the prices of their vehicles.

When looking at the results of the plans, Tesla Inc. has achieved the “Master Plan” by selling 2,400 Tesla Roadsters (low volume vehicle) at a starting price of $110,000 USD (Business Insider, 2016); currently selling two models, the Tesla sedan model S and the SUV model X (medium volume vehicles), which have a starting price of $69,500 USD and $82,500 USD, correspondingly (Tesla, 2017f, 2017g); announcing the model 3 (high volume vehicle), expecting production to start in mid-2017 and with a starting price of $35,000 USD (Tesla, 2017e); and finally the merge with SolarCity in 2016 (Bloomberg, 2016c). Clearly it can be seen that the goal of having more affordable vehicles with time has been achieved. Now, the “Master Plan, Part Deux” is in ongoing status and it seems to be feasible, which has created high expectations of investors as will be explained next.

It seems that investors believe that Tesla Inc. will succeed in the future because its market capitalization has increased significantly since 2013 (Wall Street Journal, 2017) and recently, temporarily, was considered the most valued automaker in the US as of the 10th of April 2017; with a market capitalization of $51 Billion USD against $50,9 Billion
USD of GM and $44.8 Billion of Ford (Business Insider, 2017). The interesting fact here is that Tesla does not produced the same volume of cars of those like GM or Ford. It is far lower. For instance, in 2016 Tesla Inc. sold approximately 76.000 vehicles, whereas GM sold approximately 10 million vehicles. Moreover, in 2016 it did not have profits, meanwhile GM and Ford reported more than $9 Billion USD and $4 Billion USD, respectively (Business Insider, 2016). Nonetheless, the market value for Tesla Inc. was checked again, as of 24th April 2017, and it was in second place with $45.15 Billion USD, just behind GM with $50.18 Billion USD, as reported in the Nasdaq stock market (NASDAQ, 2017).

The key point here is to see how expectations are driving Tesla Inc. as a major company. Some “old-timers” investors disagree arguing that it is overvalued because its valuation is based on promises as told by David Cole, an investor and supporter in Detroit automakers (as cited in Wall Street Journal, 2017). However, the dissertation’s author agrees with that past does not drive value. It is the investors’ expectations. In other words, in theoretically terms, is that the stock price, although methodologies differ between stock markets, is ultimately determined by the adjusted future cash flows taking into account all sources of risks, due to the fact that buyers and sellers take actions based in future profits by discounting the cash flows with a required rate of return (Madura, 2011). Consequently, depending on investors’ actions demand meets supply and the stock price is calculated in the market. Therefore, the “Master Plan: Part Deux” seems to be effective to make investors trust that profits in the future are feasible.

Another interesting point is the fact that Tesla Inc. has partnered with Panasonic and recently built a massive factory called the Gigafactory which is expected to make prices of batteries decrease by using vertical integration on it (Fairley, 2016). As told before in the theoretical background (2.3.4), the energy density and the price of the battery are critical for EVs to penetrate markets. Hence, through economies of scales, in which fixed costs of the manufacturing process are distributed over a larger number of products (Peng & Meyer, 2011), price of batteries can be decreased. Tesla Inc. is now not only supporting batteries applications in vehicles, but also in homes through its recent subsidiary SolarCity and can also can benefit from a rising demand in electric bikes which is expected to have a market size of $38,57 Billion USD by 2024 (Grand View Research Inc., 2016).
In regards of market share in the US large luxury sedan segment, Tesla Inc. was reported to be above Mercedes Benz and BMW in the third quarter of the year in 2016; Tesla Inc. had approximately 32% of all sales in the segment whereas BMW was approximately 17% summing all its models (Bloomberg, 2016a). Hence, this evidences that Tesla Inc. is as very competitive company in this segment.

### 3.3. CREATION OF THE FRAMEWORK TO EVALUATE VMS

From the research conducted it was established the ways the KDFs impact the climate change. In this subsection, the main goal was to create a strategic framework where all the stakeholders and their interactions are identified. It has to be said that the focus is on the KDFs, the VMs and the Climate Change Issue and the level of detail is high (more strategic than technical). In other words, it does not explore specific technologies, instead they are categorized depending on their impact. For instance, regenerative braking is a specific technology, but it is an efficiency gain and therefore it is classified like this. The main objective is to evidence and analyze the opportunities and strengths of the VMs compared in this framework. Hence, this framework represents a powerful tool to take corporate strategic decisions or even policy-making decisions for policy makers.

#### 3.3.1. PROCESS OF CREATION OF THE FRAMEWORK

From all the desk research done there was not a direct link between KDFs, climate change impacts and VMs. Nonetheless, the construction of this framework was developed based on the material reviewed and professional experience from the dissertation’s author. To start, in the Figure 5-6 from Bouton et al. (2015), the key players delivering mobility are depicted and they are privately owned vehicles, walking and bicycling, public transit and new mobility services. This framework is more oriented to orient policy makers understand and take decisions based on cities characteristics. It is a simple framework to start from, but it lacks interaction with VMs and other stakeholders.

Similarly, other frameworks were analyzed but they were focusing on business models, energy supply, life cycle analysis and structure of services. Despite this, they provided useful insights for the creation of the framework in this dissertation. Moreover, previous discussions during this dissertation were also the input to create the diagram block and its points-based framework.
Another framework which took three main components that were vehicle and the battery, infrastructure and system services (Kley et al., 2011) gave insights about how important was the infrastructure not only of the charging station, but the revenue models (pay-per-use or subscription model), the interaction with the electrical grid and the need to develop new business models in order to use the advantages of EVs to add value to users. However, this framework only offers possibilities to design each of those components through its morphological boxes; which helps to take strategic decisions and formulate new business models, but did not account the link to the climate change issue.

Another interesting framework reviewed only focused on the digital services provided by the automakers, auto-suppliers and technology firms (Viereckl et al., 2016). It tells that for these services the connected car and eventually the autonomous driving vehicle need to be in place, and then listed the services as consumer services, connected packages and supply-side technology. First, it is related to internet and cloud services as for example entertainments and e-commerce. Second, it is related to connected car packages which assist on the vehicle operation as for instance collision protection and fuel-efficient driving. Third, it is related to supply-side technologies as for example the ADAS, infotainment support and connectivity technology. This framework was only focused on the digital services and therefore was helpful to identify the players in this area which are the technology, automakers (or OEMs) and their suppliers, and also to learn about some of the digital services available.

The first framework analyzed which dealt with energy and GHG emissions used the LCA to evaluate environmental impacts of EVs, and specifically focused on multiple studies to find ways to improve them (Messagie et al., 2013). This framework, as was already commented in this dissertation, uses stages to calculate the total GHG emissions and other environmental impacts. There is the WTT stage which are the impacts from the primary energy supply until it reaches the input of energy of the vehicle (i.e. tank); production impacts; TTW impacts which are basically the vehicle using stage; the maintenance and infrastructure; and lastly the disposal of the vehicle. The information provided gives the link to the climate change issue. It gave the insight to segment players and actions on the production firms, the system which provides the energy, the infrastructure and maintenance, and moreover the disposal of the vehicles.
In order to establish and have insights in the energy supply topic, a framework regarding this called the energy primer was used (IPCC, 2014). This framework enabled to analyze the energy supply from primary and secondary sources to the different end-users which consume it. In regards of this dissertation what only matters is the transport sector and of course the industry sector. The key point here is to include the primary sources which is one of the most significant factors which enable the full potential of EVs, as it has been discussed throughout all this dissertation.

To summarize, the initial diagram block of the framework developed started from the analysis of these frameworks and later it was enhanced from the previous research done. The devised basic or initial framework of this dissertation was composed by the automotive industry players, the mobility environment, the users and the infrastructure and energy supply. There was an interface to the user through the digital world and another which was not given that much importance named the physical interface; which is probably due to the fact that it is obvious or taking for granted.

After a polishing procedure the final framework was created. It consists of a diagram block which can be seen in the Figure 3-1 (Section 3.3.2) and the points-based system which can be reviewed in the section 5.6.2. However, in order to provide the reader insights about the creation of this framework it is necessary to show the discussion and the dissertation’s author own ideas generated during the polishing procedure about the possible actions by VMs that impact the Climate Change Issue.

3.3.1.1. New Mobility Business Models

In regards of the new mobility business models, the possible actions by VMs that affect positively the climate change issue are divided in three categories: improving the system efficiency, data-driven business models and finally development of business models to tend to cleaner technologies. On the first category, car sharing, ride sharing, multi-modal schemes, e-hailing and private shuttles are said to be able to reduce the number of cars (Claudel & Ratti, 2015; McKinsey & Company, 2016), improve the occupancy rates of vehicles so that less energy is needed by passenger (Berman & Others, 2013; Kley et al., 2011), and in the case of robo-taxis or autonomous driving taxis more efficient driving and less energy spent (Claudel & Ratti, 2015). Nevertheless, efficiency of the public
transport need to be reviewed, because sometimes it could be less efficient than travelling by car as shown in an example in the USA (Greene et al., 2011).

On the second category, data-driven business models, research showed that consumer preferences need to be switched towards new technologies, or in other words, that consumer acceptance needs to be improved to continue with the diffusion of new technologies and new mobility services (Kley et al., 2011). However, none of the authors proposed something to deal with this. Hence, here is a gap which can be filled by involving directly users to take also part on the climate change issue. As an example of this could be creating “green” programs to improve their climate change awareness. Moreover, reward systems can be created that can add value to the customer experience and which stimulate improvement of users in driving efficiency or system efficiency.

The third and last category is the development of business models to facilitate cleaner technologies. One possible action proposed is that new business models need a strategy that overcome challenges of new technologies. For instance, if users are anxious about the electric range of their vehicle, VMs can provide chargers network, battery leasing or any other scheme. Moreover, another possible action could be to extend the utilization of vehicles, i.e. while being parked and connected to chargers they can assist the electrical grid by balancing it i.e. stabilize demand/supply of electricity (Bohnsack et al., 2014; Kley et al., 2011). Furthermore, another idea proposed by the dissertation’s author is that VMs business models should take into account a complete energy & GHG Life Cycle Analysis, like the one proposed by Message et al. (2013), so that cleaner products are produced.

In addition, there are possible actions that target the specific-purpose vehicle and urban mobility which EVs are said to have an advantage over TVs (Bohnsack et al., 2014; Kley et al., 2011; McKinsey & Company, 2016). Hence, there are incentives for increasing the market share in these segments that will favor EVs. This is an opportunity for VMs to act on. For instance, specific-purpose vehicles can decreased cost of vehicle (Grosse-Ophoff, Hausler, Heineke, & Möller, 2017) and efficiency because they maximize utility for a particular task. On the contrary, rural mobility is more difficult for EVs due to the lack of infrastructure (McKinsey & Company, 2016) and therefore there is an opportunity to integrate these users to the mobility environment, which is another possible action in the framework. Finally, one of the most important points is the fact that VMs need to start
viewing cars as a platform to provide services, not as a material form to add value (KPMG, 2016; McKinsey & Company, 2016).

### 3.3.1.2. Digitalization and Connectivity

The possible actions to impact climate change using this KDF are divided in three categories which are improving system efficiency, data-driven services and development of digital services that support cleaner technologies. On the first category, improving system efficiency, it can be achieved by collaborating or creating digital services. The framework currently has six options that are available to perform. Firstly, digital services that support new mobility business models, these can be all the schemes listed before as car sharing, ride sharing, etc. (review section 3.1). Secondly, mitigate congestion sources is for instance develop information systems that can share the identity of the drivers involved so that solving the conflict can be sped up (Claudel & Ratti, 2015; Grosse-Ophoff et al., 2017). Thirdly and fourthly come together, the capability to manage the vehicle speed to variable speed limits adapted to current traffic conditions. Moreover, a congestion pricing can be also adjustable (Greene et al., 2011). Fifthly, route and trip planning, (Greene et al., 2011) although it is an obvious action to be done it can have a huge impact if it involves real-time-accurate traffic data and street maps. Sixthly and last is a fleet management system where users, who can be commuters or commercial, can manage their fleet of cars in order to optimize their performance and usage rate.

On the second category, data-driven services, this is mainly produced because connectivity is attracting technology firms to the industry which are used to develop their business models based on data (Beiker et al., 2016; Berman & Others, 2013; KPMG, 2016; Viereckl et al., 2016). In this category, there are four subcategories that are described as follows. Firstly, it is proposed by the author of this dissertation that in order to have better measurements of the actual GHG emissions, these can directly be measured or estimated in every vehicle through digital services that take this information to a database online. In addition, in the case of an EV, when charging it, it can interact with the grid so that the current electricity mix can be taken. Hence, logging and monitoring the GHG in real-time can provide more accurate measurements of the status of climate change. Secondly, by previous experience of the author of this dissertation vehicles’ current internal networks protocols and architectures, although they are reliable, they are
not capable of meet the current and even less the future requirements of speed (bandwidth). This is proven by which says that internal networks of vehicles are slow (Viereckl et al., 2016). Nevertheless, some of the networks have evolved from the 1980’s, like the Controller Area Networks (CAN) and Local Interconnect Networks (LIN), which are not capable to meet users demand and others networks have born or penetrated vehicles starting from 2000, like Flexray, Ethernet and Media Oriented Systems Transport (MOST) which offer to meet high-speed and reliability demands. All these are integrated within vehicles. Furthermore, it is interesting how they can merge with other current technologies as the USB dongle that it is said to be a shortcut for the connected car (Roland Berger, 2016). Thirdly and fourthly, there are the digital services that provide tools to aid the users to drive efficiently and more importantly to create awareness about the climate change issue by linking their actions to their GHG emissions.

On the third category, the development of digital services that support cleaner technologies, was included to review accountability of the firms in regards of supporting cleaner or more importantly renewable-sources technologies as for example those which use the solar energy as solar photo-voltaics; wind energy using wind turbines; and even from nuclear reactors. This category is divided in two sub-categories. Firstly, digital services can integrate the secondary energy supply and its inputs with the GHG emissions of the vehicles in the mobility environment. For instance, creation of smart chargers which can interact with smart-grids so that they can balance the grid (Dijk et al., 2013; Van Themsche, 2016), or developing a network of chargers to overcome the electric range anxiety (i.e. stress caused by knowing that the battery could not have all the required energy to get to the destination) of users. Secondly and lastly, is the use of social media to create awareness on users about the Climate Change Issue and the benefits of cleaner technologies that can be used to solve it. This sub-category enables to measure the proactivity of VMs to leave behind fossil fuels in vehicles.

3.3.1.3. Electrification or E-mobility

The possible actions to impact climate change using this KDF are divided in three categories which are improvement of the system efficiency, improvement of the vehicle efficiency and development of cleaner technologies. Before exploring the categories, electrification, in the mobility context and as defined as the dissertation’s author, means
increase the use of electricity in the mobility environment, or in other words that vehicles use more electricity to create movement. Similarly, E-mobility is taken as Electrified mobility, or in other words vehicles that use electricity. It is worth noticing this because there is some conflict on the authors reviewed. Specifically, on the one hand some authors (Bouton et al., 2015; Dijk et al., 2013) use E-mobility in the same way it is used in this dissertation, i.e. Electrified-mobility, others nearly the same as Electric mobility (Laurischkat, Viertelhausen, & Jandt, 2016) but the concept is equivalent, and on the other hand other authors (Van Themsche, 2016) use it implicitly as Electronic mobility because it is related to the connected and shared economy as for example carpooling and car sharing.

On the first category, improvement of the system efficiency, there are four subcategories. These are all related to support EVs, and the first one is expand charging station network; second, support cleaner inputs to electricity by devising interfaces; third, the hardware capability to integrate EVs to the grid (Dijk et al., 2013; Van Themsche, 2016); fourth and last, it is to provide the vehicle to be used for secondary uses (Kley et al., 2011), for instance provide energy to their home or any other application.

On the second category, improvement of the vehicle efficiency, there are four subcategories. The first one is to reduce required energy to generate movement, which can be achieved by weight reduction, better fuel economy, enhanced aerodynamics, decrease rolling resistance among others (Greene et al., 2011; PWC, 2007). The second, are the efficiency gains in each subsystem of the entire vehicle system, for instance efficiency gains in powertrain, power electronics and other electric accessories, and even in the ICE which accounts most of the energy losses as was previously said (Greene et al., 2011; PWC, 2007). The third and fourth subcategories are related to the electrification process, i.e. how electric powertrains are being included in VMs portfolios starting from HEVs to BEVs.

On the third, development of cleaner technologies, there are five sub-categories. Due to the fact that many authors put the consumer acceptance as highly relevant for the diffusion of new technologies (Dijk et al., 2013; Khare et al., 2017; Kley et al., 2011), it was included the first subcategory as creating consumer acceptance programs of EVs by for instance performing demo shows, loyalty and support programs. The second, is to develop hardware that helps to overcome challenges of new technologies, this needs to
be done together with the digital services, for example smart chargers, smart-grid integration, faster chargers and eventually wireless chargers. The third subcategory is to support battery development, which is said to be the most mature technology available to replace fossil fuels (IPCC, 2014; Mamalis, Spentzas, & Mamali, 2013), as has been discussed previously. However, in the fourth subcategory, another promising powertrain technology was also included in the framework which is the FCV which uses as fuel hydrogen but has an electric motor and therefore is an EV. The fifth and last subcategory, as proposed by the dissertation’s author, is the investment in R&D in cleaner technologies and renewables.

3.3.1.4. Autonomous Driving Vehicle

In regards of this KDF, it is worth emphasizing that this technology is not already available, however due to the fact that it can significantly disrupt the automotive industry (Beiker et al., 2016; Bouton et al., 2015; Claudel & Ratti, 2015; Grosse-Ophoff et al., 2017; Matus & Heck, 2015; McKinsey & Company, 2016; Paul Gao et al., 2014; Van Themsche, 2016; Viereckl et al., 2016), it is of a high priority to include it in the points-based framework to be able to compare VMs not only by analyzing present conditions but for the potential positive impacts in the future.

The possible actions to impact climate change using the autonomous driving vehicle KDF are divided in three categories which are improvement of the system efficiency, improvement of the vehicle efficiency and development of smarter vehicles. On the first category, improving the system efficiency, there are 2 subcategories. Firstly, it is to provide vehicles with systems that interact with other vehicles. This can be through cameras, sensors or any other mean so that vehicles can take collective decisions. For instance, it is said that road capacity, i.e. the number of cars that can transit on a road, can be increased by using unmanned cars; which can be done by using a platooning configuration that has a leading car that communicate the cars properly spaced behind if it has braked, if so then the other will follow; this method is a way to reduce fuel consumption because it can reduce air lags and in overall improve the energy efficiency of all the vehicles behind; it can optimize road capacity and energy efficiency gains especially in highways (Van Themsche, 2016). Although, the latter method it shown for unmanned cars, or autonomous driving vehicles, it is clearly a method that can be applied
for ADAS systems or a semi-autonomous driving vehicle (NHTSA Level 3) where human drivers are behind the wheel just in case that any abnormality arises. Secondly, it is to provide vehicles with systems to interact also with other devices. These can be traffic lights, traffic controllers, speed limits or any other device. This option can be used together with the adjustable traffic management digital service (Greene et al., 2011) proposed in the digitalization and connectivity of this section. These two systems could work in complementary mode so that the energy efficiency will increase (Claudel & Ratti, 2015).

On the second category, improvement of the vehicle efficiency, it was found only one subcategory which it is feasible in the present and it is to provide ADAS systems or semi-autonomous systems with the purpose to limit users to be within high efficiency driving modes. For instance, as per personal experience from the dissertation’s author the Chevy Volt 2010 had a “green” driving button which limited the responsiveness of the throttle pedal (equivalent to the gas pedal in TVs), limited the maximum electrical current output going out from the battery and among other actions. However, this system was limited because it limited only users’ actions because it did not have the capabilities to sense its environment. Hence, it is proposed a system which takes inputs from its surroundings and conditions using sensors or connectivity devices to predict and increase energy efficiency based on this.

On the third and last category, it is to support the development of smarter vehicles, as was told before the technology of the autonomous driving vehicle is not ready yet. On the one hand, some authors tell that these vehicles will be introduced gradually (Claudel & Ratti, 2015), which cannot be refuted by the dissertation’s author, and moreover other authors also confirm this by publishing their thoughts about when it will be ready (Futurism, 2016; IHS, 2016; McKinsey & Company, 2016; Van Themsche, 2016). Still, some VMs, such as Tesla Inc., and technology firms, such as Google, tell they could have it ready before 2020. Regardless, of when it will be ready the truth is that support for the development need to be done. Hence, this is the first subcategory and it is R&D investment in smarter cars or autonomous driving vehicles. The second is to create consumer acceptance, which is said to be one of the biggest barriers to the technology. The third is to focus on specific projects that can develop even more the new mobility business models through the robo-fleets or robo-taxis. Altogether, remember that this
technology, as previously discussed, it is the enabler for not only increased revenues by unlocking new ways to add value to customer through digital connected services (KPMG, 2016), but new ways to increase system efficiency and vehicle efficiency so that GHG emissions are mitigated and, as thought by the dissertation’s author, can even be controlled remotely by adjusting parameters on such vehicles; hence, switching responsibility from users to the autonomous driving vehicle.

3.3.2. THE CREATED FRAMEWORK

The research done was extensive and it gave insights for the dissertation’s author to create the diagram block showing the players, the different layers in which they can exert actions and the links between them. The ultimate objective of this framework is to compare the efforts of EVMs and TVMs, specifically in this dissertation BMW as a TVM and Tesla Inc. as an EVM. Moreover, to indicate current available actions and propose new actions that can impact the Climate Change. Furthermore, this framework can be used as a starting point for other researchers.

It is the belief of the dissertation’s author that the KDF will disrupt the automotive industry, as has been discussed throughout all the document supported by different authors (especially section 3.1), and to give more momentum, or anticipate the disruption, the increasingly concern for the Climate Change Issue by the consumers can be used. To put it simpler, by using the KDFs to positively impact the Climate Change and by creating more public awareness, it can give more momentum to the disruption in the automotive sector because this new movement of people will follow. It will be a gradual process but in the end it will benefit not only the firms involved due to the increase in revenues of the shift from product-based to service-based mobility, but also all the living beings on the planet Earth by avoiding the chaos of Climate Change consequences (section 2.1.2).

To get back to the point, the created framework will be used in the next section (3.4) to compare the efforts currently done by BMW and Tesla Inc. and determine which is addressing better the Climate Change Issue through the KDFs. The diagram block will be presented first and next the points-based system of the framework.

3.3.2.1. Diagram Block of The Framework
The diagram block is a useful tool that allows to determine possible links between players and to discover new opportunities to add value to customers. The diagram block can be seen in the Figure 3-1. Now, it is described in detail as follows. To begin, it is important to notice the level of connectivity and the possibilities to choose from to impact the mobility environment. Although it is truth that the automotive industry is switching to a service-based paradigm where the individual is at the center (Berman & Others, 2013) , it has to be emphasized that the way to reduce GHG emissions in the automotive sector is by handling the emissions of the vehicles, which can be done through efficient or cleaner products (physical interface) or through services that makes them efficient (physical and digital interface). However, as has been told users’ driving behavior also affects these emissions but it is the vehicle which produces it. Therefore, the focus should be on vehicles first and then users.

Firms are grouped together so that they can interact in a new ecosystem which is tending to be digital. The value chain of the vehicles production, as it is widely known, it is dominated by the automakers or VMs. They have been in the front of users strengthening the customer relationship (KPMG, 2016). The fact is that due to the digitalization and connectivity, new entrants are coming. These are major technology
firms as Google, Apple, Uber and others. They are here because the potential profits is high in the foreseeable profits (Grosse-Ophoff et al., 2017; McKinsey & Company, 2016; Viereckl et al., 2016) and they have stronger software capabilities, stronger financial means and bring innovation (Beiker et al., 2016). Hence, there is no surprise when respondents, from China, India & Asean, in a KPMG global survey told that current automakers can become contractors or “metalsmith” (review Figure 5-10) of Information and Communication Technology (ICT) or just simply in this dissertation, technology firms (KPMG, 2015, 2016). It is also the dissertation’s author opinion that due to the mentioned “post-materialism” stage in advanced societies, in which social concerns are above material wellbeing, eventually if automakers do not evolve to see mobility as a service then they will be only hardware suppliers for the technology firms. Hence, due to there is a large option to focus in the automotive industry value change, which are design, product development of hardware, product development of software, production, sales and services, there must be cooperation between all the type of firms in order to meet users demand; which can be done through partnerships (Dijk et al., 2013; McKinsey & Company, 2016; Roland Berger, 2016); however, it is worth noticing that the value chain will be horizontally arranged not vertically (Beiker et al., 2016). To get back to the point, the created diagram block establish that these firms can interact using their products and services through a physical and/or digital interface in four different layers which are the users, the mobility environment, energy supply interface or infrastructure for the different technologies used in power train (e.g electricity, fossil fuels and hydrogen) and finally the secondary energy supply which involves the different technologies as electric power station, nuclear power plant, hydro power plant, wind energy conversion, solar power plant, bioenergy power station and others as defined by IPCC (IPCC, 2014). The primary energy supply cannot interacted with, but in order to affect positively the Climate Change Issue it is better to use cleaner sources and conversion technologies, or even better use renewable resources.

On the first layer, users, it is included all kind of users as private, public and commercial. They can interact with the mobility environment by choosing any of the mobility options offered such as private vehicles that can be directly owned by one or a group of users or companies; diverse mobility or new mobility business models, in which schemes like for example car sharing, ride sharing and e-hailing can be used; public
transport which consists of the metro system, buses and any other public means of transport; and finally other forms of transport like bikes, boats, motorcycles, etc. Moreover, users can also interact with the secondary energy supply. It happens through the utilities services which are mainly produced from centralized systems and through distributed systems. For instance, an example which is very relevant for this dissertation is the fact that EVs can be charged not only using electric energy generated from centralized systems such as a hydropower plant or an electric power station, but also from distributed systems like solar photo-voltaics or wind energy conversion which can also take the advantage of the shared economy business model. Furthermore, the other interaction is where the mobility firms can take part and it is through the physical and digital interface. The possibilities with this interface is basically that everything is connected to everything and therefore links are open to develop new business models or new actions in the points-based system of this frame work.

On the second layer, the mobility environment, its description has already be given but the key point here is that private vehicles can easily become part of the diverse mobility if their owners are connected. Then, when using inter-modality schemes all these modes of transport and its vehicles can be used together. Moreover, the traffic infrastructure and operators is included here such as streets, roads, traffic lights and any other mean of control. Furthermore, another interaction is through the energy supply interface which is presented next. Finally, in order to increase efficiency the interaction in the physical and digital interface needs to be present.

On the third layer, the energy supply interface, it is the way of how the different vehicles are supplied with the energy they need. For instance, in the case of EVs corresponds to the charging stations; TVs with the traditional gas stations or any other fossil fuel station; and FCV need a supplier of hydrogen which is the least developed of these technologies. Again, the physical and digital interface is crucial because it makes this infrastructure connected to the other blocks and can unlock system efficiencies.

On the fourth layer, the secondary energy supply, is where for example the electricity is generated from different sources or the oil is refined to gasoline or any other conversion. So far it was described before, but in terms of electricity it can be generated from distributed or centralized systems. This enables EVs users to choose whether they want to charge their vehicles from the grid or their own distributed system. Again,
efficiencies are unlocked by connecting this to the other blocks. For example, EVs can be used with a secondary mode by balancing the grid.

It could be said that there is an additional layer, which is the primary energy supply. But at the moment the only link to it seems to be how they are used. In terms of climate change, as far as it has been described it is better to avoid using fossil fuels and instead use cleaner or renewable resources.

To conclude, clearly, it can be noticed that the physical and digital interface is the one that connects all the layers with the mobility firms. Hence, these two, the digital and the physical need to be integrated, so that they can increase the overall efficiency of the entire system by connecting it.

3.3.2.2. Points-based System of The Framework

The points-based system of the framework was described in the section 3.3.1 which is the process of creation of the framework. In this section it is explained how this system works. To begin, the reader can find the system in the appendix section. It has a list of possible of actions to impact the Climate Change Issue. Each of these was used to evaluate if the target VMs, BMW and Tesla Inc., were performing any kind of activity related to it. For instance, BMW has its program called DriveNow, which is a car sharing scheme and therefore BMW scores one point. Similarly, it was done with Tesla Inc. After it was evaluated each of the categories and their possible actions in all the KDFs, then the points were summed up to determine which was addressing better the Climate Change Issue based on this framework. The points will be assigned as follows: 1 point is assigned in each possible action if VM has it already implemented, 0.5 points if has plans to do it or comply partially and 0 points if has not deal with it yet.

3.3.3. LIMITATIONS

It is worth expressing that this framework was created from all the research done by the dissertation’s author and in spite of the broad nature of the dissertation topic (climate change, key driving forces and VMs) the creation of the framework was achieved successfully. Nevertheless, this framework should be taken as the starting point for the
analyzing the topic. Further research is needed to expand the number of possible actions and also to introduce a weighted system depending on the level of impact of each of them.

3.4. FINDINGS

This section presents the main findings of the evaluation done of the VMs BMW and Tesla Inc. when using the created points-based system framework. The aim here was to address the following research question: are relevant EVMs in comparison with relevant TVMs, in the luxury segment, addressing better the Climate Change Issue through their responses to the main key driving forces that are changing the passenger segment of Light Duty Vehicles in the global automotive industry?. By answering it, it should determine if TVMs lack commitment to accept change introduced by the KDFs and more importantly to avoid Climate Change based on the results obtained.

Each of the VMs will be analyzed in all of the categories of the KDF. The reader can review the results in the appendix section 5.7.

3.4.1. NEW MOBILITY BUSINESS MODELS

3.4.1.1. Improvement of the system efficiency

On the one hand BMW has had a car sharing scheme called DriveNow from 2011 which is a joint venture with the car rental Sixt. It is only available in Europe and specifically in Germany, Austria, the UK, Denmark, Sweden, Belgium and Italy. Users can pick up anywhere and drop off anywhere, billing is per-minute, fuel costs and parking fees in public parks are included (BMW, 2017d; DriveNow, 2017). Moreover, in the USA they have another program called ReachNow, launched in 2016, which is property of BMW group and includes more mobility services as car & ride sharing and even e-hailing (Automotive News, 2016a; BMW, 2016a, 2016b). Their vehicle also include intermodal routing through their ConnectedDrive, if an alternative means of transport is faster (BMW, 2017a). On the other hand, Tesla Inc. does not have evidence of multi-modal schemes but have plans for car sharing, ride sharing and e-hailing (Automotive News, 2016b). Nevertheless, they have plans to have to turn their cars driverless. It is said that all their vehicles from October 2016 have already hardware for full autonomous driving
(Bloomberg, 2016b; Fortune, 2016; Tesla, 2016b). None of the VMs have or applies in the private shuttle action.

3.4.1.2. Data-Driven Business Models

BMW offers the technology to drive efficient, to plan the most efficient route but does not engage users to reduce their impact to the Climate Change (BMW, 2017a). Tesla Inc., is not that transparent as BMW in regards of publishing information. Nevertheless, vehicles incorporate power management options, real time power consumption and can set the navigation routes with real time traffic, but there is not efforts to engage users to reduce their impact to the Climate Change (Tesla, 2017h, 2017f).

3.4.1.3. Development of Business Models That Support Cleaner Technologies

BMW in all the stages of its value chain they mention environmental concerns as design for recycling or disposal of batteries and accounts the CO2 emissions (BMW, 2016b). BMW group through its subsidiary Alphabet is accounting the energy efficiency and sustainable fleets in the commercial segment (BMW, 2016b). It also has developed other systems as ParkNow which helps having information about parking in a city that increases system efficiency; also ChargeNow to locate the public charging station from different providers (BMW, 2017d); and Eco Route which is designed for EVs to evaluate the charge level of battery and the energy required, if low it establish new routes, activates Eco Route driving mode or indicates the nearest charging station (BMW, 2017a). Altogether, these systems are helping deploying EVs and also increasing system efficiency. Finally, the shift of paradigm of mobility as a service can be evidenced when BMW says that:

“The BMW Group offers its customers premium quality individual mobility. The focus is always on driving enjoyment. This brand promise has become a challenge, in particular in densely populated urban spaces, but also on the motorways around large cities. The increasing volume of traffic in cities often goes hand in hand with a significant rise in noise and air pollution, consumption of space as well as increased risk of accidents.” (BMW, 2016b, p. 40).
It is evidenced that they are concern about the mobility issues and therefore they are taking actions to counter act by using technologies in connected mobility and autonomous driving.

Tesla Inc, has developed a supercharger network which has the capacity to extend the electric range in just minutes of charging. It also provides multiple solutions for home and commercial places. Its website enables to see the cost advantage of having an electric vehicle by comparing the cost of recharging a EV against the equivalent cost of gasoline (Tesla, 2017c). In regards of the paradigm shift, it must be said that Tesla Inc. is a recent and small company and its product portfolio currently has only 2 models and another one is expected to be launched in late 2017 to early 2018. It has been targeting the luxury segment individual mobility to support their operations, therefore it can be analyzed that it is still with a product-based paradigm by focusing in increasing performance as acceleration.

3.4.2. DIGITALIZATION & CONNECTIVITY

3.4.2.1. Improvement of System Efficiency by Developing Digital Services

As the digitalization and connectivity is at an infant stage, it is no surprise that both vehicles do not have capabilities to communicate with other vehicles or other traffic management devices such as traffic lights. Still, BMW support shared mobility through a third-party (Automotive News, 2016a) and Tesla Inc. has plans to offer them (Automotive News, 2016b). Also fleet management is offered by BMW group through its subsidiary Alphabet (BMW, 2016b), whereas Tesla Inc. does not have this service when searching on its website. Moreover, they both offer navigation services with real time traffic.

3.4.2.2. Data-Driven Services

The capability of logging and monitoring GHG in real-time is not added to the vehicles on both VMs. They both have very advanced networks, in the case of BMW it has added remote services as remote control parking (BMW, 2017c) and Tesla Inc. has included Over The Air software updates so that vehicles are improved remotely (Tesla, 2017f). Moreover, both VMs develop digital services to drive efficiently but do not create awareness on users.
3.4.2.3. Development of Digital Services that Support Cleaner Technologies

As previously said, both VMs have business models which support cleaner technologies. These are offered to the customer as digital services app-based and web-based (BMW, 2017d; Tesla, 2017c). Finally, both VMs also use social media to create awareness about the climate change issue. BMW uses its BMW i brand, which are EVs, to do this (BMW, 2016b) and Tesla Inc., through its CEO Elon Musk, is bringing the Climate Change Issue to social media and even into the White House in the US (Ferris, 2017).

3.4.3. ELECTRIFICATION OR E-MOBILITY

3.4.3.1. Improvement of the System Efficiency

Both VMs are expanding their network of charging stations. BMW is working together with other automakers (Nissan, Renault, Volkswagen among others) and co-financed by the European Union to build the Rapid Charge Network across Europe since 2013 (RCN, 2017). Moreover, it has also partnered with Ford, Daimler and VW group to start a new project to establish a ultra-fast high-powered charging network faster than the previous one and that users should have access to them by 2020 (Automotive News, 2016c).

BMW and Tesla also support renewable energies. BMW has its program BMW I 360 ELECTRIC which through partners electric vehicles can be charged from renewable sources in 15 countries (BMW, 2016b). Tesla Inc., formerly named Tesla Motors, change its name after merged with SolarCity, a solar panels company (Bloomberg, 2016c). After this, it can be read on its website that “Tesla is not just an automaker, but also a technology and design company with a focus on energy innovation.” So that it can be evidenced that Tesla Inc. is not only playing in the mobility environment but also in the secondary energy supply layer.

Other technologies as the capability to integrate with the grid or provide the EV with a secondary energy usage could not be found.

3.4.3.2. Improvement of the Vehicle Efficiency
In terms of improving the vehicle efficiency both VMs have a continuous development on their vehicles. BMW has reduced their CO2 emissions, increased their ICE efficiencies with the Efficient Dynamic NEXT focus, introduced its fleet of PHEVs under the brand i performance and also the BMW i BEVs (BMW, 2016d). Tesla Inc. has improved their regenerative braking systems and is increasing its BEVs fleet to include a lower cost model named the model 3. It is worth noticing that Tesla Inc. does not use any fossil fuel technology (Tesla, 2017f, 2017h, 2017c).

3.4.3.3. Development of Cleaner Technologies

The consumer acceptance programs of EVs are done through demo shows. For example, Tesla Inc. on its website publishes the events around the world where users can test its models (Tesla, 2017d), but it is the major success bringing attention of the customers is the excellent performance that the cars have which can accelerate similar to the fastest sport cars from Lamborghini or Ferrari. BMW on the other hand is gaining attention to its BMW i3 series through marketing. Both VMs are constantly enhancing their technologies as has been said and both have partnerships with battery producers. In the case of Tesla Inc. it has built the biggest factory named the Gigafactory in cooperation with Panasonic; it is said to be capable to produce more lithium ion batteries per year than the number produced globally in 2013 (Tesla, 2017i). BMW support other powertrain technologies such as the FCV (BMW, 2016d), whereas Tesla Inc. only BEVs. Finally, both VMs comply to invest in R&D in cleaner technologies as has been described.

3.4.4. AUTONOMOUS DRIVING VEHICLES

3.4.4.1. Improvement of the System Efficiency

Both VMs provide the vehicles with semi-autonomous capabilities. For example, BMW uses the system Intelligent Driving, which for example provides usersto enable cruise control, traffic jam assistant and lane keeping assistant and departure warning (BMW, 2017b). Tesla Inc. uses its Auto Pilot which has been told to be capable of having autonomous driving capabilities (Tesla, 2017h), nevertheless there has been some accidents and it is yet to be fully developed. However, semi-autonomous capabilities can be achieved.
3.4.4.2. Improvement of the Vehicle Efficiency

Both firms focus on assisting the drivers, but the efficiency of this could not be found. It is left as an opportunity for development for future research.

3.4.4.3. Development Support for Smarter Vehicles

In regards of this, as has previously been discussed, both companies have already semi-autonomous driving technology implemented on their vehicles. There is the need to develop more the technology. BMW has as its future focus the digitalization, which involves connectivity, artificial intelligence and autonomous driving (BMW, 2016d) and it hopes to lead specially in the autonomous driving with its BMW iNext model by 2021. Tesla Inc. is continuously upgrading its AutoPilot (Tesla, 2017b).

3.4.5. SUMMARY OF FINDINGS

The use of the framework done and the research done generated the Figure 3-2 in which the two VMs are plotted. It can be seen that BMW is above the performance of Tesla Inc. Further details can be found in the appendix section.

![Figure 3-2 Summary of findings of Vehicle Manufacturers performance.](image-url)
3.5. DISCUSSION OF FINDINGS

In order to get to the findings it was first established the framework with its diagram block and its point-based system. Then, when using this framework to be able to compare the chosen relevant TVM and EVM, i.e. BMW and Tesla Inc. correspondingly, the research revealed that in overall BMW is addressing better the Climate Change Issue through the KDFs. The Autonomous driving vehicles KDF is the only one that Tesla Inc. was above BMW. Next, the findings are discussed.

In regards of the new mobility business models, what can be seen at first sight is that BMW has a considerable advantage in the development of business models categories that support cleaner technologies. BMW has focus one of its EV models, the BMW i3 in the urban mobility issue, focusing in specific-purpose vehicles so it earned points because of this. Moreover, it is also working together with commercial users which gives him more points. The key point to notice here is that by focusing on urban mobility the benefits of the EVs will be maximized (Kley et al., 2011) against the TVs. Nevertheless, Tesla Inc. continues to focus in multi-purpose vehicles which are bigger and not that efficient.

In terms of system efficiency, BMW is using almost every sharing economy scheme, in specific car sharing, ride sharing and e-hailing. This is no surprise, due to the fact that from 2010 other automakers have invested or created partnerships to deal with the digitalization and connectivity KDF; it is said that in total R&D budgets increased 61% to $137 billion (EVANNEX, 2016). On the contrary, Tesla Inc. has only made plans for it. It has lag behind.

It is the dissertation’s author opinion that there is an opportunity to introduce new business models by creating a reward system or a punishment system in which depending on the driving efficiency of the user it gets a reward or punishment. The inspiration of this idea was from the pay-how-you-drive proposed system in car rentals (Roland Berger, 2016), but with this one is applying it to the climate change. Ultimately, a direct carbon tax can be charged to users. Neither BMW nor Tesla Inc. link user driving behavior to Climate Change. In the case of BMW only the efficiency of the trip, which is half of the story.

In regards if digitalization and connectivity, BMW is above Tesla Inc. but this time subtly above. It is worth to remark that both players are using well the digital services to
overcome challenges of new technologies. Both VMs have a very sophisticated infotainment system with advanced capabilities. They can also be controlled remotely, us in the case of BMW or its firmware updated as the case of Tesla Inc. Nevertheless, both players have not developed connectivity with other devices or was not found. More research is needed here because there is also another trending technology change called the Internet Of Things (IoT). New efficiencies will be unlock when the car gets connected with others devices.

In regards of electrification or E-mobility, it was a surprise to find that BMW is in a very advanced position. The main advantage of BMW over Tesla Inc. in this framework is the fact that oil transition to cleaner technologies will take some time, so in order to impact positively the Climate Change ICE efficiencies need to be increased and HEV and/or PHEV need to be used and the problem is that Tesla Inc. does not produce any of these; hence, it is in disadvantage for it in this framework. Nevertheless, BMW has another advantage and it can be explained using the three-horizons framework. Its horizon 1 is the ICEV, which will decline in the future as has been discussed and therefore it is being defended and extended; the horizon 2 comprises all the KDFs, which as has been already indicated are on BMWs strategy documents; and in the case of the horizon 3 it needs more research. The highlight here is that BMW is benefiting from this framework because it continues to use ICEVs and enhancing their efficiency.

It is also worth noticing that both VMs are penetrating in new layers of interaction as can be seen in the diagram block of the framework (Figure 3-1). VMs are doing this through partnerships, as is the case of BMW, or by M&A as is the case of Tesla Inc. This depicts a new activity in the mobility value chain.

In regards of autonomous driving vehicles, Tesla Inc. is the one that is above but only for a minor margin. The race for autonomous driving vehicles is fierce, Tesla Inc. seems to be ahead but by 2020 other automakers will be selling these kind of vehicles and then it would be seen which company has the best capabilities.
4. CONCLUSION

The automotive industry is facing an imminent disruption from the Key Driving Forces (KDFs) and also needs to reduce its impacts on the Climate Change Issue. This dissertation set out to merge these three topics, the auto industry, KDFs and the Climate Change Issue, so that it could determine which Vehicle Manufacturers (VM), Electrical or Traditional VM, was addressing better the Climate change by evaluating their responses to the KDFs. In order to do this, a framework was created based on an extensive research.

The research started from the Climate Change Issue, where the main target was to understand its relationship with the automotive industry. This was successfully achieved. The most important point was that there is a sense of urgency because the CO2 concentration levels in the atmosphere are already in critical levels. It is above 400 ppm and depending on the climate sensitivity it needs to be stabilize below 600 ppm but recommended value is 350 ppm (Azar, 2009).

The automotive industry can help to mitigate the CO2 emissions and this was found to be through improvements in its efficiency and through decarbonizing the sources. Here, the EVs were shown to have a great potential to abate emissions, due to their zero-emissions nature during its usage. However, EVs have challenges as the energy density, the charging infrastructure and that their benefits depends on the electricity supply mix of the grid. The more cleaner and renewable the mix, the better the benefits. Furthermore, EVs not only were found to have a good environmental performance, but also they can provide additional benefits like balancing the grid (Dijk et al., 2013; Kley et al., 2011).

Next, the research continued and the most relevant KDFs to the Climate Change Issue were new mobility business models, digitalization and connectivity, electrification or e-mobility, and autonomous driving. These KDFs are currently creating change in the automotive industry and a disruption is imminent as has been discussed. Digitalization and connectivity will accentuate the transition from a product to a service-based mobility. Fortunately, for the Climate Change this will unlock further efficiencies that will help to abate GHG emissions. Moreover, new mobility business models are currently a solution for the increasing population where ownership model is not sustainable. Lastly, it is important to mention that all the KDFs reinforce each other and the next level of
improvement is when the autonomous driving vehicle would be ready so that vehicles could become “mobile data rooms” as said by KPMG (2016).

Moreover, another key point is that the KDFs are attracting technology firms and these can increase the pace to disruption as they bring innovation and financial means (McKinsey & Company, 2016; Viereckl et al., 2016).

The research done showed that the literature was focusing on one or two of the topics, but it was never found a single article which addressed the three topics: auto industry, KDFs and Climate Change Issue. Therefore, in order to address this gap the research consisted of the review of the three topics, then their analysis and finally the creation of the framework. This is composed by a diagram block detailing all the key players in the supply and demand side in the mobility environment which can be reviewed in the Figure 3-1 and a points-based system which is used to evaluate the VMs.

This dissertation was successful in filling the gap of merging the three topics. The created framework can be used as a starting point to check if current actions of VMs are embracing change of the KDFs while addressing the Climate Change Issue. On the one hand, the KDFs topic is very important for VMs because they will create disruption sooner or later, as has been discussed in this dissertation. Hence, it is better for VMs to anticipate change and notice any opportunity using the created diagram block or the points-based system. On the other hand, the Climate Change Issue can be addressed through the KDFs and therefore there is a social responsibility from VMs to reduce impacts to it. Again, the framework can guide to notice opportunities and strengths.

It is worth mentioning that the diagram block of the created framework provides tools to the firms involved to see new business models and policymakers to make new standards. This diagram block suggests that firms involved need to interact with the extended mobility environment through a physical and digital interface, which is basically formed by 4 layers which are the users, the mobility environment, the energy supply interface and the secondary energy supply. The truth is that by connecting all these layers the whole system can work more efficient. Moreover, if each block of the framework is improved in its efficiency and decarbonized, further GHG mitigation can be met.

Finally, the findings after answering the research question revealed that in overall the TVM BMW is addressing better the EVM Tesla Inc. through its responses to the KDFs.
It is worth mentioning that it is good to see that leading VM in the industry are committed with the Climate Change Issue. This commitment will eventually spread to other VMs. On the contrary, Tesla Inc., although it is a recent automaker, has also a high performance. Nevertheless, it has to be said that due to its size, it is limited to perform more actions. But through its “Master Plan: Part Deux” it seems that it will succeed in its mission to accelerate the world’s transition to sustainable energy and investors support it.

In regards of the future of automotive industry there is concern among the VMs of how and when the KDFs will disrupt it. New entrants as Google, Apple and Uber are coming. Disruption is predicted in the near future (Beiker et al., 2016; KPMG, 2016; McKinsey & Company, 2016; Viereckl et al., 2016). VMs have already started to strengthen their software skills or they could finish working as contractors. Partnerships with Tech players are needed. Lastly, EVs should penetrate markets in urban areas, but TVs are going to keep strong until the transition from fossil fuels to renewable energy is completed.

The created framework should be considered in its infant stage it only takes into account the key players. Government regulation is not included, but it is clearly a constraint in some countries. The points-based system of the framework points are equally distributed, but for future research a weighted system can be established so that it can produce an accurate result. Finally, this framework has focused only in the climate change issue but other negative impacts of new technologies may arise. A full LCA needs to be done and also this FW can be extended to include it.

In regards of a suggestion for future research, it has to be said that this topic was also chosen in order to bring it to the Corvinus University of Budapest and create awareness about the Climate Change Issue. It is a real problem that can be solved from a business or economics perspective. The university can offer in the future courses in energy economics and sustainable economics.

Moreover, the created framework can be expanded to suit the further needs. For instance, the points-based system can be improved by establishing a weight system in their points. In order to do this, more research is required in each of the KDFs.

It is the responsibility of every human being on the planet Earth to mitigate our impact to the Climate Change. In this dissertation it was only shown one aspect of the problem, it need to be accounted from every single source of GHG.
5. APPENDIX

5.1. CLIMATE CHANGE

Figure 5-1 Carbon Dioxide concentration during the last 400,000 years
Source: (NASA, 2013)

Figure 5-2 Common era trends of global mean temperature anomaly
Source: (Salawitch et al., 2017)
5.2. LIFE CYCLE ASSESSMENT

Figure 5-3 Life Cycle Analysis for vehicles and fuels
Source: (Messagie et al., 2013)

5.3. PRIMARY ENERGY SUPPLY

Figure 5-4 Energy Primer. Flow of energy from source until end-users.
Source: (IPCC, 2014, p. 519)
<table>
<thead>
<tr>
<th>TYPE OF FUEL</th>
<th>GLOBAL ENERGY SUPPLY</th>
<th></th>
<th>GLOBAL ELECTRICITY SUPPLY</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>24.5</td>
<td>28.6</td>
<td>38.3</td>
<td>40.8</td>
</tr>
<tr>
<td>Oil</td>
<td>46.2</td>
<td>31.3</td>
<td>24.8</td>
<td>3.3</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>16</td>
<td>21.2</td>
<td>12.1</td>
<td>21.6</td>
</tr>
<tr>
<td>* Fossil Fuels</td>
<td>86.7</td>
<td>81.1</td>
<td>75.2</td>
<td>66.7</td>
</tr>
<tr>
<td>Renewable</td>
<td>0.1</td>
<td>1.4</td>
<td>0.6</td>
<td>6.3</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0.9</td>
<td>4.8</td>
<td>3.3</td>
<td>10.6</td>
</tr>
<tr>
<td>Hydro</td>
<td>1.8</td>
<td>2.4</td>
<td>20.9</td>
<td>16.4</td>
</tr>
<tr>
<td>Biofuels and waste</td>
<td>10.5</td>
<td>10.3</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 5-1 Global Energy Supply & Electricity Supply 1973-2014

Made by the author based on (IEA, 2016).
5.4. KEY DRIVING FORCES

![Table: New mobility business models](image1)

**Figure 5-5** New mobility business models.
*Source: (Bouton et al., 2015)*

![Diagram: Main components of urban mobility](image2)

**Figure 5-6** Diagram block showing the main components of urban mobility.
*Source: (Bouton et al., 2015)*
Figure 5-7 Examples of digital services offered to the connected car
Source: (Roland Berger, 2016)

Figure 5-8 Players and their digital services.
Source: (Viereckl et al., 2016)
5.5. KEY PLAYERS

5.5.1. BMW

![Diagram of BMW Strategy]

Figure 5-9 Summary of 2016 BMW Group Strategy. Made by author.

5.6. THE CREATED FRAMEWORK

5.6.1. FRAMEWORK: DIAGRAM BLOCK

![Diagram of the redefined automotive value chain]

Figure 5-10 VMs: Metal Smith or Grid Master.
Source: (KPMG, 2015).
### 5.6.2. FRAMEWORK: POINTS-BASED SYSTEM

#### New Mobility Business Models

<table>
<thead>
<tr>
<th>Possible Actions to impact CLI</th>
<th>Description</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Improvement of the system efficiency</td>
<td>Develop digital services to integrate to the smart grid.</td>
<td>3</td>
</tr>
<tr>
<td>2.</td>
<td>Increase market share on specific purposes vehicles</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>Develop strategies that overcome challenges of new technologies</td>
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</tr>
</tbody>
</table>

#### Digitalization and Connectivity

<table>
<thead>
<tr>
<th>Possible Actions to impact CLI</th>
<th>Description</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Improvement of system efficiency</td>
<td>Develop digital services to support NMBM</td>
<td>3</td>
</tr>
<tr>
<td>2.</td>
<td>Minimize congestion sources</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>Management of vehicle speed</td>
<td>1</td>
</tr>
<tr>
<td>4.</td>
<td>Optimize traffic conditions to ensure flow</td>
<td>1</td>
</tr>
<tr>
<td>5.</td>
<td>Route &amp; trip planning</td>
<td>1</td>
</tr>
<tr>
<td>6.</td>
<td>Fleet management</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Electrification or E-Mobility

<table>
<thead>
<tr>
<th>Possible Actions to impact CLI</th>
<th>Description</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Improvement of the system efficiency</td>
<td>Expand charging station network</td>
<td>3</td>
</tr>
<tr>
<td>2.</td>
<td>Support clean inputs to electricity generation</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>Integrate EVs in the grid</td>
<td>1</td>
</tr>
<tr>
<td>4.</td>
<td>Provide EVs with secondary energy usage capability</td>
<td>1</td>
</tr>
<tr>
<td>5.</td>
<td>Use of social media to create awareness about CLI and cleaner technologies</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Autonomous Driving Vehicle

<table>
<thead>
<tr>
<th>Possible Actions to impact CLI</th>
<th>Description</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Improvement of the system efficiency</td>
<td>Develop autonomous systems to increase efficiency</td>
<td>3</td>
</tr>
<tr>
<td>2.</td>
<td>Use of social media to create awareness about CLI and cleaner technologies</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Electricity Access to Energy

<table>
<thead>
<tr>
<th>Possible Actions to impact CLI</th>
<th>Description</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Improvement of the system efficiency</td>
<td>Increase BEV share on portfolio</td>
<td>3</td>
</tr>
<tr>
<td>2.</td>
<td>Increase the share of EV products in the market</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>Use of social media to create awareness about CLI and cleaner technologies</td>
<td>1</td>
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</table>

### Table 5-2 The Created Framework: Points-based system

<table>
<thead>
<tr>
<th>Possible Actions to impact CLI</th>
<th>Description</th>
<th>Points</th>
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<tbody>
<tr>
<td>1. Improvement of the system efficiency</td>
<td>Develop autonomous systems to increase efficiency</td>
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**Author:** Jorge Reyes
**CUB – Master in Arts IEB**

**Thesis Work**

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**Jreyes085@gmail.com**

**02 May 2017**
5.7. FINDINGS

5.7.1. TABLES OF FINDINGS

Table 5-3 Tables of findings for all KDFs
5.7.2. GRAPHS OF FINDINGS

Figure 5-11 New mobility business models findings

Figure 5-12 Digitalization and connectivity

Figure 5-13 Electrification or E-mobility findings
Figure 5-14 Autonomous driving vehicles findings
6. REFERENCES


KPMG. (2015, November). Metalsmith or Grid Master.


