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Automotive Corporations' Performance in the Environmental Field

A Comparison between the European Union and the United States

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Ai miei genitori, che ci hanno creduto
prima che ci credessi io.
A John, che mi ha ispirato a raggiungere
traguardi sempre più grandi.
A Tere, che silenziosamente mi ha dato la forza
di affrontare anche i momenti più difficili.
A tutti coloro che porto nel cuore.

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Abstract

Nowadays, the commitment to reduce emissions in all productive sectors is more than ever a paramount goal that each country in the world should try to achieve.

The Kyoto Protocol and the Paris Agreement have contributed to spreading the unavoidable need of reducing greenhouse gas emissions and making the production processes more sustainable. Countries like the European Union and the United States of America work as examples to others due to their long experiences in regulating emissions from multiple sectors and in implementing key strategies for incentivizing the change towards sustainability. Either through effective emission trading schemes or specific directives and regulations, both the European Union and the USA are currently covering the majority of their productive sectors.

In this paper, the focus will be on the automotive industry, a major source of CO_2 emissions, and harmful pollutants. An analysis of the actions taken in the two similar markets of the European Union and the USA will be conducted, and, in particular, the attention will be put on the legislation affecting the light-duty vehicle manufacturers.

The standards, the targets and their levels of stringency for reducing GHG emissions will be examined, taking into account the changes that took place throughout the years since the beginning of their implementation and the ultimate goals of limiting global warming to 1.5°C and of reducing CO_2 emissions by 45% by 2030. Also, particular attention will be devoted to incentives encouraging carmakers to invest in, produce, and sell low-emission and alternative-fueled vehicles.

This paper aims to investigate whether the instruments adopted by the European Union and the United States of America to regulate the environmental side of the automotive sector have a strategic impact on carmakers' strategy, beyond their true effectiveness. Considering the different targets and standards set by the EU and the US, an analysis through the strategic models of the Business Ecosystem and the Business Model Canvas will be conducted to determine what makes the two systems, the EU and the US, intrinsically different when it comes to the environmental policies implemented for regulating the automotive corporations.

Introduction

"Today the world is united in the fight against climate change. Today the world gets a lifeline, a last chance to hand over to future generations a world that is more stable, a healthier planet, fairer societies and more prosperous economies. This robust agreement will steer the world towards a global clean energy transition". These words have been pronounced by Jean-Claude Junker, President of the European Commission from 2014 to 2019 after the ratification of the Paris Agreement in 2015. This agreement was set to further commit countries to act against global warming.

It is now ascertained that man-made emissions are the major cause of climate change, and, specifically, carbon dioxide (CO_2) emissions must be reduced to maintain the global temperature below 2°C. Between 1990 and 2017, the change in total CO_2 emissions amounted to a 60% increase as it is shown in *Figure 1*.

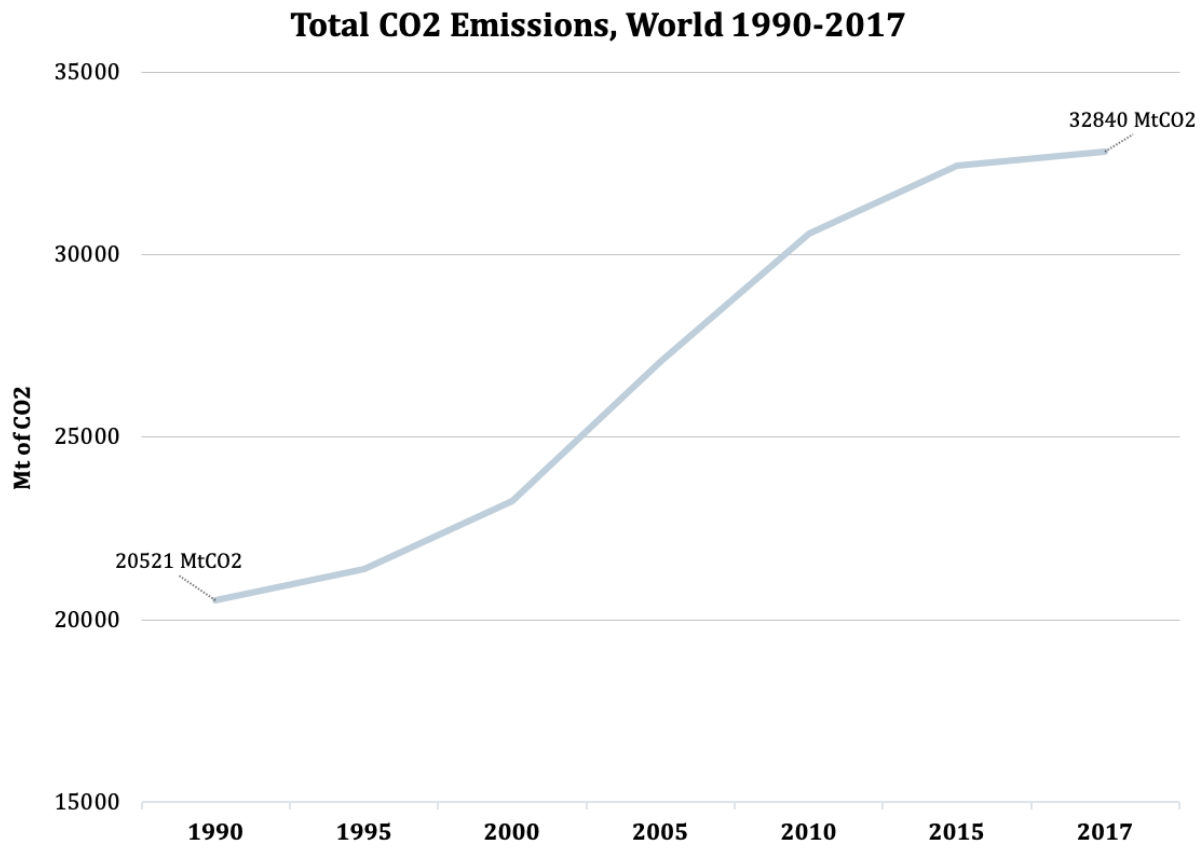

Figure 1 Total CO_2 Emissions, World 1990-2017.

Source Author's adaptation of the data contained in IEA, 2019. Retrieved in https://bit.ly/39hc7j0 on 25.03.20

Everyone from international institutions to countries, from industries to individual citizens must contribute to the reduction of GHG emissions, which are too high to be sustainable not only for human beings but especially for the world it is hosting us. The required change is surely not easy to be achieved, however, it is a mandatory action to be taken at all levels.

Considering corporations, they were used to operate in globalized contexts, which are dynamic and certainly complex but characterized by uniform business strategies that have evolved throughout the years. The climate change and challenges with their annexed environmental policies that started being developed among the major institutions and government came as disruptive, unexpected forces in the business world. Corporations were and are asked to completely re-think their processes, their production, and even their strategies. This is because the environmental issue requires a systemic change in their operations and affects the architecture of their products.

At the institutional level, most of the developed countries, being the highest emitters worldwide, took action mainly through carbon taxes and emission trading initiatives.

The majority of the emission trading schemes (ETSs) work as cap-and-trade systems, where entities covered are allowed to emit a certain amount of emissions each year and to trade emission allowances in case of necessity. These flexibilities help businesses to achieve their emissions reductions' obligations, thus, when an installation fails to do so, then it is subject to a penalty which is set by the government.

Currently, a total of 20 ETSs are in force with many more scheduled or considered in every part of the world. They differ in terms of GHGs covered, some of them include all GHGs, others focus just on CO_2; they also differ in terms of sectors covered, with the majority of them setting emission caps on power, energy, and industry sectors.

One of the oldest ETSs is the European Union Emission Trading Scheme (EU ETS), that is in force since 2005. Its coverage includes all GHG emissions coming from high-polluting sectors such as industry, energy, and aviation. In the United States, instead, in addition to a multi-sectoral ETS, there is an automotive-only ETS which made it interesting to investigate which impact the EU's and the US' legislations have on this specific industry.

The choice of focusing on the automotive industry has different reasons:

1. This industry is responsible for almost 72% and 82% of GHG emissions from the whole transport sector in the EU and the US, respectively;
2. Lately, the industry began to face numerous and even increasing challenges, namely the rise of automated and connected vehicles, the increasing power of the car-sharing business, and, last but not least, the rising importance of developing zero- and low-emission fleets. All these factors are contributing to a major change in the nature of the industry itself;
3. The corporations operating in this sector must comply with ever-stringent standards and targets coming from different regulatory bodies, whose requirements differ depending on the market in question.

As a consequence, this paper will focus on how two similar markets from the automotive industry's point of view, the EU and the US, are regulating the corporations operating in this sector. In particular, it will be analyzed the impact on the corporations' strategies of having a command-and-control type of legislation, implemented in the EU, and a market-based one, implemented in the US.

The intrinsic difference between the two systems is that while in the EU the Commission defines the standards and the Member States must think how to achieve them, in the US, the National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) determine the standards and targets that automakers should achieve also through the use of flexibilities in the form of credits trading among them. This implies that the nature of the relationships between the corporations and the stakeholders has a different value in the two markets.

Relationships with regulatory institutions and trade associations seem to play a major role in the EU context, while in the US the most important relations are those with other competitors. These different behavioral approaches affect the automotive corporations' *modus operandi*, despite they are investing in and offering the same products to satisfy the legislative requirements and the consumers' wants.

The question is: does the type of legislative instruments for regulating emission, command-and-control versus market-based, affect the corporations' strategies? If so, to what extent and how are the automotive businesses adapting?

The paper is organized as follows: the first chapter will provide an overview of the main ETSs implemented worldwide with a particular focus on the EU and the US ones. It will also present information on the automotive regulations implemented in the different areas of the world to determine which is the level of harmonization globally in terms of standards and incentives. The second chapter will focus specifically on a juridical comparison between the EU and the US. Here, the author will deeply analyze the main laws applied to the automotive industry and related to the environmental sphere. Moreover, at the end of the chapter, the main technical legislative differences will be presented allowing the analysis to move to an even deeper level in the third chapter. This last chapter will focus on the ultimate goal of the thesis, that is understanding through the use of management models, specifically the Business Ecosystem and the Business Model Canvas, how the European and the American legislations on emissions impact on the strategic operations of the main automotive corporations. Finally, the main conclusions derived from the analysis conducted from the first to the third chapter will be presented.

Chapter 1 – Emissions Trading Practices in the Automotive Industry

As of 2020, countries all around the world have understood the paramount effort they have to put in acting against climate change. It is largely agreed that the two most common ways to decrease greenhouse gas (GHG) emissions are either market-based instruments (carbon taxes or emissions trading) or command-and-control instruments (regulations or directives) (Gorski, 2019).

Emission Trading Schemes or Systems (ETSs) have spread globally, in particular after the implementation of the Kyoto Protocol[1] in 1997. ETSs have become so common because they have proven to be cost-efficient in reaching emissions reduction targets and because they provide an incentive to reduce emissions more than under command-and-control mechanisms (Ellerman et al., 2003). ETSs vary in terms of GHGs and sectors covered, but the overall goals and structure stay the same.

Concerning their structure, ETSs work as cap-and-trade mechanisms, since they set a cap on emissions that installations included in the ETS can emit. In turn, these installations can trade the emission allowances at their disposal (Narassimhan et al., 2018). The allowances are generally provided by the government either through free allocation (grandfathering or benchmarking) or auctioning. Auctioning is an efficient way to generate revenues that can be invested in R&D towards better technologies or in projects to combat climate change. Thanks just to the ETSs, governments collected a total of $57.3 billion in auction revenues in 2018 (ICAP, 2019).

Figure 2 shows the main industries where ETSs are adopted. Despite the Asia-Pacific covers all sectors, it is also worth mentioning that the majority of the ETSs in force in this area are pilots. As it will be seen later, China has created a series of ETSs in different cities and regions covering different industrial sectors and offering different flexibilities, penalties, or allocation procedures. The Chinese choice reflects the need to experiment

[1] The Kyoto Protocol is the outcome of the United Nations Framework Convention on Climate Change (UNFCCC). It set legally binding emission limits for the developed countries of the globe (Annex B countries). They are required to reduce GHG emissions to 20% compared to 1990 levels over the period 2013-2020 (UNFCCC, 2020a).
The Kyoto Protocol was then reinforced by the Paris Agreement in 2015, when both developed and developing countries commited at keeping global warming below 2°C and at reaching the target of 1.5°C (UNFCCC, 2020b).

with different procedures to determine which one works better. Also, all the ETS implemented worldwide are inspired by the EU ETS, which, despite it does not cover all the industrial sectors, it opted for including only the most polluting ones: industry, power, aviation, and buildings. The focus on these four sectors has allowed the EU ETS to maintain a high level of control all over the European territory and it has also determined its success throughout the years since its implementation. The same holds in the case of the United States, they do not cover the totality of industrial sectors to maintain a highly efficient system.

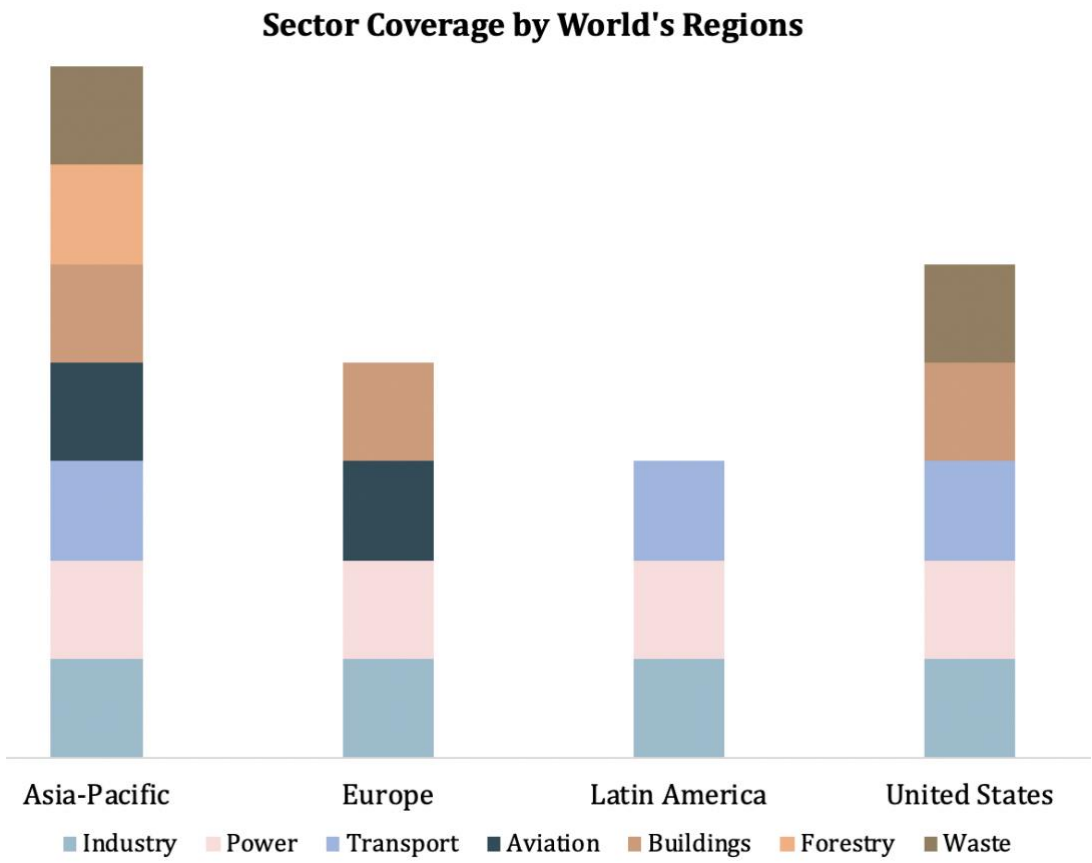

Figure 2 Sector Coverage by World's Regions.

Source Author's adaptation of the data contained in WB (2019), p.17

Among the sixteen[2] ETS considered in *Figure 2*, only five of them cover the transport sector. The reason is related to the fact that this industry accounts for 24% of global CO_2 emissions, which is a smaller but still relevant percentage compared to the CO_2 emissions caused by the power, industry, and the aviation sectors. Another reason

[2] Tokyo ETS, Korea ETS, the eight Chinese ETS, New Zealand ETS, RGGI, California ETS, Mexico ETS, European Union ETS and the Switzerland ETS.

explaining why the transport sector is not included in the ETS might be attributable to the impact that the restrictions imposed by policymakers could have on this industry and on the ultimate goal of decreasing the amount of GHG emissions in the atmosphere. In fact, including the transport sector into the ETS would not lead to significant reductions in GHG emissions, resulting as an inefficient instrument in environmental terms. As a consequence, it is better to have a specific focus on the transport sector only rather than mixing it with others.

This might be partly the reason for explaining why there is no transport sector in the EU ETS, except for the aviation industry. The Commission has only allowed non-ETS sectors to partially achieve their emission reductions requirements with one-off flexibility with ETS sectors under the Effort Sharing Decision (EC, 2009). However, the transport sector in the EU remains under command-and-control legislation.

In the case of the US, instead, it was opted for another frequently suggested solution to regulate the automotive sector through market-based instruments: an automotive-only ETS. As it will be seen later, the instruments used by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA), officially regulating the GHG emission reductions and the fuel economy improvements, work almost in the same way as in a normal ETS with the difference that the only sector covered is the automotive one.

The image emerging from the worldwide analysis of the ETS implemented and the automotive sector suggests that the instruments adopted to reduce GHG and especially CO_2 emissions are still very fragmented. That is, there are many different options available which work differently depending on the state of implementation, the amount and type of sectors covered, and the market where they are developed. Another relevant aspect that emerges is that the amount of ETSs that are in force suggests that this market-based instrument truly works for many different purposes and in different combinations, but its efficiency highly depends on the sectors included. For this reason, the transport/automotive sector should be regulated under an independent ETS. In this way, not only GHG emissions will be truly lowered, but also motor vehicle manufacturers will put a concrete effort in achieving the ultimate goal of reaching low-emission mobility.

In the following paragraphs, a review of the emission trading initiatives and regulations worldwide, in the European Union (EU) and the United States of America

(USA) will be presented. In the end, a section dedicated to the main conclusions emerging from this first analysis will be listed to identify the current automotive sector's conditions.

The reason why the focus will be on the European Union and the United States lies in the type of markets they are. They both have a long history in vehicle production, distribution, and trading. Besides, they are at a historical point where their markets are almost saturated. Specifically considering the automotive industry, they are struggling between achieving the environmental goals and not losing their competitiveness considering the surprisingly rapid emergence of new markets like the Chinese and Japanese ones.

1.1 Emissions Trading and the Automotive Sector Worldwide

This section of the chapter presents some facts about the ETSs implemented worldwide. They are divided into two macro-areas: Latin America and the Caribbean, and Asia-Pacific. Moreover, information about the current situation concerning the automotive sector will be presented.

1.1.1 Latin America and the Caribbean: Mexico ETS

The Mexican ETS is scheduled for the next years, as the authorities are preparing the framework for the three-year pilot phase required before the official adoption of the ETS. The option of linking the Mexico ETS to the California ETS is also taken into consideration.

Despite not being already implemented, it was interesting to mention the Mexican ETS since the country is the first Latin American one to move towards the implementation of an emission trading initiative. Also, Mexico has already adopted several measures for reducing GHG emissions and for controlling the emissions of its businesses, which have submitted individual reports since 2014 to the National Emissions Register (RENE) (ICAP, 2019).

The Mexican ETS is planned to cover almost 45% of GHG emissions caused by the energy and industry sectors, which will obtain allowances through grandfathering for the three-year pilot phase. At the same time, penalties will not be assigned for noncompliance in this first period. The preliminary targets for the Mexico ETS aim at reaching a 22% reduction in GHG emissions compared to the BAU scenario set in the Paris Agreement by 2030 and a 50% reduction in GHG emissions compared to 2000 levels by 2050.

Considering the automotive sector's regulations, it can be said that Mexico is highly influenced by its proximity to the US states. As a matter of fact, the *Secretaria de Medio Ambiente y Recursos Naturales* (SEMARNAT) has adopted NHTSA standards for Model Years 2012-2016 to regulate LDVs' fuel economy. The credits system works very similarly to the one used in the US, carmakers are under an average, banking and trading (ABT) program and can benefit from incentives in case of introduction of highly efficient technologies or EVs (electric vehicles), PHEVs (plug-in hybrid electric vehicles), and hybrid vehicles. Incentives are also related to improvements in A/C systems or technologies for reducing fuel consumption and advance fuel economy, and finally, credits are granted for early action, that is if car manufacturers can reach the targets in advance. Considering GHG emissions, Mexico has implemented regulations and testing procedures similar to those set by EPA in the GHG Program and by the EU (TransportPolicy, 2018a).

1.1.2 Asia-Pacific: China ETS

China is a non-Annex B country under the Kyoto Protocol, thus it has no binding targets for GHG emissions reductions. However, due to its exponential growth in productive terms, and consequently in pollution, the country decided, during the UN Climate Change Conference in Copenhagen in 2009, to take action and reduce emissions by 40-45% compared to 2005 levels by 2020 (Dong et al., 2016) and a 60-65% reduction compared to 2005 levels by 2030 (ICAP, 2019).

This initiative led to the creation of pilots in eight Chinese provinces and cities: Beijing, Chongqing, Fujian (added in 2016), Guangdong, Hubei, Shanghai, Shenzhen, and Tianjin. Each pilot was independent of the others and built its own cap-and-trade system according to its economic development, emissions level, and market (Dong et al., 2016). *Table 1* shows the main characteristics of each Chinese pilot as of 2020.

	Beijing	Chongqing	Fujian	Guangdong
Year	2013	2014	2016	2013
Emissions		50%		
Only CO_2	45%		60%	60%
Target (2020)	-20.5%	-19.5%	-19.5%	-20.5%
compared to	*2015*	*2015*	*2015*	*2015*
Sectors				
Power	✓	✓	✓	✓
Industry	✓	✓	✓	✓
Transport	✓			
Buildings	✓			
Domestic aviation			✓	✓
Allocation	Free	Free	Free	Mixed
Flexibilities	Banking	Banking	Banking	Banking
Offset	Up to 5%	Up to 8%	5%-10%	Up to 1.5 million
Penalties	Max $7,558	Non-financial	$1,512-$4,535	$1,512-$7,558

	Hubei	Shanghai	Shenzhen	Tianjin
Year	2014	2013	2013	2013
Emissions				
Only CO_2	45%	57%	40%	55%
Target (2020)	-19.5%	-20.5%	-45%	-20.5%
compared to	*2015*	*2015*	*2005*	*2015*
Sectors				
Power	✓	✓	✓	✓
Industry	✓	✓	✓	✓
Transport		✓	✓	
Buildings		✓	✓	
Domestic aviation		✓		
Allocation	Free	Mixed	Free	Free
Flexibilities	Banking	Banking	Banking	Banking
Offset	Up to 10%	Up to 1%	Up to 10%	Up to 10%
Penalties	$1,512-$4,535	$1,512-$15,115	Max $15,115	Non-financial

Table 1 Summary of the Chinese Pilot ETSs.

Source Author's adaptation of the information contained in ICAP, 2019.

Note By "mixed allocation" is meant both free allocation and auctioning.

The experiences and the results derived from these pilots have contributed to the creation of the national Chinese ETS which officially started in 2017. The first part of the national ETS has been divided into three phases, each with a specific role, covering only the power sector and 30% of the country's GHG emissions.

According to the "Automobile Industry Pocket Guide 2019/2020" published by ACEA, Chinese motor vehicle production has exponentially increased between 2003 and 2018, moving from 8% to 29% (ACEA, 2020) leading to a substantial increase in CO_2 emissions.

Considering the regulations approved by the Chinese government, passenger cars (PCs) and light-duty vehicles (LDVs) follow the European regulations of Euro 6 with some tiny differences, especially regarding stringency. PCs and LDVs are also subject to the Corporate Average Fuel Consumption (CAFC), with specific limits for individual vehicle models and manufacturers/importers. Flexibilities and incentives offered to comply with the standards regard off-cycle fuel-saving technologies or tax exemptions and subsidies for EVs, PHEVs, and FCVs (fuel-cell vehicles) through the New Energy Credit Vehicle (Continental, 2019).

The link with the EU is visible also in the testing system since China is phasing out New European Driving Cycle (NEDC) in favor of Worldwide Harmonized Light Vehicles Testing Procedure (WLTP) and RDE (Real-Driving Emission) tests (Continental, 2019).

Another interesting aspect of Chinese regulations for carmakers is that stringency of standards increases with the weight of the vehicle. In this way, car manufacturers are encouraged to produce lighter vehicles, and thus to lower emissions (An, Sauer, 2004).

1.1.3 Asia-Pacific: Korea ETS

The Korean ETS (KETS) began in 2015 becoming the second largest carbon market in the world after the EU ETS. KETS covers several sectors: power, industry, domestic aviation, buildings, and waste, which amount to 68% of national GHG emissions (Narassimhan et al., 2018).

Before its implementation, Korean authorities have developed a solid legal basis creating a framework able to establish a strong cap-and-trade system. As of 2020, KETS is under its second phase, launched in 2018, and which brought some major changes compared to the past: the reduction of benchmark-based allocation, the introduction of auctioning, new banking rules, and some restrictions in the use of international credits

(ICAP, 2019; WB, 2019). For the next phase (2021-2025), a further reduction in the free allocation and an increase in auctioning is already planned (ICAP, 2019).
KETS' target includes a reduction of 37% compared to the BAU scenario by 2030. All installations must do their best to achieve this goal to comply with the Paris Agreement's goals. If an entity is found to be non-compliant, then it has to pay a fine of maximum $90.85 per tonne of GHG in excess (ICAP, 2019).

Concerning the automotive sector, South Korea's Average Fuel Economy (AFE) standards are in force since 2006 following the American model. In fact, in 2012, it started using the EPA's "2-test cycle" (ICCT, 2015) and the Corporate Average Fuel Economy (CAFE) standards (TransportPolicy, 2018b).
The most recent measures aim to reach a 31.1% and a 15.1% reduction compared to 2013 by 2020 in LDVs, respectively (ICCT, 2015; TransportPolicy, 2018b). Together with the reduction targets, the incentives for Model Years 2016-2020 have been established. They include credits for a more efficient air-conditioning (A/C) system, eco-innovations, and credit multipliers for ZEVs (zero-emissions vehicles), manual transmission, mini-vehicles, and gasoline, diesel, or liquified petroleum gas (LPG) vehicles. Other incentives are addressed to small-volume manufacturers (SVMs) who are eased by 8% for 2020 compared to the standards (ICCT, 2015; TransportPolicy, 2018b).

1.1.4 Asia-Pacific: New Zealand ETS

The New Zealand ETS (NZ ETS) is in force since 2008 and is famous for having the broadest sectoral coverage of any ETS. The power, industry, domestic aviation, transport, buildings, waste, and forestry sectors are all covered by the ETS, which, thus, regulates more than half of GHG emissions in the country (ICAP, 2019).
In the beginning, the NZ ETS did not set a cap on emissions, thus installations could emit as much as they wanted as long as they had enough allowances to cover their emissions (Villoria-Sáez et al., 2016; Narassimhan et al., 2018; ICAP, 2019). The lack of a cap was maintained until 2016 when the government set a nationwide emissions cap to reach the goals established in the Paris Agreement (WB, 2019). New Zealand has to reduce its emissions by 11% and 50% compared to 1990 levels by 2030 and 2050, respectively, to reach the Paris Agreement's objectives.

Concerning the allocation method, the NZ ETS has always provided free allowances to its entities. However, from 2018, the free allocation was left only to the forestry sector, whereas all the others had to buy the allowances through auctioning (ICAP, 2019).
In case of noncompliance, a business is required to pay $20.76 for each unit if it did not surrender allowances by the due date, or up to $16,607 if it failed to collect emissions data or other necessary information. Penalties are even higher if an entity is found guilty of falsification or alteration of information (ICAP, 2019).

Concerning the automotive sector, two aspects must be immediately highlighted. First, New Zealand is more an importer than an exporter of vehicles, thus most incentives for the introduction of lighter or low-emissions vehicles are addressed to consumers. Second, due to a lack of regulations for the transport sector for a long time, emissions caused by this industry have increased continuously since 1990, becoming the country's first source of pollution.
The most recent governmental action towards GHG emissions reduction in the transport sector took place in 2019 when the authorities decided to strengthen the fuel standards by setting a 105gCO_2/km target to be reached by 2025. Together with this action, the government decided to provide more incentives for alternatively fueled vehicles through the Clean Car Discount, consisting of a discount of maximum NZ$8,000 for a hybrid or battery electric car (NZ Ministry of Transport, 2019).

1.1.5 Asia-Pacific: Tokyo ETS

Tokyo ETS was launched in 2010, becoming the first cap-and-trade program activated in Asia and it is currently in its third compliance period (2020-2024). The goals of this ETS are to reduce emissions by 25% compared to 2000 levels by 2020 and by 30% by 2030 (ICAP, 2019).
Differently from many ETS that have already been discussed, the Tokyo ETS' coverage focuses on large installations, namely those consuming energy "more than 1,500kL of crude oil equivalent or more per year", and industry sector as a consequence only 20% of emissions are included in the ETS (ICAP, 2019). Interestingly, large installations are divided between those emitting more and those emitting less, in turn, these two categories have two different compliance factors: a higher one for the former, and a lower one for the latter (ICAP, 2019). Whenever an installation fails to comply, then it undergoes two stages. First, the government requires the installation to reduce its emissions "by the

amount of the reduction shortfall multiplied by 1.3" (ICAP, 2019). Second, if the installation is not able to complete the first stage, then it is required to pay a penalty up to $4,528, a surcharge of 1.3 times the shortfall, and it is "named and shamed" by the government (ICAP, 2019).

Regarding the transport sector, Tokyo has recently implemented a strategy to accelerate the adoption of zero- and low-emission vehicles (ZLEVs), namely EVs, PHEVs, and FCVs, as it is happening in the EU. In particular, the aim is to increase ZEVs' sales by up to 50% of total PCs by 2030 (ICCT, 2017).

Overall, Tokyo follows the Japanese regulations concerning the automotive sector and its emissions. In 2010, the Japanese Ministry of Environment set the "Post New Long-Term Emissions Standards"; these are equivalent to the European Euro 6 standards. The Japanese authorities have used their own drive-cycle emission tests, but, as of 2018, they adopted the WLTP procedures (TransportPolicy, 2018c).

Since 1999, Japan has adopted the Top Runner program under the Energy and Conservation Law for regulating the fuel economy of LDVs. The program consists of identifying first the "top runner", that is the most efficient vehicle of a certain category, and then setting standards according to the top runner's performance. The 2030 targets set in 2019 aim at reaching a 32.4% increase in fuel efficiency compared to 2016 levels (TransportPolicy, 2018c).

Progressive taxes for lighter vehicles or additional taxes for those exceeding the targets are examples of financial measures provided by Japanese authorities to encourage the achievement of targets and standards (TransportPolicy, 2018b).

1.2 The European Union

The EU has implemented many initiatives towards GHG emissions reductions. It has an ETS in force since 2005, and a wide variety of directives and regulations for the non-ETS sectors[3], and a "Climate and Energy Package" which covers both the EU ETS and the non-ETS sectors and summarizes the ultimate goals, shown in *Table 2*, that the EU as a whole has to reach by 2020 and 2030 (ICCT, 2019; EC, 2020a).

[3] The non-ETS sectors include agriculture, housing, waste, and transport (excluding aviation). They are covered by the Effort Sharing Decision which sets binding annual targets to reduce GHG emissions for each Member State (EC, 2009; EC, 2020a)

Climate Strategies and Targets		
	2020	**2030**
Main Targets	• -20% in GHG emissions from 1990 levels • 20% share of renewable energy • +20% in energy efficiency	• -40% in GHG emissions from 1990 levels • 32% share of renewable energy • +32.5% in energy efficiency
EU ETS	-21% in GHG emissions from 2005 levels	-43% in GHG emissions from 2005 levels
Non-ETS	-10% in GHG emissions from 2005 levels to be reached under the Effort Sharing Decision	-30% in GHG emissions from 2005 levels to be reached under the Effort Sharing Decision
Transport	10% share of renewables	

Table 2 EU's Climate Strategies and Targets.
Source Author's adaptation of the information contained in EC, 2020a.

The EU ETS is the most famous and largest cap-and-trade system in the world (EC, 2020a). It aims at "promoting reductions of emissions in a cost-effective and economically efficient manner" (Bagchi, Velten, 2014) and is the outcome of the negotiations made between 1992 and 1997 through the UNFCCC and the Kyoto Protocol, respectively.
The legal basis has been published in 2003 with the Directive 2003/97/EC, which has recently been revised with the Directive 2018/410/EC (EC, 2020a).

The EU ETS works as a classical cap-and-trade system, setting a cap on emissions, distributing allowances through auctioning, and for free to installations covered and asking them to surrender enough allowances to cover their emissions at the end of each year. If an entity reduces its emissions, then it can either keep the allowances or sell them. Instead, if an entity fails to reduce its emissions, it has two main options:

1. Take measures to reduce the emissions through R&D investments, or
2. Buy extra allowances and/or CDM[4]/JI[5] credits from the Kyoto Protocol.

[4] CDM stands for Clean Development Mechanism that allows Annex B countries to invest in projects reducing emissions in developing countries (UNFCCC, 2020a).

[5] JI stands for Joint Implementation which allows Annex B countries to meet their requirements in GHG emissions reduction by paying for projects that reduce emissions in other industrialized countries (UNFCC, 2020a)

As of 2020, the EU ETS covers almost 45% of GHG emissions in the EU and more than 11,000 installations, and it underwent a total of three Phases, with the fourth one already approved.

Shortly, Phase I (2005-2007) was a pilot phase needed to test the system. Member States could decide how many allowances to allocate according to their National Allocation Plans. Grandfathering based on historical emissions was the main allocation method, and the installations covered belonged to the power, heat generations, and energy-intensive industrial sectors. The penalty amounted to €40/tonne of CO_2 in excess.

Phase I ended up being inefficient since there was an over-supply of allowances allocated to businesses (EC, 2020a).

Phase II (2008-2012) tightened the emission cap by 6.5% below 2006 levels, included the aviation sector within the EU ETS in 2012, and increased the penalty to €100/tonne of CO_2. However, there was still an over-supply of allowances. For this reason, things changed a lot for Phase III (2013-2020). A single, EU-wide cap was established with a decreasing rate of 1.74% each year to reduce emissions by 21% in 2020 compared to 2005. Auctioning became the main allocation method because it encourages businesses to fulfill their obligations and generates revenues to use for climate and energy purposes[6], however, the free allocation was maintained for manufacturing sectors at risk of carbon leakage. Finally, action to face the over-supply of allowances took two forms:

1. Short-term measure: "backloading" of 900 million allowances
2. Long-term measure: Market Stability Reserve (MSR) that "improves the system's resilience to major shocks by adjusting the supply of allowances to be auctioned" (EC, 2020a).

Finally, Phase IV (2021-2030) has already been approved and further changes are going to be implemented. First, the reduction factor of the cap will move from 1.74% to 2.2%. Second, the industry and power sectors will be helped in reaching their innovation goals through the Innovation Fund[7] and the Modernisation Fund[8] (WB, 2019; EC, 2020a).

[6] Between 2012 and 2016, the EU ETS generated about $17 billion in revenue. 50% of it was addressed to climate- and energy-related purposes or to improvements in the existing infrastructure (ICAP, 2019).

[7] "The Innovation Fund will provide financial support in the areas of renewable energy and carbon capture and storage utilization" (WB, 2019).

[8] "The Modernisation Fund supports investments in energy efficiency and the modernization of energy sectors in lower-income Member States" (WB, 2019).

As already anticipated, the EU ETS like many others ETSs does not cover the transportation sector. The reason for this is attributable not to an underestimation of the emissions caused by this sector, but for the interest of maintaining the EU ETS an efficient system. According to the 2018 data, the transport sector is responsible for 27% of the overall GHG emissions in the whole EU (Transport & Environment, 2018) with road transport being the largest source of GHG emissions (EEA, 2019) as it can be seen from *Figure 3*.

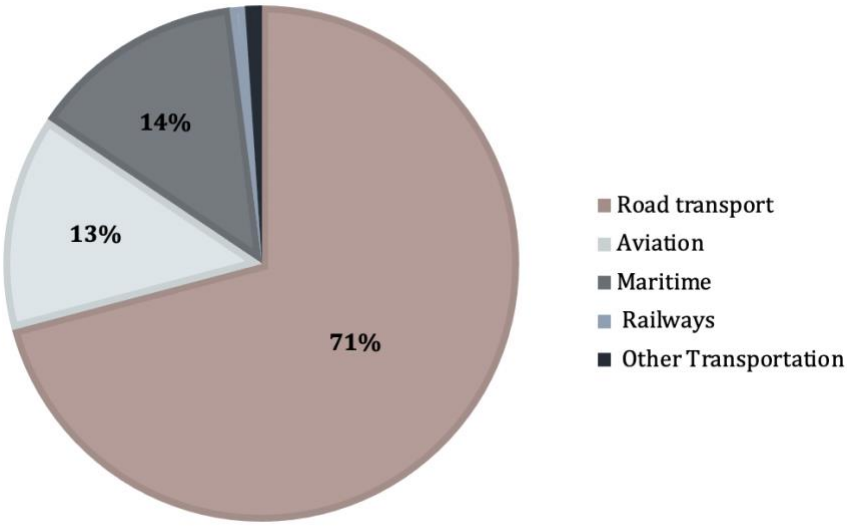

Figure 3 Share of Transport Greenhouse Gas Emissions in EU.

Source Author's adaptation of the EEA data retrieved from https://bit.ly/39hdr69 on 22.02.20

The fact that the transport sector is not included in the EU ETS does not mean that the European Union did not implement significant and powerful strategies to control and reduce the emissions caused by this sector. Specifically, the commitment of the EU institutions and car manufacturers towards the reduction of GHG emissions started in 1998 with the "ACEA Agreement" that encouraged European carmakers to voluntarily reduce CO_2 emissions of vehicles to 130gCO_2/km by 2015. The goal that was successfully achieved (An, Sauer, 2004).

In 2011, the EU published the White Paper to further increase the commitment of car manufacturers and to reduce emissions by 60% below 1990 levels by 2050 (EC, 2011). After the White Paper, in 2016, the EU took another action for regulating the automotive

sector by developing and approving a "European Strategy for Low-Emission Mobility" which presents three main goals (COM, 2016):

1. Reach 10% of renewable energy for each Member State by 2020
2. Limit emissions to 96gCO_2/km by 2021 for PCs and 147gCO_2/km by 2020 for light-commercial vehicles (LCVs)
3. Reduce the lifecycle GHG emissions per unit of energy from fuel and energy suppliers by up to 20% by the end of 2020.

The most recent measures taken concerning mobility and transportation consist of three Mobility Packages and the Directive 2019/631/EC. The former, established between 2017 and 2018, aim at "promoting growth and job creation, strengthening social fairness, widening consumers' choices and putting Europe on the path towards zero-emissions mobility" (EC, 2020b). The Directive sets new goals for PCs, LCVs, and ZLEVs[9] to be reached by 2025 and 2030 (ACEA, 2019a). These are summarized in *Table 3*.

Targets for PCs, LCVs and ZLEVs		
	PCs	**LCVs**
2025 *(2021 baseline)*	-15% = 81gCO_2/km	-15% = 125g CO_2/km
ZLEVs *(sales)*	15%	15%
2030 *(2021 baseline)*	-37.5% = 59g CO_2/km	-31% = 101g CO_2/km
ZLEVs *(sales)*	35%	30%

Table 3 Targets for Passenger Cars, Light-Commercial Vehicles, and Zero- and Low-Emissions Vehicles in the EU.

Source Author's adaptation of the information contained in ICCT, 2019.

According to the recent estimates and report of the European Environmental Agency (EEA), the progress of EU transport towards decarbonization is far from being in line. Improvements have been made with no doubts, but they are too small to be considered enough and satisfying (EEA, 2020). Also, according to the data reported by the EEA and as it can be seen in *Figure 4*, passenger cars and vans are not becoming more efficient,

[9] ZLEVs are "vehicles with CO_2 emission values from 0 up to 50gCO_2/km" (ICCT, 2019).

actually the trend was positive up to 2017 when the CO_2 emissions from these two types of vehicles started to rise again.

Several reasons have contributed to this failure. First, car manufacturers and the automotive industry overall have a manipulative power on regulations. Second, governments are often unwilling to constrain demand for mobility and car ownership. Third, in the past years, sport-utility vehicles' (SUVs) market has grown continuously, as a consequence, the emissions increased because the heavier the vehicle, the higher the emissions. Fourth, market penetration of alternatively powered PCs is still low all over the EU Member States. However, since decarbonization is the EU's main goal, the introduction of alternatively fueled vehicles is essential for its achievement. Fifth, there has been a change in the testing procedures to calculate emissions after it was found out that the NEDC test provided unreliable results underestimating the real driving emissions. The NEDC has been phased out starting from 2017-2019, this corresponds to the rise in emissions from LDVs that is visible in *Figure 4*.

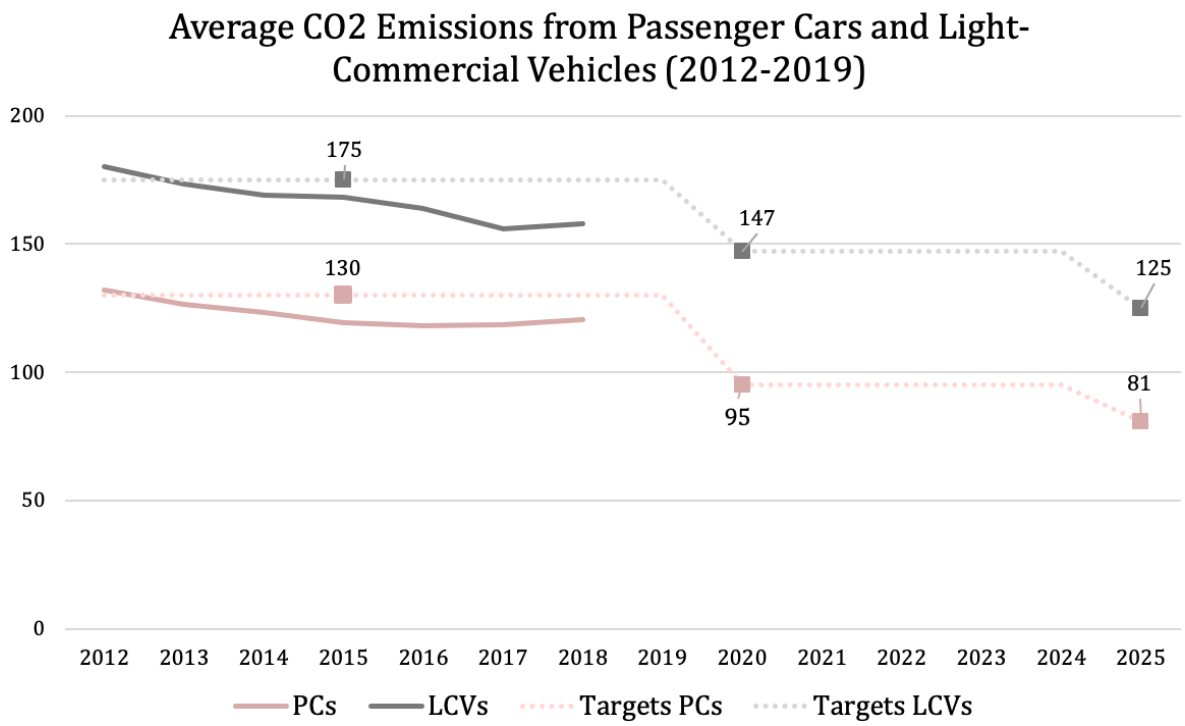

Figure 4 Average CO_2 Emissions from Passenger Cars and Vans (2012-2019) and their Respective Targets for 2015, 2020, and 2025.

Source Author's adaptation of the data from the European Environmental Agency, retrievable from https://bit.ly/3csX1tQ and https://bit.ly/2SZHJFj.

Notes Values are expressed in *gCO_2/km*.

Focusing on the spread of alternative-fueled vehicles (AFVs), *Figure 5* demonstrates that their sales accounted just for 7.4% of 2018's sales, whereas the petrol-powered cars remained the majority (56.7%) despite being the least sustainable (ACEA, 2019a).
Besides, research has demonstrated that more than 80% of the EVs sales are concentrated in rich countries, such as Germany, UK, France, Italy, and Spain. This means that the spread of alternatively powered vehicles is even more difficult because there is a strong and positive correlation between the GDP of a country and the rate of adoption of AFVs, which, consequently, influences the type of infrastructure as well as the incentives provided to carmakers and consumers (ACEA, 2020).

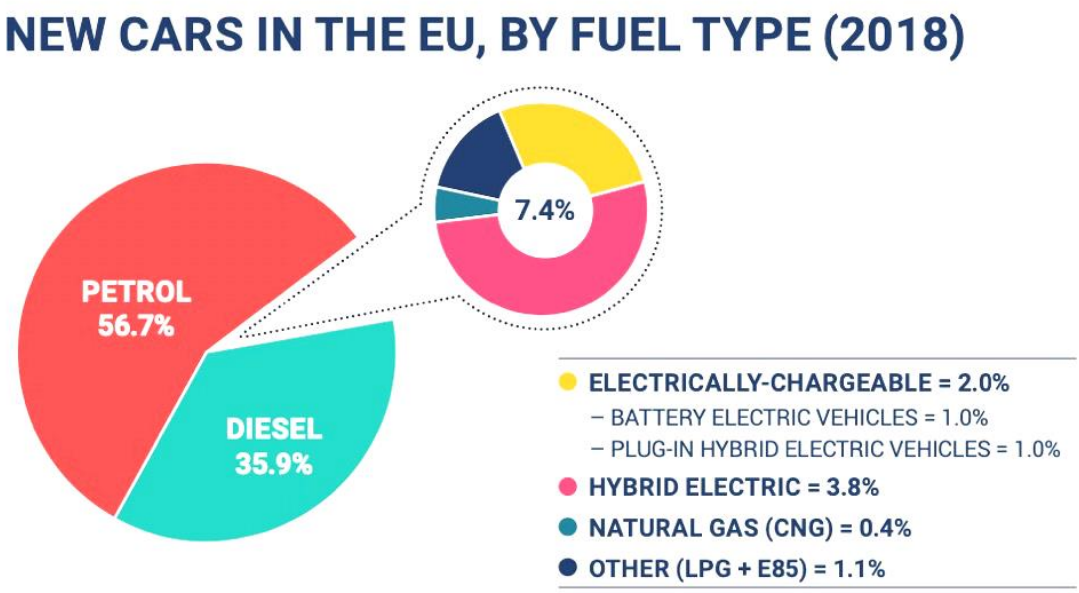

Figure 5 Market Shares of Fuel Types in the EU28 (full-year 2018).
Source ACEA, 2019a.

Finally, an overview of emissions testing, flexibility mechanisms, penalties, and incentives provided by the EU to car manufacturers is shown in *Table 4*.

Tests, Flexibility Mechanisms, Penalties and Incentives	
Tests	NEDC substituted by the WLTP and the RDE Test
Flexibility Mechanisms	• Pooling among car manufacturers ~~of the same type~~ (no pooling between PCs and LCVs) • Exemptions of manufacturers registering less than 1,000 vehicles • Derogation for small volume PCs and LCVs manufacturers
Penalty	€95 for each g/km in exceedance for PCs and €120 for each g/km in exceedance for LCVs (since 2019)

Incentives	• Eco-innovations credits for manufacturers that implemented innovative emissions reduction technologies not covered by the standard test procedure. The cap for eco-innovations is 7g/km per year.
	
	• Super-credits for ZLEVs will be counted as follows:
	  ○ 2 vehicles in 2020
	  ○ 1.67 vehicles in 2021
	  ○ 1.33 vehicles in 2022
	The cap for super-credits will be 7.5g/km per manufacturer over 2020-2022.
	
	• ZLEVs factors for the Member States whose share of ZLEVs is lower than 60% of the total national fleet and whose ZLEVs registrations are lower than 1,000 per year. In this case, ZLEVs are counted 1.85 vehicles until 2030.

Table 4 Tests, Flexibility Mechanisms, Penalties, and Incentives for PCs and LCVs in the EU.
Source Author's adaptation of the information contained in Continental (2019) and EC (2020a).

1.3 The United States of America

The USA has a long history with emission trading initiatives starting in 1990 with the Acid Rain Program established under the Clean Air Act (CAA). Currently, the main ETSs in force in the US are the Regional Greenhouse Gas Initiative (RGGI) and the California ETS.

The RGGI has been activated in 2009 and currently covers fossil fuel-fired power generators, for a total of 23% GHG emissions. This ETS sets the cap based on emissions estimates of future economic growth and each year is reduced by 2.5% until 2020 and 3% thereafter (Narassimhan et al., 2018; ICAP, 2019).

Participation in the RGGI is voluntary, and, as of 2020, the participatory states are ten, namely Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont (RGGI, 2020). These have committed to two main reduction targets: -50% of CO_2 emissions compared to 2005 levels by 2020, and -30% of CO_2 emissions compared to 2020 levels by 2030.

Auctioning is the only allocation method for obtaining allowances, which can be banked in case of surplus at the end of the year. In 2018, thanks to auctioning, RGGI has generated a total of $239.39 million in revenue, which has been partly used for "consumer benefit or strategic energy purpose" (Narassimhan et al., 2018). Also, a cost-containment reserve with the same function of the European Market Stability Reserve has been implemented to face the issue of over-supply of allowances (ICAP, 2019).

Interestingly, the participatory states have their own statutory authority, and, in case of noncompliance, penalties are assigned on a state-by-state basis (ICAP, 2019).

The California ETS became the largest carbon market in North America after the inclusion of the Québec ETS in 2014. Currently, the California ETS covers almost 85% of GHG emissions coming from the power, the industry, the transport, and the buildings sectors. These sectors have agreed on reducing by 40% and by 80% the GHG emissions compared to 1990 levels by 2030 and 2050, respectively (ICAP, 2019).

The emission cap is based on future estimates and reduces by 3% each year until 2021 when the reduction rate will increase to 4.1%. Allocation of allowances is free for industrial facilities at risk of carbon leakage, instead, auctioning is addressed to natural gas suppliers and transport. In 2018, revenues from auctioning amounted at $3.02 billion, which have been invested "in high-speed rail, low carbon transit, weatherproofing of low-income homes and environment conservation" (Narassimhan et al., 2018; ICAP, 2019).

Concerning the automotive sector, the US government has decided to create an ETS-like structure for regulating this industry. The reason lies in the percentage of CO_2 emissions attributable to the transport sector. As it can be seen from the figure below, transportation is responsible for 34% of the overall CO_2 emissions of the United States, with PCs and light trucks being the major source of such emissions.

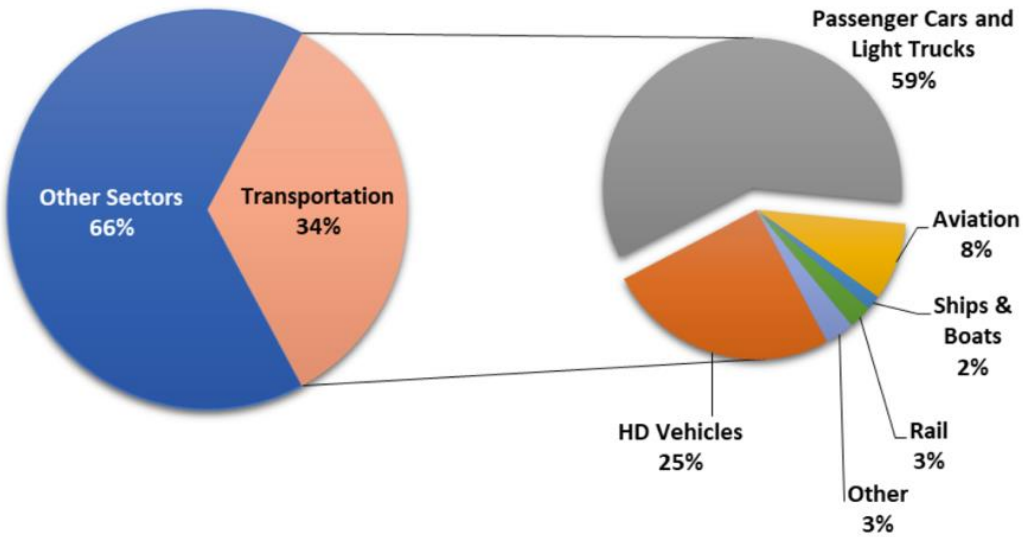

Figure 6 Contribution of Transportation to U.S. Carbon Dioxide Emissions and Proportion Attributable by Mode, 2017

Source DOT, NHTSA, 2020.

As a consequence, the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) have been given the authority to set GHG emission and Corporate Average Fuel Economy (CAFE) standards, respectively. They started working together to create a "national program for GHG emissions and fuel economy standards for light-duty vehicles" and to reduce dependence on imported oil (Continental, 2019; EPA, 2020c).

The cooperation between these two institutions started in 2010 by setting the standards for two phases: Phase I (Model Years 2012-2016) and Phase II (Model Years 2017-2025). However, despite these attempts towards harmonization, EPA and NHTSA maintain many differences in terms of standards that must be simultaneously met by car manufacturers (Leard, McConnell, 2017).

Both NHTSA CAFE and EPA GHG Program put at the carmakers' disposal some credits under an ABT system. If a car manufacturer has a positive credit balance at the end of the year, then compliance is ensured, and the credits can be carried forward. If the credit balance is negative, then the carmaker is required to offset the credit deficit within three years from the non-compliance one.

Every year NHTSA and EPA increase the stringency of their standards while providing incentives to car manufacturers, such that visible and concrete improvements for the industry and the environment can be made. Thanks to this rationale and the expiration

date set to credits earned (5 years), the US automotive industry has contributed to an overall reduction of GHG emissions from this sector (EPA, 2019c).

In 2012, Phase II of CAFE and GHG emissions standards was discussed, and NHTSA and EPA targets for the Model Years 2017-2025 have been set (NHTSA, 2020). Emissions from LDVs should have been reduced by half by 2025 compared to 2010, which is reaching an average of 163g/mi of CO_2 and an average fuel economy of 54.5mpg (EPA, 2012). However, due to the rapid changes related to environment and emissions, the standards set in 2012 were not considered appropriate anymore, for this reason, NHTSA and EPA proposed the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule in 2018 to establish new targets for the Model Years 2021-2026 and to harmonize even more the requirements of the two institutions (EPA, 2020c). The SAFE Vehicles Rule was officially approved in 2019 and the new targets and standards for the CAFE and the GHG Programs were officialized in April 2020 (DOT, EPA, NHTSA, 2019; DOT, EPA, NHTSA, 2020b).

The table below summarizes the main points in common and differences between NHTSA CAFE and EPA GHG Program.

Points in Common and Points of Difference between NHTSA CAFE and EPA GHG Program		
	Points in Common	
Credits	Credits are earned whenever automakers over-comply with the standards	
Flexibilities	• Transfers within the fleet • Carry forward/banking (5 years) • Carry back (3 years)	• Trading • Averaging • Lead time flexibility to small volume manufacturers
Incentives	Preferential treatment to PHEVs and NGVS	
Tests	• 2-cycle test (Federal Test Procedure and Highway Federal Emission Test) • 5-cycle test	
	Points of Difference	
	NHTSA	**EPA**
Policies	Energy Policy and Conservation Act (EPCA)	Clean Air Act (CAA)

Unit of measure	Average miles per gallon (mpg)	Grams of CO_2 per mile (g/mi)
Flexibilities	It sets a limit on the number of credits that can be transferred within a manufacturer's fleets	It does not limit averaging within a manufacturer's fleets
Penalties	$5.5 per credit shortfall	Penalty set on a case-by-case basis. (Maximum $37,500 per vehicle)
Incentives	• Adjustments attributable to A/C improvements and off-cycle credits given by EPA • Dual and alternative-fueled vehicles' energy is counted 15%	• Advanced Technology Vehicles (EVs, PHEVs, FCVs, and CNG[10]) are counted with an incentive multiplier from Model Years 2017-2021 • Gasoline-Ethanol Flexible Fuel Vehicles (FFVs) and Compressed Natural Gas (CNG) Vehicles are counted multiplying the CO_2 emissions by a 0.14 factor • Air Conditioning (A/C) improvements • "Off-cycle" CO_2 credits for technologies not captured in the "2-cycle test"

Table 5 Points in Common and Points of Difference between NHTSA CAFE and EPA GHG Program.
Source Author's adaptation of the information contained in EPA (2012) and Leard, McConnell (2017)

According to "The 2018 EPA Automotive Trends Report", overall, the industry-wide trend has improved since 2005. In 2017, the automotive sector reached its record low in GHG emissions and its record high in fuel economy, meaning that the industry is moving in the right direction. However, data confirm the same trend that took place in the EU, that is the share of SUVs sold increased over the years, partly offsetting the advancements made in

[10] PHEVs = Plug-in Hybrid Electric Vehicles; FCVs = Fuel Cell Vehicles; CNG = Compressed Natural Gas.

CO_2 reductions. At the same time, it is important to highlight that, despite SUVs emit more since they are heavier vehicles, their emissions are 50% lower than those emitted by vehicles of the same weight in 1978 (EPA, 2019c).

Finally, also the US case confirms the positive correlation between a state's GDP and the penetration of EVs, PHEVs, FCVs, and other alternatively powered vehicles.

1.4 Automotive Sector: Worldwide Overview

This section of the first chapter is needed to give a worldwide overview of the automotive sector considering what can be derived from the previous sections.

1. Emission trading initiatives have been widely recognized as cost-efficient ways to reduce GHG emissions. They provide flexibilities for the installations covered while setting stringent targets to reach the emission reduction goals. Differently from command-and-control mechanisms, ETSs work efficiently also with a broad number of sectors covered. However, most of the times, ETSs' coverage is limited to the power and the industry sectors, despite transport is a major source of pollution in every country.

2. Many countries have recognized the importance to take action and regulate the transportation and automotive sectors. They are aware that CO_2 emissions caused by transport have increased continuously since 1990 (+42.8%), and much work has still to be done (IEA, 2019).

3. All countries considered set their GHG emissions/CO_2 reduction goals according to the Kyoto Protocol and the Paris Agreement ones. The changes made in regulations, directives, or between Model Years are done considering the country's position in the path towards the achievement of those goals.

4. Regulations addressed to the automotive and transport sectors differ country-by-country considering the country's economy and GDP, the infrastructure and technology at its disposal, and whether the country is more a producer or an importer of vehicles.

5. In the majority of countries, the authorities have established a credit mechanism for car manufacturers such that they are encouraged in improving their performances year by year while being able to benefit from flexibilities.

6. All countries follow the rationale that the stringency of regulations, targets, and standards should be increased as time goes by.

7. All countries are trying to harmonize the testing procedures and the units of measure used to communicate the goals. In general, gCO_2/km (gCO_2/mi for the USA) is the standard measure for CO_2 emissions from vehicles and L/km (mpg for the USA) is the standard measure for the vehicles' fuel economy. Concerning the testing procedures, the USA maintains its own with the "2-test cycle" and the "5-test cycle", while all the other countries moved from the NEDC, or their own tests to WLTP and the RDE.
   Some countries are even adopting other countries' frameworks for reducing GHG emissions from transport, as in the case of Mexico, China, and Tokyo.

8. Incentives are mostly similar because the majority of them are addressed to the adoption and production of ZLEVs in all their forms. In all countries, tax exemptions and subsidies are offered to car manufacturers. Other common incentives are credit multipliers, eco-innovations, and also derogations for small-volume manufacturers.

9. Failures to comply are not left unpunished and penalties are applied by every government. They differ in terms of how much a business is required to pay in case of noncompliance, but in general, the principle applied by authorities is that the penalty should be higher than the average market price of allowances.

10. All countries aim at increasing the share of ZLEVs. However, for doing it, infrastructure, capital, and resources are needed. As a consequence, the countries which are actively working towards a zero- and low-emissions mobility are those with a higher GDP.

Chapter 2 – Policy Background: A Comparison between the European and United States Legislations

It is widely accepted that changes and actions take place at all levels if they are supported by a strong policy base, especially when it comes to the environment. Having focused policies is extremely important because the entire architecture of the products must be thought in a new way. Both the EU and the US have developed policies and regulations to guide the automotive industry within their territories.

To make a proper comparison between the EU and the US, it is necessary to go through the *ratio iuris* of the regulations and directives implemented. Starting from the broader base and then going in depth, this chapter will provide an overview of the legal requirements concerning the automotive sector in terms of emissions reduction and how the political institutions are incentivizing the achievement of low-carbon mobility.

The focus will be on the legislation directly impacting motor vehicle manufacturers regarding CO_2 and other CO_2-equivalents, that is NO_x and PM, and covering light-duty vehicles, that is cars, vans, SUVs, and pick-up trucks.

2.1 The European Union

The European Union is one of the main producers of motor vehicles worldwide (EC, 2020c), it accounted for 20% of the global motor vehicle production in 2018 (ACEA, 2020). The automotive sector is particularly important to the EU for three main reasons (EC, 2020c):

1. It has a multiplier effect in the economy, meaning that other sectors are positively influenced by the automotive one,
2. It is a major source of employment. As of 2017, 13.8 million people were employed in manufacturing, services, and construction for the automotive industry (ACEA, 2020), and
3. It generates a significant turnover amounting to 7% of the total EU GDP.

For these reasons, the EU addressed €57.4 billion to the R&D of the automotive industry (ACEA, 2020), showing the willingness of remaining a competitive and innovative market. The European Union is the region investing the most in this industry compared to other

top producers in the world, such as the US, Japan, and China (ACEA, 2020). At the same time, the EU strives for global technical harmonization of the automotive sector, which is the development of common technical regulations that contribute to cost reductions and avoidance of administrative duplications. For this purpose, the EU is a contracting party of both the 1958 Agreement and the 1998 Parallel Agreement of the United Nations Economic Commission for Europe (UNECE) whose main aim is to "Promote pan-European economic integration" (UNECE, 2020). In particular, the 1998 Parallel Agreement developed the global technical regulations (GTR) strengthening the path towards international harmonization (EC, 2020 C; UNECE, 2020).

As time went by, the issues related to global warming and the changes in consumers' behaviors and lifestyles influenced the EU's vision of the automotive sector and transport in general. Currently, the European Commission is working on developing a new image of the industry contextualized in a circular economy environment, where vehicles are not anymore only means of transportation, but also places for working, relaxing and even socializing (DRIVES, 2019).

Besides, the Commission is constantly working for maintaining a high level of competitiveness through frameworks and legislations adapting to the changes that are taking place in the automotive industry. These elements are so important because the risk of losing the market leadership will cost the EU a lot, not only in economic terms but also because of the threat of emerging economies such as China or India. The High-Level Group for the automotive industry, GEAR 2030, suggests that Europe needs to respond by implementing a future-oriented, comprehensive and harmonized regulatory framework characterized by a "management-by-objectives" approach and by cooperating internationally (EU, 2017).

The history of the European Union with regulations regarding the automotive sector and, specifically, its emissions is long. However, for this paper, only the most recent and the in-force ones are going to be considered. Also, only the legislation concerning the LDVs will be analyzed, in particular, the focus will be on vehicles belonging to category M and N, that is passenger cars and light commercial vehicles[11].

Before going through the main directives and regulations, it is important to understand the European vision for a low-emission economy and then, specifically, for

[11] The EU defines vehicle category "M" as vehicles carrying passengers, and category "N" as vehicles carrying goods. Light-duty vehicles are those not exceeding 5 tons and 3.5 tons, respectively (EC, 2020c).

the mobility and the automotive sector. The most recent strategies at the basis of the European vision for reducing GHG emissions and for protecting the environment, except for EU ETS, are the Effort Sharing Decision and the European Green Deal.

The Effort Sharing Decision (Decision 406/2009) contains binding GHG emission reductions for the years 2013-2020. In 2018, with the Regulation (EC) 2018/842, the Commission implemented the Effort Sharing Decision for the years of 2021-2030. In summary, this legislation covers the effort that each non-ETS sector of each Member State has to put in achieving a specific emission reduction (EC, 2018). The decision takes into consideration the objectives set to during the UNFCCC and the Paris agreement, implying that GHG emissions should be decreased by 50% below 1990 levels by 2050 (EC, 2009; EC, 2018).

The European Green Deal was approved in December 2019 and represents a new growth strategy for all Member States to transform Europe into a modern, resource-efficient, and competitive economy. The Green Deal is a roadmap for every actor in the EU defining the actions to be taken, the efforts to be put, the investments to be made by private and public parties to smoothly transition towards a zero- and low-emission economy (COM, 2019). The figure below clearly shows how the Commission has decided to operate under this renovated low-carbon circular economy view:

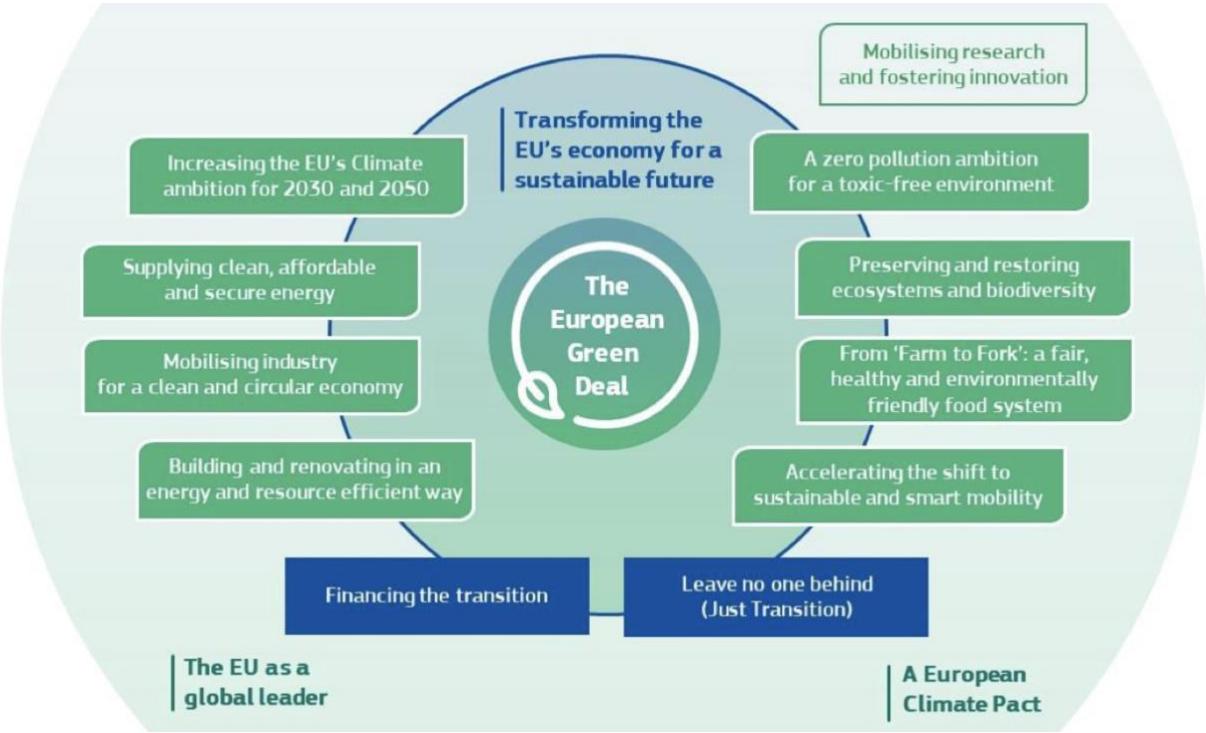

Figure 7 The European Green Deal.
Source COM (2019), p. 3

Interestingly, the Green Deal states that transport emissions should be lowered by 90% to achieve climate neutrality by 2050. For this reason, in addition to the already-applied strategies and actions to reach this goal, such as the support to multimodality, the investments, and incentives for the production and the purchase of ZLEVs, the Commission is thinking about applying an ETS for the road transport. This decision is suggested by the impelling need to drastically decreasing transport pollution in cities.

Concerning the European vision of the automotive industry and the climate challenges to be faced by this sector, seven main goals are emerging from the strategies about these topics:

1. Reduce GHG emissions and improve the air quality,
2. Maintain the competitive and leadership position of the European automotive industry,
3. Speed up the adoption of alternative fuels and zero- and low-emission vehicles to reduce oil dependency and emissions,
4. Spread all over the European Union the adequate infrastructure for alternative refueling/recharging stations,
5. Develop a reliable, clear and harmonized framework valid all over the EU,
6. Decrease the gap between the laboratory-measured emissions and the real-driving emissions.

The section dedicated to the European Union is organized as follows: first, the underlying strategies upon which the regulations and directives on motor vehicles are based will be presented giving a short summary of their content. Second, the main regulations and directives are going to be analyzed dividing them by topic, spreading from those related to type-approval requirements, exhaust emissions, CO_2 standards to those about testing procedures, and alternative fuels vehicles and infrastructure.

2.1.1 Underlying Strategies

A European Strategy on Clean and Energy Efficiency Vehicles. This strategy, published in 2010, represents an initial action by the Commission to encourage the adoption of more energy-efficient, cleaner and greener vehicles. The direction towards a low-carbon economy emerges clearly from this Communication, which already mentions the future takeover of alternative fuels and propulsion technologies in the automotive industry. At

the same time, it emerges that the Commission aims at maintaining the competitiveness of Europe, while achieving critical environmental goals. For this reason, it is stressed the need of anticipating trends and innovations (COM, 2010).

The key actions to be taken at the Union and the Member States levels according to the Strategy on Clean and Energy Efficient are:

1. Strengthening the CO_2 emission targets for motor vehicles,
2. Developing a clear integrated approach, especially for regulatory purposes, such that all the parties have a transparent view and understanding of the requirements,
3. Ensuring that testing procedures to calculate and verify emissions are reliable and similar to real-driving emissions,
4. Promoting additional measures or incentives to encourage the decrease of CO_2 and other pollutants,
5. Investing in research, development, and innovation
6. Involving consumers and provide demand-side incentives to encourage the purchase of clean and energy-efficient vehicles, and
7. Engaging in international standardization activities.

The White Paper. This document represents another important milestone in the underlying vision for the mobility sector of the EU. The title already shows the ultimate goal of this communication: setting a "roadmap to a single European transport area towards a competitive and resource-efficient transport system" (EC, 2011). More importantly, the White Paper aims at lowering the dependence on oil and at reducing GHG emissions by 60% compared to 1990 by 2050. The roadmap is divided into three parts which make it clear how to reach the goal of making the transport more sustainable while maintaining the European leadership in this industry. In summary, the White Paper highlights the need to drastically reduce GHG emissions, to face the threats coming from new emerging economies, to deploy and build a strong infrastructure for alternative-fueled vehicles (AFVs), and to provide both supply- and demand-side incentives for improving the transport and its infrastructure. Besides, it is emphasized the need of investing not only in R&D but also in human capital, such that future employees have the necessary skills to face the new challenges presented by the new mobility (EC, 2011).

CARS 2020. The communication representing the new European vision of the automotive industry in terms of priorities, incentives, goals, and requirements, was published in 2012 and consists in an action plan, called CARS 2020, developed following the recommendations made with the High-Level Group called CARS 21[12], but also considering the strategies and the objectives presented with the 2010 European Strategy on Clean and Energy Efficient Vehicles (COM, 2010) and the White Paper (EC, 2011).

The action plan is based on four pillars aiming at strengthening the automotive industry for the years 2012-2020:

1. Promotion of investments in advanced technologies and innovation for clean vehicles with the aid of European funds
2. Improvements in the European market conditions
3. Support of the industry's access to the global market
4. Promotion of investments in skills and training (COM, 2012).

Clean Fuels Strategy. Following the recommendations of CARS 21 and the CARS 2020 Action Plan, a new strategy has been implemented in 2013: the European alternative fuel strategy or the Clean Power for Transport Package.

This framework proposes measures for ensuring the construction of an adequate network of alternative recharging/refueling stations covering a comprehensive mix of alternative fuels (COM, 2013). Why are the alternative fuels and the related infrastructure so important to the EU? The answer is simple: they represent a crucial instrument in the achievement of the goals defined in the White Paper, they will contribute to the growth of the EU and the decreased dependency on oil.

However, why has it been and still is so difficult to spread AFVs and build a strong infrastructure all over Europe? The answer is simple also to this question: there are technological and commercial deficiencies among the Member States and, more importantly, there is a lack of consumer acceptance for these types of vehicles especially after the Dieselgate case.

The Clean Fuels Strategy makes every Member State responsible for its actions favoring the deployment of alternative fuel stations and vehicles. For this reason, there

[12] The High-Level Group CARS 21 published its final report in 2012, where it provides important advices in legislative terms with respect to the actions to be taken to maintain the European automotive industry solid and strong. The report can be found here: https://bit.ly/2yaYzK2.

must be continuous and clear communications between the Member States and the Commission containing the relevant information regarding current and future development of alternative fuels and related legislation at the national level (COM, 2013).

The European Strategy for Low-Emission Mobility. The year 2016 represents an important turning point for the whole European automotive sector because a new direction was set with the Commission's proposal of a strategy for low-emission mobility (COM, 2016).

The strategy sets clear and fair guiding principles based on three specific objectives:

1. Improve the efficiency of the transport system as a whole,
2. Promote low-emission alternative energy for transport, and
3. Promote and spread ZLEVs.

For the first time, the Commission's proposal deals with the automotive sector and mobility in a circular economy perspective. It emphasizes the opportunity that other sectors and manufacturers could benefit from the advances made in the automotive industry.

The low-emission mobility strategy stresses the crucial role that an integrated and coordinated approach has in achieving innovation and sustainability goals. Decarbonizing while maintaining competitiveness remains the key objective for the European car manufacturers, who are supported by the Union's funds and investments.

Furthermore, with the 2016 Strategy, the Commission introduces the gradual shift from the NEDC test to the WLTP. The former has been proven to be inadequate and unreliable after the report by the High-Level Group CARS 21. In 2011, an expert group was assigned the task of finding a new testing procedure filling the NEDC's gaps. The new measurement procedure became the WLTP, which, despite remaining a laboratory test, delivers more realistic and accurate values for CO_2 emissions (COM, 2016).

Europe on the Move: The Mobility Packages. In 2017, President Junker proposed a new strategy as a continuum of the previously mentioned "European Strategy for Low-Emission Mobility" of 2016 to modernize the European mobility and transport sector, specifically road transport. "Europe on the Move" is a long-term strategy that delivered three sets of measures from May 2017 to May 2018. Safer traffic, fairer road charging, and

reduced CO_2 emissions, air pollution, and congestion are the main topics covered by the strategy to be achieved through a harmonized and a "management-by-objectives" approach (COM, 2017a).

The three keywords of the Mobility Packages are "digitalization, automation and alternative energy sources" (COM, 2017a) addressed to everyone in the Union following the principle of leaving no one behind and encouraging all actors to work together through a comprehensive and integrated approach (COM, 2017a; COM, 2018a, COM, 2018b).

The vision behind "Europe on the Move" goes beyond road transport. The commission aims of promoting job creation, growth, and investments, especially concerning alternative fuels infrastructure all over Europe, fairly and taking into account relevant stakeholders' opinions (COM, 2017a; COM, 2018a; COM, 2018b).

2.1.2 Directives and Regulations

Type-approval of motor vehicles. The legal basis for the technical harmonization of type-approval vehicles, safety, and environmental requirements is contained in Directive 2007/46/EC of 5 September 2007. This Directive determines how a vehicle should be and how it should perform before it is sold into the European market (EC, 2007). The common framework established by the European Commission specifies the roles covered by the EU and the Member States. The former sets the requirements that a motor vehicle should meet, the latter conduct the tests through designated national authorities.

Directive 2007/46/EC has recently been repealed by Regulation (EU) 2018/858 of 30 May 2018 which will become mandatory from September 2020 and which increases the the stringency of requirements, the level of market surveillance[13] of motor vehicles and strengthens the overall oversight of the EU on the Member States, national authorities, and car manufacturers (EC, 2018a).

[13] By "market surveillance" the Regulation (EU) 2018/858 provides the following definition: "the activities carried out and measures taken by the market surveillance authorities to ensure that vehicles, systems, components and separate technical units as well as parts and equipment made available on the market comply with the requirements set out in the relevant Union harmonisation legislation and do not endanger health, safety, the environment or any other aspect of public interest protection" (EC, 2018a)

The legislation on type-approval vehicles also determines the opportunity for the Commission to run the so-called in-service conformity tests, that are done on vehicles after a certain amount of time or kilometers of usage (EC, 2020c).

Testing procedures. Regulation (EC) No 715/2007 laid down the technical requirements concerning testing procedures, which have been specified in Regulation (EC) No 692/2008. This Regulation states that the testing procedure for measuring LDVs emissions is the New European Driving Cycle (NEDC) test. The NEDC is a laboratory test used to measure all the GHGs emitted from a vehicle, namely NO_x, CO, CO_2, PM, and others (EC, 2008).

However, a big issue emerged when the CARS 2020 Action Plan has been published. It was found out that the emissions measured through the NEDC test were not reliable, that is the emissions generated by Euro 5 and Euro 6 vehicles in real-driving conditions greatly exceeded the emissions calculated through the NEDC procedure (COM, 2012). Specifically, in RDE tests they were almost 42% higher than those assigned under the NEDC (Transport & Environment, 2018). This, of course, was an undeniable issue to be solved in the shortest possible time.

Consequently, the Commission decided to create new and improved testing procedures distinguished by the emissions they measure. As a consequence, the Real-Driving Emission (RDE) test for NO_x and ultrafine particles, and the World Harmonized Light Test Procedure (WLTP) for CO_2 emissions have been adopted.

Beginning from the RDE test, it consists of a complement of the measurement procedures done in the laboratory. Emissions are captured through the Portable Emission Measuring Systems (PEMS) which are attached to the car while driving on a normal road. The RDE test has been adopted in four phases:

Phase 1. The testing procedure entered into force in 2016 through the Regulation (EC) No 2016/427. In its initial phase, the RDE was used only for monitoring purposes without interfering with the results given by the NEDC procedure (EC, 2016a).

Phase 2. From 2017, as indicated in Regulation (EC) No 2016/646, the RDE testing started having an impact on type-approvals. In particular, it was agreed that RDE

measurements for NO_2 were compulsory for new car models and all new vehicles from 2019. Also, a conformity factor[14] of 2.1 was applied. (EC, 2016b).

Phase 3. Regulation (EU) No 2017/1154 extends the RDE to particle number (PN) emissions for all new vehicle types by September 2017 and all new vehicles by the year after. Phase 3 also brought some improvements in the testing procedure because it included shorter trips and a broader range of conditions. Finally, the Technical Committee of Motor Vehicles required that car manufacturers displayed in their certificates of conformity the RDE performance of the vehicle (EC, 2017b).

Phase 4. Regulation (EU) No 2018/1832 pushes RDE testing's transparency and reliability one step further. Since 2018, type-approval authorities have to run in-service conformity tests, that is each year they have to check the emissions of vehicles that are already in circulation. Besides, starting from January 2020, the conformity factor is reduced to 1.5, with the aim of reaching a conformity factor of 1 by 2023 (EC, 2018b).

Moving on to the WLTP, it became mandatory for all new car models from September 2017 and all new vehicles from the year after as it is indicated in the Regulation (EC) No 2017/1151, which is the legal act for the implementation of the WLTP (EC, 2017a). This testing procedure completely substitutes the NEDC, providing fuel consumption and CO_2 values that are much more reliable, accurate and similar to real-driving emissions, despite being measured in a laboratory context (EC, 2017a).

The second WLTP act corresponds to the Regulation (EU) No 2018/1832, where it is stated that the testing procedure has been improved and made stricter. Also, the Regulation obliges all LDVs to be equipped with "on-board fuel consumption monitoring devices" by 2021 such that laboratory results of CO_2 obtained through WLTP become comparable to the real-driving emission values (EC, 2018b).

Despite the ultimate goal of the Commission is to provide values that are as nearer as possible to the real-driving emissions, the WLTP is a laboratory test as the NEDC was. As a consequence, also the WLTP does not take into account real driving, weather, and

[14] A conformity factor is defined as a "not to exceed limit" taking into account a margin of error because PEMS are strongly affected by external, uncontrollable conditions, which might provide different results for each test. A conformity factor is needed to fill the lack of repeatability of PEMS with respect to laboratory tests (EC, 2017a).

traffic conditions, however, the Commission recognizes that laboratory testing will always be needed. Such testing procedures are comparable, repeatable, and precise with a lower margin of error than the RDE testing procedure (EC, 2020c), and because it makes it easier for consumers to compare CO_2 emissions and fuel consumption between different car models.

Exhaust emissions standards. The EU has always suffered from GHG emissions caused by road transport, which account for 73% of the GHG emissions in the transport sector as a whole (EEA, 2019). As a consequence, starting with the Directive 91/441/EC, the Commission has developed regulations setting emission standards known as "Euro" standards. The most recent ones are the Euro 5 and Euro 6 standards which have been initially set with Regulation (EC) No 715/2007. This Regulation has two main objectives: create an internal market by introducing a common framework for all Member States concerning emission limits and technical requirements for type approval vehicles, and guarantee access to vehicle repair maintenance information. The creation of a common framework valid for all Member States helps to avoid differences and ensures environmental protection (EC, 2007a).

Concerning financial incentives and penalties, the former are guaranteed to motor vehicles meeting the standards set, however, they "should not exceed the additional cost of the technical devices introduced to ensure compliance with emission limits" (EC, 2007a). Penalties are determined at the Member State level, and they should be "effective, proportionate, and dissuasive" (EC, 2007a).

The table below indicates the current emission limits for Euro 5 and Euro 6:

		Limit values			
		Euro 5		**Euro 6**	
Category	**Reference mass – RM** (kg)	**NOx** (mg/km)	**PM** (mg/km)	**NOx** (mg/km)	**PM** (mg/km)
M	All	180	5.0/4.5	80	4.5
N1[15]	RM ≤ 1 305	180	5.0/4.5	80	4.5
	1 305 ≤ RM ≤ 1 760	235	5.0/4.5	105	4.5
	1 760 < RM	280	5.0/4.5	125	4.5

Table 6 Euro 5 and Euro 6 Emission Limits.

15 N_1 vehicle category includes vehicles carrying goods and with a maximum mass of 3.5 tons (EC, 2007b).

Source Author's adaptation of the tables contained in Regulation (EC) No 715/2007 on p. 12-13 (EC, 2007a).

CO_2 emissions. The first CO_2 emission regulations have been implemented in 2009 for PCs and 2011 for LCVs through Regulations (EC) No 443/2009 and 510/2011. Differently from the legislation of NO_x and PM, the emission limits for the carbon dioxide are set at the fleet level (EC, 2020c). However, why are CO_2 emissions regulated by a separate legislation? The reason is that despite carbon dioxide does not cause directly health issues, it does contribute extensively to global warming, and since it is the main GHG emitted from vehicles, CO_2 must be tightly controlled (EC, 2020c).

In 2019, Regulation (EC) No 2019/631 repealed the ones of 2009 and 2011 and includes in a single document the requirements for both PCs and LCVs. This Regulation became operative in January 2020 and maintains the targets established in the past for 2020, but sets the new ones for 2025 and 2030, the so-called post-2020 targets for cars and vans which are "competitively neutral, socially equitable, and sustainable" (EC, 2019a).

Since the changes in the testing procedure took place only recently, the fleet-wide targets for CO_2 emissions set before the 2019 Regulation are based on NEDC tests, instead, the post-2020 ones are based on the WLTP. As a consequence, the Regulation also provides indications on how to adapt the NEDC values to the WLTP requirements[16]. The table below summarizes the EU fleet-wide targets to be applied for 2020, 2025, and 2030:

EU Fleet-Wide Targets for PCs and LCVs		
	PCs	**LCVs**
2020	95gCO_2/km	147gCO_2/km
2025 *(2021 baseline)*	-15% = 81gCO_2/km	-15% = 125g CO_2/km
2030 *(2021 baseline)*	-37.5% = 59g CO_2/km	-31% = 101g CO_2/km

Table 7 EU Flee-Wide CO_2 Targets for PCs and LCVs.

Source Author's adaptation of the information contained in ICCT, 2019, and EC, 2019a.

[16] This information is contained in Annex I – Part A and Annex I – Part B of Regulation (EC) No 2019/631 (EC, 2019a).

The new Regulation clearly states the need to move and accelerate the transition towards a zero- and low-emissions transport system through a stepwise and integrated approach strongly stimulating innovation. In particular, it is highlighted the need for a coherent action at all levels involving different stakeholders as well as consumers.
Furthermore, with this Regulation, the Commission offers to car manufacturers strong incentives to increase the share of ZLEVs[17] or AFVs, namely EVs, PHEVs, or FCVs.
The table below resumes the incentives and flexibilities at the manufacturers' disposal:

Incentives for Car Manufacturers	
Super-credits	New PCs emitting less than 50gCO_2/km should be counted as: • 2 PCs in 2020 • 1.67 PCs in 2021 • 1.33 PCs in 2022 • 1 PC from 2023 onwards Subject to a cap of 7.5 gCO_2/km.
Eco-innovations	CO_2 savings may be considered to manufacturers using verified innovative technologies or a combination of them, or improvements in the A/C systems subject to a cap of 7gCO_2/km.
Incentive mechanism for ZLEVs	From 2025 a manufacturer will be released from meeting the CO_2 targets if its share of ZLEVs registered in a given year exceeds • 15% from 2025 and 35% from 2030 for cars • 15% from 2025 and 30% from 2030 for vans Subject to a cap of maximum 5%.
Flexibilities for Car Manufacturers	
Pooling	All manufacturers belonging to the same vehicles' category, except those with a derogation, can form a pool to achieve in a cost-effective way the targets set.
Derogations	A carmaker producing less than 10,000 new PCs and 22,000 new LCVs can access a derogation to the CO_2 targets for at most 5 years.

[17] With Regulation (EC) No 2019/631, the Commission gives a definition of ZLEVs as LCVs with CO_s emissions between 0 and 50 g/km (EC, 2019a).

Exemptions	A manufacturer producing less than 1,000 new vehicles is exempted from the CO_2 targets.

Table 8 Incentives and Flexibilities for Car Manufacturers Related to PCs and LCVs.
Source EC, 2019a; EC, 2020a.

If a motor vehicle manufacturer is found non-compliant or violates the requirements set by the Commissions, it will be sanctioned with €95 for each g/km of CO_2 in exceedance for PCs and with €120 for each g/km of CO_2 in exceedance for LCVs (EC, 2019a).

Alternative fuels. The importance given by the Commission to the deployment, development, and use of alternative fuels in new low-emission vehicles is linked to the efforts put in supplying an adequate infrastructure for refueling/recharging such types of vehicles. After many communications where the Commission clearly stated the unavoidable necessity to sustain alternative fuels, Directive 2014/94/EU establishes definite requirements on this matter. Member States are required to ensure a minimum coverage of alternative refueling/recharging points, specifically containing hydrogen, natural gas (liquified natural gas, LGV and compressed natural gas, CNG), and electricity (EC, 2014). In particular, Member States will define how they are going to meet the requirements for the alternative fuels infrastructure through their National Policy Frameworks. These should be comprehensive of all transport modes available in the country's territory, provide support measures and "be in line with the Union's environmental and climate-protection legislation" (EC, 2014).

The need for an integrated and coordinated approach involving all parties at all levels is highlighted also in the Directive 2014/94/EU. Only in this way, the EU can achieve long-term goals for alternative fuels and vehicles. Moreover, the Commission puts in place funds and Union's investments to help countries lying in difficult economic situations (EC, 2014).

Despite the Directive has been in force for six years, the European infrastructure for alternatively fueled vehicles is still inadequate, with great disparities between the "rich" and the "poor" countries. According to the 2019 Progress Report published by ACEA, 70% of the EV's charging points are located in the Netherlands, Germany, France, and the United Kingdom. Considering the hydrogen refueling stations, out of the 28

Member States[18] of the EU, 17 do not have any. Finally, 3,400 natural gas filling stations are present in the EU with an increase of 17.4% compared to 2014, however, they are concentrated in just two countries, namely Italy and Germany. Despite the number of recharging/refueling stations has increased in the past 8 years (as it can be seen in *Figure 8*), all these data confirm that much work has still to be done. A way to fill the wide gap between countries must be found promptly to put all Member States in the conditions to make an efficient transition towards a low-carbon economy, leaving no one behind.

[18] The data of the ACEA report refer to the year 2018, when the United Kingdom was still part of the European Union, as a consequence the Member States taken into account are 28, not 27 as they are in 2020.

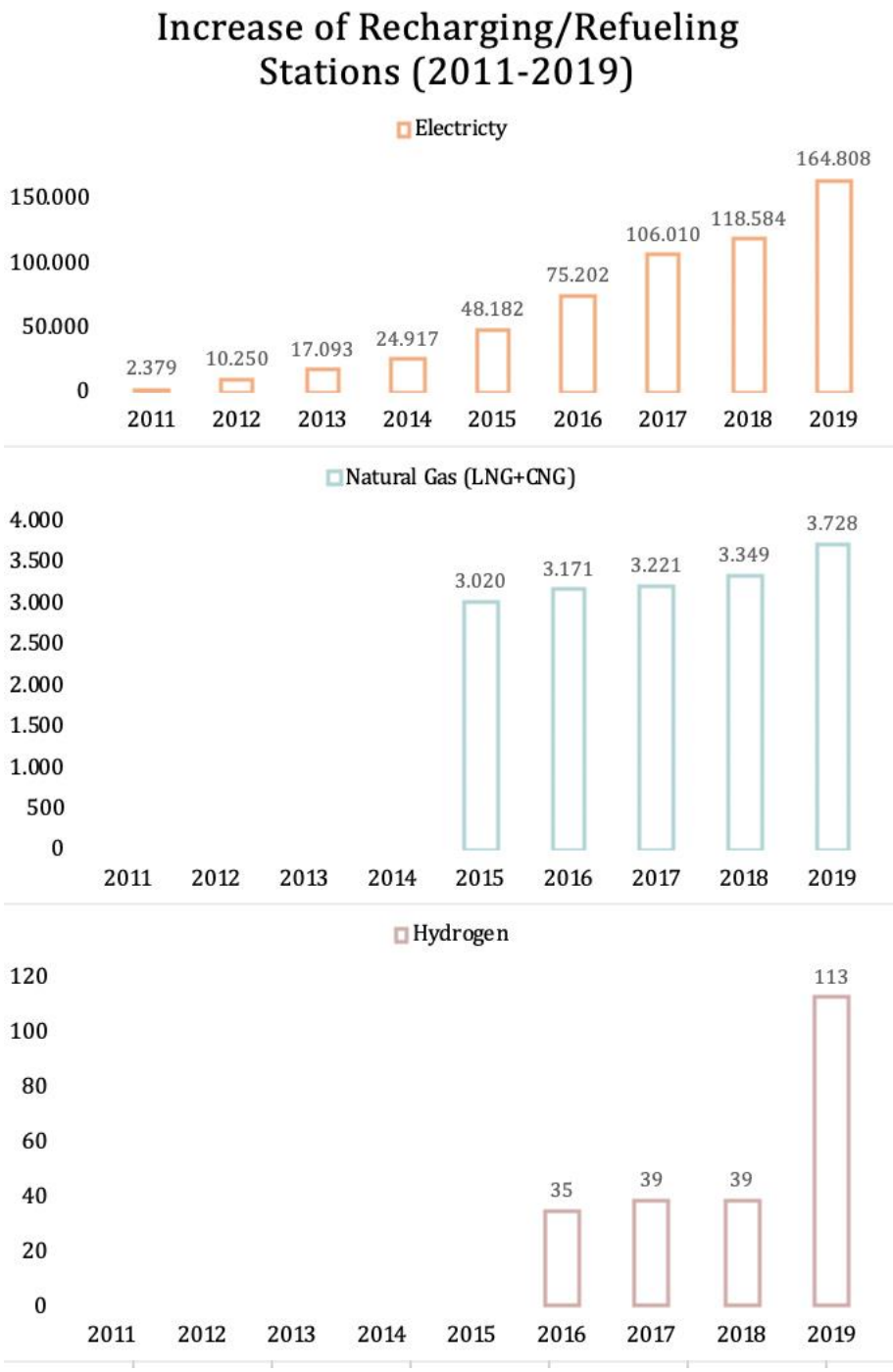

Figure 8 Increase of Recharging/Refueling Stations in the EU between 2011 and 2019.

Source Author's adaptation of the data retrieved from European Alternative Fuel Organization (EAFO), https://www.eafo.eu on 12.04.20.

Clean vehicles. The three Mobility Packages presented between 2017 and 2018 implemented many changes, including a revision of the Clean Vehicles Directive (CVD) which has been repealed Directive 2019/1161/EC (EC, 2019a).

This piece of legislation is particularly important because it encourages and even obliges authorities and carmakers to consider the environmental issues that are putting at risk the entire world. CVD pushes car manufacturers to improve year by year the environmental friendliness of their vehicles.

On the one side, the Revised CVD sets minimum targets for procuring clean vehicles for each Member State to be reached in 2025 and 2030, and thus it forces them to make investments in low- and zero-emission mobility. On the other side, the Directive takes into account the GDP per capita and the urban population density (their exposure to pollution) of each Member State setting different targets accordingly (EC, 2019b). To reflect this fairness, the life-cycle costing methodology chosen by the authorities for a specific country and the support received by the Union through EU Funds follow the principle of leaving no one behind.

Table 9 shows the emission thresholds for LDV set with the CVD in 2019. It indicates that until 31st December 2025, a clean LDV should emit no more than 50gCO_2/km and up to 80% of applicable real-driving emission limits for NO_x and PM. From 1st January 2026, only zero-emission vehicles will be considered under this Directive.

	Until 31 December 2025		**From 1 January 2026**	
Vehicle categories	**CO_2 g/km**	**RDE air pollutant emissions**	**CO_2 g/km**	**RDE air pollutant emissions**
M1[19]	50	80%	0	n/a
M2[20]	50	80%	0	n/a
N1	50	80%	0	n/a

Table 9 Emission Thresholds for Clean Light-Duty Vehicles.
Source EC, 2019b (p.129).

2.2 The United States of America

This section of the second chapter focuses on the legislation regarding light-duty vehicles that is applied in the United States of America, another historically big and relevant

19 M1 vehicle category includes vehicles carrying passengers with at most eight seats in addition to the driver's and with a maximum mass of 5 tons.

20 M2 vehicle category includes vehicles carrying passengers with more than eight seats in addition to the driver's and with a maximum mass of 5 tons.

market in the automotive sector, which registered its record high fuel economy and its record low CO_2 emissions in 2018 (EPA, 2019c; EPA, 2020d).

At the basis of the US legislation on motor vehicles, there are two main acts: the Clean Air Act (CAA) of 1970 and the Energy Policy and Conservation Act (EPCA) of 1975. These two acts give authority to two agencies, the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA), respectively. EPA is responsible for setting the GHG emission standards of motor vehicles, instead NHTSA determines the fuel economy targets under the Corporate Average Fuel Economy (CAFE).

The two institutions set the standards at the federal level and they work in close cooperation. However, it has not always been like this. EPA and NHTSA were and still are two independent agencies, they determine different standards for different purposes, but, during Obama's administration, they realized the complementarity of their goals and challenges. Besides, on the one side, many automakers were asking for more harmonized requirements, an integrated approach for regulating the automotive industry, and for mitigating their costs. On the other side, the two agencies needed to join their powers to face the challenges of global warming and energy independence.

In the 2010 Final Rule, when the One National Program was officialized, it is clearly stated that NHTSA and EPA can work together "because the relationship between improving fuel economy and reducing CO_2 tailpipe emissions is a very direct and close one" (DOT, EPA, NHTSA, 2010). The amount of "CO_2 emissions is essentially constant per gallon combusted of a given type of fuel" (DOT, EPA, NHTSA, 2010). Saying it in other words, the more fuel efficient a vehicle, the less fuel it burns, the less CO_2 it emits.

The two agencies set standards in an attribute-based way, such that every vehicle model has a performance target, expressed either in *mpg* (miles per gallon) or gCO_2/mi (grams per mile of CO_2) depending on the program considered. The target levels depend on a specific vehicle's attribute, its footprint[21]. Also, EPA and NHTSA have agreed on establishing inversely proportional targets, that is "the greater the footprint, the less

[21] NHTSA and EPA define the footprint of a vehicle as the "product of wheelbase times average track width (the area defined by where the centers of the tires touch the ground)" (EPA, 2020d, p.27).

stringent the standards". As a consequence, the compliance requirements for light-duty trucks[22] are less demanding than those for light-duty vehicles[23].

Concerning the compliance mechanisms of CAFE and the GHG program, NHTSA and EPA have their own credit systems, flexibilities, and penalties that are going to be presented later.

The most recent action taken by the two agencies is the approval of the Safer Affordable Fuel-Efficient (SAFE) Vehicle Rule in 2019 (DOT, EPA, NHTSA, 2019), which was proposed after the Midterm Evaluation (MTE) conducted in 2018 when the agencies found out that the standards they set in 2012 were too stringent and economically harmful to be achieved by American carmakers.

This section is organized as follows: first, the acts at the basis of EPA's and NHTSA's authority will be presented, then the roles of the two agencies will be discussed in terms of what they do and how they do it. In the third subchapter, a list of the most relevant and recent legislative actions taken by the two agencies will be presented. Finally, a separate subchapter will be dedicated to the penalties and the incentive mechanisms in place for encouraging the production of alternative-fueled technology-efficient, and low-emission vehicles.

2.2.1 Legislative Milestones behind EPA and NHTSA

Clean Air Act (CAA), 1970. The Clean Air Act gives power to EPA for protecting and improving air quality. Specifically, EPA is required to set and revise national air quality standards (NAAQS) for motor vehicles, power plants, industrial plants, and other non-mobile facilities. In doing so, EPA must always use updated information based on science without considering the costs. This shows that the American government believes that the protection of the environment, of the air, and consequently of the population comes at no costs. A major change in the CAA happened in 1990 with its amendment when

[22] Light-duty trucks are defined as "any motor vehicle rated at 8,500 pounds gross vehicle weight rating (GVWR) or less which has a curb weight of 6,000 pounds or less and which has a basic vehicle frontal area of 45 square feet or less, which is: (1) designed primarily for purposes of transportation of property or is a derivation of such a vehicle; or (2) designed primarily for transportation of persons and has a capacity of more than 12 persons; or (3) available with special features enabling off-street or off-highway operation and use." (40 CFR § 86.1803-01, Retrieved from https://bit.ly/3aWnNcv on 24/02/20.

[23] Light-duty vehicles are defined as "Light-duty vehicle means a passenger car or passenger car derivative capable of seating 12 passengers or less." (40 CFR § 86.1803-01, Retrieved from https://bit.ly/3aWnNcv on 24/02/20).

market-based instruments such as banking and trading started being used as innovative approaches to reduce emissions. Besides, the amendment fostered the development of clean and alternative fuels.

Energy Policy and Conservation Act (EPCA), 1975. The EPCA gives NHTSA the power to set the CAFE standards to improve the overall efficiency of the American fuel economy. The act was approved following the oil embargo and shocks that took place during the 1970s intending to make the US as oil-independent as possible. Under the EPCA, NHTSA is required to set CAFE standards for a maximum of five years and at the maximum feasible level achievable by carmakers (EPCA, 1975). The EPCA was amended in 2007 with the Energy Independence and Security Act (EISA).

Alternative Motor Fuels Act (AMFA), 1988. The AMFA sets incentives for automakers for the production, deployment, and improvement of AFVs. This Act works in close cooperation with the EPCA, the EISA, and, consequently, with NHTSA, which strongly foster investments in R&D for the spread of these cleaner and innovative vehicles (AMFA, 1988). AMFA does not cover EVs, liquified petroleum gas (LPG) vehicles, and biodiesel vehicles since they are under the control of EPA.

Energy Policy Act (EPAct), 1992 and 2005. The EPAct was created following the EPCA and the AMFA, such that it aimed to make the US more independent from imported oil, improve air quality, and encourage the production and sale of AFVs. What distinguishes this Act from the others is that it requires federal, state, and alternative fuels provider fleets to acquire a certain amount of AFVs (EPAct, 2005).
According to the *Alternative Fuel Vehicle Acquisition Report* published in February 2020, the target of having 75% of the federal fleets composed of AFVs by 2019 has been largely accomplished with a total of 77% AFVs (EPA, 2020b).

Energy Independence and Security Act (EISA), 2007. The EISA amends the EPCA of 1975 even though it maintains the same goals. The difference lies in the creation of a mandatory Renewable Fuel Standards under EPA's control aiming at reaching 36 billion gallons of renewable fuel by 2022 and in requiring NHTSA to establish domestically manufactured passenger car fleets' standards (EISA, 2007).

From the legislative milestones presented here, it emerges that the US has always put the attention towards two main objectives:

1. Reduce as much as possible the dependence on oil and
2. Improve air quality by reducing the harmful effects of GHG emissions.

To reach these goals, the US did not only set specific targets for improving the fuel economy, but it also fostered and encouraged the production of AFVs. The latter has been difficult to be implemented since many carmakers were reluctant to invest in technologies that consumers did not demand, mainly because of skepticism toward and high costs of these new vehicles. As a consequence, NHTSA and EPA had to develop an incentive system for effectively rewarding car manufacturers for their efforts in producing AFVs (DOT, NHTSA, 2004), while making consumers more aware of the benefits of such vehicles through clear and transparent communication.

2.2.2 NHTSA and EPA: An Overview

The US government has paid a lot of attention to reaching higher and higher fuel economy levels. The reasons making fuel economy so important spread from the economic sphere to the environmental one. As a matter of fact, improved fuel efficiency leads to cost savings and oil independence, and it encourages car manufacturers to invest in alternative fuels consuming and consequently polluting less.

Through CAFE, NHTSA issues minimum performance requirements expressed in miles per gallon (*mpg*). For the targets to be fair, NHTSA is required to determine the maximum feasible standards to be reached both by PCs and light trucks in every Model Year (MY) according to four factors (DOT, NHTSA, 2004).

- Technological feasibility
- Economic practicability
- Energy conservation
- Other standards' effects on fuel economy.

Another important aspect related to NHTSA's CAFE is that the agency determines, for each MY, the minimum standards for domestically manufactured passenger car fleets. This decision was brought by the EISA of 2007, where carmakers were required to "meet

the greater of either 27.5mpg on average, or 92% of the average fuel economy projected by the Secretary for the combined domestic and non-domestic passenger automobile fleets manufactured for sale in the U.S. by all manufacturers in the model year" (EISA, 2007).

EPA's role, conferred by the CAA, is to reach higher levels of air quality controlling emissions of mobile sources and to contribute to increased consumer awareness. To achieve this goal, every year EPA publishes the *Green Vehicle Guide* which helps consumers making more informed decisions regarding efficient and low-emissions vehicles that satisfy specific emission and fuel economy requirements.

With the 2010 Final Rule, the two agencies agreed on leaving the compliance procedure under the authority of EPA to make it consistent and non-duplicable (DOT, EPA, NHTSA, 2010). This means that EPA determines whether both the CAFE and the GHG requirements are met through the testing procedures that are run in a special laboratory, the National Vehicle and Fuel Emission Laboratory (NVFEL) (EPA, 2019a), which is the only authority in the US with the power to:

- Certify, through a certificate of conformity, that the vehicles tested meet the standards of the GHG program and CAFE,
- Certify, through the in-use compliance tests, whether a vehicle still meets the standards of EPA and NHTSA while it is used, and
- Analyze fuels, fuel additives, and exhaust compounds.

The testing procedures used by EPA are mainly two: the Federal Test Procedure (FTP) and the Highway Fuel Economy Test (HWFET). The former tests driving emissions in the city, the latter in the highways. The results obtained by these two tests are then combined and weighted 45% and 55%, respectively, to get a single CO_2 emission value (EPA, 2020d). EVs undergo the same testing procedures as if they were normal vehicles. However, they will need additional requirements and tests to provide a reliable value in terms of CO_2 emissions and fuel economy (Continental, 2019).

EPA has the authority to determine the CO_2 standards and the exhaust emissions standards including gases such as NO_X, PM, and NMOG[24]. The latter are set through the

[24] NMOG are Non-Methane Organic Gases and the current Tier 3 standards of harmful pollutants consider them together with NO_x.

so-called Tiers, which are emission standards divided by "bins"[25]. In the beginning, emission standards were set separately for LDVs and LDTs, but with the approval of the Tier 2 ones, they were addressed jointly for the two vehicle categories. The newest standards are the Tier 3 emission limits (shown in *Table 10*), which have been phased in since 2017 (Continental, 2019; EPA, 2019b). Thanks to EPA's work and carmakers' effort, current NO_x emissions are 98% lower than 1975, however, a lot has still to be done since these emissions keep being a threat for the American air quality (EPA, 2019b).

Standard	**Emission limits (mg/mi)**	
	NO_x+NMOG	**PM**
Bin 1	0	0
Bin 20	20	3
Bin 30	30	3
Bin 50	50	3
Bin 70	70	3
Bin 125	125	3
Bin 160	160	3

Table 10 Tier 3 Emission Limits.

Source Author's adaptation of the table contain in Continental, 2019, p.104.

Considering the CO_2 and the corresponding fuel economy targets, the two institutions use the standard curves[26] methodology, which consists in equations that are slightly different not only from NHTSA to EPA but also from one vehicle category to another (DOT, EPA, NHTSA, 2020a).

The AMFA and the EPAct strongly influence EPA and NHTSA in their actions for ensuring the development of AFVs fleets all over the US. The attention towards the deployment of low-emission, alternative-fueled vehicles is visible also in the investments done by the government for offering a good network of recharging/refueling stations all

[25] A "bin" is equivalent to a horizontal row of federal testing procedure (FTP) standards established by EPA. Normally, a car manufacturer can decide the "bin of standards that will apply to a certain test group of vehicles" even though each automaker's fleet must meet a specified average emission standard (40 CFR § 86.1803-01, Retrieved from https://bit.ly/3aWnNcv on 24/02/20).

[26] The standard curves equations are presented in the Appendix-A.1.

over the US. According to the data contained in the Alternative Fuels Data Center, the trend of alternative fuel stations has been the following:

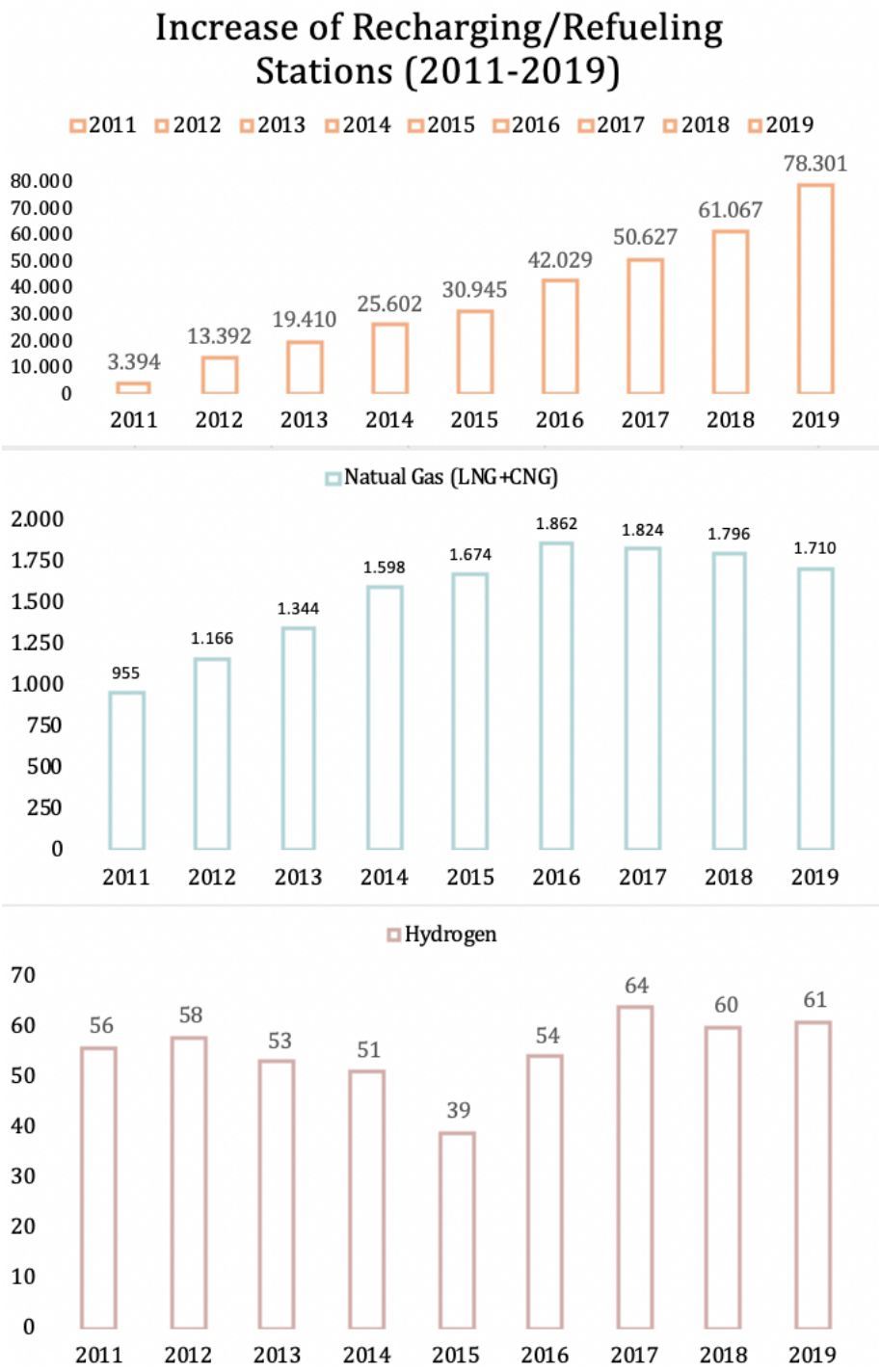

Figure 9 Increase of Recharging/Refueling Stations in the US between 2011 and 2019.

Source Author's adaptation of the data retrieved from Alternative Fuels Data Center (AFDC), https://bit.ly/2WEXyT0 on 29.04.20.

2.2.3 Legislative Milestones of NHTSA and EPA

Light-duty vehicles GHG emissions and CAFE standards for MYs 2017-2025. Leveraging on the success of the first phase's standards (MYs 2012-2016), EPA and NHTSA presented, in 2012, the Final Rule with the new targets for the MYs 2017-2025. With this action, the cooperation between the two agencies was further strengthened bringing more benefits to motor vehicle manufacturers, who, in turn, could satisfy the requirements of both agencies with a single fleet, had clearer standards and flexibilities, and lower costs (EPA, 2012).

The main aim set by the final rule was to reach 163gCO_2/mi corresponding to 54.4mpg by 2025 with a 5% stringency rate per Model Year for PCs and 3.5% for light trucks until MY 2021. Considering the combined standards for LDVs and LDTs, the projected fleet-wide emission targets approved in 2012 were the following:

Projected Fleet-Wide Emission Targets for Passenger Cars and Light Trucks
CO_2 Standards (g/mi) and Fuel Economy Standards (mpg)

	2016 base	2017	2018	2019	2020	2021	2022	2023	2024	2025
CO_2	250	243	232	222	213	199	190	180	171	163
Fuel economy	35.5	36.6	38.3	40.0	41.7	44.7	46.8	49.4	52.0	54.5

Table 11 Standards (g/mi) and Fuel Economy Standards (mpg).
Source Author's adaptation of the table "Projected Fleet-Wide Emissions Compliance Targets under the Footprint-Based CO2 Standards (g/mi) and Corresponding Fuel Economy (mpg) (EPA, 2012, p.4).

Differently from the first phase's standards, in the 2012 Final Rule, the two agencies committed to a Midterm Evaluation (MTE) to be conducted by 2018 to determine whether changes to the MYs 2022-2025 targets should have been applied. The reason why an MTE was necessary was twofold: on the one hand, the standards were established in 2012 and covered almost 10 MYs, thus the agencies took into account the possibility of unexpected changes affecting the standards. On the other hand, NHTSA is required by EPCA to set fuel economy targets for a maximum of five years, thus in 2012, the agency approved the targets for MYs 2017-2021. Instead, for MYs 2022-2025, NHTSA only proposed "augural" standards (DOT, EPA, NHTSA, 2012).

Midterm Evaluation. The MTE of 2018 (EPA, 2018) is a legislative milestone because it greatly affected the standards for MYs 2022-2025, which were previously determined with the 2012 Final Rule (DOT, EPA, NHTSA, 2012).

A first MTE was done in 2017 when EPA did not propose any changes to the 2012's targets (EPA, 2017). However, many stakeholders disagreed with this decision and requested another MTE, which was conducted in 2018 and concluded that the targets for MYs 2022-2025 were not applicable anymore. EPA lists a series of reasons for explaining the inappropriateness of the standards, and especially of their stringency (EPA, 2018):

1. **Technology and lead time**. EPA stated that the availability of the technology for meeting the standards was too uncertain for maintaining them. This was due to a change in the sale of EVs, which, after 2013, started decreasing creating a misalignment between the stringency of the standards and the consumer demand of fuel-efficient vehicles. Also, EPA let emerge some doubts on the pace of development and adoption of new technology.

2. **Costs**. The standards set in 2012 put an excessive burden on producers, which they poured on consumers. In turn, purchasers, especially low-income ones, were less and less willing to pay more for a fuel-efficient, low-emission vehicle.

3. **Impact of the standards on consumers**. The rate of adoption from consumers of new low-emission vehicles, the cost of fuel, and the rebound effects greatly influence emission reduction, oil conservation, energy security, and fuel savings. Thus, lower demand for new fuel-efficient vehicles led to the lower effectiveness of both CAFE and EPA's GHG program.

4. **Impact of the standards on carmakers**. Motor vehicle manufacturers would have faced significant and unreasonable costs leading to lower sales both on the part of automakers and on the part of auto-dealers. According to TC/NERA, with no changes, the MYs 2022-2025 standards would have led to -1.3 million vehicles sold. An unacceptable scenario for carmakers, which would have suffered not in terms of lost profit but also of damages to the employment.

5. **Impact on other factors**. EPA identified in regulatory uncertainty another factor incentivizing the change of standards. Carmakers found many difficulties in planning for compliance for MYs 2022-2025 since they had to wait for the finalization of NHTSA's standards, which had only set "augural" targets for those model years.

Safer Affordable Fuel Efficient (SAFE) Vehicles Rule. The SAFE Vehicles Rule has been proposed jointly by EPA and NHTSA following the discoveries made with the MTE of 2018. Before finalizing the SAFE Vehicles Rule, the agencies analyzed different alternatives to identify the most appropriate one for the MYs 2021-2026 standards. The eight alternatives explored different stringency rates, spreading from 0% to 3% increase per year (DOT, EPA, NHTSA, 2018). These have been discussed together with many stakeholders and the Final Rule was presented in 2019, setting the grounds for guiding the agencies' work towards the definition of the new standards. This Final Rule is particularly important because it officializes the withdrawal of California's waiver[27] (DOT, EPA, NHTSA, 2019) that increased the agencies' power imposing a single set of federal fuel economy and GHG standards.

On April 30, 2020, EPA and NHTSA finalized the new standards for MYs 2021-2026 (DOT, EPA, NHTSA, 2020b). The Final Rule changes the stringency rate to 1.5%/year with no distinctions between PCs and light-trucks and brings several benefits (NHTSA, 2020):

- It will maintain and even increase US competitiveness,
- The sales of new vehicles will be boosted up to 2.7 million vehicles through 2029,
- Motor vehicles will become more affordable. Estimates suggest a $1,000 reduction on the average price,
- The average fuel economy will be 40.4mpg by MY 2026, and
- The environmental protection will continue to be at the center of the agencies' concern and actions by making new vehicles subject to tighter pollution standards in terms of exhaust and CO_2 emissions.

[27] The waiver granted to California for setting its own GHG emission standards and the zero-emission vehicles (ZEV) mandate was an exception officialized in the Clean Air Act, which normally preempts state and local emission standards to be set. California was granted this waiver because "the state had adopted standards (other than crankcase emission standards) for the control of emissions from new motor vehicles or new motor vehicles' engines prior to March 30, 1966" (DOT, EPA, NHTSA, 2012). However, EPA in 2019 stated that California's standards were inconsistent with section 202(a) of the CAA and were technologically infeasible (DOT, EPA, NHTSA, 2019).

The final standards for MYs 2021-2026 adopted with the SAFE Vehicles Rule by EPA and NHTSA are shown Appendix-A.2, however, below the graphical form of the standards will be presented to have an insight about how the stringency is going to change.

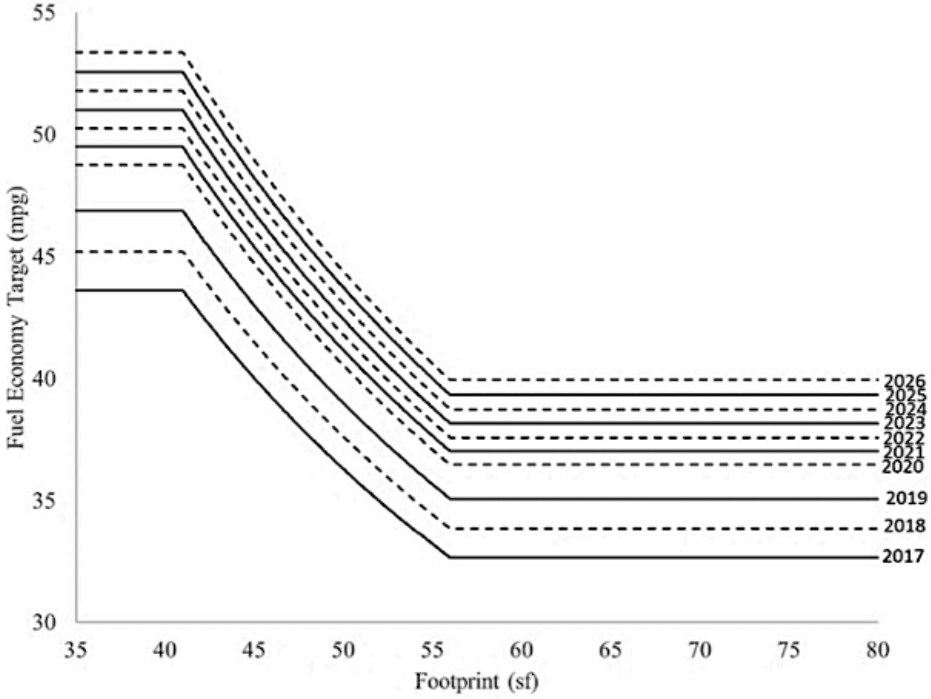

Figure 10 Passenger Cars Fuel Economy Targets.
Source DOT, EPA, NHTSA, 2020a, p.68.

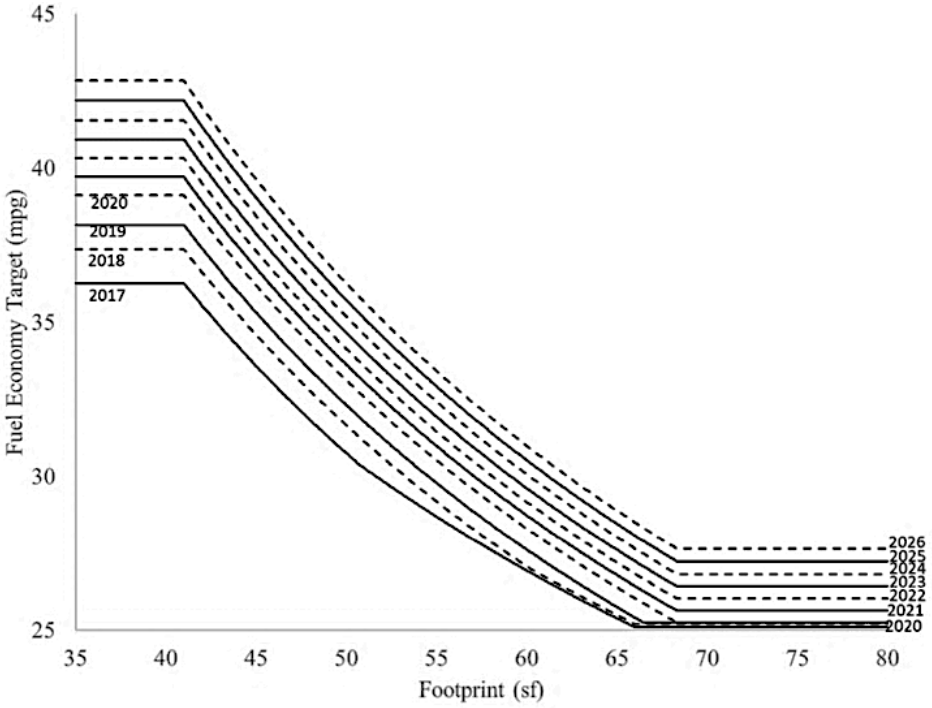

Figure 11 Light Trucks Fuel Economy Standards.
Source DOT, EPA, NHTSA, 2020a, p.69.

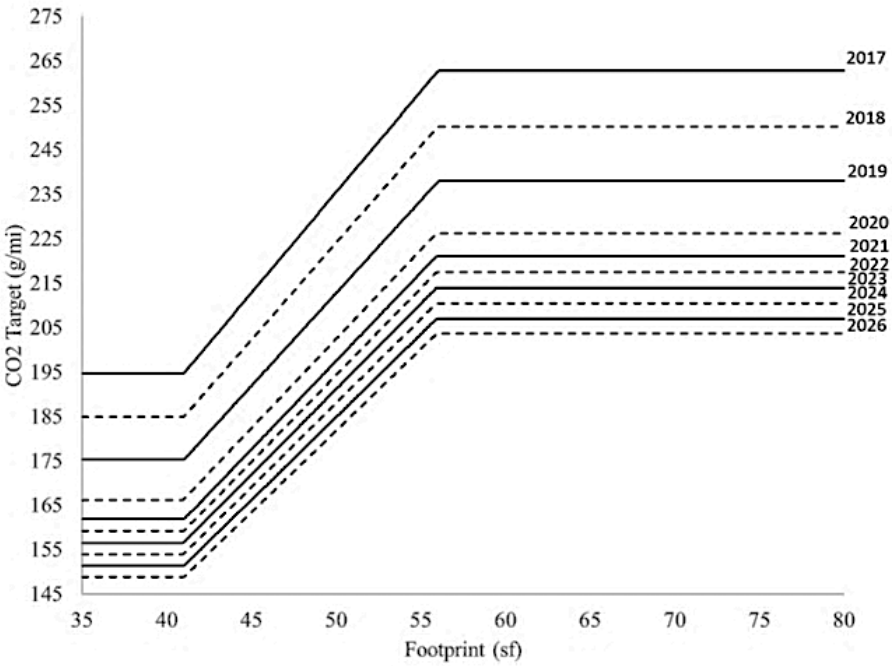

Figure 12 Passenger Car CO_2 Targets.

Source DOT, EPA, NHTSA, 2020a, p.74.

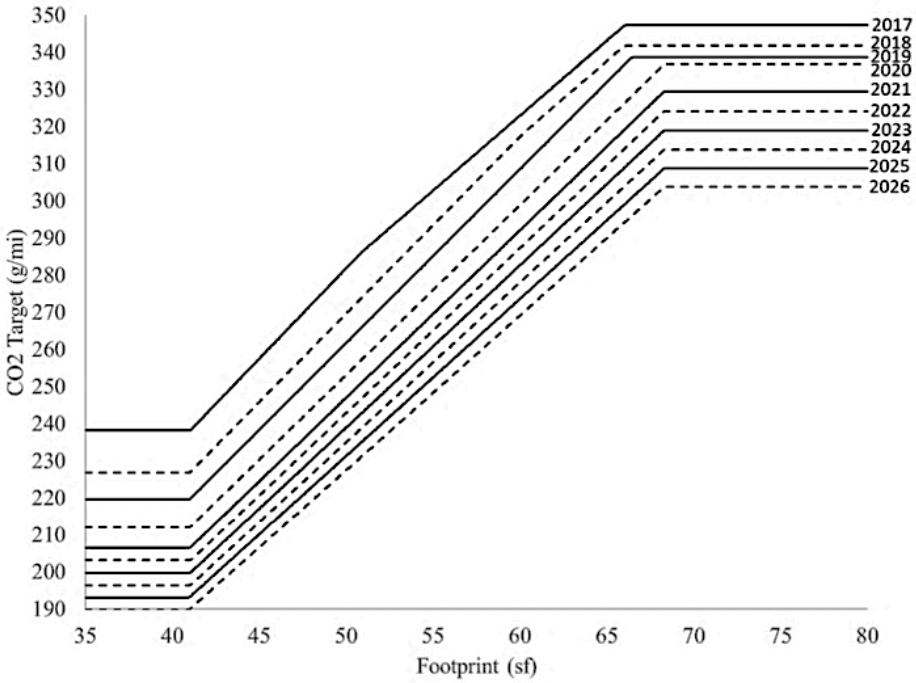

Figure 13 Light Trucks CO_2 Targets.

Source DOT, EPA, NHTSA, 2020a, p.75.

These graphs are interesting because they provide an immediate insight into what carmakers are expected to achieve in the next years. Besides, they show the complementarity existing between CAFE and GHG goals. The final objective is to provide vehicles with higher fuel economy and lower CO_2 emissions. In particular, it is expected that by MY 2026:

- Passenger cars will have a fuel economy of ~54mpg and will emit ~150gCO_2/mi,
- Light-trucks will have a fuel economy of ~44mpg and will emit ~190gCO_2/mi.

2.2.4 Penalties and Incentives Provided by NHTSA and EPA

This last subchapter presents the penalty mechanisms and incentives provided by the two agencies considering the ones that are already in force until the end of MY 2020 and those that are going to be changed, implemented, or maintained from MY 2021 following the approval of the SAFE Vehicles Rule.

The compliance mechanisms of EPA and NHTSA are very similar and, simply, compliance depends on two factors: how a manufacturer performs and how many vehicles a manufacturer sells. Normally, compliance is achieved when a carmaker outperforms the standards set by the agencies. In this case, a manufacturer earns credits that are useful when the motor vehicle producer is in a "credit deficit", that is when a manufacturer is not able to reach the standards of EPA and NHTSA. If a carmaker is not able to recover its credit deficit and is not able to fill its performance gaps, then it must be subject to a "punishment". Concerning this aspect, the agencies have some differences. According to the EPCA, whenever a manufacturer is found non-compliant and is not able to recover its deficit, then it is liable to a civil penalty. The "penalty rate is $5.50 for each tenth of an mpg that a manufacturer's average fuel economy falls short of the standard for a given model year multiplied by the total volume of those vehicles in the affected compliance category manufactured for that model year" (DOT, EPA, NHTSA, 2020a; DOT, EPA, NHTSA, 2020b), expressed as:

$$\boldsymbol{Potential\ Civil\ Penalty} = \$5.50 \times (Avg.FE\ Performance - Avg.FE\ Standard) \times 10 \times Total\ Production$$

Moreover, whenever a carmaker is found guilty for violating other CAFE's provisions, then it might be liable for a civil penalty of no more than $42,530 for each violation (DOT, EPA, NHTSA, 2020b).

Concerning the penalty mechanism of EPA, in 42 U.S.C. § 7524(a) of the CAA, it is stated that car manufacturers that are found non-compliant or that violate the requirements set by CAA are punished on a case-by-case level. This means that EPA decides the amount a carmaker should pay. In general, the CAA sets the maximum penalty for violation of the vehicle or engine requirements at $37,500 per vehicle (CAA, 1970).

Having a "credit deficit" does not necessarily mean that a carmaker is liable for the payment of the penalty because there is a series of options that might help the manufacturer in achieving the standards. The first option is represented by the typical ABT alternatives, valid for both EPA and NHTSA (DOT, EPA, NHTSA, 2020b):

- Carry forward the credits up to five years,
- Carry backward the credits up to three years,
- Transfer credits from one fleet to another of the same manufacturer, and
- Trade credits with other carmakers.

Credit, banking, and trading are important to manufacturers especially in the planning and the implementation of the GHG reduction technologies. These allow car makers the lead time necessary to adapt their production to the requirements set by the agencies (EPA, 2012).

The second option to recover the "credit deficit" is represented by the compliance flexibilities offered by EPA and NHTSA, which take different forms and ensure different amounts of credits to carmakers. The flexibilities are granted because, on the one side, they encourage manufacturers to improve their fleets in terms of low-emission and fuel-efficient vehicles, and, on the other side, they help manufacturers in complying with the targets.

Starting with NHTSA, it must be highlighted that, compared to EPA, the DOT's agency offers fewer flexibilities to American auto manufacturers. With Phase II of its cooperation with EPA, NHTSA has agreed on considering certain credits, recognized by EPA, as "adjustments" to the fuel economy. These include off-cycle technologies and air conditioning (A/C) systems improvements (DOT, EPA, NHTSA, 2012). These are only adjustments because they are not bankable, tradable, or transferable. The only credits

existing under CAFE are those earned by the motor vehicle manufacturer for over-compliance (DOT, EPA, NHTSA, 2020a).
Among the flexibilities offered by NHTSA, one needs to be mentioned and it is related to dual and alternative-fueled vehicles.

Fuel economy calculations for dual[28] and alternative-fueled vehicles (AFVs). From 1992, with the approval of the manufacturing incentives for AFVs, it was agreed that a gallon of alternative fuel "is deemed to contain 0.15 gallon of fuel" (49 U.S. C. § 32905). Concerning dual-fueled vehicles, the incentive provided by the agency is very similar to that for AFVs. NHTSA will count only 15% of the actual energy used when determining the average fuel economy for a carmaker (DOT, EPA, NHTSA, 2020a).

Moving to EPA, the flexibilities offered for recovering a "credit deficit" can be divided into the following categories:

- Credit flexibilities
- Advanced technology incentives
- Off-cycle credits
- Air conditioning (A/C) systems improvement credits.

Due to the greater amount of flexibilities provided, EPA has often been criticized of facilitating the compliance to more stringent standards to auto manufacturers and of not effectively reducing real-world CO_2 emissions (DOT, EPA, NHTSA, 2020a). Despite these criticisms, according to the Automotive Trends Report of 2019, thanks also to the incentives offered by EPA, the overall tailpipe CO_2 emissions have been lowered by 7% from MY 2012 (EPA, 2020d).
The first type of flexibilities offered by EPA have already been mentioned before and they are the same as NHTSA's. The remaining three, instead, are a unique feature of EPA and some of them truly encourage motor vehicle manufacturers to improve their fleet in terms of low-emissions vehicles.

[28] Dual fueled vehicles are defined as vehicles that are able to run on either alternative fuels or gasoline/diesel, but not a mixture of the two (DOT, EPA, NHTSA, 2020a).

Credit flexibilities. As for NHTSA, credits owned by a carmaker can be carried forward (or banked) up to five years, carried back up to three years, transferred within a manufacturer's fleet, and traded among different manufacturers. Concerning the transfers, EPA, differently from NHTSA, does not set any limit (DOT, EPA, NHTSA, 2020b).

Advanced technologies incentives. In 2012, EPA agreed on providing a specific incentive to EVs, FCVs, PHEVs, and NGVs: electric-powered vehicles could be counted using an emission factor of 0gCO_2/mi and advanced technology vehicles could be counted using a multiplier, that is they counted more than one vehicle. The multipliers started in MY 2017 and will last until MY 2021 with the following distribution:

	EVs and FCVs	PHEVs and CNG vehicles
MY 2017	2.0	1.6
MY 2018	2.0	1.6
MY 2019	2.0	1.6
MY 2020	1.75	1.45
MY 2021	1.5	1.3

Table 12 Advanced Technology Vehicles' Multipliers for MYs 2017-2021.
Source DOT, EPA, NHTSA, 2012.

With the proposal of the SAFE Vehicle Rule, EPA took into consideration whether discontinuing the 0gCO/mi emission factor for electric-powered vehicles. In the final rule, the agency agreed with the majority of stakeholders on continuing its use with no limitations (DOT, EPA, NHTSA, 2020a; DOT, EPA, NHTSA, 2020b).

Many stakeholders had also requested EPA to extend or even increase the multipliers for advanced technology vehicles, however, the agency opposed to this since providing additional multipliers would damage the effectiveness of the GHG program and would not contribute toward the achievement of lower emissions. The only additional multiplier that EPA accepted is the one for dual-fuel NGVs, nonetheless, it will be implemented in MYs 2022-2026 since these vehicles have not been produced or sold yet. In particular, the agency agreed on extending the multiplier of 2.0 for 5 years after the expiration planned for MY 2021 (DOT, EPA, NHTSA, 2020a; DOT, EPA, NHTSA, 2020b; EPA, 2020c).

Off-cycle credits and A/C systems are statutory incentives both for EPA and for NHTSA's CAFE[29], however, their calculation is in the hands of EPA during the testing of vehicles. These flexibilities have been established since, in some cases, carmakers might use technologies whose real-world CO_2 emission reductions are not appropriately captured by the 2-cycle tests, that is FTP and HWFET, used by EPA (DOT, EPA, NHTSA, 2020a; EPA, 2020d).

Nonetheless, there are a few differences between how EPA and NHTSA count these incentives. NHTSA does not consider the fuel consumption improvement values (FCIVs) as credits, they are only adjustments to the individual vehicle compliance. For this reason, EPA has developed a methodology that allows the agency to convert the CO_2 reductions, fully recognized as credits under the GHG Program and expressed in g/mi, into fuel consumption improvements under CAFE.

Off-cycle credits. Whenever a motor vehicle manufacturer proposes a technology that reduces real-word tailpipe CO_2 emissions which are not appropriately captured by the 2-cycle test, then it has at its disposal three options, explained below. EPA caps off-cycle credits to 10gCO_2/mi due to the uncertainties associated with these uncaptured technologies (DOT, EPA, NHTSA, 2020a). At the basis for the calculation of the off-cycle credits, there is the requirement that the reduced CO_2 emissions are "measurable, demonstrable, and verifiable" (40 CFR 600).

1. **Off-cycle credits menu**. The carmaker can use a predetermined list of off-cycle technology credits without necessarily proving the benefits of the technology developed. The technologies listed in the menu are chosen by EPA, which gives them a default value with no additional testing needed. The agency puts a lot of attention when manufacturers use this pathway in order to avoid any potential profiteering (DOT, EPA, NHTSA, 2020b; EPA, 2020d).

2. **5-cycle test**. EPA has developed, starting in MY 2008, a new testing procedure: the 5-cycle test. This pathway is used whenever the technology used by the carmaker is either not listed in the off-cycle technology menu or it requires a demonstration of its actual benefits. The 5-cycle test calculates the fleet-wide

[29] NHTSA has started recognizing these flexibilities from MY 2017 (DOT, EPA, NHTSA, 2020a).

averages by weighting the city and highway test results by 43% and 57%, respectively (EPA, 2019c).

3. **EPA approval**. This third option allows manufacturers to seek EPA's approval by submitting a notice to the agency for using a technology that is both not listed in the off-cycle credits menu and not captured by the 5-cycle methodology. This option requires a lot of analysis and data to be provided and it is run on a case-by-case basis.

A/C systems improvement credits. These credits are earned either because the improvements made reduce the tailpipe CO_2 emissions or because they reduce the refrigerant leakage (DOT, EPA, NHTSA, 2012). The total credits attributable to A/C improvements are calculated "by summing the individual credit values for each efficiency improving technology" (DOT, EPA, NHTSA, 2020a) that is listed in the A/C credit menu[30]. A carmaker can use these credits up to 5gCO_2/mi for LDVs and up to 7.2gCO_2/mi for LDTs (DOT, EPA, NHTSA, 2012; DOT, EPA, NHTSA, 2020a; DOT, EPA, NHTSA, 2020b).

It must be said that in addition to all these flexibilities, both EPA and NHTSA provide some derogations and exclusions to small-volume manufacturers (SVMs). However, for this thesis, they are not going to be presented since they do not stimulate and encourage these manufacturers to improve the fuel economy and the environmental friendliness of their fleets in a significant way.

2.3 A Comparison between the EU and the US

In this last section of the second chapter, the analysis will focus on a comparison between the legislative background of the EU and the US to determine how these two systems are similar or different. The order in which the following conclusions are presented moves from the most similar aspects of the two systems to the most different features.

[30] The complete A/C credit menu with the default values established by EPA can be found in 40 CFR § 86.1868-12, retrievable from https://bit.ly/3ceofob.

The focus will remain on the instruments that actually encourage motor vehicle manufacturers to do better by providing ZLEVs. Nonetheless, broader considerations will also be made.

1. **Three common goals**. The first emerging similarity is that both the EU and the US have three main aims: reduce the dependence on imported oil, maintain and protect against newcomers the competitiveness of their long-existing markets, and combat against climate change and global warming by committing to reduce emissions caused by many sources, including the automotive industry.

2. **Harmonization**. Both the US and the EU put a lot of effort in providing to all manufacturers operating in their territories an integrated approach for achieving specific objectives. In the case of the EU, a coordinated and comprehensive direction has always been at the center of the Commission's guidelines, such that car manufacturers benefit from clear and transparent communications.
   In the American case, EPA and NHTSA worked independently for many years, but then, following the explicit request from President Obama, the Alliance of Auto Manufacturers and other stakeholders operating in the automotive industry, they implemented a comprehensive approach.
   A harmonized system of goals and standards, as well as compliance mechanisms and incentives, facilitates the automakers' job, especially in terms of costs that are lowered.

3. **Fleet-wide average standards**. A partial commonality between the EU and the US is identifiable in how the standards are set. They are based on the fleet-wide average. The similarity is partial because on the one side there is the US which, for both the CO_2 emissions and the fuel economy, establishes fleet-wide emission targets based on the vehicles' footprint. On the other side, there is the EU which, only for the CO_2 emissions, sets emission limits at the fleet level.

4. **Penalty mechanisms**. The Commission and NHTSA set a predetermined monetary amount of penalty in case of noncompliance by a carmaker. In the case

of the EU, this is equal to €95 or €120 for each g/km of CO_2 in exceedance for PCs or LCVs, respectively. NHTSA, instead, imposes a $5.50 penalty rate.

The second type of penalty mechanism adopted both in the EU and the US is the case-by-case penalty. Specifically, this takes place in case of non-compliance with exhaust emission limits in the EU and with EPA's standards in the US.

5. **Flexibilities and incentives**. The majority of the flexibilities and incentives provided by the EU finds a correspondence with those provided by the US agencies of EPA and NHTSA. The table below will make a simple comparison between the two markets to obtain an overall view of the similarities in these terms.

Flexibility/Incentive	EU	US	*Notes*
Credit flexibilities		✓	
Derogations/exemptions	✓	✓	Addressed in both cases to small-volume manufacturers.
Pooling	✓		
Credit multipliers	✓	✓	The EU applies super-credits to ZLEVs. The US applies credit multipliers to advanced technology vehicles, such as EVs, FCVs, PHEVs, and NGVs.
Innovative technologies	✓	✓	The EU identifies as "eco-innovations" all those innovative technologies that lead to a verifiable reduction in CO_2 emissions. The US provides incentives for off-cycle technologies and A/C systems improvements that lead to CO_2 savings but are not directly verifiable with the usual testing procedures.

Table 13 Summary of Flexibilities and Incentives provided by the EU and the US.

Source Author's elaboration.

6. **Exhaust emissions**. Both the EU and the US limit the emissions of harmful pollutants, such as NO_x, PM, and NMOG. These limits are comparable because Europe sets the Euro standards and the United States establish the Tier standards. However, they present some differences in the way they are implemented. The US imposes emission limits for both passenger cars and light trucks, instead, the European limits change according to the vehicle category. Also, comparing the stringency of these limits, it is derived that the European ones are looser than the American ones, especially for light trucks. The table below will show a comparison of the emission limits of harmful pollutants between the European Euro 6 standards and the American Tier 3 ones:

European Union (Euro 6)			**United States of America (Tier 3)**		
Category	**NO_x**	**PM**	**Bin**	**NO_x+NMOG**	**PM**
M	80	4.5	**Bin 0**	0	0
N	103	4.5	**Bin 20**	12	2
			Bin 30	19	2
			Bin 50	31	2
			Bin 70	43	2
			Bin 125	78	2
			Bin 160	99	2

Table 14 Euro 6 and Tier 3 Emission Limits.

Source Author's elaboration.

Notes The values of the American emission limits have been converted into mg/km to make them comparable with the European ones.

7. **Alternative fuels**. The attention towards the deployment of alternative fuel vehicles is high in both regions. This is strongly linked to the desire of decreasing the dependence on oil and reduce emissions. However, it must be said that there are some differences in the type of alternative fuels that have been produced. For example, in the US the distribution and the production of vehicles running on

ethanol, the so-called flex-fuel vehicles (or E85) is very high[31]; instead, in the EU, the majority of AFVs are hybrid vehicles (ACEA, 2020, p.36).

A further difference between the two markets is that the US committed to spreading the use of AFVs starting from the federal fleets, which are obliged to be composed of AFVs for a specific minimum percentage indicated in the EPAct. In the EU, there will be no such requirement until 2025 due to the Clean Vehicles Directive which sets minimum targets for procuring clean vehicles for each Member State.

8. **Acts vs. strategies**. A big difference between the US and the EU lies in how the legislation concerning the standards for motor vehicles is developed. In the US case, there are two main Acts (the Clean Air Act and the Energy and Policy Conservation Act) upon which two agencies (EPA and NHTSA) gained the power to set the targets for the automotive industry and its manufacturers. These Acts are the same since the 1970s and they have been amended according to the changes proposed by the two agencies as time went by. Saying it in other words, the basic structure of the motor vehicles' legislation has always remained the same.

   In the EU, the Commission and the Parliament have developed a series of strategies throughout the years which brought to major changes in many of the directives and regulations about the automotive industry. These changes covered the type-approval requirements, the standards and the targets, and the testing procedures, which underwent a major modification. This has made the European legislation much bigger than the American one, and eventually more confusing.

9. **Testing procedures**. Another great difference between the two markets of the US and EU lies in the testing procedures adopted. As it was explained in the European section of this chapter, the tests for determining the conformity of a vehicle changed from the NEDC to the WLTP and the RDE test. The reason was related to the unreliability of the test results provided by the NEDC test. Besides, the

[31] According to the data of 2019, FFVs accounted for 81.6% of light-duty alternative fuel vehicle registrations, instead EVs and PHEVs accounted for the 1.41% and 1.36%, respectively. (Data retrieved from the Alternative Fuels Data Center, https://bit.ly/2ST6cfF on 7.5.20).

Commission leaves to predetermined authorities in each Member State the role of testing the motor vehicles. At the same time, the Commission has the power to run "in-service conformity" tests for vehicles that are already being used.

In the US, instead, the testing procedures are the 2-cycle test, composed of the FTP and the HWFET, and the 5-cycle test adopted occasionally for verifying off-cycle technologies proposed by carmakers. Despite the US also provides certificates of conformity and "in-use" certificates as in the EU, the only authority which can issue these approvals is the EPA, which runs the tests in a specific laboratory, the NVFEL.

10. **Federal vs. national**. The biggest difference between the US and the EU lies in the freedom left to the states. In the US, the CAA preempts any state and local emission standards to be set. Thus, the GHG emission standards and the fuel economy targets are established at a federal level and valid overall the US territory, with no exception.

    In the case of the EU, the Commission sets the guidelines, meaning that it determines the goals to be achieved, but then it is in the hands of the Member States how to achieve these goals at the national level. The main example is related to the alternative fuel infrastructure development, which requires the Member States to publish their national policy frameworks where they indicate how they are going to fulfill the requirements determined by the Commission. Also, in the Clean Air Strategy of the EU is stated that every Member State is responsible for its own action favoring the deployment of alternative fuels stations and vehicles. Moreover, the certificate of conformity for a vehicle is issued at the Member State level, following the guidelines of the Commission, but it is the Member State's designated authority that determines whether a new vehicle can be put on the market or not.

From this summary showing the similarities and differences between the European Union and the United States legislations regulating motor vehicles and carmakers, it can be said that the two of them a very similar. They manage the policy side of reducing GHG emissions with almost the same instruments, especially when it comes to the incentives and flexibilities provided.

At the same time, the biggest difference lies in how these regulations are implemented. On the one side, the US government, through the authority of EPA and NHTSA, establishes federal requirements that must be met by all motor vehicle manufacturers operating all over the American territory. On the other side, despite the European Commission determines the main standards and targets, many decisions are left to the Member States. Leaving them the authority to approve new motor vehicles or to build the alternative fuels infrastructure to support the spread of AFVs may lead to great discrepancies among the Member States, especially between countries with higher GDP per capita and those with a lower GDP per capita. Despite the numerous aids in the form of funds and investments directly coming from the European Union, the gap among the Member States has not been fulfilled.

Another emerging fact is that, in both cases, some flexibilities are granted to small volume manufacturers (SVMs). These are in the form of exemptions or derogations allowing SVMs not to comply with the standards since their production is so restrained that, even though they produce highly polluting vehicles, their impact on the overall GHG emissions is almost irrelevant. If these derogations and exemptions are comprehensible, they do not really foster the improvement in terms of fuel efficiency and GHG reductions among these SVMs. Instead, it would be advisable that SVMs might be subject to less stringent standards for producing more low-emission vehicles rather than being completely exempted from them.

A further conclusion that could be made is that apparently, the US system is more stringent than the European one, in the sense that American carmakers are subject to tighter standards and requirements of two agencies simultaneously.

Finally, both the EU and the US had to frequently revise their standards or their plans for low-emission mobility. For example, the EU had proposed many strategies throughout the years, in particular starting from the White Paper. The US had to change its targets after the MTE in 2018. This implies three possibilities:

1. The institutions might have set too stringent targets such that they were extremely hard to be achieved by motor vehicles manufacturers,
2. The carmakers might not have been able to significantly improve their fleets in terms of fuel economy and GHG reductions, or
3. There is a critical lack of efficient communication from the institutions to the consumers.

Apparently, there is a coexistence of all these factors. However, as the Neoclassical economy teaches us, supply is greatly affected by the demand and this is true also for carmakers. In recent years, consumer demand moved its interest in sport-utility vehicles (SUVs). These types of vehicles generally have a larger footprint, and as it has already been said: larger footprint equals higher emissions. Consequently, many manufacturers started producing SUVs which basically offset the emission reductions achieved in other motor vehicles' categories. At the basis, there is a lack of awareness among consumers. When they do not know the benefits, or they do not have clear in their minds the positive aspects of purchasing low-emission vehicles, then they become skeptical, and their demand will continue to follow the old trend of petrol-running vehicles. Thus, to conclude, a significant focus on consumers must be created such that they will increase their willingness to move towards zero- and low-emission mobility.

The table below provides a summary of the conclusions derived from the analysis in Chapter 2:

Similarities
Three common goals: reduce the dependence on imported oil, maintain and protect the competitiveness of their markets, and act against climate change and global warming.
Road to harmonization: provision of a harmonized, integrated, coordinated, and comprehensive approach for regulating automakers' operations and for reducing the emissions caused by their products.
Fleet-wide average standards: fleet-wide emission targets for regulating CO_2 emissions.
Case-by-case penalties: EPA and the European Commission adopt a case-by-case penalty for noncompliance with CO_2 and exhaust emission standards, respectively.
Derogations and exemptions to small-volume manufacturers who are not required to meet the emission standards.
Incentives: credits multipliers to low-emission or advanced technology vehicles such as EVs, FCVs, PHEVs, and NGVs. Other incentives addressed to vehicles equipped with innovative technologies which lead to significant and verifiable reductions in CO_2 emissions.

Differences	
European Union	**United States of America**
Acts v. Strategies	
Directives and Regulations changed throughout the years following the strategies established at the European level.	Two main Acts upon which the entire legislation on emission is set. These are the Clean Air Act and the Energy Policy and Conservation Act.
Federal vs. National	
Member States have decision-making power regarding how requirements set by the Commission should be met.	Federal, state, or local emission standards are prohibited Only EPA and NHTSA can establish targets valid all over the US.
Penalties	
€95 or €120 for each g/km of CO_2 in exceedance for PCs and LCVs, respectively.	$5.50 for each mpg in exceedance of the required one.
Flexibilities	
Pooling of car manufacturers	Credit flexibilities: carry forward, carry back, transfers, and trade.
Exhaust emissions	
Euro-standards	Tier-standards (more stringent, see *Table 13*)
Alternative fuels	
Lack of an efficient alternative fuel infrastructure with great disparities in the refueling/recharging points between Member States.	Good alternative fuel infrastructure network.
Most common alternative fuel vehicles: hybrid vehicles.	Most common alternative fuel vehicles: flex-fuel vehicles or E85 running on ethanol and gasoline.

	Mandatory requirement for federal fleets to be equipped with a certain percentage of alternative fuel vehicles.
Testing procedures	
NEDC (unreliable) gradually substituted by the WLTP (for CO_2 emissions) and the RDE testing procedure supported by portable-emission measurement systems (PEMS).	2-cycle tests: FTP and HWFET. 5-cycle test for off-cycle technologies that are not captured by the 2-cycle tests.
Testing procedures are done by certified authorities in each Member State. The Commission eventually runs in-service performance test, when the vehicles are already being used.	The only authority capable of running the testing procedures and certifying compliance with standards of EPA and NHTSA is EPA.

Table 15 Summary of the Similarities and Differences between the EU and the US Legislation addressed to Automotive Corporations.

Source Author's elaboration.

Chapter 3 – Impact of the EU and US Legislations on Automotive Corporations' Strategies

3.1 Automotive Corporations in the EU and the US: An Overview

In chapter 2 the regulatory framework for car emission in the US and the EU has been investigated and described, to highlight a series of differences. Such differences are, in the writer's opinion, a harbinger of relevant impacts on carmakers' strategies, more specifically, on technological trajectories and innovation strategies.

From the technical analysis conducted in chapter 2, it can be concluded that the European and the United States legislations are intrinsically different. In a nutshell, while the EU has developed a system based solely on regulations and directives - which are promulgated by the Commission and adopted by the Member States after ratification -, the US system joins a system based on regulations with a market-like emissions trading scheme between carmakers.

In this chapter the implications of the two regulatory frameworks in the light of business and strategic implications for carmakers at the corporate level are discussed. Therefore, the question tackled by this chapter is: to what extent the different regulatory framework affects the strategies of carmakers?

The majority of motor vehicle manufacturers operate in both markets, although with some significant differences in the product range and technical aspects even within the same car models, to ensure vehicles fit the different market conditions.

The main groups that sell significant car shares in both the EU and the US have been identified. *Table 16* shows an overview of the most significant data describing the relative dimensions of the groups, specifically: a) the yearly production, its variation between 2018 and 2019; b) the number of car sold in the same years and its variation; c) the share of overall production sold in US and EU.

Automotive Corporations							
Volkswagen Group (VW)	**11,018,000**	**10,823,000**	**-1.8**	**10,900,000**	**10,956,000**	**+0.5**	
European Union				*3,475,401*	*3,627,693*	+4.4	*33.5*
United States				*638,274*	*654,152*	+2.5	*6.0*
Renault-Nissan-Mitsubishi Alliance	**10,788,583**	**9,989,601**	**-7.4**	**10,781,973**	**10,056,912**	**-6.7**	
European Union				*1,709,617*	*1,596,946*	-6.6	*16.0*
United States				*1,611,951*	*1,466,726*	-9.0	*14.7*
Toyota Group*	**8,964,000**	**8,985,186**	**+0.2**	**8,964,000**	**8,976,795**	**+0.1**	
European Union				*968,000*	*994,060*	+2.7	*11.1*
United States				*2,166,374*	*2,097,294*	-3.3	*23.3*
Hyundai Group**	**7,889,538**	**7,218,391**	**-8.5**	**4,684,932**	**4,411,318**	**-5.8**	
European Union				*932,010*	*1,001,000*	+7.4	*13.9*
United States				*1,423,005*	*1,275,555*	-10.4	*17.7*
Ford**	**6,457,773**	**6,386,818**	**-1.1**	**6,651,000**	**6,607,000**	**-1.0**	
European Union (EU21)				*1,539,000*	*1,582,000*	+3.0	*24.8*
United States				*2,588,000*	*2,565,783*	-0.9	*40.2*
Honda Motor*	**5,357,013**	**5,170,595**	**-3.5**	**5,199,000**	**5,323,000**	**+2.4**	
European Union				*183,000*	*169,000*	-7.7	*3.3*
United States				*1,639,000*	*1,612,000*	-1.6	*31.2*
FCA***	**4,807,000**	**4,399,000**	**-8.5**	**4,756,000**	**4,569,000**	**-4.0**	
European Union				*1,276,000*	*1,162,000*	-7.3	*26.4*
United States				*2,235,204*	*2,203,663*	-1.0	*50.0*
Daimler	**3,394,663**	**3,337,763**	**-1.6**	**3,352,415**	**3,344,951**	**-0.2**	
European Union (only cars)				*982,674*	*992,215*	+1.0	*29.7*
United States (only cars)				*327,211*	*313,150*	-4.3	*9.4*
BMW Group	**2,541,534**	**2,564,025**	**+0.9**	**2,483,292**	**2,538,367**	**+2.2**	
European Union				*1,097,000*	*1,083,700*	-1.2	*42.3*
United States				*355,400*	*375,800*	+5.7	*14.7*
Subaru*	**1,049,700**	**989,100**	**-3.1**	**1,066,929**	**999,894**	**-6.3**	
European Union				*40,228*	*32,000*	-20.5	*3.2*
United States				*670,931*	*659,702*	-1.7	*66.7*

Table 16 Top Automotive Corporations Overview Concerning Production, Sales, and Percentage of Production Sold in the European and the US Markets.

Source BMW, 2020a; Daimler, 2020a; FCA, 2020a; Ford, 2018; Honda, 2019; Honda, 2020; Hyundai, 2020; Hyundai EU, 2020; Hyundai US, 2020; Mitsubishi, 2020; Nissan, 2020; OICA, 2018; OICA, 2020a; OICA, 2020b; OICA, 2020c; OICA, 2020d; Renault, 2020a; Subaru, 2019a; Subaru, 2019b; Toyota, 2019; VW, 2020a.

Notes The majority of the data is taken from the Corporate Annual Reports, where the production and the sales volumes were not distinguished between passenger cars, light commercial vehicles, trucks, or buses. Besides, all the reports provided data about Europe, not specifically the European Union. In some cases, there was a distinction between EU 28, EU 15, or EU + EFTA, however, for sake of consistency data on Europe as a whole are reported as a proxy for the European Union.

* FY2019 for Toyota, Honda and Subaru started on 1.04.18 and ended in 31.03.19, differently from all the other automakers.

** It was not possible to retrieve data on production and market sales for Hyundai and Ford. Thus, the author's choice was to consider the data on production for these manufacturers published by OICA for the FYs 2016-2017. They are still considered a good approximation for the current situation for these corporations.

*** In the 2019 Annual Report issued by FCA, it is stated that "vehicle shipments are generally aligned with current period production which is driven by our plans to meet consumer demand", as a consequence, vehicle shipments have been used as a proxy for production.

It can be noted that PSA and GM are absent among the relevant groups. GM's presence in the European continent ended in 2017 when it sold the Opel and Vauxhall brands to PSA Groupe, which owns Peugeot and Citroën (Washington Post, 2017). The main reasons explaining why GM decided to leave the European market are four: (1) for many years GM registered continued losses, (2) it had many difficulties in managing the Opel and Vauxhall brands, (3) it feared the threat of even more losses following the Brexit vote of 2016 (NBC News, 2017) and (4) it considered the European market as stagnant and too competitive, with an overcapacity of vehicle production (Quartz, 2017).

The history of GM leaving the European market is similar and tightly linked to that of the French PSA, which operated in the American market until the 1990s. The reasons for its exit from the US are related to "a recession, slumping sales, and the rising costs of U.S. regulations" (Automotive News, 2019).

However, it seems that PSA Groupe is thinking about a return around 2026. The corporation believes that it might have some good opportunities in the American market by selling vehicles that are produced in its European and Chinese factories and starting from a single US state. Also, PSA has intensively analyzed the American market to understand exactly what consumers are looking for, such that the group will be able to make a finely tuned selection of the kind of vehicles that are more likely to be sold there (Phys.org, 2019). This has been possible through Free2Move, an app launched in 2018 (CNBC, 2019). Through this initiative PSA has been able to exploit a growing market, the car-sharing one, and to collect a great amount of data, providing extremely relevant information on consumer preferences (Automotive News, 2019).

Moreover, when GM sold Opel and Vauxhall to PSA, the two corporations agreed on maintaining a cooperation, especially in the development and deployment of EVs and advanced technologies (NBC News, 2017). Consequently, in its way back to the US, PSA Groupe can leverage its association and relationship with GM.

In conclusion, in both the GM and the PSA cases the reason for leaving the European and the American market, respectively, is the same: on the one side GM was not able to create a significant market share since the European industry was dominated by European motor vehicles manufacturers; on the other side, PSA Groupe could not achieve a relevant level of sales because the US market was in the hands of the main American manufacturers.

Looking at the table presented above, it can be assumed that a relevant determinant in the reputation of an automaker is the cultural- and traditional-related reason behind the consumers' choice when it comes to purchasing a motor vehicle. This suggests that, even if globalization spread in the past decades and it is undoubtedly a phenomenon that affected the purchasing behavior of consumers, the cultural component maintains a certain influence.

Consequently, it can be assumed that the cultural variable is relevant, and it is fascinating to notice that the European and the American markets are still dominated by local motor vehicle manufacturers. Thus, it would be interesting to study how and how much the cultural determinant influences the positioning of the main corporations in terms of sales.

This chapter aims to finalize the ultimate goal of this thesis, which is understanding how the different legislative systems, the European and the United States ones, create a condition that influences the automakers' strategies.

3.2 Strategic Impact of the Legislations

As it has already been said in section 3.1, the legislation related to the automotive sector in the EU and the US is intrinsically different and this is due to how the regulations are approved and the process necessary to make the Member States adopt them.

In these terms, one of the biggest differences lies in the fact that, while in the US the exchange between automakers is allowed thanks to the so-called ABT flexibilities and the regulatory authority cannot intervene in the business; in the EU, things are conducted differently. Exchange among motor vehicle manufacturers is not possible, but negotiations between them and the regulatory institutions are very common and most of the times they affect the decisions taken at the political level. Thus, there is bargaining in the EU, which puts the auto manufacturers in a favorable position, and a credit system in the US, which represents a flexibility that facilitates short-term operations but pushes carmakers to take significant actions in making their fleets more sustainable and in showing visible results in the long-term.

These differences impact on how the businesses operate in the two markets and, using two strategic models, it will be analyzed how the American and the European emission legislations impact on the businesses' strategies.

3.2.1 The Business Ecosystem

A useful concept to understand the different sets of relationships triggered by the two environments is the concept of the "business ecosystem". This term was coined by Moore in 1993, who made a comparison between the biological ecosystem and the business environment. Moore states that companies in a business ecosystem "coevolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations" (Moore, 1993). Thus, the key characteristic of companies operating in business ecosystems is that they cooperate with other businesses while acting strategically to maintain their competitiveness. Each entity in a business ecosystem influences and is influenced by others, then the only way to survive is to be flexible and adaptable.

Analyzing the business ecosystem model in the automotive industry context is reasonable because automotive corporations operate in a highly competitive environment and need to respond effectively and cooperatively to the disruptive innovations brought by technology improvements and environmental issues.

Moreover, automotive corporations must respond to many different needs coming from many different stakeholders and generally have common interests, namely produce appealing vehicles for consumers, thus achieving high sales levels while meeting the environmental targets and standards set by the regulatory bodies. Most of the times, in macro business ecosystems there is a group of firms leading the industry, in our case, the top three automakers in both countries, which may have two main goals: either create industry standards, thus make other businesses followers of what they do, or lobbying to encourage a change in the regulations. Here, the first main difference between the American and the European systems can be found, and it lies in the goals of the business ecosystems.

Below a general graph suitable to both countries with the main players in the automotive business ecosystem is presented.

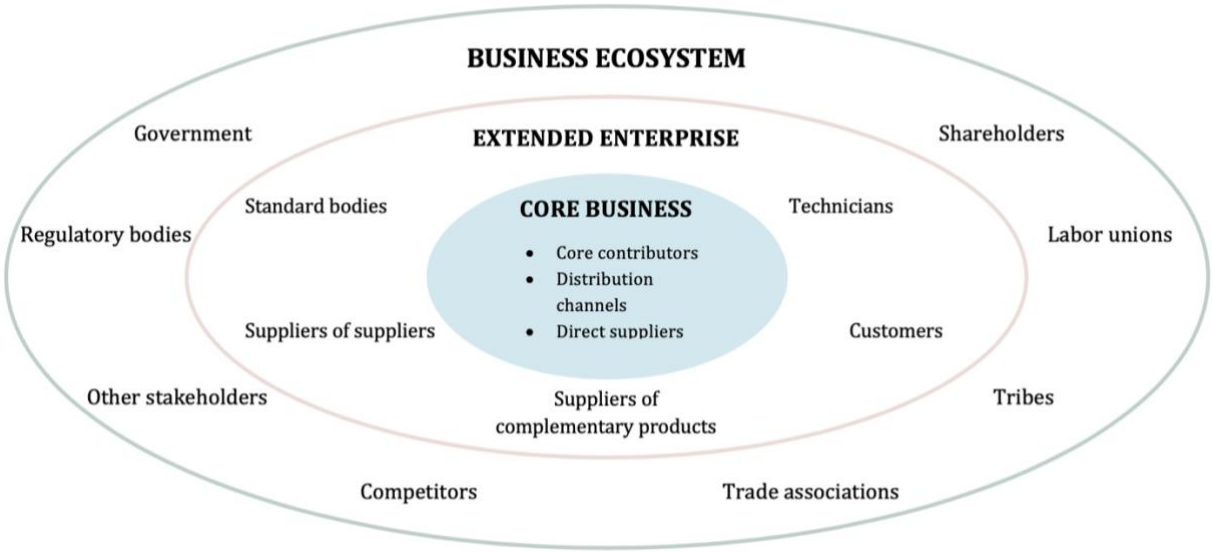

Figure 14 Automotive Industry Business Ecosystem.
Source Author's adaptation from Moore, 1996.

In the European case, great importance is given to trade associations, government and the regulatory bodies, the customers, and the shareholders.

1. **Trade associations**. In section 2.3, it was mentioned that while the US implemented laws valid all over the country through two main Acts, in the EU, not all the legislation is directly applicable to Member States. The Union approves either Regulations or Directives: the former have immediate applicability on the States akin to national legislation. This does not leave any space for free action to the Member States. Directives, instead, need to be transposed into national legislation and Member States are free to choose what should be done to achieve the goals set in the implementing Directive. In turn, this gives power to the lobbying made by trade associations, primarily the European Automobile Manufacturers Association (ACEA). ACEA is a bridge between automakers and European institutions deciding about targets, standards, and regulations related to motor vehicles. However, both ACEA and European institutions are strongly affected by the power of other lobbying entities belonging to the individual Member States, above all Germany.

2. **Regulatory bodies**. Being aware of how much the regulatory environment can affect every aspect of a business, the major automakers operating in the EU have always tried to interact with policymakers of the European regulatory bodies, that is the Commission and the Parliament, through their influence in the political parties of their own country. Before going in depth, it is necessary to understand why lobbying is done by motor vehicle manufacturers. The reason lies in the fear they have of regulations, especially the environmental ones: tighter targets are perceived as opportunities, but, most of the times, as disruptive forces ready to undermine the competitiveness and the revenues of the automotive sector. This fear is particularly high among those Member States whose major source of revenue comes from the automotive industry, namely Germany and France. This implies that Member States' political parties having voting right in the Union are strongly affected by their relationships with automakers. Also, the Commission and the Parliament implicitly favor lobbying from these relevant carmakers, since they are perfectly aware of the strong impact their sales have on the European economy and competitiveness as a whole.

3. **Customers**. In the EU, customers become so relevant because the entirety of the automakers tend to adopt a consumer-centric approach, providing to these stakeholders what they want. It seems that customers are demanding for bigger vehicles, such as SUVs, and remain loyal to the petroleum-fueled vehicles. This suggests a general skepticism towards AFVs and explains the lack of significant investments by Member States on the alternative refueling/recharging stations. If there is no demand for such vehicles, then it seems pointless to make large investments in an infrastructure that would cost more than the revenues that could be made. This, in turn, affects the European automakers, which, as it was mentioned in chapter 2, keep on maintaining a great portion of their fleet with petroleum- and diesel-fueled vehicles. At the same time, automakers should reduce their emissions, thus it is in their hands the role of making consumers aware of the benefits derived from the purchase of ZLEVs. This relationship between automakers and customers must be carefully managed in the future if the European automotive industry and its manufacturers want to maintain a high level of competitiveness.

4. **Shareholders**. The attention towards the achievement of the shareholder value maximization[32] is still very high among European motor vehicles manufacturers, despite the spread of the corporate social responsibility's stakeholder theory, which, instead, states that "the firm is an organization with responsibilities towards multiple stakeholders" (Freeman, 1984). This implies that even if European carmakers have adopted CSR practices and vision, the goal of shareholder value maximization is still predominant, following the statement made by Jensen, who was firmly convinced that businesses following the stakeholder theory "will do less well in the competition for survival than those who follow a well-defined single-valued approach such as value creation" (Jensen, 2002).

   Another reason explaining why the relationship with shareholders is important in Europe lies in the numerous financial activities conducted by carmakers, such as leasing, financing, and used cars.

   An example contributing to emphasize the significant role played by shareholders is the one of VW Group. The German carmaker, considering the revenue derived from the financial sector, is the one with the highest and most influential participation from the financial sector (Do Carmo, Neto, Donadone, 2019).

   As a consequence, also in the European case, financialization is becoming more and more relevant to the businesses' profitability. However, this makes corporations' survival and competitiveness too dependent on financial services and, thus, shareholders, which may lead them to favor practices that only satisfy shareholders' needs and maybe underestimate the ultimate objective of creating a zero- and low-emission mobility in the next 30 years.

In the American case, as it has already been said, EPA and NHTSA allow motor vehicle manufacturers to exchange credits within their fleets but also among themselves. This represents a short-term flexibility with a two-sided benefit: on the one hand, businesses can fill the gap of their "bad" performances with credit forward, back, transfers or trading; on the other hand, the crediting system provides automakers with enough time to plan their GHG reduction technologies. Also, since credit flexibilities have precise expiration

[32] Jensen and Meckling in 1976 proposed that businesses have an ultimate duty in maximizing and creating shareholders wealth (Jensen, Meckling, 1976).

dates, carmakers cannot exploit the exchanges in their favor in the long-term. This means that the two agencies, EPA and NHTSA, grant a 5- and 3-years flexibility for the carry forward and back, respectively because this amount of time allows businesses to concretely improve their fleets and take action for achieving environmental goals.

In the following part, we focus on key-stakeholders' differences between the two competitive environments.

1. **Competitors**. They are so relevant to an automaker in the American automotive industry because of their role as possible suppliers of credits. The credit flexibility makes relationships with other carmakers crucial when a business has a credit deficit. At the same time, having a credit surplus due to a good performance and having good relationships with automakers in need of credits is a great strategic advantage. The case of Tesla is the prime example. Tesla's production is well known for being entirely electric, as a consequence, the technologies and the vehicles produced allow the firm to earn an enormous amount of credits derived from the incentives granted by EPA and NHTSA. Tesla, despite not being in a top position in terms of sold vehicles, is not only in a good place for compliance with the agencies' requirements but is also able to sell the credits to other motor vehicle manufacturers and obtain a great profit from them. In the first quarter of 2020, Tesla's automotive revenues from regulatory credits amounted to a record high of $354 million with an increase of 64% compared to last year (Tesla, 2020).

   This seems to lead to the conclusion that, in the American automotive industry, thanks to the presence of a crediting system between corporations, the relationships with other competitors are so relevant that coalitions are very likely to take place. In turn, these allow corporations to gain more power and even perform corporate political activities (CPAs) to influence the decisions of EPA and NHTSA.

2. **Trade associations**. These entities are organizations supporting and representing companies and employers with the role of protecting the rights of the businesses and intermediary between the regulatory institutions such as the government or the agencies and the carmakers, in this case. In the US context, trade associations

such as the Alliance for Automotive Innovation[33] aim at creating a common vision and fair cooperation between entities like EPA and NHTSA and all the American auto manufacturers. Being a participatory party in the Alliance for Automotive Innovation allows motor vehicle manufacturers to be protected, to have their voice heard, and to require reasonable changes to any decision taken by the agencies. An example is the one that occurred for the Midterm Evaluation of 2017, which left the targets for 2022-2025 unchanged, when, instead, they were not appropriate anymore. In this case, different automakers thanks to the trade associations complained about EPA's decision, which recognized its fault in assessing a wrong analysis.

3. **Technicians/engineers**. Being aware that all the levels of the human capital working for a business are equally important and contribute to the success of the firm, it is worth emphasizing that a great difference is made when high-quality engineers and technicians are employed in a motor vehicle company. These stakeholders have the skills and the knowledge to propose completely new technologies or small changes that contribute to the overall performance of the automaker in terms of compliance with the EPA and NHTSA requirements. Consequently, motor vehicle manufacturers, which want to improve their fleets regarding vehicle emissions and fuel economy, invest in R&D, and provide incentives to the human capital working in this department.

4. **Shareholders**. These stakeholders are, with no doubt, another main player in the automotive business ecosystem. In the US, as in all the other countries, companies try to encourage and convince shareholders to invest and maintain their investments in their business. Shareholders are attracted by good reputation, good performance, and low risk: a triad that is not easy to achieve from the business side. The American automakers, in recent years, have tried to attract also a new type of shareholders, the Socially Responsible Investors (SRIs). These are most likely to invest in companies with particular attention on environmental-friendly

[33] The Alliance for Automotive Innovation is a recently created trade association after the merger between the two largest US automotive trade associations: Global Automakers and The Alliance of Automobile Manufacturers (Lutz, 2020).

products or production processes and on socially responsible behavior. Of course, the relationship between the automotive businesses and the SRIs is not so straightforward, however, the interests in attracting them gave motor vehicle manufacturers a further incentive to produce advanced technology vehicles and AFVs and to reduce emissions of both their production and fleets.

Moreover, American automakers, especially the largest ones are increasingly giving importance to the financialization[34] of their businesses. An example is the one of Ford, which was "saved" from bankruptcy thanks to the profits earned through the financial services (Do Carmo, Neto, Donadone, 2019).

3.2.2 The Business Model Canvas

After having analyzed the role of the relationships within the business ecosystems in the European and American markets, the focus will now move to the concept of the value proposition using the Business Model Canvas.

The model aims at formalizing the description of key aspects of a company value-creation process, the so-called "building blocks" which can be organized in three main areas:

1. **Value creation**: key partners, key activities and key sources;
2. **Front-end**: value proposition, customer relationships, channels and customer segments;
3. **Economic feasibility**: cost structure and revenue structure

Specifically, a crucial benefit of the Business Model Canvas approach is to highlight the interdependency between the various parts of a business, which should not be considered as independent entities operating on their own.

[34] By "financialization" it is meant the increasing importance of the financial services over the society and the economy. Financialization often leads to greater importance of the financial activities over the real sector ones, transfers of profits from the real sector to the financial one, and increased income inequality (Do Carmo, Neto, Donadone, 2019).

Here we summarize the Business Model Canvas for the Automotive industry. Beyond the general model, that is more or less aligned between the US and the EU, we will try to highlight to what extent the different legislations affect the value proposition of automotive corporations in terms of how they respond to the need of reducing emissions.

BUSINESS MODEL CANVAS

Key partners
- OEM alliances
- Rental companies
- Key suppliers (manufacturing partners, technology providers)
- Government and other regulatory bodies

Key activities
- R&D
- Design
- Innovative technologies
- Low-emission vehicles production
- Software development
- Sales and marketing
- Security and safety devices development

Key sources
- Technological and technical knowledge
- Market knowledge
- Engineering
- Employees/human capital

Value proposition
- Advanced vehicles production
- Zero- and low-emission vehicles production
- Emissions reductions
- Travel safety
- High performance
- Consumer satisfaction

Customer relationships
- Reputation
- Brand
- Incentives for purchasing alternatively fueled vehicles
- Test drives
- Customization

Channels
- Retail stores
- Online point of sales
- Car rentals
- Exhibitions/Fairs
- Offline advertising

Customer segments
- High-end customers
- Mid- and low-end customers
- Mass market
- Green customers
- Tribe members

Cost structure
- Selling costs
- Administrative costs
- R&D costs and investments
- Maintenance expenditures
- Taxes and other expenses
- Production plant costs

Revenue Streams
- Asset sales
- Advertising
- Lending/renting/leasing

Figure 15 Business Model Canvas for the Automotive Industry.

Note OEM stands for Original Equipment Manufacturer. OEM Alliances are the equivalent of trade associations.

For the European motor vehicle manufacturers, the relationship between the auto manufacturers and the OEM alliances (trade associations) weighs much more than in the American market. In fact, to European carmakers, OEM alliances are the bridge to the governmental institutions, which are often under the power of lobbying entities. Consequently, in the EU, the role of and the relationship with the government is more strategic than in the US, as it was explained before. However, in the US, while the governing bodies do not interfere with the businesses, they have more power in terms of regulatory institutions, in the sense that the stringency of the standards, the penalty mechanisms applied and the incentives granted do not leave space of unfair lobbying activities from either OEM alliances or single automakers.

American automakers rely on the role of OEM alliances because of their power in protecting the rights of businesses from any unfair action taken either by the regulatory institutions or other carmakers. Considering what was mentioned before on the growing importance of financialization in companies, rental businesses are a relevant source of income, thus the relationship with them tends to be solid and last in the long-term. Furthermore, within the OEM alliances, great importance is given to the relationships between competitors, that is between carmakers. Differently from the European case, where automobile manufacturers are mainly competitors, in the US, the existence of credit flexibilities pushes the businesses to cooperate.

Moving on to the value proposition box of the Business Model Canvas, the analysis takes into consideration two sides, following the Value Proposition Canvas offered by Strategyzer[35]. This model highlights the ultimate goal of businesses: creating a meeting point between their products/offers and the needs and wants of customers.

Starting from the carmakers' perspective, in the automotive industry context, the value proposition they convey is vital, especially in their relationships with the main stakeholders, who change according to the environment created by the institutions' regulatory decisions. Inferring on the cultural model created by the regulatory authorities, the Commission and the Parliament, in the case of the EU, EPA, and NHTSA, in the case of the US, it can be assumed that a corporation "born and raised" in a specific market has a different communication of its value proposition.

Besides, in recent years, greater importance has been acquired by the concept of the sustainable/environmental value proposition, which can be defined as "promise on the economic, environmental and social benefits that a firm's offering delivers to customers and society at large, considering both short-term profits and long-term sustainability" (Patala et al., 2016).

Analyzing the different environmental value propositions emerging from the sustainability pages of the corporate websites and the proposed payoffs of the corporations considered before (see *Table 16*), some minor but still interesting differences between the EU-based and the US-based ones can be identified.

It is worth emphasizing that all the corporations analyzed are perfectly aware of their role at this delicate time. In their sustainability reports and corporate websites, they show

[35] The Value Proposition Canvas is retrievable from the following webpage: https://www.strategyzer.com

their engagement in practices contributing to the betterment of the current dangerous conditions associated with the increased global warming and GHG emissions.

This implies, as a common environmental value proposition, that all automotive businesses are operating beyond their core businesses. Of course, this is a great strategic but also moral choice from their side. They tend to invest in projects related to climate change also to offset the emissions that they produce and that they are not able to lower to zero.

Despite these similarities, the differences in the value propositions between the US and the EU corporations lie in how they communicate their effort in achieving a zero- and low-emission mobility.

For example, VW uses "Go to Zero" (VW, 2020b) as statement for its sustainability strategy, the French Renault uses "Respect for the Environment" (Renault, 2020b), PSA opts for "Push to Pass" (PSA Groupe, 2020) and BMW advertises its "Number ONE > Next" (BMW, 2020b) strategy with great emphasis. All these statements communicate the idea that these corporations have developed clear future-oriented plans to make their fleet more sustainable and environmental-friendly. The value proposition perceived by customers as well as other major stakeholders is that these automotive businesses are extensively investing in future mobility technologies using a forward-looking approach.

On the American side, for example, GM uses "Transformation in Progress" (GM, 2019) as environmental statement highlighting the constant effort the automotive business performs for improving, environmentally-speaking, its fleet. The same value proposition is communicated by Ford, which uses "Progressing Sustainability" (Ford, 2019) as environmental statement. In these cases, the value propositions emphasize that automotive corporations are shifting, changing, and even revolutionizing their operations, visions, and products.

To summarize, while it seems that the majority of the European automotive corporations have already in mind the path to follow and already know what kind of technologies to invest in, the American automakers emphasize their ongoing and gradual shift to embrace the requirements coming by the environment itself as well as from the institutions.

At the same time, it is worth mentioning that Daimler, a European-based automotive corporation, suggests the same value proposition as the American Ford and GM do. In particular, the business talks about "changing lanes" and a "time of

transformation" (Daimler, 2020b) that is contributing to changes in the corporate strategy and culture.

Finally, FCA stands in the middle since it is the outcome of a merger between FIAT, an Italian motor vehicle manufacturer, and Chrysler, a historical US brand. In this case, the value propositions the company is stressing are two: on the one side there is the "Engine Revolution" (FCA, 2020b); on the other side, there is "Building a Better Tomorrow" (FCA, 2020c). As a consequence, it might be reasonable to think that also when it comes to environmental value propositions, FCA stands in the middle.

In particular, the "Engine Revolution" suggests the ongoing process of changing engines and the effort the automaker is investing in producing new, more sustainable, and lower-emitting engines. Through "Building a Better Tomorrow", FCA is communicating a long-term, planned and continuous effort for improving not only its fleet in sustainability terms, but also the overall environment such that future generations, customers, and employees will benefit from the investments made in advanced technologies and alternative fuels.

Moving to the customers' perspective, it is worth mentioning the different perceptions they have when it comes to car emissions and the ultimate needs to lower them and spreading the use as well as the purchase of e-vehicles.

The information retrieved from different studies and surveys analyzing the consumers' perception related to car emissions show a similar trend for the EU and US citizens, especially when it comes to electric-powered vehicles. There is instead a different perception for alternatively powered vehicles because in the US the tendency is to prefer FCVs or PHEVs; instead, in the EU, the power of Diesel vehicles is still pretty strong.

Nonetheless, in both markets, citizens value the effort that the institutions as well as the carmakers put in developing cleaner and greener products. At the same time, the main reasons retaining consumers to purchase low- and zero-emissions vehicles is attributable to the (1) costs, (2) the lack of infrastructure and (3) the lack of significant incentives either from the authorities or the carmakers (Thiel et al., 2012; Archer, 2018; Deloitte, 2020).

An interesting fact concerning Europe is that, among the consumers interviewed, those who were less likely to purchase an electric car came from France and Germany (Thiel et al., 2012), countries that, as it was already mentioned, are homes of the two biggest and more powerful automotive corporations in the EU. This might be a curious relationship

to investigate. Another emerging aspect is that on the one side European carmakers complain about low demand of alternatively powered/fueled vehicles, however, the surveys made show that, instead, consumers are more than willing to buy these kinds of vehicles and think that motor vehicles manufacturers and institutions are not putting enough effort in advertising or making them aware of the benefits attributable to the purchase of such cars (Archer, 2018).

It is worth mentioning that the surveys conducted focused on countries where the presence of alternative-fueled vehicles is not new, and it is increasing every year. These are Germany, France, Italy, Great Britain, Sweden, Poland, and Belgium. This might imply a bias in the results because poorer countries, where the share of advanced technology vehicles and infrastructure is almost zero, are not included. As a consequence, the results take into consideration the answers provided by citizens whose knowledge on EVs or alternative-fueled vehicles is medium to high.

In the case of the US, it appears, from the Deloitte analysis of the global automotive industry's trends, that the acceptance of alternative powertrain is widely spread among consumers mainly due to lower operating costs and incentives. Besides, the data retrieved show that the willingness to buy advanced technology vehicles is increasing year by year (Deloitte, 2020).

Considering both the demand and the supply side of the Value Proposition Model, the following table aims at showing the minor yet existing differences between the EU and the US, especially from the consumer segment's perspective:

European Union	United States of America
Consumer side	
Wants	
• Cleaner/low-emission vehicles • Government/automakers incentives • Appealing design • Well-performing vehicles • Good safety ratings • Affordability of vehicles • Brand recognition • Supporting infrastructure for alternative-fueled/powered vehicles • Freedom and access to mobility	• Cleaner/low-emission vehicles • Government/automakers incentives • Appealing design • Well-performing vehicles • Good safety ratings • Affordability of vehicles • Engine performance
Needs	
• Safety • Personal mobility • Better infrastructures for alternative-fueled/powered vehicles	• Safety • Personal mobility • Comfortable spaces that enrich the driving experience • Good performance during long-distance trips
Fears	
• Skepticism about connected and automated vehicles • Lack of safety • Lack of monetary incentives/high costs • Lack of knowledge/awareness • Low battery life • Lack of infrastructure	• Skepticism about connected and automated vehicles • Lack of safety • Lack of knowledge/awareness • Low battery life • High/prohibitive costs
Business side	
Benefits	
• Lower emissions • Safer vehicles • Autonomous vehicles	• Lower emissions • Safer vehicles • Autonomous vehicles
Features	
• Alternative-powered/fueled engines • Improved A/C systems • Infotainment technologies • Investments in re-charging/refueling infrastructure • Improvements in safety on-board devices	• Alternative-powered/fueled engines • Improved A/C systems • Infotainment technologies • Investments in re-charging/refueling infrastructure • Improvements in safety on-board devices
Experience	
• Automated and connected vehicles • Alternative powered/fueled vehicles • Customizable vehicles	• Automated and connected vehicles • Alternative powered/fueled vehicles • Customizable vehicles

Table 17 Value Proposition Analysis. European Union vs. the United States of America.

Source Author's elaboration.

From this table, it seems that there is no difference in how automotive corporations respond to their customers. This suggests that carmakers agree on the direction future mobility should take: low-emission, advanced-technology, and alternative-fueled/powered vehicles with the promotion of automated and connected vehicles.
The real difference lies in how automotive corporations change their value proposition depending on the legislation applied in the market they are operating in:

- **Diversity of regulations**. The European regulatory bodies approve legislations that on the one side are fair for each Member States, while on the other side contribute to widening the gap among countries. This implies that carmakers need to respond to a highly diversified consumer segment, that values differently certain features related to the new advanced technology vehicles. As a consequence, carmakers need to adapt their value proposition depending on the country.

- **Homogeneity of regulations**. EPA and NHTSA prohibit any state and local emission standards to be set, making the overall regulations on emissions homogeneous all over the US. This is due to the regulatory power exercised by EPA and NHTSA on carmakers' products, which must comply with the standards otherwise they are simply not put into the market.

- **Fragmented incentives**. European legislation does not offer EU-wide incentives for the adoption of alternative-fueled/-powered vehicles. This will contribute to widening the gap in the adoption rate between the Member States offering incentives and those that do not. This might greatly affect the value proposition of the automotive businesses because as long as the incentives for the purchase of low-emission vehicles are promoted only in certain countries, the value perceived by consumers in buying such vehicles will remain different.

- **Homogeneous incentives.** In the US, there exists a US-wide incentive mechanism favoring the purchase of low-emission, advanced technology vehicles. These incentives are supported by those offered by the individual states. This makes it easier for carmakers to develop a value proposition that

works all over the US since consumers have at their disposal more than one instrument to change their motor vehicles' purchasing behavior.

- **Lack of infrastructure**. In Europe, the alternative re-charging/-fueling infrastructure is concentrated only in few countries whose GDP is particularly high. Again, this implies that carmakers' value proposition is affected by this condition, which leads to widening the gap among the Member States in the adoption of low-emission vehicles rather than aligning it.

- **Different authorities, different outcomes**. In Europe, different designated authorities have the power to approve the vehicles to be put into the market. This might imply that despite the Commission sets the overall standards to comply with, these authorities may produce different outcomes in terms of vehicles approved. European carmakers, in turn, might take advantage of this weakness in the system.

- **Unique authority, unique outcome**. In the US, only EPA is in charge of testing vehicles. In turn, the final approval comes with certainty and does not allow carmakers to influence the result of the emissions and fuel-economy tests.

- **Competitive-oriented behavior**. In Europe, the emission regulations do not allow for credit flexibilities among automakers. In turn, the market and the value propositions of automotive corporations are guided by strong competition, especially from the most powerful businesses.

- **Cooperative-oriented behavior**. The American legislation favors a cooperative-oriented behavior between the automotive businesses operating in its market due to the market-based instruments at their disposal. In turn, it appears that the cooperation network and the value proposition mutually-affect each other.

From this analysis, it might be inferred that despite the difference between the American and the European markets is not obvious and straightforward, carmakers' strategies to lower emissions are affected by the legislative environment where they operate. The European one, based on command-and-control instruments, namely regulations, and directives, makes automotive businesses aware that they have to lower their CO_2, but this system leaves them enough space to exercise lobbying activities and eventually take advantage of the flaws in the legislation.

The American one, based on market-like instruments, namely credit mechanisms, pushes automotive corporations to integrate the need of reducing emissions in their internal activities, giving a new and higher value to the relationship with other carmakers. Additionally, the American system's strict and coordinated requirements leave motor vehicle manufacturers no other choice but to comply with the standards approved by EPA and NHTSA. In turn, the American automotive industry seems to produce a mutually enhancing structure, where authorities set ever stringent targets, and businesses are encouraged to continuously outperform themselves.

Conclusion

The goal of this thesis was to determine the different impacts of a command-and-control versus a market-based system on a productive sector that is considered a high-polluting one: the transport sector with a particular focus on the automotive industry. To do so, a comparison between the EU legislation and the US one has been made. The reasons for the choice of these two markets are several:

1. They are both saturated and highly competitive markets from the automotive industry perspective;
2. They are home to some of the most powerful and well-known automotive corporations;
3. The turnover generated by the automotive industry in both regions is significant and it is in the interests of the regulatory bodies to maintain the competitiveness in these regards;
4. The EU regulates the automotive businesses through command-and-control instruments, that is directives and regulations;
5. The US regulates the automotive corporations through market-based instruments allowing them credits flexibilities in the form of average, banking, and trading mechanisms.

The research questions around which this thesis has been developed are mainly three:

1. How are the two markets regulating the automotive industry and what kind of targets and standards are they imposing on the corporations operating in this sector?
2. How are the corporations adapting to these requirements, especially from a strategic point of view?
3. How are the two types of legislation influencing the automotive corporations' environment?

To answer these questions the thesis conducted a detailed analysis of the European and the American legislations: on the one side the European Union with the Commission and the Parliament, on the other side the US, with the Environmental Protection Agency (EPA) and the National Highway Traffic and Safety Administration (NHTSA).

Going through the *ratio iuris* of the European and the American systems, similarities and differences can be easily identified. Both legislations are actively dealing with the emission issues and are proposing ever-stringent targets and standards to carmakers, such that the fleets become greener and the low-emission mobility objectives can be achieved by 2050. Moreover, in both markets, there is a strong emphasis on three common goals: oil-dependence reduction, maintenance of the competitiveness and protection from newcomers, and fight against climate change.

Also, the EU strongly encourages the cooperation between the Commission, the Parliament and the Member States for determining targets and applying laws as it happens in the US, where EPA and NHTSA, that are legislatively two independent authorities, collaborate since 2010 to harmonize the requirements and lower costs for automakers.

Despite these similarities, mainly in the approach by the regulatory bodies, the European and the American systems are intrinsically different when it comes to the flexibility mechanisms and incentives applied and provided to motor vehicle manufacturers. More specifically, some similarities can be identified also at this level, but the difference lies in their implementation and in the nature of the automotive business ecosystems that exist in the European and the US markets.

While derogations to small-volume manufacturers and credit multipliers for certain categories of vehicles (EVs, PHEVs, FCVs, NGVs) or certain technologies that contribute to verifiable CO_2 emissions reductions are implemented almost equivalently in both cases, credit flexibilities are ensured to automakers only in the US.

Through this mechanism American automakers can earn credits when they over-comply with the standards set by EPA and NHTSA. These can be carried forward, back, transferred among the same manufacturer's fleet, and, more interestingly traded with other carmakers.

It is in this trading opportunity that lies the intrinsic difference between the European and the American systems that greatly affects the environment, both from the legislative and the competitive points of view, where the automotive corporations operate.

In particular, the American crediting system leaves space to strategic actions by carmakers in the short-term while making it less likely that they will cheat in the long-term.

Other relevant differences are related to the emission testing procedures. Apart from the differences in the methodology to test vehicles, the greatest point of difference lies in the authority in charge of approving motor vehicles into the market. In the European case, the Commission establishes some authorities in each Member State to conduct these testing procedures while maintaining the supervision upon them.

In the US case, instead, EPA is the sole authority in charge of testing motor vehicles that are going to be sold in the American market. This implies that whether a vehicle is considered compliant with the targets and standards of both EPA and NHTSA in terms of emissions and fuel economy is in the hand of a unique entity making it less likely for automakers to get around the law.

Another great point of difference between the EU and the US lies in the power associated with the regulatory bodies. In the EU, despite the Commission and the Parliament are supranational authorities, they leave in the hands of the Member States the decisions on how to achieve certain targets. Besides, there are many examples of the Commission's decisions where the stringency of the requirements depends on the level of development and GDP of the different Member States. On the one side this implies that the targets are fair for each Member State, but, on the other side, this leads to widening the already-existing gap in development terms among the European Member States.

In the US, instead, the Clean Air Act preempts any state and local emission standards to be set, meaning that targets are established at a federal level with no exception and in a homogenous way.

These technical regulatory differences put the bases for creating an intrinsically different environment for automotive corporations.

On the one side, there is the European Union that developed a system solely based on regulations and directives, that is command-and-control instruments, that, for sure, led the Union as a whole and the automakers to move closer to the emission reduction goals set. On the other side, there is the United States, which implemented regulations to control the motor vehicle manufacturers' behavior, while creating a market-like environment, where a typical system of demand, supply, and exchanges exists.

In the third chapter, the main and most powerful automotive corporations for both markets have been presented, such that useful insights for answering the research questions of this thesis could be derived.

First, it was noted that not all carmakers operated in both markets, such as in the GM and the PSA cases. Second, it was assumed that a cultural- and traditional-related component partly explained the ranking of some automotive corporations in one market or the other. Third, due to the nature and the process for the approval and the adoption of the regulations, it was derived that the role of negotiations has a different weight in the two markets. In the EU, bargaining between the carmakers and regulatory institutions is greatly affected by lobbying and corporate political activities that put the auto manufacturers in a favorable position.

In the US, instead, another type of bargaining exists, the one among automotive corporations, which leads to the creation of a cooperative/competitive environment. That is, on the one side American motor vehicle manufacturers value their relationships with other carmakers to ensure themselves credits in case they are not able to comply with the stringent standards set by EPA and NHTSA. On the other side, these apparent cooperative relationships are the outcome of strategic decisions made at the corporate level to maintain competitiveness and survival.

The relationship US automakers have with the regulatory authorities, mainly EPA and NHTSA has a different nature compared to that of the European carmakers. In fact, despite lobbying does exist also in the US, it seems that its strength depends on how the trade associations of motor vehicle manufacturers can affect the decisions of the institutions. Things seem to be different in Europe, where the strength of an individual carmaker can greatly affect the decisions taken at the Union level.

To support these derived conclusions, two strategic models have been presented: the Business Ecosystem and the Business Model Canvas.

The former can be considered the product of globalization, where corporations enlarged their businesses to other markets, changing their scopes and type of competition. Despite the business ecosystem is different among the corporations, throughout the years, some key characteristics of this environment have been identified that put the bases for creating uniform evolutionary processes.

From the general business ecosystem model presented, it was derived that in the American market, greater importance is given in cultivating cooperative-competitive relationships with other carmakers and that relationships with trade associations are valuable for their intermediary role with the regulatory institutions. In the EU, instead, solid and strategic relationships are built with trade associations and regulatory bodies

such that intense lobbying activities both from individual carmakers and Member States are more likely to happen

With the Business Model Canvas, it was further emphasized the different role covered by OEM alliances both in the relationship with automakers and as an intermediary between motor vehicle manufacturers and the regulatory bodies. Also, the attention was put on the value proposition box of the Canvas and the annexed Value Proposition Model to analyze from the automakers' and the customers' perspectives how are automotive corporations acting towards climate change, what are they communicating, what is the perceived effort by customers, and what consumers want, fear and desire.

Analyzing the environmental value proposition statements of the major automotive corporations, it was derived a minor but still relevant difference in the communication of the European versus American carmakers. In synthesis, while in the EU the focus and the emphasis are put on the long-term plan that the corporations have developed to produce greener fleets and fight climate change, in the US it is stressed the ongoing effort that manufacturers are investing in new technologies and cleaner vehicles.

From the customers' point of view, in both markets, there is no clear-cut position concerning what they are looking for in a greener vehicle. This suggests that carmakers and the institutions must extensively work on making consumers more and more aware of the changing behaviors that are required at all levels to combat global warming. While consumers recognize the importance of adopting greener vehicles, most of them have too little knowledge to make informed decisions on the type of vehicles to purchase or too little trust in alternative fuels. Moreover, most of them retain from investing in buying advanced technology vehicles because of the prices, which are still too high and considered prohibitive from the mass market.

Besides these considerations, it was derived that the differences in the nature of the legislative system seem to affect the corporations' value propositions. The federal system implemented in the US makes it easier to automakers to convey the same value proposition throughout the states. This is because the standards and targets established by EPA and NHTSA are valid at a federal level and any local standard is prohibited by the Clean Air Act.

In Europe, instead, carmakers face a much more heterogeneous consumer segment that affects their value propositions. This might be related to the number of regulations

concerning environmental-related requirements that are fitted to the type of Member State. These follow the principle of "leaving no one behind" and fairness considering the level of development and GDP of an individual Member State. However, this approach might have a double-sided impact. On the one side, it might lead to a gradual shift towards new technologies, an improved infrastructure for low-emission vehicles and incentives for spreading such vehicles. On the other side, it might widen the gap between those Member States, the rich ones, which already have a good distribution of ZLEVs, compared to those where there is a lack of these technologies and motor vehicles. The gap between the Member States might be even more widened due to the fragmented nature of the incentives for consumers to purchase cleaner vehicles. While in the US there is a US-wide incentive system for helping consumers, in the EU these aids are under the control of individual Member States. Thus, also, in this case, the rich Member States are more likely to offer such incentives rather than those European countries with a lower GDP.

Another key difference that affects the value proposition of carmakers, their strategies and that is related to the type of system implemented concerns the authority designated for the tests and the approval of motor vehicles before they are put into the market. While in the US, the control is centralized under the power of EPA, which is the sole authority that can approve a motor vehicle into the American market, in the EU this is not the same. The Commission can perform testing procedures on motor vehicles, but the first authorities to determine whether a vehicle can be accepted into the European market are distributed across the Member States. This does not make the approval of a motor vehicle a centralized decision, and, in turn, it might leave enough space for powerful carmakers to perform lobbying and corporate political activities or take advantage of these weaknesses in the system.

To conclude, from the analysis conducted throughout the three chapters, the author came to the following conclusions: the European and the American markets where the automotive corporations operate have two completely different approaches to the goal of zero- and low-emission mobility. More broadly, having a command-and-control type of legislation or a market-based one seems to greatly affect the strategies that the corporations can implement and completely changes the businesses' *modus operandi* despite the uniformity of the goals to be pursued.

It is well-known that the environmental issue came as a disruptive force into the business world. Many corporations have been threatened by it, because, as it was already

mentioned, businesses were forced to re-think their processes and their products' architecture.

The environmental issue also affected the institutional *modus operandi*, because, also in their case, regulatory bodies have been forced to re-think the way they implemented regulations, creating either command-and-control instruments or market-based ones.

The type of legislative instruments chosen further influenced the corporations' strategies. It might be said that the combined action of the environmental issue and the institutional response to deal with it has greatly contributed to the destabilization of the corporate ecosystems which was characterized by uniform evolutionary processes independently from the market.

In conclusion, climate change has been so disruptive that business models started diverging after a long period of convergence given by the globalization. These diverging models are further fostered by the annexed environmental policies proposed that are treated differently by institutions, which, in turn, are highly affected by a specific political and cultural model. Specifically, it appears that a market-based approach that fosters a competitive-cooperative behavior is more likely to create a proactive environment, where carmakers strictly comply with the standards, are less likely to cheat in the short-term and have enough lead time to make strategic decisions for their long-term performance.

Appendix

A.1 Standard Curves

All the information contained below is retrieved from EPA, 2020a.

A.1.1 NHTSA

For passenger cars, NHTSA uses the following fleet standards' equation:

$$TARGET_{FE} = \frac{1}{MIN\left[MAX\left(c \times FOOTPRINT + d, \frac{1}{a}\right), \frac{1}{b}\right]} \quad (1)$$

Where

- $TARGET_{FE}$ is the fuel economy targets expressed in *mpg*
- *a* is a minimum fuel economy target expressed in *mpg*
- *b* is a maximum fuel economy target expressed in *mpg*
- *c* is the slope (in *gpm* per square foot) of a line relating fuel consumption to footprint
- *d* is the intercept (in *gpm*) of the same line
- *MIN* and *MAX* are functions taking the maximum or minimum values.

For light trucks, NHTSA uses the following fleet standards' equation:

$$TARGET_{FE} = MAX\left(\frac{1}{MIN\left[MAX\left(c \times FOOTPRINT + d, \frac{1}{a}\right), \frac{1}{b}\right]}, \frac{1}{MIN\left[MAX\left(g \times FOOTPRINT + h, \frac{1}{e}\right), \frac{1}{f}\right]}\right) \quad (2)$$

Where

- $TARGET_{FE}$ is the fuel economy targets expressed in *mpg*
- *a,* is a minimum fuel economy target expressed in *mpg*
- *b* is a maximum fuel economy target expressed in *mpg*

- *c* is the slope (in *gpm* per square foot) of a line relating fuel consumption to footprint
- *d* is the intercept (in *gpm*) of the same line
- *e* is a second minimum fuel economy target expressed in *mpg*
- *f* is a second maximum fuel economy target expressed in *mpg*
- *g* is the slope (in *gpm* per square foot) of a second line relating fuel consumption to footprint
- *h* is the intercept (in *gpm*) of the second line
- *MIN* and *MAX* are functions taking the maximum or minimum values.

A.1.2 EPA

EPA's standards are expressed either through flat standards applied above or below a specific footprint or through a linear function applied between those footprints. In general, the targets are presented as follows:

Passenger cars	$\boldsymbol{f \leq 41\text{ft}^2}$	$\boldsymbol{41\text{ft}^2 < f \leq 58\text{ft}^2}$	$\boldsymbol{f > 58\text{ft}^2}$
Light trucks	$\boldsymbol{f \leq 41\text{ft}^2}$	$\boldsymbol{41\text{ft}^2 < f \leq 66 - 74\text{ft}^2}$	$\boldsymbol{f > 66 - 74\text{ft}^2}$
	Flat standards	$Target\ CO_2 = [a \times f] + b$ Where • a and b are specific targets defined by EPA (see *Tables 9* and *10*) • f is the vehicle footprint	Flat standards

Table 18 EPA's Formulas for Determining Standards for Passenger Cars and Light Trucks
Source DOT, EPA, NHTSA, 2020a, p. 70-73.

A.2 Final Standards

A.2.1 NHTSA

Using the fleet standards' equation (1) shown in Appendix-A.1, the following targets must be substituted.

Fuel Economy Standards for Passenger Cars						
	2021	**2022**	**2023**	**2024**	**2025**	**2026**
a (mpg)	49.48	50.24	51.00	51.78	52.57	53.37
b (mpg)	37.02	37.59	38.16	38.74	39.33	39.93
c (gpm per s.f.)	0.000453	0.000447	0.000440	0.000433	0.000427	0.000420
d (gpm)	0.00162	0.00159	0.00157	0.00155	0.00152	0.00150

Table 19 Final Fuel Economy Standards, Passenger Cars
Source DOT, EPA, NHTSA, 2020a, p. 67.

Fuel Economy Standards for Light Trucks						
	2021	**2022**	**2023**	**2024**	**2025**	**2026**
a (mpg)	39.71	40.31	40.93	41.55	42.18	42.82
b (mpg)	25.63	26.02	26.42	26.82	27.23	27.64
c (gpm per s.f.)	0.000506	0.000499	0.000491	0.000484	0.000477	0.000469
d (gpm)	0.00443	0.00436	0.00429	0.00423	0.00417	0.00410

Table 20 Final Fuel Economy Standards, Passenger Cars
Source DOT, EPA, NHTSA, 2020a, p. 67

A.2.2 EPA

Below are shown the specific flat standards and the targets to be put in the linear functions depending on the vehicle's footprint.

CO_2 Targets for Passenger Cars				
	$f \leq 41ft^2$	$41ft^2 < f \leq 58ft^2$		$f > 58ft^2$
		a	*b*	
2021	161.8	3.94	0.2	220.9
2022	159.0	3.88	-0.1	217.3
2023	156.4	3.82	-0.4	213.7
2024	153.7	3.77	-0.6	210.2
2025	151.2	3.71	-0.9	206.8
2026 and later	148.6	3.65	-1.2	203.4

Table 21 Final CO_2 Targets for Passenger Cars
Source DOT, EPA, NHTSA, 2020a, p.70-71.

The CO_2 targets for light trucks whose footprints are between $41ft^2$ and 66-74ft2, and greater than 66-74ft2 must comply with certain maximum and minimum footprint values, respectively, that are shown in *Table 23*.

CO_2 Targets for Light Trucks				
	$f \leq 41ft^2$	$41ft^2 < f \leq 66 - 74ft^2$		$f > 66 - 74ft^2$
		a	*b*	
2021	206.6	4.51	21.7	329.7
2022	203.1	4.44	21.0	324.4
2023	199.7	4.38	20.3	319.2
2024	196.3	4.31	19.6	314.0
2025	193.0	4.25	19.0	308.9
2026 and on	189.8	4.18	18.3	303.9

Table 22 Final CO_2 Targets for Light Trucks
Source DOT, EPA, NHTSA, 2020a, p. 72-73.

Maximum and Minimum Footprints for CO_2 Targets of Light Trucks		
	$41\text{ft}^2 < f \leq 66 - 74\text{ft}^2$	$f > 66 - 74\text{ft}^2$
	Maximum footprint	Minimum footprint
2021	73.5	
2022	74.0	
2023	74.0	
2024	74.0	
2025	74.0	
2026 and later	74.0	

Table 23 Maximum and Minimum Footprints for CO_2 Targets of Light Trucks

Source DOT, EPA, NHTSA, 2020a, p. 72-73.

List of Abbreviations

Abbreviations	Meaning
ABT	Averaging, Banking, and Trading
A/C	Air-Conditioning
ACEA	European Automobile Manufacturers Association
AFE	Average Fuel Economy
AFV	Alternative-Fueled Vehicle
AMFA	Alternative Motor Fuels Act
CAA	Clean Air Act
CAFC	Corporate Average Fuel Consumption
CAFE	Corporate Average Fuel Economy
CDM	Clean Development Mechanism
CFR	Code of Federal Regulations
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPA	Corporate Political Activities
CSR	Corporate Social Responsibility
CVD	Clean Vehicles Directive
DOT	Department of Transportation
EC	European Commission
EEA	European Environmental Agency
EFTA	European Free Trade Association
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
EPAct	Energy Policy Act

EPCA	Energy and Policy Conservation Act
ETS	Emission Trading Scheme or System
EU	European Union
EU ETS	European Union Emission Trading Scheme
EV	Electric Vehicle
FCA	Fiat Chrysler Automobiles
FCV	Fuel-Cell Vehicle
FCIV	Fuel Consumption Improvement Values
FTP	Federal Test Procedure
GDP	Gross Domestic Product
GHG	Greenhouse Gas
g/km	Grams per kilometer
GM	General Motors
g/mi	Grams per mile
GTR	Global Technical Regulations
HWFET	Highway Fuel Economy Test
ICAP	International Carbon Action Partnership
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
JI	Joint Implementation
KETS	Korean Emission Trading Scheme
LCV	Light Commercial Vehicle
LDT	Light-Duty Truck
LDV	Light-Duty Vehicle
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
mpg	Miles per gallon

MSR	Market Stability Reserve
MTE	Midterm Evaluation
MY	Model Year
NEDC	New European Driving Cycle
NGV	Natural Gas Vehicle
NHTSA	National Highway Traffic Safety Administration
NMOG	Sum of Non-Methane and the Oxygenated Hydrocarbons
NO_x	Nitrogen Oxide
NVFEL	National Vehicle and Fuel Emissions Laboratory
NZ ETS	New Zealand ETS
OEM	Original Equipment Manufacturer
OICA	International Organization of Motor Vehicle Manufacturers
PC	Passenger Car
PEMS	Portable Emission Measuring Systems
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter
PN	Particle Number
PSA	Peugeot Société Anonyme
RDE	Real-Driving Emission
RENE	National Emissions Register
R&D	Research and Development
RGGI	Regional Greenhouse Gas Initiative
RM	Reference Mass
SAFE	Safer Affordable Fuel-Efficient
SEMARNAT	Secretaria de Medio Ambiente y Recursos Naturales
SRI	Socially Responsible Investor
SUV	Sport Utility Vehicle

SVM	Small-Volume Manufacturers
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
VW	Volkswagen
WB	World Bank
WLTP	Worldwide Harmonized Light Vehicles Testing Procedure
ZEV	Zero-Emission Vehicle
ZLEV	Zero- and Low-Emission Vehicle

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