Università Ca'Foscari Venezia

Master's Degree

in

Management

Final Thesis

The Environmental Issue faced by the Automotive Industry

From a regulatory-pull perspective to a business-push implementation

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Introduction

We hear more and more about green mobility, electric and hydrogen cars, the environmental impact of the automotive industry and infrastructures. This has been an incentive to try to better investigate and understand these aspects, hence the origin of this work, the aim of which is to provide as complete an overview as possible of a mature industry that is experiencing a period of enormous change.

This work has attempted to point out and analyse the evolution we are witnessing: it is not just a change in one sector but represents a new way of thinking about our lives in a less selfish way and more integrated with the environment.

To this end, we will first provide an overview of the history of the automotive sector. In addition, we will attempt to shed light on the current market structure and key players in the sector. It is believed that understanding the size and strength of an industry helps to interpret events and predict where the strategies of different companies and groups will lead. Furthermore, understanding the size of this industry allows us to understand its social and environmental impact and explains why it is considered so strategic in triggering a new environmental awareness and in stimulating industries that are not directly linked to the automotive sector, but which are interconnected and can receive a strong impetus for innovation that can then be transferred to other industries.

The second chapter is devoted to how humans and their activities have affected (and are affecting) the environment, with a particular focus on the effects of rising temperatures. Following this train of thought, we will focus on the impacts that the automotive industry is having, the technologies that could reduce these impacts, and the barriers to the adoption of these technologies.

The third chapter looks at the role of institutions and how they address problems at the regulatory level and how agreements between nations can prevent the collapse of the world we live in. The Green Deal and the goals derived from it are highlighted, with a detailed analysis of how they have been incorporated into regulation in the automotive sector.

After understanding how the automotive industry is structured, its environmental impacts, and the regulatory limits imposed on it, chapter four analyses the technical outcomes resulting from environmental problems and the incentives to find solutions.

We will try to understand in detail what are the vectors of technological development that car manufacturers are implementing to reduce the environmental impact of cars throughout their life cycle, from design and production to disposal and recycling.
Finally, chapter five analyses the application of what has been said in the previous chapters by studying a real case, Toyota, which in many aspects represents a company able to combine profit with environmental protection. The company is analysed from a historical, economic and financial perspective, as well as the technological innovations it has introduced to the market and the way it has organised itself to minimise the environmental impact of its products and the company as a whole.

1. General overview of the Global automotive Industry

1.1. Historical Outline in the Automotive Industry

To have a greater understanding of the industry, it is necessary to follow step by step the evolution of vehicles that has occurred in terms of industrial and strategy development.
The history of the automobile started to experience its most exciting pioneering ferments in the decades of the late 19th century. The first cars were called *Horseless Carriage*. The part relating to quadricycles and electric cars is a proof of the extraordinary foresight of the first automotive entrepreneurs and it is even more if we compare it to the project-oriented wave, conceptually similar to the one we are experiencing today in the name of sustainable mobility. The first quadricycles were essentially motorized carriages and enormous efforts were made by the designers of the time around the concept of electric car.
From the late 19th century to nowadays key changes have been made: in one side there is the evolution of automotive market (the first concepts of cars were bought just from the elite class while lately, thanks to the development of mass production, there has been a boost of cars sold, even the poor class could have access) and vehicle usage conditions; and from the other, the access of new technologies, and safety and environmental restrictions.
Competition between competitors leads to different speeds of development at different times. Each historical phase can be divided through the examination of the social, economic and technological context. The first phase is the so called "pioneering era" and started at the end of the 19th century. In the early stages of the 1905, Taylorism and mass production were innovative solutions in terms of organization and production until the end of the year 1925, where a change in the management generation brought new concepts of diversification and plant specialization. The first oil crises in the 1973 boosted exports and welcomed an international diffusion of mass production while 40 years ago, Japanese cars manufacturers brought a completely different concept in the automobile sector: *total quality* and *lean production* were the bases of the new organizational model.

The latest international crise, new regulations concerned safety protection and pollution[1], and digitalization have introduced to the era of radical change.

As we said, everything started in Europe. The phase "pioneering" saw cars as real artisan products equipped with operative instructions. These quadricycles were called "motorized coaches" but despite the beauty and uniqueness of the product, they had several dysfunctionalities that long times to fix were needed.

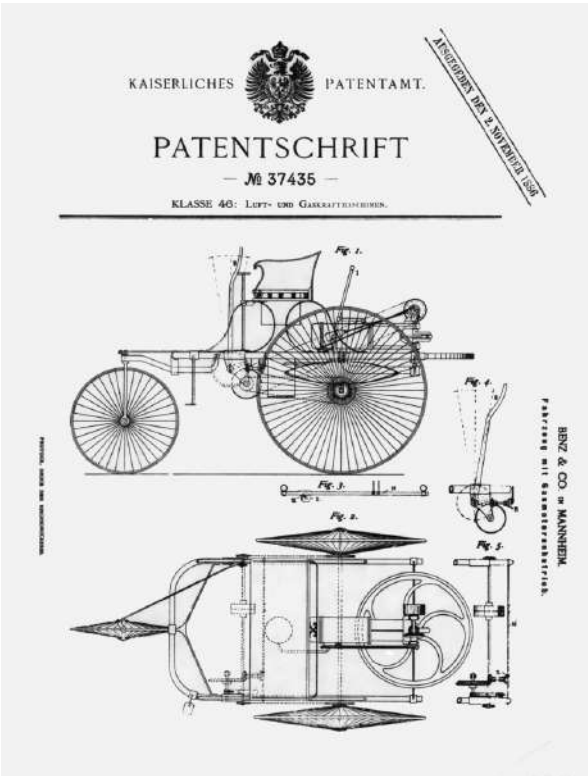

Figure 1: Mercedes Benz Patent nr. 37435

During this period, each European state contributed with different techniques and craft schools: Austria and Germany brought the best engine solutions, England were distinguished by their remarkable luxurious beauty while Italian and French cars were different for its space frame solutions and design[2].

With the introduction of the first automatic machine tools, production was significantly improved: it was the period of the transformation of automotive production from an

[1] The UE Regulation 2018/858 clarifies the importance to implement an EU framework that is robust, transparent and sustainable; and ensures a high level of safety and protection for the health and the environment.

[2] Flink, James J. "Three Stages of American Automobile Consciousness." *American Quarterly*, vol. 24, no. 4, 1972, pp. 451–473. *JSTOR*, www.jstor.org/stable/2711684.

artisanal to an industrial method, leading to the concept of standards and mass production.

In Europe, during the decade 1903-1913, there was the growth of small and medium-sized car manufacturers, which respond to the most demanding requests from a clientele formed exclusively by nobles and middle class.

Motor engine wasn't the only innovation at that time that improve the development of cars. Among the countless transformations in the industrial field that took place at the end of the nineteenth century, there were some particularly important ones that marked the history of the industry. Among these we find the organizational innovations that applied the ideas of F. Taylor. In fact, he created the basis for a "scientific organization of work", with the aim of responding to the needs expressed by the newborns American industries, which was firstly a more rational use of the large mass of workforce without any qualifications. Taylor believed that the reason most organizations failed was because they lacked successful systematic management. The fundamental principle upon which Taylor's "Scientific Management" was based on the rigid division between intellectual and manual labor and on the fragmentation of labor. As he himself wrote: "*The study and planning of production it is exclusively the responsibility of a specific office; the task of the workers must be limited to the execution of predetermined tasks, broken down by scientific criteria into simple operations performed with standardized tools and in chronometrically established times* "[3].

The goal of the fragmentation of the work was to limit or delete the discretion of old work systems which, according to Taylor, represented the greatest source of waste of time and inefficiency. With the assumption of certain fundamental features such as reliable functionality and high versatility, Henry Ford, successful entrepreneur with mechanical intuition, understood the opportunity to transform the artisan good into a mass product. To win competition, he had to create a rapid production capacity in order to satisfy the increasing demand. To do that, he combined his idea with F.W. Taylor's model for the scientific organization of work, which was based on (i) re-playable and interchangeable elements of the product; (ii) production organized by method and predefined working times; (iii) simplification of job tasks by specialization and (iv) blue collar motivation to

[3] Taylor F. W., The Principles of Scientific Management, Cosimo Classics, New York, 1911

speed-up production in a short period of time[4]. In this way there was a cut on cost of manpower in the workforce, and in an attempt to reduce the space among different product lines, he proposed a continuous flow line (assembly line) on which materials and components were progressively added at different stations, and at which workers followed standard operating procedures. This could increase time and work efficiencies and cut overall costs. To overcome the logistic difficulties and the change of management with the suppliers, Ford primarily concentrated the production process at its own Detroit-Rive Rouge plant, reaching the production rate of 1 million vehicles a year. Ford officially entered in the automotive history on June 16th, 1903, when Henry Ford and 11 partners signed the company's birth certificate. With a starting capital of $28,000, the industrialists start a pioneering business project that will later lead to one of the largest corporations in the world. Few companies are so closely identified with the history and progress of an entire business sector. The success of the Model ''T'', produced in a number of different styles on the same frame and with the same engine, allowed Ford to reach 60% of the American market and maintain 50% of it up to 1920. The Ford model has been an example for foreign carmakers, included European ones, that tried to adopt the same production system, even though no foreign company reached his production volume.

The so-called "roaring twenties" was an era in which the United States of America experienced tremendous prosperity. The nation's total income rose from $74.3 billion in 1923 to $89 billion in 1929. The automobile industry was the driving force behind many other booming industries in the 1920s. In 1928, with over 21 million cars on the road, there was roughly one car for every six Americans. If Henry Ford's model provided the opportunity to standardize and compete, various automakers offered more creative and customized products during this time.

The leading actor of this era is certainly General Motor. The company was established in 1908 as a holding company and then rapidly expanded with the acquisition of existing car companies such as Chevrolet, Cadillac, Oldsmobile and Buick. In 1921 the third president of General Motors, Alfred P. Sloan, developed the so-called *product diversification*, where dozens of products were offered with the slogan "A Car for every Purse and Purpose".[5] The new strategy was building series cars with a wider product range depending on a

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[4] Di Nicola P., Da Taylor a Ford. Appunti per lo studio dello «Scientific Management» e della catena di montaggio, Saggi, 2006

[5] Dale, Ernest. "Contributions to Administration by Alfred P. Sloan, Jr., and GM." Administrative Science Quarterly, vol. 1, no. 1, 1956, pp. 30–62. JSTOR, www.jstor.org/stable/2390839.

customer's economic needs. You could build your own car together by your own taste and view.

The GM Holding Company controlled the production activities: each plant was established by brand and car class, and scale synergies were set up for "capital intensive" productions. The production was allocated to specific plants connected by railways to the final assembling. Furthermore in 1921, Alfred P. Sloan, had to reshape a huge company that had been loosely run by William Durant. The Sloan idea was to implement a decentralized organizational structure that could improve initiative, innovation, and entrepreneurial behavior for those who were responsible for each GM's division. In addition to the basic concept of controlled autonomy he wanted to determine clearly each function of the various division, to coordinate operation between central organization and corporation and to centralize all executive functions of the CEO.[6]

During the 1930s, there was a turning point in the philosophy of automobile manufacturing. Around this time the shape of the cars began to take on a smoother shape, more aerodynamic in design, thus offering less wind resistance. Aerodynamics and aerodynamic design likewise increased the volume of the car's engine. Streamlining a car also meant that more fuel, which was already cheap in the US, could be saved due to this streamlining. The interesting invention made by GM was the re-styling or face-lift of automobiles: the face-lift strategy, followed by several car manufacturers, is a lighter restyling with major or minor upgrades that keep a car updated throughout its life cycle. In addition, during the 1930s, various car manufacturers offered increasingly complex and sophisticated cars, especially for the few survivors of the Great Depression. Since then, cars have seen the implementation of heaters and radios.

The 1930's, was the decade of new production methods, new inventions, new engines and the rise of car designers like Harley Earl.

[6] Houghton J. D., What is Good for General Motors:The Contributions and Influence of Alfred P. Sloan, Jr., Journal of Management History, Vol. 19 No. 3, 2013, pp. 328-344.

The long pent-up demand for cars caused by the Depression and World War II exploded into an irrational excess in the decade of the ’50’s. Tailpins and chromes was the norm, and that design was the brainchild of Harley Earl. In 1950, Ford has been inspired by the diversification strategy implemented by GM and proposed its product diversification with different car models for different archetypes.

Figure 2: Ford magazine ads from 1950s

In Europe, especially in Italy, Germany, and France, mass production of super fuel-efficient cars was the leading concept, although it did not fully take hold until after World War II. The main difference between American and European mass production’s cars was that the last ones were small sized and more agile. Lancia, Fiat and Citroen proposed different engine and frames system that were after followed by all European and Japanese carmakers. During these years, the European cars focused on design: all cars of the 1950s had rounded and clean lines. By welcoming the new decade, global carmakers started to being specialized on their unique industrial local feature, at the same time they absorb the innovation and strategy models implemented by the competitors. This was the time of mutual influence and interpretation that led to new type of vehicles, outcome of different points of view. Europe and Japan had begun using similar production solutions of Ford and GM, and their production capacity rose year by year, which was highly correlated to the growing of exportation rate. In the 1950s, the American automobile industry consolidated into the Big Three: General Motors, FordChrysler, and American Motors. These companies dominated not only the domestic market with sales of 1950s cars, but also the world market. In 1960 American companies built 93% of the autos sold in the United States and 48% of world. However, from mid-1950s to 1980, the growing imports and oil prices challenge Detroit. Neither Chrysler, Ford, nor GM wanted to enter the market for small cars on its own. The Detroit automakers felt the market for small cars needed to be big enough to accommodate all three of them. Higher per capita incomes, lower gasoline prices, longer driving distances, and wider roads all accounted for the fact that vehicles purchased in the U.S. market tended to be larger than those in other markets. Conversely, a foreign producer would be somewhat reluctant to produce a U.S.-style automobile that it could not sell in significant numbers in its home market. As the U.S. economy moved into recession during the second half of 1957, small, inexpensive European cars quickly became very successful in the American marketplace.

After the time of important changes during the 1960s as the Civil Rights movement as led by Martin Luther King Jr. and the Women's Movement with its demand for equal rights, by the early 1070s, the bigger carmakers reached the maximum level of employment in their historical plants and their influence on socio-economic development in industrial countries was very high. Indeed, at the end of the 1060s, the unions and general social uplift limited the increase of production volumes, especially in Italy, France and England. However, during the 1970s Italy had different centers of engineering and style model design, many dedicated to special designs for sports and luxury cars. Style design and functional features, such as vehicle aerodynamics, were developed with scientific methodology and experimental techniques that allowed for significant results on both the technical and style sides. These solutions would later be used for mass series production by even the biggest carmakers worldwide.

The 1973 oil crisis (and again in 1979), emphasized the importance of fuel economy worldwide thereby putting pressures on both US markets as well as foreign markets to build cars with an increasing proportion of the cost of vehicle operation into fuel economy. Its impact in the United States with its greater distances was worse compared to that of, for example Europe with its short distances. The energy crises turned fuel economy into an important automobile policy goal for the U.S. government. In 1975, Congress imposed mandatory Corporate Average Fuel Economy (CAFE) standards for the first time. The standards were to become effective by year 1978. To check for compliance, the U.S. Environmental Protection Agency was to test the vehicles in a lab. The policies approved in the United States became a limit to product development for many carmakers. The auto lifecycle lasted for 12-15 years and the production for new models required great investments and long period of interruption of production.

Programmable production (Operational Machine Centres, Robot Equipment) and IT systems became strategic and both improve supply chain management. In Europe, there was the first generation of flexible production systems (called CIMS, Computer Integrated Manufacturing System), but difficulties arose because these complex technologies were difficult to manage. This period was also the golden age of diesel: automakers Peugeot, Mercedes and Opel began to introduce diesel as alternative fuel to react over the severe oil crisis.

Safety and environmental restrictions, along with customer demands for comfort and functionality, led to a new era of progress in the automotive industry. This was an important time of change as design parts were replaced by functional parts.

According to Volpato G. and Zirpoli F. *"The continuous changes in customer needs, in terms of style, performance and on-board equipment, led manufacturers to implement two strategies:*

1) Expansion of the range of models offered by each manufacturer that is interested in serving every niche of the market through a multiplication of the available models: no longer just cars divided into a few segments (4-5) according to the different size and displacement, but also specialist cars for large families (station wagons and mono-volumes), holiday cars and off-road vehicles (SUVs and 4-wheel drive cars), motorway and city cars, for a total of at least 12-14 segments of market.

2) An accelerated pace of replacement of the models, which were previously renewed every 10-12 years, and which now need to be refreshed every 2-3 years with a face-lifting operation, mainly concentrated on the bodywork and on the interior furnishings of the vehicle, and every 4-5 years with an accentuated renewal that also involves the engines, transmission, suspensions and electronic equipment of each model."[7]

[7] Volpato G. e Zirpoli F., L'auto dopo la crisi, Francesco Brioschi Editore, Milano, 2011

In this way, car manufacturers have managed to overcome stalled growth rates with a higher unit value of cars sold while significantly increasing the competitiveness of car manufacturers. The model of cooperation between final and middle producers was structured in different strategic profiles based on a macro-industrial necessity: In Germany, car manufacturers tended to promote local suppliers in their R&D activities and their priority was innovation (German model), Japanese car manufacturers, in order to increase their R&D capacity, invested through capital participation (Japanese model) and finally, in America, the first priority was to maximize short-term economic results. To do this, they chose independent suppliers with market leadership (American model). During this historical period, the Japanese companies implemented a completely new manufacturing and organizational model. Japanese manufacturers were able to grasp the new demands of replacement demand earlier than their Western competitors. They have implemented more incisive strategies of extending the range and renewing the models. These strategies, accompanied by attention to product quality and reliability, have contributed to the success of Japanese manufacturers in all major markets. The second oil crisis and the rise in fuel prices have certainly helped the orientation of customers from across the Atlantic towards smaller and low-consumption cars offered by Japanese manufacturers.

The company aimed at quality, lean production and personnel high satisfaction. Thanks to the new models, the company gained more and more market share, which guaranteed a first place among competitors. In Chapter 4 and 5 we will discuss more in deep about *Total Quality Management* and *Lean Production*.

The creation of Free Exchange Areas and free trade policies led carmakers (i) to build relevant industrial integration and joint ventures and (ii) to create commercial relationships with eastern suppliers and build new plants in Eastern Europe. For a long time, manufactures were expecting the opening of these markets as it was thought that this would lead to an easing of competitive pressure and a return to profitability levels of car manufacturers in the pre 1980s phase.

This historical period saw the introduction of new multipurpose vehicle as SUV, MPV and LCV. In the 90s Fiat will distinguish itself by projecting the innovative common-rail Multijet system. The diesel engine will soon be applied by greater European and Japanese carmakers. Introduction of new technology for the assembly of material allowed for lighter vehicle structures, and improved performance, fuel consumption and safety. At the end of the 20th century, the sector complained of a quota of excess production capacity of 30%. This has resulted in the implementation of very aggressive commercial policies by the main manufacturers, based on discounts and forms of purchase incentives, in an attempt to increase sales and saturate their plants to the detriment of competition. The results obtained however was a natural reduction in profit margins. Even though the greater competition was stifling small-size companies, they didn't disappear, but they have been absorbed by bigger carmakers. The main strategic goals of these *liasons* were (i) reaching important synergies from an economic point of view by using R&D on common platform and new investment, (ii) increasing contractual power in material, component and equipment acquisition, (iii) increasing market shares on worldwide markets by widening the number of models offered and leaving exclusive missions to single brands. Even though efficiency through synergies, production organization and mergers, was the key factor of this historical phase, elite vehicles never end to be requested: Porsche and Ferrari were the best brands of supercars.[8]

In recent years, the problem of global warming deriving from greenhouse gases and in particular from CO2 emissions was gaining increasing visibility. This led the governments of the major industrialized countries to counteract the negative effects of inflation through policies to incentivize the sales of replacement cars for older cars to be scrapped. The financial crisis that began in 2007 and the accompanying sharp deceleration of vehicle sales during 2008 raise serious challenges for all automakers. Before its event, best analysts forecasted a market recovery phase, with positive growth rates. The actual results, however, were drastic. Rising oil prices and falling demand (where American car manufacturers were particularly affected) soon led to a loss of corporate value with serious consequences of risk of bankruptcy and job losses. Indeed, GM's, Ford's and Chrysler's bond ratings were declining. At the end of 2008, GM's bond rating had fallen to CC, a full level below Chrysler's bond rating in 1981.

[8] Kumar B.R. (2012) Mergers and Acquisitions in the Automobile Sector. In: Mega Mergers and Acquisitions. Palgrave Macmillan, London. https://doi.org/10.1057/9781137005908_9

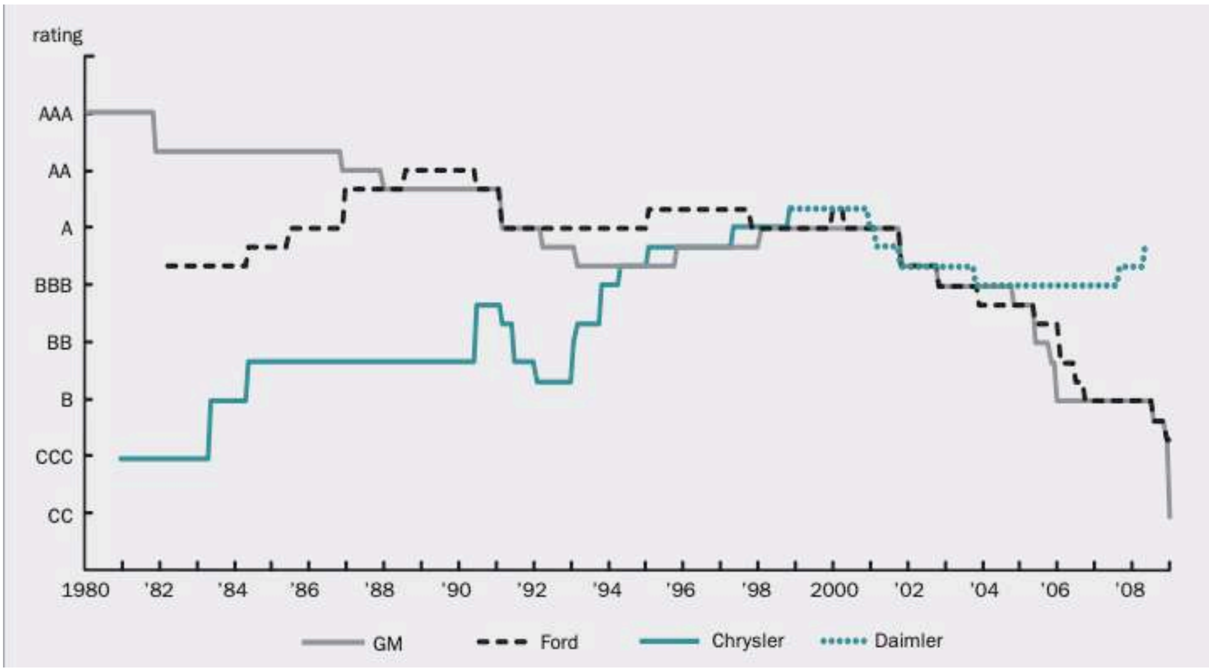


Figure 3: The Detroit Three's bond ratings, 1980-2008[9]

In 2009, the US government had to intervene to save jobs and proposed to carmakers the chance of a controlled administration, providing temporary funding to encourage new investments. While GM and Ford managed to persuade the government to implement a recovery plan thanks to the solid industrial organizational structure, Chrysler failed in an attempt to joint venture with Daimler. The government proposed FIAT as a possible part of the merger, which after two years allowed Chrysler to pay off the government debt and completely get out of the risk of bankruptcy.

The end of this phase, and the approach to the present day, leaves the sector with great changes and challenges:

1) Growth in the worldwide market in certain specific areas characterized by low manpower cost and a big potential market like in China and India.

2) Increase in the cost of petrol and natural gas (always critical resources in the global geopolitical situation);

3) Adoption of new energy-saving and anti-pollution policies;

4) access limitation of vehicles to urban centers and commercial vehicle on highways in order to reduce traffic density.

[9] Klier T. H., From tail fins to hybrids: How Detroit lost its dominance of the U.S. auto market, Thomas H. Klier, Econ Perspect, 2009

At the end of this chapter we will see what the feedbacks to these challenges are, in particular we will see the new trends that characterize the sector (paragraph 1.3), what is the regulatory position in terms of climate change (Chapter 3) and how the sector faces the worrying growth recorded in carbon dioxide emissions through technological and organizational solutions, parts of the supply chain management in the automotive sector (Chapter 4).

1.2. Leading carmakers worldwide

As we will see in the next paragraph, the automotive sector heavily affects the GDP and employment of nations. Carmakers offer three product levels. But first we need to establish what is meant by "product". The most generic definition of "product" can be cars, industrial vehicles, all-terrain vehicles, buses, tractors and sport utility vehicles (SUVs) without forgetting that some also produce motorcycles. Candelo E. proposes a more circumscribed definition, arguing that product means the various product lines / brands[10]. Like, for example, Fiat Chrysler Automobiles has various brands including Abarth, Alfa Romeo, Chrysler, Dodge, Fiat, Fiat Professional, Jeep, Lancia, Maserati, Mopar, Ram and Srt.

There are three level of products. The first level of product or “core products” is what the buyer acquires, for instance a car or a motorbike. The second level of product is the benefit obtained from a plurality of elements such as the assembled component parts, the quality, the characteristics, the style and the brand. Third level of product is obtained when the company offers additional benefits and services like financial services, insurances, warrantees and after-sales services.

The biggest auto manufacturers have a large global footprint, selling vehicles to consumers and businesses throughout the world. Next, we will see who the largest companies in terms of turnover are. We will see that these companies have their headquarters in Japan, Germany, U.S, Italy and South Korea. In terms of revenues and vehicle sale, Toyota and Volkswagen were the leading automakers worldwide in 2019.

[10] Candelo E., Il marketing nel settore automotive, G. Giappichelli Editore, Torino, 2009

Toyota generated around 30 trillion Japanese yen, or more than 280 billion U.S. dollars, in revenue in 2019[11]

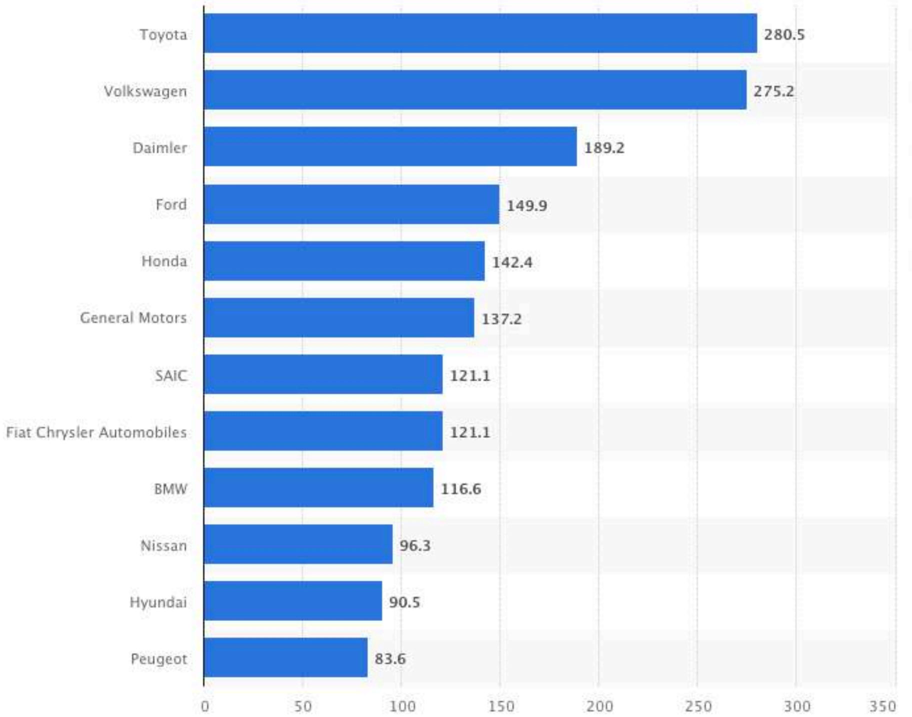


Figure 4: Revenue of leading automakers worldwide in 2019, in billion U.S. dollars

<u>#1 Toyota Motor Corp. (TM)</u>
Revenue: ¥30,225.6 billions ($272.3 billion)
Net Income: ¥1,882.8 ($16.9 billion)

Toyota is a Japan-based multinational. It is engaged in the manufacture and sale of motor vehicles. The company's products include mid-size, luxury, sports and specialty cars, recreational and sport-utility vehicles, pickup trucks, minivans, trucks and buses. It also provides financing, vehicle and equipment leasing, credit cards and insurance services to its dealers and their customers to support the sales of vehicles and other products manufactured by Toyota. It also offers intelligent transport systems, information technology and telecommunications, and housing. The company has operations in Japan, North America, Europe, and Asia. The company is headquartered in Toyota City, Aichi,

[11] Statista, https://www.statista.com/statistics/232958/revenue-of-the-leading-car-manufacturers-worldwide/

Japan and with its affiliates produce automobiles and related parts and components through 50 and above overseas manufacturing companies in 27 countries. Toyota sells its vehicles through approximately 169 distributors in more than 194 countries and regions. It was the first foreign manufacturer to build a dominant market share in the U.S. automobile market by setting the industry standard for efficiency and quality. Toyota's Automotive operations include the manufacture, design, assembly, and sale of passenger cars, minivans, and commercial vehicles such as trucks and related parts and accessories. Vehicle models include the Corolla, Camry, Avalon, Mirai, 86, GR Supra and the Prius.[12] Lexus is the company's luxury car division. The company has also stake in Subaru and Suzuki. Toyota shares are traded on the following domestic and overseas stock exchanges: Tokyo, Nagoya, Fukuoka, Sapporo, New York and London.

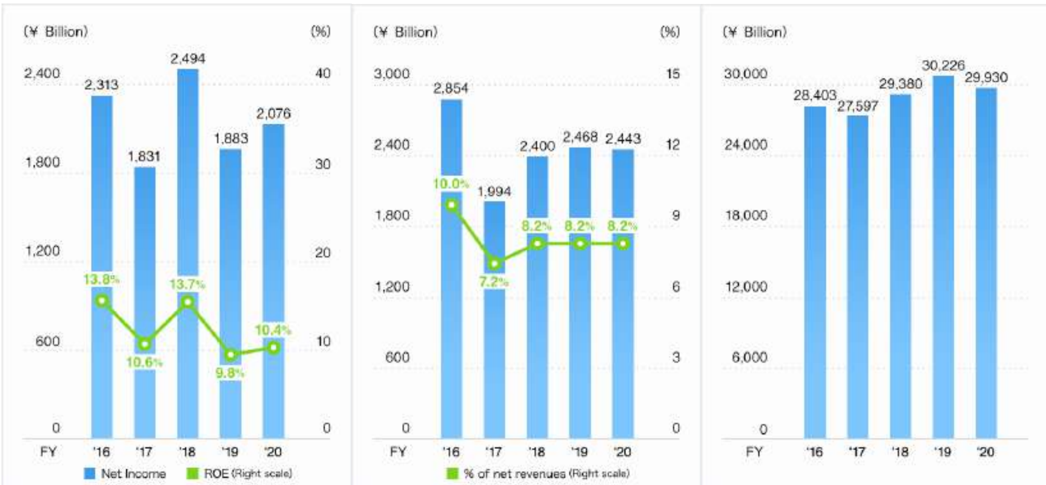


Figure 5: Financial Highlights of Toyota Motors Corporation, Net Income, Net Revenues and Total Revenues, 2016 - 2020[13]

[12] Toyota, https://www.toyota.com/cars/
[13] Toyota, https://global.toyota/en/ir/finance/

#2 Volkswagen AG (VWAGY)
Revenue: €252.6 billion
Net Income: €4.9 billion

Volkswagen is a Germany-based multinational automotive manufacturing company and is one of the world's leading automobile manufacturers and the largest car manufacturer in Europe. The group markets its vehicles under multiple brands, including Audi, SEAT, Skoda, Bentley, Bugatti, Lamborghini, Porsche, Ducati, Volkswagen Commercial Vehicles, MOIA, Scania, and MAN. Volkswagen conducts its business through four segments namely, passenger cars; Financial Services; Commercial Vehicles; and Power Engineering. The group performs operations across North and South America, Europe, Asia-Pacific and the Middle East. It is headquartered in Wolfsburg, Germany. On September 18th, 2015, the U.S. Environmental Protection Agency's (EPA) notice that Volkswagen's "clean diesel" vehicles were found to be in violation of the Clean Air Act. Indeed, the German auto maker admitted that "*it had deliberately equipped its line of Turbocharged Direct Injection (TDI) diesel engines with a "defeat device" that was intended to "bypass, defeat, or render inoperative elements of a vehicle's emission control system" during emissions testing*."[14] The estimated number of vehicles affected were 11 million vehicles. This scandal is also known as "*Dieselgate*". Volkswagen shares are traded on the following stock exchanges: Berlin, Düsseldorf, Frankfurt, Hamburg, Hanover, Munich, Stuttgart.

#3 Daimler AG (DMLRY)
Revenue: €172.7 billion
Net Income: €2.7 billion

Daimler is a Germany-based multinational automobile manufacturer with the headquarter in Stuttgart. The company is engaged in the development and manufacturing of various automotive products, primarily passenger cars, vans, off-road vehicles, and commercial vehicles, such as transport trucks and buses. It produces vehicles under a number of different brands, including Mercedes-Benz, AMG, BharatBenz, Maybach, EQ, Mercedesme, Smart, Fuso, Freightliner, Western Star, BharatBenz, Setra, Athlon and

[14] Blackwelder B. et. al., The Volkswagen Scandal, Robins School of Business, Richmond, 2016

Thomas Built Buses. Daimler offers also financing, leasing, fleet management, investments, credit card and insurance brokerage as well as innovative mobility services to private and vendors under the brands of Mercedes-Benz Financial Services, Mercedes-Benz Bank, Daimler Truck Financial. Daimler is owned by European, U.S. and other international investors. More than one billion shares (December 31, 2019) are circulating. The stock is listed on the stock exchanges in Frankfurt and Stuttgart.

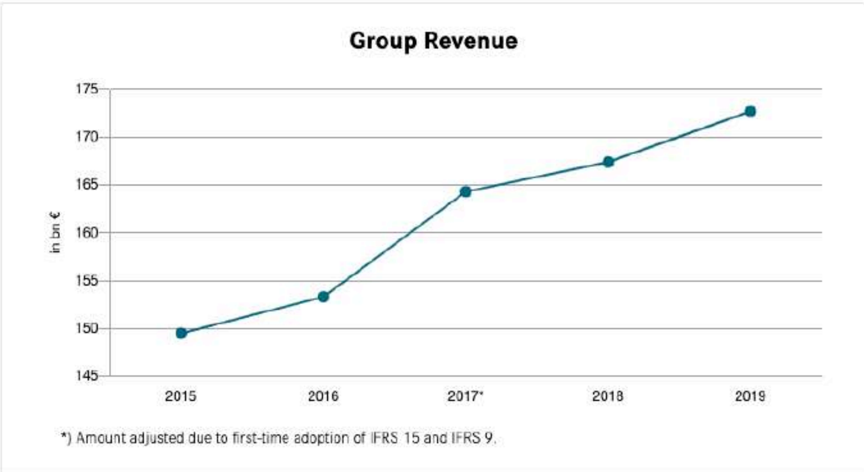


Figure 6: Daimler AG Total Revenues, 2015 - 2019[15]

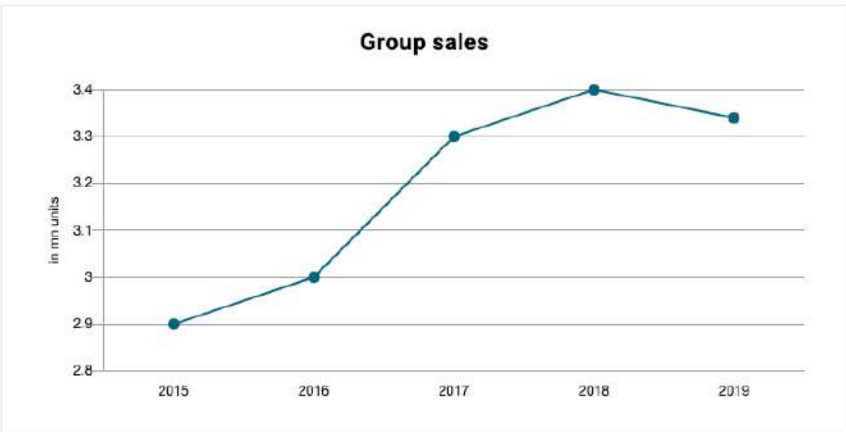


Figure 7: Daimler AG Sales, 2015 - 2019

[15] Daimler AG, https://www.daimler.com/investors/reports-news/annual-reports/2019/#tab-module-11472881

#4 Ford Motor Co. (F)

Revenue: $155.9 billion

Net Income: $84 billion

Ford is a multinational automotive manufacturer and one of the largest automotive manufacturers in the world. It is headquartered in Dearborn, Michigan. Its products inlcude cars, crossovers and sport utility vehicles (SUVS), trucks and vans, hybrids and EVS, commercial trucks, fleet vehicles, utility vehicles, vehicle accessories, and after sales vehicle parts and other related products. The company manufactures and distributes automobiles across six continents. It also provides financial services through Ford Motor Credit. Through Ford Certified Collision Network (FCCN), the company supports collision centers in delivering a higher standard of safe and quality collision repairs.

The company's key automotive vehicle brands include Ford and Lincoln. The company primarily operates in 61 plants globally, in North America, Europe, Asia Pacific, South America, and the Middle East and Africa.

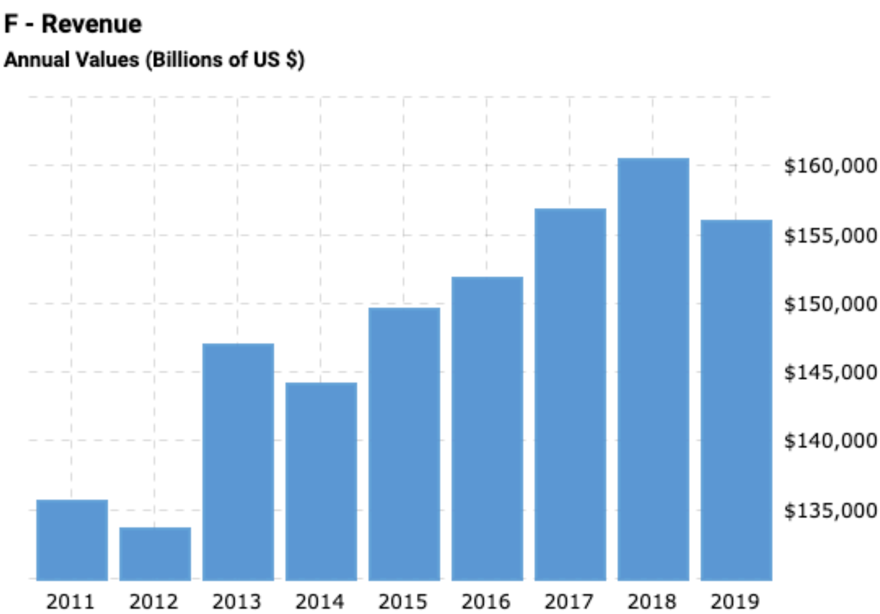


Figure 8: Ford Motor Total revenues, 2011 - 2019[16]

[16] https://www.macrotrends.net/stocks/charts/F/ford-motor/financial-statements

#5 Honda Motor Co. Ltd. (HMC)

Revenue: ¥11.8 billion ($143.1 billion)

Net Income: ¥680 million ($5.493 billion)

Honda is a Japan-based multinational automobile company. It manufactures passenger cars, trucks, vans, all-terrain vehicles, and motorcycles, as well as related parts. Honda also makes power products including tillers, generators, snow throwers, outboard engines, and lawnmowers, and aircraft and jet engines. The company also ventures into robotics and advanced technologies in the spirit of utilizing technology to help people with a prime focus on environment and sustainability. Honda has operations spread across different geographies, including, Asia and Oceania, Americas, Europe, Africa and the Middle East. The company is headquartered in Tokyo, Japan. Vehicle models include the Civic, Accord, Insight Hybrid, Passport, Odyssey, Fit and more. Acura is the company's luxury car division. The company also provides financial and insurance services. The stock is listed on the stock exchanges in New York and Tokyo.

#6 Bayerische Motoren Werke AG (BMWYY)

Revenue: $116.7 billion

Net Income: $5.5 billion

Bayerische Motoren Werke, known as BMW, is a German-based multinational headquartered in Munich, Bavaria. The company designs and manufactures luxury vehicles and motorcycles under several brands, including BMW, MINI, and Rolls-Royce Rolls-Royce, Alphera, Alphabet and Motorrad. BMW sells spare parts and accessories manufactured in-house, by foreign subsidiaries and by external suppliers. The company also offers insurance, automobile leasing, fleet management, retail and dealership financing, and customer deposit services. BMW operated 30 production and assembly facilities in 14 countries and had a global sales network in more than 140 countries. It operates globally with major presence in China, the US, and Germany. The company's stock is traded publicly on the Frankfurt Stock Exchange under the symbol BMW.

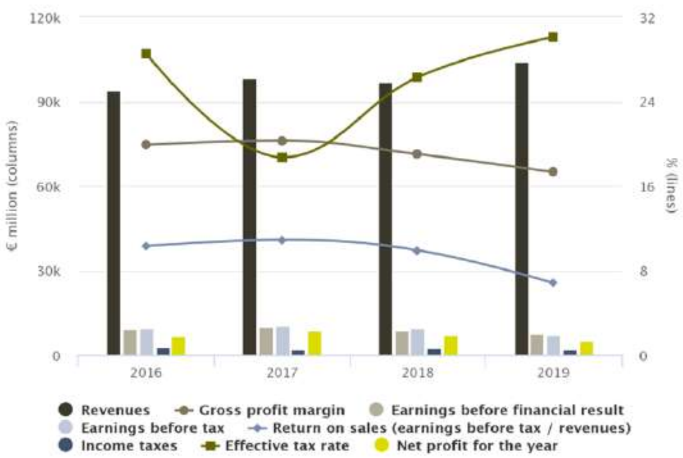


Figure 9: BMW Group Key Figures, Income statement, 2016 - 2019[17]

#7 General Motors Co. (GM)

Revenue: $137.2 billion

Net Income: $2.2 billion

General Motors is a multinational automobile manufacturer headquartered in Detroit, Michigan, that design, build and sell trucks, crossovers, cars and automobile parts worldwide. Cruise, formerly GM Cruise, is its global segment responsible for the development and commercialization of autonomous vehicle technology. The company also provides automotive financing services through General Motors Financial Company, Inc. (GM Financial). It produces vehicles under a number of different brands, including Chevrolet, Buick, GMC and Cadillac. It operates globally with major presence in North America, Europe, and South America.

#8 Fiat Chrysler Automobiles NV (FCAU)

Revenue: €108.2 billion

Net Income: €6.6 billion

Fiat Chrysler Automobiles NV is an Italy-based multinational automotive company headquartered in London, engaged in designing, engineering, manufacturing, distributing and selling vehicles, components and production systems worldwide through over a

[17] BMW Group, https://annualreport.bmwgroup.com/2019/company-key-figures

hundred manufacturing facilities and over forty research and development centers. The company has operations in more than forty countries and sell their vehicles directly or through distributors and dealers in more than a hundred and thirty countries. The company and its subsidiaries design, engineer, manufacture, distribute and sell vehicles for the mass-market under the Abarth, Alfa Romeo, Chrysler, Dodge, Fiat, Fiat Professional, Jeep, Lancia and Ram brands and the SRT performance vehicle designation. In addition, they design, engineer, manufacture, distribute and sell luxury vehicles under the Maserati brand. They make available retail and dealer financing, leasing and rental services through their subsidiaries, joint ventures and commercial arrangements with third party financial institutions. In addition, they operate in the components and production systems sectors under the Teksid and Comau brands. The company has 111 manufacturing facilities and 46 R&D centers across the world. FCA's Ordinary Shares are listed and tradable: (i) on the New York Stock Exchange (NYSE), in US dollars and (ii) on the Mercato Telematico Azionario (MTA) managed by Borsa Italiana, in euros.[18] On December 17, 2019, FCA N.V. and Peugeot S.A., a French Société Anonyme entered into a combination agreement (the "Original Combination Agreement") providing for the combination of FCA N.V. and Peugeot S.A. through a crossborder merger, with FCA N.V. as the surviving company in the merger.

#9 Hyundai Motor Co. (HYMTF)

Revenue: ₩105.7 billion ($90.5 billion)

Net Income: ₩3.1 billion ($2.6 billion)

Hyundai is a South-Korea based multinational automobile manufacturer, headquartered in Seoul. The company designs and manufactures passenger cars, trucks, and commercial vehicles. Vehicle models include the Centennial / Equus, Creta, Veloster, Azera, Sonata, i40, Elantra, Accent, ix35 Fuel Cell, Sonata Hybird, County, Aero Town, Super Aero City Santa Fe, Tucson / ix35 Universe and its Genesis luxury division. The company is part of the Hyundai Group, which includes companies with diverse market range, including steel, construction, auto parts, finance and services, information technology and software, and

[18] FCA Group, https://www.fcagroup.com/it-IT/investors/stock_info_and_shareholder_corner/Pages/stock_info.aspx

logistics. It has manufacturing presence in the US, China, India, Czech Republic, Turkey, Brazil, and Russia, besides South Korea.

#10 Nissan Motor Co. Ltd. (NSANY)
Revenue: ¥9.8 billion ($80.2 billion)
Net Loss: -¥671.2 billion (-$8.9 billion)

Nissan is a Japan-based multinational automotive company headquartered in Yokohama, Japan. It designs and manufactures passenger vehicles, forklifts, marine equipment, and related parts Vehicle models. The group markets its vehicles under Nissan, Datsun and Heritage brands while the company's luxury division is Infiniti. As well as the other brands, it also offers financing and leasing services. The group markets its vehicles under Nissan, Infiniti, Datsun and Heritage brands. It offers these products and services through its retail outlets in Japan and the countries across Europe, the Middle East, Africa, Asia Pacific and the Americas.

1.3. Evolution of mobility and trends transforming the auto industry

1.3.1. Global Automotive Industry 2019-2020

The automotive market is constantly expanding. Statistics provided by the International Organization of Motor Vehicle Manufacturers (OICA) gives us a global overview of total vehicle sold. In order to understand statistics we must understand the categorization of vehicles: (i) the number of Passenger Cars (PC) sold, (ii) the number of Light Commercial Vehicles (LCVs) and (iii) the number of Heavy Commercial Vehicles (HCVs) sold.
According to OICA glossary, passenger cars (PC) are "*motor vehicles with at least four wheels, used for the transport of passengers, and comprising no more than eight seats in addition to the driver's seat*." Light commercial vehicles are "*motor vehicles with at least four wheels, used for the carriage of goods. Mass given in tons (metric tons) is used as a limit between light commercial vehicles and heavy trucks*." This limit depends on national and professional definitions and varies between 3.5 and 7 tons. Minibuses, derived from light

commercial vehicles, are used for the transport of passengers, comprising more than eight seats in addition to the driver's seat and having a maximum mass between 3.5 and 7 tons. Transport sector consists mainly of rail and road segments: railways carry long distance heavy cargo such as fertilizer, steel, grain, salt etc. and HCVs are considered as vehicles that compete with (or can replace) railways. LCVs are preferred for high volume low bulk cargo such as consumer goods, textiles, for short distance haulage. An LCV is defined in the Motor Vehicles Act as a vehicle with gross vehicle weight (GVW) of not more than 6 ton. An HCV is defined as vehicle with GVW of more than 6 ton. Gross vehicle weight is defined as vehicle weight plus rated payload. Rated payload is the maximum weight permitted to be loaded on the vehicle under Motor Vehicle Act.

Heavy trucks are vehicles intended for the carriage of goods. Maximum authorized mass is over the limit (ranging from 3.5 to 7 tons) of light commercial vehicles. They include tractor vehicles designed for towing semi-trailers. Buses and coaches are used for the transport of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass over the limit (ranging from 3.5 to 7 tones) of light commercial vehicles.[19]

Global Production: Total Vehicles

In the last decade, vehicle sales in 2010 were about 75 million and turned into 96 million in 2017, with a growth of 28%, equal to 21 million new vehicles. Then the market has dropped to 95.8 million in 2018 and 91.5 million in 2019. In the decade, the contribution to the increase in demand (16.4 million) is attributable for 45% to the BRIC countries (Brazil, Russia, India and China), for 51% to the traditional markets of Western Europe, USA / Canada and Japan and 4% to the rest of the world. In Europe there are 226 automobile assembly and production plants, Germany, France, the United Kingdom, Italy and Spain are the main producers in terms of the number of plants and cars.

[19] Hernandez U., Miller J., Methodological notes: global vehicle sales database, Working Paper 2015-7, International Council of Clean Transportation, 2015

Figure 10: Automobile assembly and engine production plants in Europe, 2019

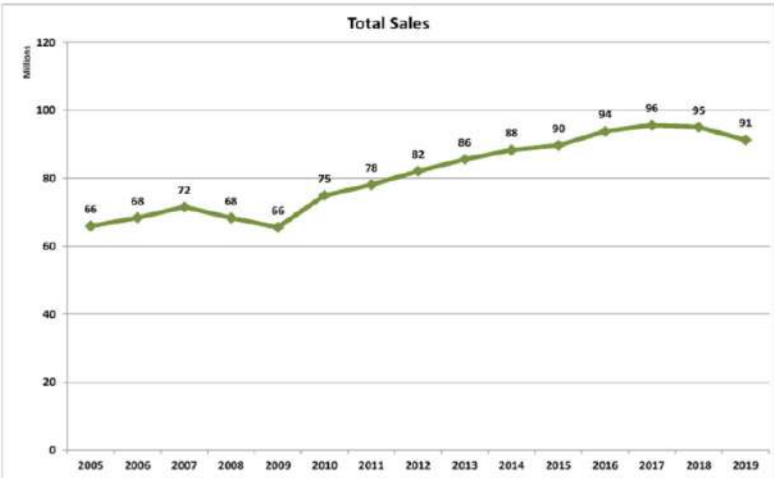
49% of the 226 European automobile assembly and production plants are for the production of passenger cars, the other 50% is dedicated to the production of VANs, Trucks, Buses and engine.

Figure 11: Type of vehicles distribution in Europe[20]

During FY 2019 91.5 million vehicles were sold (-4.5% on 2018), over 4.3 million less than in 2018, of which 3.7 million in the Asian continent. The world sales trend was marked above all by the downturns in the motor vehicle market in China, -8.1%, following the previous one of 3% in 2018, and in India (-13.3%).

[20] ACEA

REGIONS/COUNTRIES	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EUROPE	21.063.326	21.863.840	23.006.722	21.872.430	18.645.351	18.808.688	19.740.019	18.663.178	18.343.409	18.587.650	19.035.989	20.134.829	20.755.099	20.813.423	20.868.884
NAFTA	20.242.979	19.899.024	19.301.479	16.240.451	12.859.351	14.203.961	15.597.614	17.526.688	18.764.508	19.910.156	21.174.615	21.497.241	21.119.818	21.207.105	20.815.530
CENTRAL & SOUTH AMERICA	3.095.875	3.457.651	4.307.586	4.662.450	4.637.694	5.516.020	5.980.425	6.144.205	6.265.497	5.565.375	4.513.544	4.051.971	4.333.536	4.752.970	4.493.646
ASIA/OCEANIA/MIDDLE EAST	20.408.597	21.818.586	23.625.638	24.284.313	28.267.659	35.191.633	35.405.435	38.225.604	40.579.135	42.556.996	43.410.904	46.857.884	48.546.885	47.647.121	44.003.150
AFRICA	1.113.017	1.314.275	1.321.974	1.255.851	1.158.774	1.251.221	1.446.927	1.569.463	1.653.587	1.717.921	1.549.556	1.314.463	1.137.481	1.228.924	1.177.247
ALL COUNTRIES	65.923.794	68.353.376	71.563.399	68.315.495	65.568.829	74.971.523	78.170.420	82.129.138	85.606.136	88.338.098	89.684.608	93.856.388	95.892.819	95.649.543	91.358.457



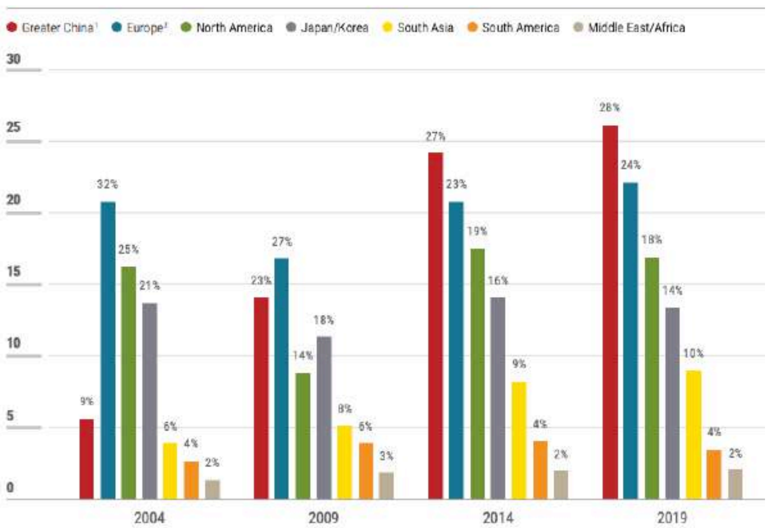


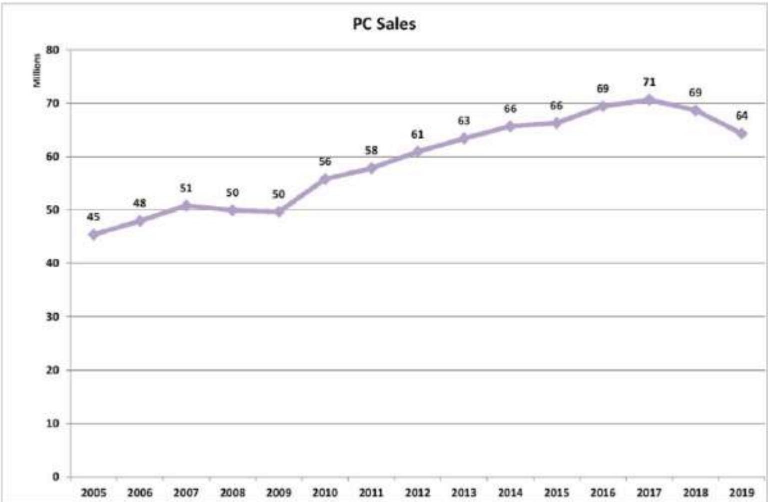
Figure 12: World motor vehicle production, million units, % share, 2004-2019[21]

[21]ACEA, IHS MARKIT, OICA

Global Production: Passenger Cars

During FY 2019, the global demand for PC amounted to 64.3 million units (-6.4% on 2018 volumes), while the demand for commercial and industrial vehicles was 27.22 million (+ 0.2%).

REGIONS/COUNTRIES	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EUROPE	17.906.455	18.685.556	19.618.588	18.821.599	16.608.761	16.499.863	17.167.600	16.191.269	15.942.273	16.154.279	16.410.563	17.291.819	17.974.281	17.909.677	17.972.774
NAFTA	9.221.429	9.301.364	9.045.313	8.230.872	6.569.033	6.833.529	7.363.460	8.639.763	9.039.173	9.194.809	9.121.342	8.599.729	7.704.315	6.752.475	5.973.328
CENTRAL & SOUTH AMERICA	2.397.500	2.747.450	3.477.058	3.646.651	3.711.649	4.298.085	4.584.491	4.749.693	4.780.657	4.269.758	3.543.111	3.146.431	3.579.086	3.810.517	3.566.864
ASIA/OCEANIA/MIDDLE EAST	15.097.677	16.293.923	17.754.371	18.389.909	21.938.382	27.278.736	27.673.657	30.201.657	32.470.264	34.843.066	36.110.706	39.445.239	40.594.317	39.283.920	35.959.799
AFRICA	784.237	926.966	939.201	889.206	827.160	908.357	1.050.745	1.154.025	1.196.833	1.246.318	1.128.433	981.214	842.835	921.623	868.928
ALL COUNTRIES	45.407.298	47.955.259	50.834.531	49.978.237	49.654.985	55.818.570	57.839.953	60.936.407	63.429.200	65.708.230	66.314.155	69.464.432	70.694.834	68.678.212	64.341.693



In 2019, the market mix changes, with diesel car sales falling by 13.9%, petrol car sales rising by 5% and alternative fuel vehicles rising by 41% to account for 11.2% of the market. This sudden turnaround in the sales mix is the result of the "*Dieselgate*" scandal (falsification of emission values for diesel vehicles sold in the USA and Europe), which caused considerable damage to the image of the European car industry and triggered a veritable campaign of "demonisation" of diesel by the media and local institutions. The latter have responded by restricting or banning traffic in city centers.

Among the major markets, diesel car sales represent the 32% of the market in Germany, with a slight volume recovery of 3.7% on 2018, 34% in France (-10.6%), 28% in Spain (-26%), 25% in the United Kingdom (-22%) and 39.8% in Italy (-22%). The effects of the demand decline for diesel cars materialized already in 2017 with an increase of 0.4 g / km in the overall average CO_2 emissions of new cars sold, followed by an increase of almost

2 g / km in the 2018 and again in 2019 by 2.8 g / km, due to the increase in sales of petrol cars that have higher CO2 emission levels than diesel versions and the increase in vehicle mass. The sales increase of alternative-fuel cars was not enough to contain the increase in carbon dioxide emissions.

The manufacturers have had to change strategic plans, the production mix for power supply and arrange massive investments for the electrification of vehicles. Achieving the CO2 emission reduction targets for 2020-2021, but especially for 2025-2030, is hard without a massive release of electric vehicles on the market. In addition to the widespread diffusion of the charging infrastructure throughout the territory, there are still two other types of problems: one linked to the production of batteries, now on China hands, the other linked to the production of energy from renewable sources to bring the pollution level produced by vehicles closer to zero.

During the FY 2020, world economic activity suffered a drastic decline due to the containment measures of the pandemic. In the 1st half of 2020 the production losses, due to Covid-19, in the main production macro areas, amounted to over 11 million units and correspond to 15% of the total production of the areas considered in 2019.

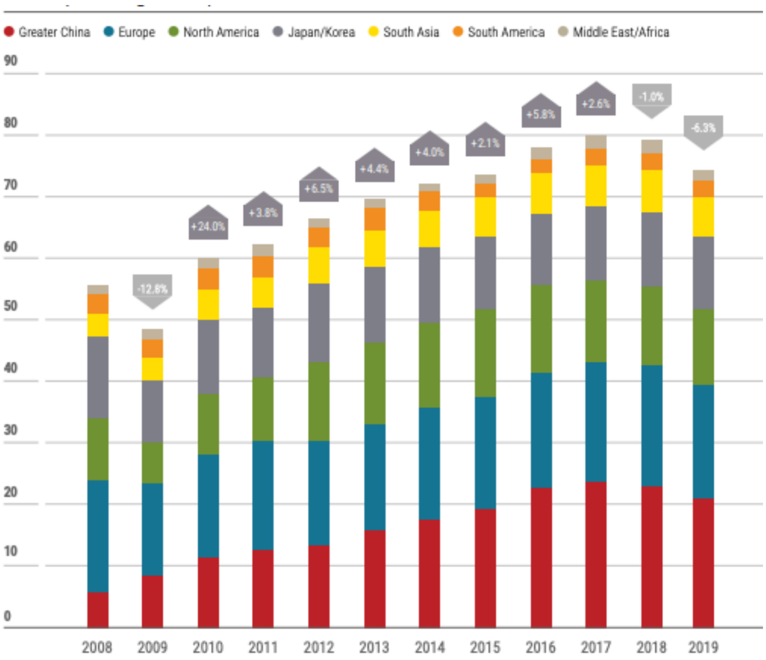


Figure 13: World passenger car production, million units, % change, 2008 - 2019[22]

[22] IHS, MARKIT, OICA

International trade in goods decreased in volume by 12.5%, a value without historical precedent.[23] Assets such as autonomous driving and shared mobility could instead be very damaged by the extension of the epidemiological emergency. The sharp drop in oil prices may also slow demand for electric vehicles in the short-term, but growth will continue in the long term. In the first half of the year, the demand for electrified cars in the EU / EFTA / UK is however growing (+ 61% ECV and 7.9% share, + 16% HEV and 10.1% share), despite the strong contraction of market (-39%). Recall that 2020 is the target year for EU CO2 emissions standards, which limit the average CO2 emissions per kilometer of new car sales. Moreover, ECV car sales in some countries such as Germany, which increased subsidies for the purchase of electric cars in February, and Italy, which introduced zero- and ultra-low-emission car purchase incentives, have started to affect the market.

Employment

At the end of 2018, in Europe the automotive sector provides direct and indirect work to 14.6 million Europeans, representing a sizeable 6.7% of total employment in the European Union. With 2.7 million people working on the manufacturing of vehicles across 226 factories in the EU, the auto industry accounts for 8.5% of total manufacturing jobs in the region. Indirect jobs include non-manufacturing jobs (11.0m) and indirect manufacturing jobs (9.7m), while direct jobs include direct manufacturing jobs (2.7m).

Figure 14: Employment in the EU automotive sector, million jobs, 2014-2018[24]

[23]ANFIA, L'industria automotive mondiale nel 2019 e trend 2020, Area Studi e Statistiche, 2020

[24] EUROSTAT

EU automotive employment	2014	2015	2016	2017	2018	% change 18/17
Direct manufacturing	2,369,951	2,441,910	2,491,693	2,597,345	2,685,478	3.4
Indirect manufacturing	892,885	910,004	899,647	958,152	967,925	1.0
Automobile use	4,264,490	4,304,382	4,453,169	4,531,379	4,657,198	2.8
Transport	4,980,618	5,047,587	5,229,789	5,390,441	5,591,549	3.7
Construction	641,931	675,338	650,011	705,199	727,230	3.1
TOTAL	**13,149,875**	**13,379,221**	**13,724,309**	**14,182,516**	**14,629,380**	**3.2**

Direct manufacturing means motor vehicles, bodies (coachwork), trailers and semi-trailers, parts and accessories. Indirect manufacturing includes rubber tyres and tubes, retreading and rebuilding of rubbery tyres, computers and peripheral equipment, electric motors, generators and transformers, bearings, gears, gearing and driving elements, cooling and ventilation equipment. Under automobile use we find sales of motor vehicles, maintenance and repair of motor vehicles, sale of motor vehicle parts and accessories, retail sale of automotive fuel in specialised stores, renting and leasing of motor vehicles. Transport includes other passanger land transport and freight transport by road. Finally, construction involves road and motorways construction plus bridges and tunnel construction.

Aftermarket Industry

The aftermarket industry includes the maintenance and repair of vehicles and the sale of replacement parts and services.

The service business accounts for approximately 45% of total aftermarket sales in Europe, while the retail and wholesale of vehicle parts accounts for the remaining approximately 55%. Together, the two businesses are an important part of the overall automotive industry, delivering significant sales of approximately $760 billion globally (2015), or approximately 20% of total automotive sales, and higher profitability than most other subsectors of the industry.[25] The challenges are manifold: the vehicle fleet in Germany, for example, is getting older and older, with an average age of 9.3 years. This means that familiar tasks are becoming even more demanding: spare parts have to be

[25] Breitschwerdt D., Cornet A., Kempf S., Michor L., Schmidt M, The changing aftermarket game – and how automotive suppliers can benefit from arising opportunities, McKinsey & Company Inc. Report, 2017

made available for an even longer period at reasonable cost. In addition, there are completely new challenges, for example due to the transition from old to new technologies or the advancing automation. Repair concepts and training requirements must therefore be updated.

New players are starting to enter the automotive market and incumbents are changing their business models - a trend that will continue in the future. In addition, the younger generation is no longer interested in owning a car and the now stricter emission regulations are pushing the purchase of electric vehicles.

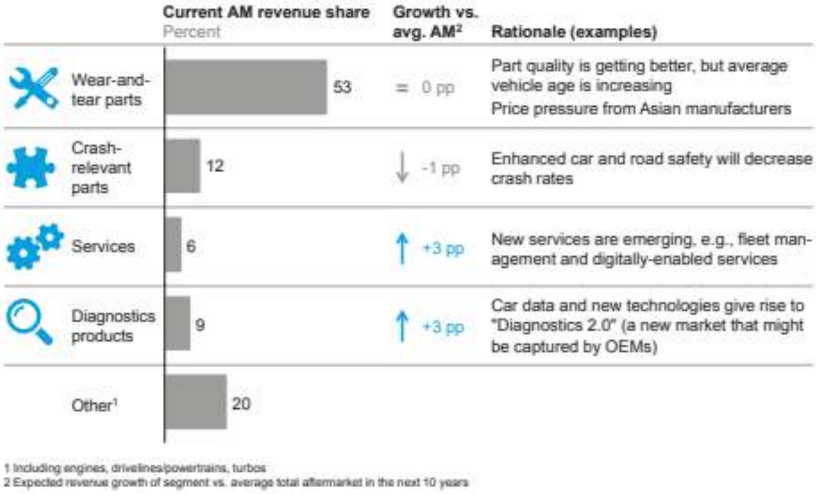


Figure 15: Current Aftermarket revenue share in 2017[26]

Advancing digitization and rising trend of Internet-of-Things (IoT) is expected to significantly impact the industry growth.

The global automotive aftermarket was estimated at $ 378.4 billion in 2019, and before the existence and impact of COVID -19 was known, it was expected to grow at a CAGR of 4.0% from 2020 to 2027.

As we have seen, not only cars, but also the aftermarket sector has suffered a loss of income due to prolonged maintenance intervals and lower annual distances traveled due to the limitation to the movement of people and non-essential goods during the lockdown.

[26] McKinsey&Company

COVID-19 impact

COVID -19 remains one of the main factors impacting the global automotive sector, but a slowdown in the automotive industry was already underway before the pandemic, with a declining trend due to the decreasing contribution from mature markets.[27]

The effect of the coronavirus on the European automobile industry is unprecedented. Most vehicle manufacturers have had to shut down their development and production sites for several weeks or even months this year.[28] These figures show the impact of the coronavirus on production and employment at the peak of the crisis (March-May 2020):

	Employees affected[1]	Estimated loss in production[2] (number of vehicles)	Average shutdown duration[1] (in working days)
Austria	14,307	26,480	34
Belgium	30,000	33,360	25
Croatia	700	–	29
Czech Republic	45,000	155,060	29
Finland	4,500	11,604	25
France	90,000	278,425	34
Germany	568,518	616,591	30
Hungary	30,000	51,552	22
Italy	69,382	157,933	41
Netherlands	13,500	30,819	25
Poland	17,284	101,957	36
Portugal	20,000	41,525	35
Romania	20,000	68,673	31
Slovakia	20,000	114,632	24
Slovenia	2,890	19,399	27
Spain	60,000	452,155	34
Sweden	67,000	23,464	15
United Kingdom	65,455	262,715	41
TOTAL (EU+UK)	1,138,536	2,446,344	30

Figure 16: Impact of COVID on the EU automobile industry[29]

Jobs of more than 1.1 million Europeans working in the automotive sector were directly affected by factory shutdowns during the lockdown period. EU-wide production losses amounted to more than 2.4 million vehicles during the peak crisis months of March, April and May 2020 alone; which is 13% of total production in 2019.[30]

[27] Vitale J., Understanding COVID-19's impact on the automotive sector, Deloitte, 2020
[28] Carriero A. et. al., Settore Automotive e Covid-19. L'economia italiana, dalla crisi alla ricostruzione: Scenario, impatti, prospettive, CDP, Ernst & Young, Luiss Business School, 2020
[29] ACEA, OEM, IHS Markit Production Forecast
[30] European Automobile Manufacturers Association, The Automobile Industry Pocket Guide, 2020

In April 2020 new car registrations in European Union reached their lowest level since World War II. The crisis is rather due to the negative sentiment around the demand side as confirmed by the collapsing consumer confidence index (CCI) in all European markets. Most of those who were intending to buy a car before the crisis are now undecided and it is likely to take several months before the market makes a full return.

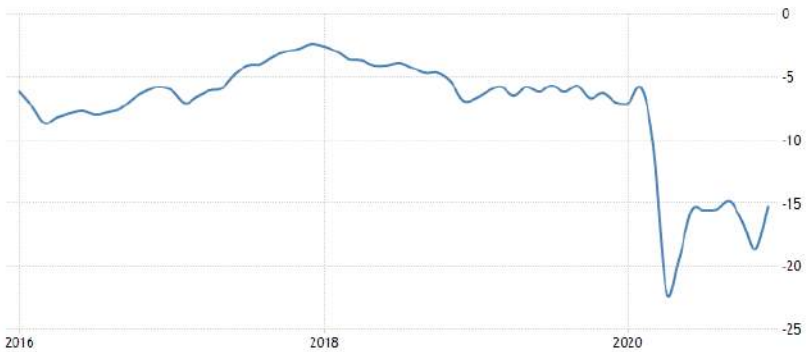


Figure 17: Euro Area Consumer Confidence 2016 - 2020[31]

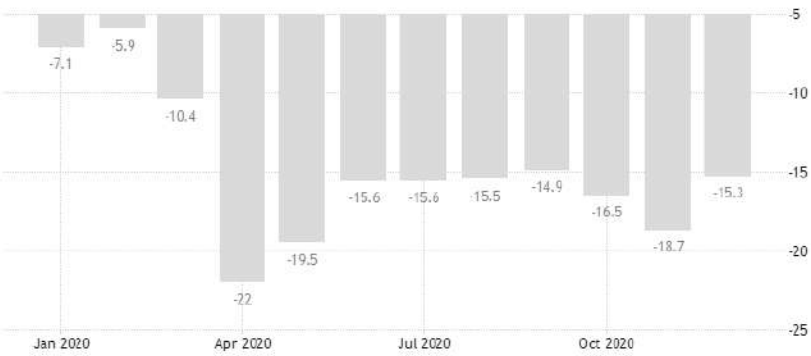


Figure 18: Euro Area Consumer Confidence Jan 2020 - Dic 2020[32]

New car registrations at European Union fell 12% year-on-year to 897,692 in November 2020, following a 7.8% drop in the previous month, as several European governments introduced new measures to curb the second wave of the COVID -19 pandemic. The EU's four main car markets all posted declines. France (-27%) and Spain (-18.7%) suffered

[31] Trading economics, European Commission
[32] Trading economics, European Commission

double-digit declines, followed by Italy (-8.3%) and Germany (-3%). From January to November, the EU passenger car market contracted by 25.5% to around 9 million units.

Figure 19: Passenger cars registrations Gen 2016 - Dec 2020[33]

Potential long-term impact on automotive companies is:

- A peak of consumer demand since countries has to tackle national problems like recession and loss of consumer confidence. Also the automotive sector revenues and profitability are, and will be, affected.
- Automaker may have to relocate funds from R&D investments into loss coverage.
- Strategic decisions may be accelerated for instance, to exit unprofitable global markets and vehicle segments.
- Companies dealing with liquidity problems may rapidly give up, causing widespread disruption and potentially catastrophic consequences across the entire global automotive manufacturing ecosystem.
- A significant amount of restructuring may be expected in the auto retail sector as dealers are unable to pivot quickly enough to changing demand conditions[34]

The recession caused by the pandemic could take the automotive sector a while longer to overcome than in previous crises, analysts estimate a period variable between 3 and 5 years.[35]

[33] Trading economics, European Automobile Manufacturers Association
[34] Crawford S., How can your industry respond at the speed of COVID-19's impact?, Ernst & Young Report, 2020
[35] Sorensen J., Telang R., COVID-19 and the automotive industry, PwC Report, 2020

1.3.2. New trends in the auto industry

The automotive industry has constantly invested in innovation and research to offer all combinations of products to meet every need and preference of the end user. Younger, tech-savvy and sustainability-conscious generations are leading to the need to restructure the industry. Business model and strategy development are just two examples of the transformation required of the Automotive Industry in this "era of change." Moreover, since the introduction of smartphones, consumers are able to adapt quickly to any technological change and are willing to invest in complex and expensive changes if they make the user's life easier.[36]

In addition, as environmental awareness grows and efforts to connect vehicles increase, automakers face a host of new challenges. Market trends such as the shift towards lighter materials and the trend towards electric and autonomous vehicles will revolutionize the industry. External factors such as climate change and pressure from supranational and national institutions are forcing the industry to meet urgent climate change mitigation and related stringent regulations to be more protective of the environment and human health. For years, the global automotive industry has been investing in research and development aimed at reducing Co2 emissions and improving road safety. An evolution of mobility, encompassing vehicles, infrastructures and energy resources, requires a reassessment of how investments and the uptake of new technologies are managed, and involves new players from outside the industry. New technologies are being implemented: digital technologies (e.g. 3D printing, the Internet of Things, advanced robotics), new materials, new processes (e.g. data production, artificial intelligence, synthetic biology). This evolution of the supply chain will have far-reaching consequences for productivity, employment, skills, income distribution, trade, well-being and the environment.

Many existing skills will be overtaken by new technologies and new software, making the audience of stakeholders ever wider and more competitive. Hence the need to transform current business models and search for new skills as a differentiating factor for traditional players. The creation of new partnerships and the creation a corporate culture to foster innovation, are key features to compete in new technological areas. Social context and

[36] Kuhnert F. et. al., Five trends transforming the Automotive Industry, PwC Report, 2018

new forms of mobility are changing (imagine shared mobility), driven (i) by a more society awareness to environmental problems and road safety; (ii) by growing urbanization; (iii) by new mobility models related to the use and not to the ownership of the car; (iv) by improvements in technologies.

The new requirements for the components supply that will be needed in the evolution towards electric, connected and self-driving vehicles will concern traction (electric motor, batteries and transmission components) since the electric motor is much less complex than the ICE motor; advanced driver assistance systems and autonomous functions (adaptive suspension, active steering and braking systems, vision sensors); the application of new materials; new technologies (extended infotainment solutions); the interior design (increased internal insulation, gesture recognition, augmented reality display).[37]

Low or zero emission vehicles, connected vehicles, shared vehicles and self-driving vehicles are the new paradigms of the global automotive industry.

Low or zero emission vehicles

The first paradigm considers the shift from conventionally powered vehicles to alternatively powered vehicles. *Conventional vehicles* use fossil fuels (diesel and petrol) to power an internal combustion engine (ICE). Both diesel and petrol engines convert fuel into energy via combustion, with the main difference being the way the combustion process occurs.

Diesel fuel has a higher energy content per litre than other fuels. Moreover, diesel engines convert more of this energy into useful work. Due to these two factors, diesel vehicles consume less fuel by volume than equivalent petrol vehicles.

Consequently, diesel vehicles have lower average CO2 emissions per kilometre than equivalent petrol-powered ones. Although this gap is narrowing, it still remains significant. According to a recent report by the European Environment Agency (EEA), "*if similar petrol and diesel segments are compared, new conventional petrol cars emitted 10-40% more [CO2] than new conventional diesel cars*".

[37] Saglietto M., L'evoluzione della mobilità e la trasformazione dell'industria automotive, Edizioni Ca' Foscari, Torino, 2018

Alternatively-powered vehicles (APVs) are vehicles powered by technologies alternative to, or supplemental to, conventional internal combustion engines using fossil fuels. APVs are:

(1) Electric vehicles,
(2) Hybrid Electric vehicles and
(3) Natural Gas vehicles.

As explained by ACEA, the main types of APVs are the following:

(1) Electric vehicles include *electrically chargeable vehicles* (ECVs) and *Fuel Cell Electric vehicles* (FCEVs). Both are powered by an electric motor, but require very different infrastructure:

A. *Electrically-chargeable vehicles* (ECVs) include full battery electric vehicles and plug-in hybrids, both of which require recharging infrastructure which connects them to the electricity grid: *Battery electric vehicles (BEVs)* are fully powered by an electric motor, using electricity stored in an on-board battery that is charged by plugging into the electricity grid. *Plug-in hybrid electric vehicles (PHEVs)* have an internal combustion engine (running on petrol or diesel) and a battery-powered electric motor. The battery is recharged by connecting to the grid as well as by the on-board engine. Depending on the battery level, the vehicle can run on the electric motor and/or the internal combustion engine.

B. *Fuel cell electric vehicles (FCEVs)* are also propelled by an electric motor, but their electricity is generated within the vehicle by a fuel cell that uses compressed hydrogen (H2) and oxygen from the air. So, unlike ECVs, they are not recharged by connecting to the electricity grid. Instead, FCEVs require dedicated hydrogen filling stations.

(2) *Hybrid electric vehicles (HEVs)* have an internal combustion engine (running on petrol or diesel) and a battery-powered electric motor. Electricity is generated internally from regenerative braking, cruising and the combustion engine, so they do not need recharging infrastructure. The *hybridisation* level ranges from mild to full.

A. *Mild hybrid electric vehicles* are powered by an internal combustion engine, but also have a battery-powered electric motor that supports the conventional engine. These vehicles cannot be powered by the electric motor alone.
B. *Full hybrid electric vehicles* are powered by both an electric motor and a combustion engine, each of which (or together) can power the wheels.[38]

(3) *Natural gas vehicles (NGVs)* run on compressed natural gas (CNG) or liquefied natural gas (LNG), the latter mainly being used for commercial vehicles such as trucks and the former for passenger cars. NGVs are based on mature technologies and use internal combustion engines. Dedicated refuelling infrastructure is require.[39]

In order to drive the shift to zero- and low-emission vehicles, governments across the EU need to ramp up investments in charging and refueling infrastructure and need to put in place meaningful and sustainable incentives to stimulate sales of alternatively-powered vehicles.

	2014	2015	2016	2017	2018	2019
Petrol	5,358,452	6,036,564	6,800,116	7,563,739	8,521,418	8,964,034
Diesel	6,599,462	7,039,611	7,175,630	6,617,051	5,402,079	4,650,558
Electrically-chargeable	69,958	148,027	155,634	218,083	300,258	458,915
— Battery electric	37,517	59,165	63,479	97,667	147,428	284,812
— Plug-in hybrids	32,441	88,862	92,155	120,416	152,830	174,103
Hybrid electric	176,525	218,755	278,729	426,769	598,462	896,785
Fuel cell	38	176	123	253	266	535
Natural gas (CNG)	97,214	78,511	57,609	49,553	65,023	68,581
Other (LPG + E85)	141,452	140,321	118,430	156,710	164,270	187,378

Figure 20: Trends over time in the EU, units, 2014-2019[40]

Some people presume that the term ‘electrified’ or ‘electric’ refers exclusively to battery electric vehicles (BEVs) that are fully powered by electricity and have no CO2 coming from their tailpipe. However, in practice ‘electrified’ and ‘electric’ are often used as blanket terms for all available electrification technologies, ie BEVs, PHEVs and HEVs. The reality

[38] ACEA, Making the transition to zero-emission mobility: 2020 Progress Report, 2020
[39] Zeinab Rezvani, Johan Jansson, Jan Bodin, Advances in consumer electric vehicle adoption research: A review and research agenda, Transportation Research Part D: Transport and Environment, Volume 34, 2015, pp. 122-136
[40] ACEA

is that each of these technologies has different requirements in terms of infrastructure as well as varying CO2 reduction levels.

Connected vehicles

In the early stages of 2000, the U.S Department of Transportation (DOT) developed the Vehicle-Infrastracture Integration (VII), a program that was part of its Intelligent Transportation System (ITS). The main goal was to improve significantly safety and mobility on roadways. It resulted with the creation of "*intelligent vehicles*" which communicate wirelessly[41]. This term actually represents two concepts at once. On the one hand, it applies to Vehicle-to-Vehicle (or Car2Car) and Vehicle-to-Infrastructure (or Car2X) communication, which is the networking of the car with other cars or with the transport infrastructure (such as traffic lights). On the other hand, the term also covers the networking of vehicle occupants with the outside world. In future, they will be able to communicate, work, surf the internet or access multi-media services during the journey.
A connected car may therefore be defined as "*the presence of devices in an automobile that connect devices within the car/vehicles together or with devices, networks and services outside the car including other cars, home, office or infrastructure*"[42]
Among other benefits, this technology will help provide for increased capacity of existing transportation networks in addition to increased roadside safety for motorists through the development of an overall Intelligent Transportation System. However, before we can even consider how to integrate the technology of CV into our transport system, professionals must understand and realize its environment and how future cities to be created. Environmental benefits arisen when connected vehicles are settled. As we will discuss more deeply on the next chapter, the principal pollutants of vehicle emission include nitrous oxides, Sulfur oxides, and Carbon monoxide, which have negative health effects. Connected vehicle technologies will generate real-time data that drivers and transportation managers can use to make green transportation choices[43].

There are different, but not necessarily separate, types of connected applications:

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[41] Brunch J. et. al., Intelligent Transportation Systems Benefits, Costs, Deployment and Lessons Learned: 2011 Update, Research and Innovative Technology Administration, Washington DC, 2011, pp. 16-17
[42] Jadaan K. et. al., Connected Vehicles: An Innovative Transport Technology, Procedia Engineering, Volume 187, 2017, pp. 641-648
[43] Hill J. C., AASHTO Connected Vehicle Infrastructure Deployment Analysis, American Association of State Highway and Transportation Officials Report, Washington DC, 2011.

Safety applications: Connected car safety applications that increase situational awareness and reduce or prevent accidents include driver cues, driver alerts, and vehicle and/or infrastructure controls.

V2V applications: V2V applications warn drivers of impending collisions, such as merging trucks, cars in the driver's blind spot, or when a vehicle ahead suddenly stops. These include: Forward Collision Warning, Emergency Electronic Brake Light, Blind Spot/Lane Change Warning, No Passing Warning, Intersection Movement Assist, and Left Turn Assist.

V2I applications: V2I apps alert drivers when they are entering a school zone, when workers are on the side of the road, and when a traffic light is about to change. These include: Curve Speed Warning, Red Light Violation Warning, Stop Sign Gap Assistant, Smart Roadside, and Transit Pedestrian Warning.

Mobility applications: mobile phone bandwidths and current wavelengths used for wireless traffic detection equipment, can be used for mobility applications. Collecting real-time transportation data from CVs, can provide more timing data to travelers and traffic institutions.

Environmental applications: Environmental applications for connected vehicles can provide drivers with real-time information on how to save fuel through changes in maintenance and driving style. They also improve the integration of public transport and private vehicles by offering the possibility to get advice on when to plan trips (outside peak hours).[44]

Even though these vehicles provide to the entire society a step up on different levels of efficiency; potential misuses of personal data and violation of privacy, a poor security

[44] Jadaan K. et al., Connected Vehicles: an Innovative Transport Technology, Procedia Engineering 187, 2017, pp. 641-648.

system that could easily hacked and high cost of implementation are still considered as the main constraints and both public and private concerns.

Autonomous/Self-driving vehicles

Mobility is now on the threshold of one new frontier, the digital one, which, with the increase of automation and connectivity, will allow vehicles to communicate with each other, with the road infrastructure and with other users of the streets. These developments thanks also to achievements in the field of artificial intelligence, they open the way to a totally new level of cooperation between road users, which could bring enormous benefits to them and to the entire mobility system, for example by making safer, more accessible and more sustainable transport.[45] Autonomous vehicles will change our lives, as has happened in the past with stream trains and cars, and will define the future of road transport, with the possibility of significantly reduce costs. Such vehicles could give birth to new services and offer innovative methods to respond to the growing demand for mobility of people and goods. Autonomous vehicles could significantly improve road safety, as it is estimated that the 94% of accidents are attributable to human error.[46] Such vehicles could guarantee the mobility to people unable to drive independently (for instance the elderly or disabled) or not sufficiently served by public transport, encouraging car systems sharing and the concept of "*mobility as a service*" (selling, for example, ran instead of Automobiles). Thanks to autonomous vehicles, it could also speed up the process electrification of vehicles and electromobility. Finally, autonomous vehicles could allow to free up the spaces used unnecessarily as parking lots and thus revolutionize urban planning.

Autonomous vehicles require no human intervention, even in complex traffic situation. This is possible thanks to rtificial intelligence, machine learning and deep neural networks.

However, it is impossible to expect that such technological changes will be sufficient to solve the problem of traffic congestion, transport emissions and road accident victims. It is therefore necessary to properly manage the long transition phase and ensure that future vehicles are part of a transport system capable of promoting social inclusion, low emissions and global efficiency. It is necessary to strengthen the link between vehicles

[45] EU Communication COM 2018/237, L'intelligenza artificiale per l'Europa, 2018
[46] EU Communication COM 787/2016, Salvare vite umane: migliorare la sicurezza dei veicoli nell'UE,

and traffic management, between public and private data, between transport collective and individual and between all transport service providers and related methods.[47]

Shared vehicles

According to Shaheen S., shared mobility is "*the shared use of a vehicle, bicycle, or other low-speed mode that enables users to have short-term access to transportation modes on an "as-needed- basis*".

Shared facilities have been available in major cities for a number of years, but this phenomenon is growing rapidly around the world. Ridesourcing services, like Lyft and Uber, are growing at a rapid pace as well. As of June 2016, Uber claimed more than 50 million riders worldwide had taken more than 2 billion rides total since its founding in 2009. There are two manifestations of car sharing, namely station-based and free-floating. The fundamental difference lies in the availability of the vehicles. While in station-based car sharing the vehicles can only be picked up at predefined stations, the availability area in free-floating car sharing reflects the business area of the provider. Carsharing allows consumers the benefits of a private vehicle while relieving them of the costs of purchase and maintenance. Users can access vehicles owned by carsharing companies as part of a shared fleet on an as-needed basis.[48] Members typically pay an initial or yearly membership fee and usage fees by the mile, hour, or a combination of both.

Ridehailing, by contrast, is about sharing a journey. Ridesharing services facilitate shared rides between drivers and passengers with similar origins and/or destinations.

They can be online car sharing agencies that create driving communities, online platforms that act as brokers for drivers offering journeys in private cars or taxi companies that offer their services via an app. Although automated vehicles do not necessarily have to be connected and vehicles connected do not require automation, connectivity is expected in the medium term it will be a determining factor for autonomous vehicles. The European Commission will follow an integrated approach between automation and connectivity in vehicles. As vehicles become more connected and automated, they will be able to

[47] EU Work Programme 2018-2020, Smart, green and integrated transport, 2020

[48] Liao, F., Molin, E., Timmermans, H. *et al.* Carsharing: the impact of system characteristics on its potential to replace private car trips and reduce car ownership. *Transportation* 47, 2020, pp 935–970.

coordinate maneuvers through the support of active infrastructures and the use of a system intelligent traffic management system for smoother and safer flows.[49]

[49] EU Commission, COM 2018/283: Verso la mobilità automatizzata: una strategia dell'UE per la mobilità del futuro, 2018

2. The environment issue and the automotive industry

2.1 The human impact on the environment

To truly understand the impact of the automotive industry on the environment, it is best to first clarify the dimension of human's environmental impact on the ecosystem.
Human's impact on the environment is primarily due to overpopulation. As we will see below, the world's population has grown disproportionately in recent years.
It is estimated that from 1980 to 2010 the world population growth rate was 2% per year, potentially doubling every 35 years. This growth, which is estimated to reach 9.7 million in 2060, is largely due to improved sanitary conditions, medicine and the development of food technology.
Obviously, it is not being asserted that such progress is bad, but there is a downside to this, which is a degradation of environmental conditions.
Population growth has had the effect of increasing human productive activity and demand for goods, and since the industrial revolution in the early 1800s, the use of non-renewable resources such as coal, oil and fuels have triggered the emission of greenhouse gases into the air, especially Co_2, CH_4 and N_2O. Population growth has also led to deforestation, firstly because timber was and is used as a raw material, and secondly because deforestation is associated with human's need for agricultural and housing land.
Population growth and deforestation come together negatively and synergistically when determining the amount of CO_2 emitted. This is because forests play an important role in lowering the greenhouse gases emitted into the air. They capture CO_2 by trapping it in roots, trunks and branches, which is not done in a marginal way, but it is estimated that forests are retaining 1,100 gigatons (Gt, or billion tones) of CO_2. This amount is 1.3 times the CO_2 crammed into unmined fossil fuel reserves, and almost twice the CO_2 emitted into the air since 1870 (600 GT).
It is therefore clear how much deforestation impacts on the increase in greenhouse gases, as it is estimated that since 1750 forests have absorbed half of the naturally sequestered CO_2, while the other half has been absorbed by the oceans. Oceans and forests are therefore a natural buffer, and the more deforestation increases, the less the natural capacity to absorb CO_2 becomes.

A further aspect to consider is the use made of the chopped vegetation. When burned in fires, it releases CO2 back into the air, but when used in construction, it retains it. Deforestation from 2000 to 2015 is estimated to have occurred for the following reasons:

- Commodity-driven deforestation 27%
- Forest conservation activities 26%
- Conversion to agricultural land 24%
- Fires 23%
- Urbanisation 0.6%

Deforestation and CO2 emissions add up to a negative synergy: as the population increases, so do the greenhouse gases emitted (we will see in the following that technology is limiting this relationship) and the greater the population the greater the deforestation, so on one hand the CO2 emitted increases and on the other, the natural capacity to absorb is reduced.

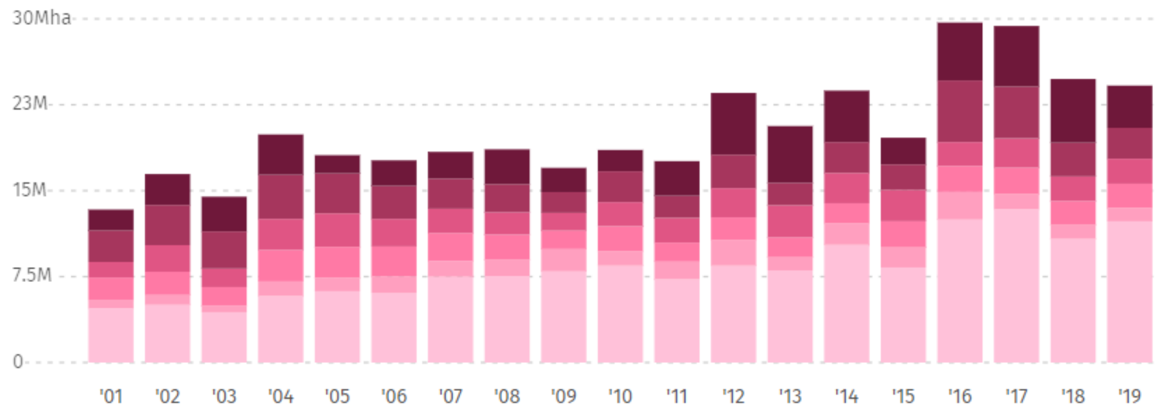

Figure 21: Global annual tree cover loss in millions of hectares [50]

According to Global Forest Watch, 9.7% of the area covered by forests was lost between 2001 and 2019.

CO2 that is emitted and not reabsorbed has an impact on global warming, which in turn has a knock-on effect on melting ice and rising oceans. Emissions of CO2 and other

[50] https://gfw.global/3artbpL

greenhouse gases are considered to be the main cause of climate change and rising temperatures.

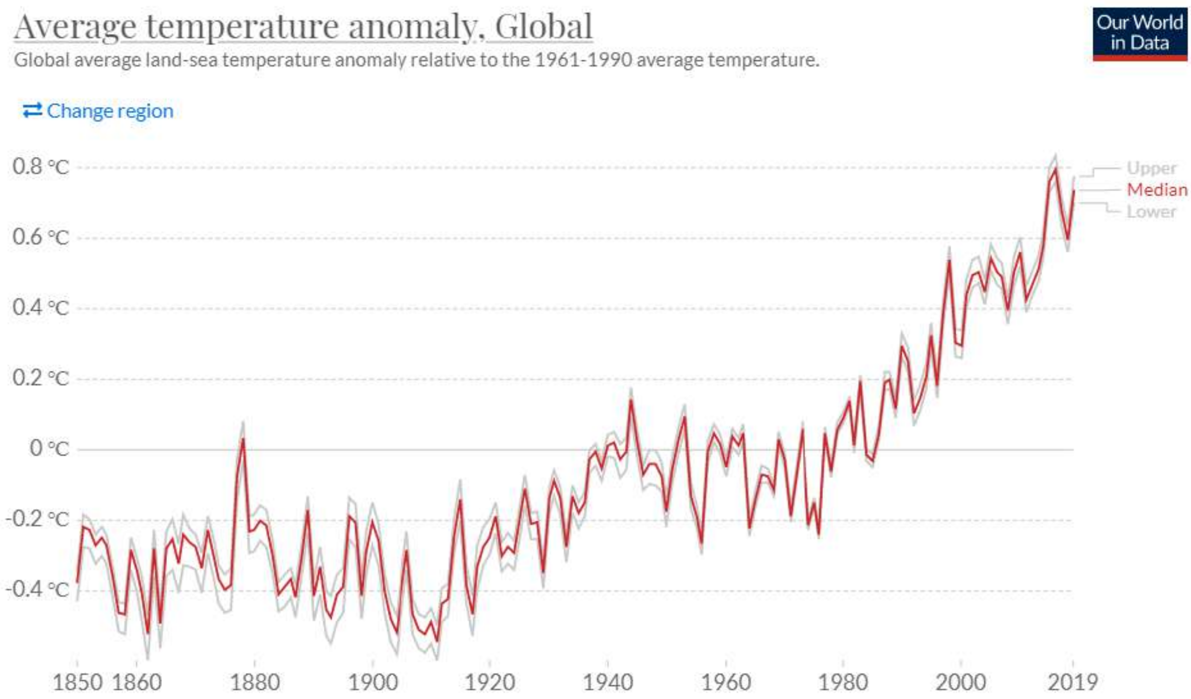

Figure 22: Global average temperature rise [51]

From the graph above you can see that the rise in temperature from 1850 to 2019 has increased by about 1.2 °C.

The low value amount might suggest that it is not a big problem, but in fact an 1.2 °C rise is only an average value for all geographical areas. To better understand this aspect and its implications, consider that the temperature rises more on land than in the oceans, and take into account that the Boreal Hemisphere (northern hemisphere) has more land than the southern hemisphere.

The sum of these components has determined that at the North Pole the warming is actually between 3 and 5 degrees. This is leading to the melting of ice and permafrost, i.e. the perennial ice on the surface and in the oceans. The melting of these surfaces has two consequences: on one hand, the rise in water levels due to an increase in mass and therefore the increase of ocean temperatures; on the other, there is a risk that large

[51] https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

quantities of methane gas trapped in the ice for thousands of years will be released into the air, further exacerbating the already delicate situation of greenhouse gases.

This is leading to a dangerous vicious circle that can destroy the environment in which we live and which we often take for granted.

Emissions of CO2 and other greenhouse gases, as we will see below, are at the root of much of the climate change that is taking place. Human production is responsible for this change, and although there are streams of thought that rising temperatures are only a cyclical and natural phenomenon, the scientific community is united in stating the opposite.

The cyclical nature of temperature changes is a reality, but the human impact has altered the patterns.

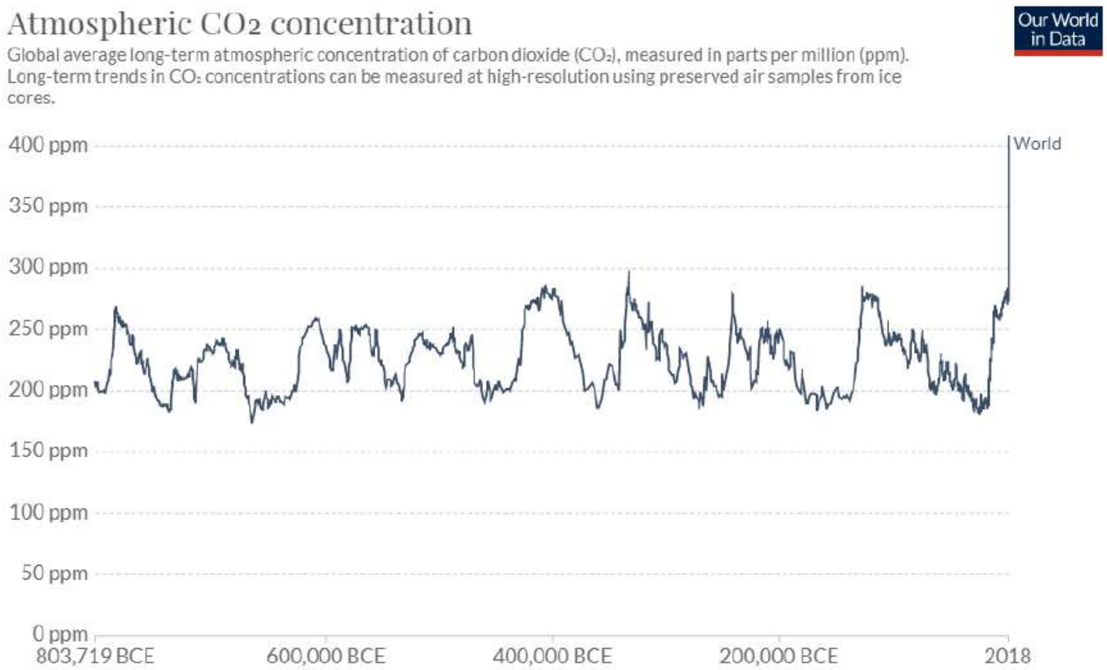

Figure 23: Atmospheric CO2 concentration [52]

The graph above shows the CO2 concentration trends over the past eight hundred thousand years. Clearly, there are fluctuations in the CO2 concentrations, which depend on the variation of the earth's rotation axis around the sun, which affects the temperature and the greenhouse gases (even tough today have a negative connotation actually this makes life on earth possible).

[52] https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Since the beginning of the industrial revolution, the increase in CO2 emissions has resulted in unprecedented air concentrations, which can be observed by narrowing down the years of monitoring. As you can see below, it shows a continuously increasing trend.

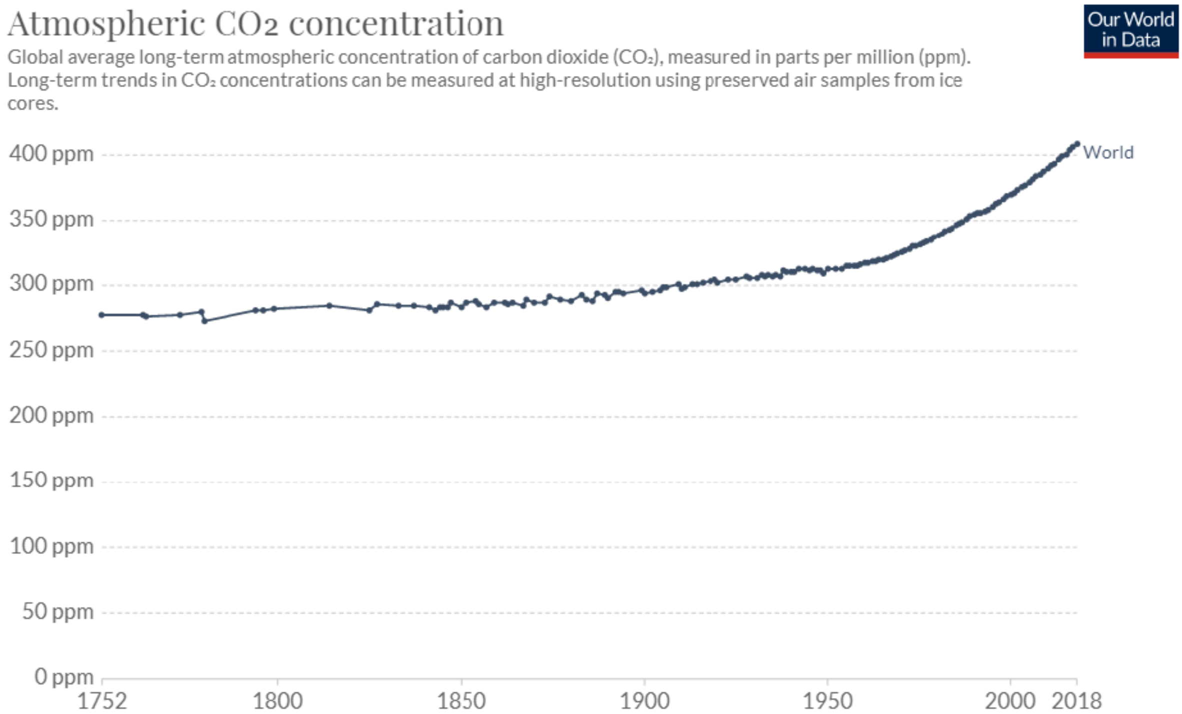

Figure 24: Atmospheric CO2 concentration, 1752 - 2018[53]

Despite the severity of the situation, everything possible must be done to try to reverse a trend that will lead to the collapse of the planet, but what emerges and will emerge again in the course of this discussion is that many specialists believe that the policies that states are adopting are too little aggressive in attempting to reduce CO2 emissions.

[53] https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

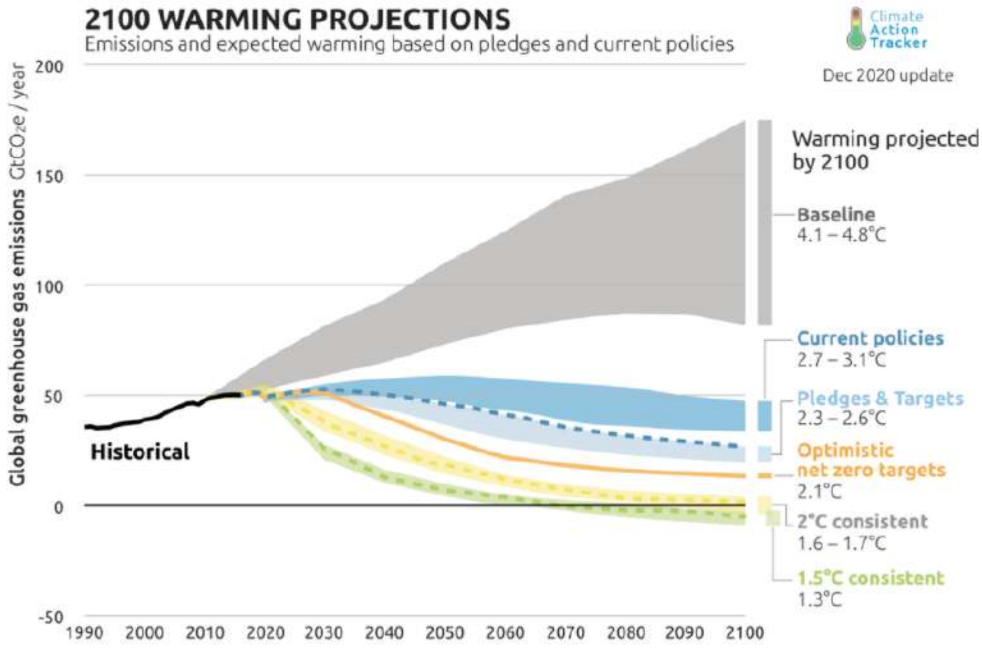

Figure 25: Green House emission and different scenario trends [54]

According to Climate Action Tracker, even if the global policies being adopted will certainly succeed in curbing the growth of emissions, they are not sufficient to achieve decarbonization by 2100. The policies refer to the Paris Agreement adopted in 2015 by 190 states including European states, which aims to limit the rise in temperature to below 2 degrees and then to 1.5 degrees.

This graph demonstrates that the steps taken would not be sufficient to bring temperatures back to a pre-industrial level, and further reductions in emissions will be necessary.

The data in this study is based on the Global Warming of 1.5°C[55] study published by the IPCC Intergovernmental Panel on Climate Change, which helped redefine the targets needed to meet the 2015 target that was planned in the Paris Agreement.

Anyway the graph tells us we have to urgently find a way to reverse this dangerous trend otherwise it could be too late.

In the following, we will discuss the impact of the automotive industry and transports on the environment.

[54] https://climateactiontracker.org/global/temperatures/
[55] https://www.ipcc.ch/sr15/

2.2 The automotive industry contribution on the environment issue

Cars play a fundamental role in society and in our lives. The way we work, treat ourselves, relate to others and enjoy ourselves depends on our ability to move around quickly.
The speed of travel underpins the development of certain areas of the world as the backwardness of transport and infrastructure lags behind the development of communities and services, and this can be seen in developing countries where owning or using a car is not taken for granted. Even these multiple positive aspects, deterioration of the environment is the hidden price we have to pay.
In this section, we will try to understand how much the automotive industry and its products are responsible for the environmental conditions seen in the previous chapter.

2.2.1 Pollutants emitted by the industry

The automotive industry is responsible for the production of several substances that boost the environmental damage. The production of these substances occurs not only during the use of cars, but also during production and disposal of vehicles.
The most impactful substances are the following:

Carbon dioxide (CO_2): An inert, colorless, odorless gas, non-toxic to humans, which is naturally present in the atmosphere in limited concentrations.
Once CO_2 is emitted, it goes into the atmosphere where it remains for long periods and together with other GHS (GreenHouse Gases) contributes to the greenhouse effect, which is a natural thermoregulation phenomenon.
The problem arises when there is an excess production of CO_2 and the other GHS, which cause the earth's warming to rise unnaturally.

No	Type	Chemical Formula	GWP 100-year
1	Carbon dioxide	CO_2	1
2	Methane	CH_4	28
3	Nitrogen oxide	N_2O	265
4	CFC-11	CCl_3F	4,660
5	CFC-12	CCl_2F_2	10,200
6	CFC-13	$CClF_3$	13,900
7	CFC-113	CCl_2FCClF_2	5,820
8	CFC-114	$CClF_2CClF_2$	8,590
9	CFC-115	$CClF_2CF_3$	7,670

Figure 26: Global Warming Potential Value [56]

From the graph above, you can see that CO2, which is considered as the reference value (1), is the least powerful greenhouse gas, but despite this, it is the most produced and therefore the most impactful, contributing 55% to the greenhouse effect, and for this reason it is the one on which is necessary to pay attention to.

In the graphs below you can also see how much the different sectors affect CO2 production in billions of tons per year. It should also be noted that the "transport" sector, which is at the second place, only represents emissions from the car cycle and does not also take into account the impact resulting from the entire supply chain.

The latter is included in “Industries”, and although it is difficult to find clear data on the impact of the entire automotive industry, it is still possible to understand how necessary it is for institutions and companies to reduce CO2 production.

[56] Dwipayana, Garniwa I., Herdiansyah H., CO2 Emission Reduction from Solar Power Plant in Rural Area, E3S Web of Conferences 65, 05017, 2018, Jakarta, pag 4

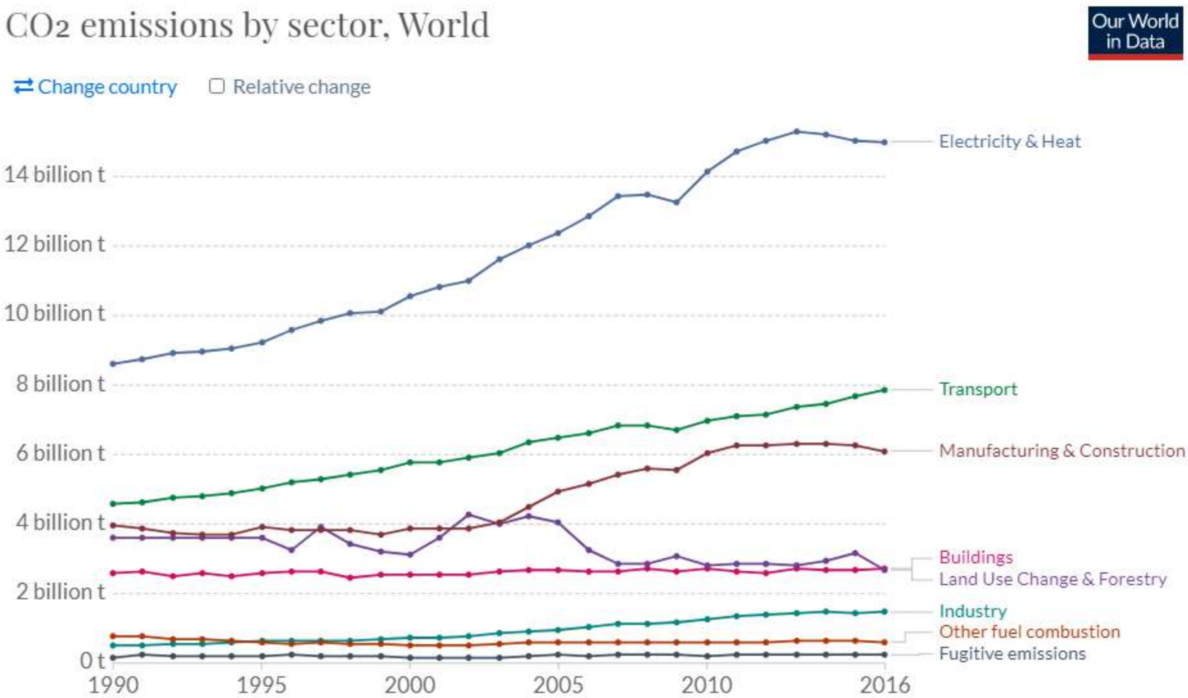

Figure 27: CO2 emissions by sector, Word [57]

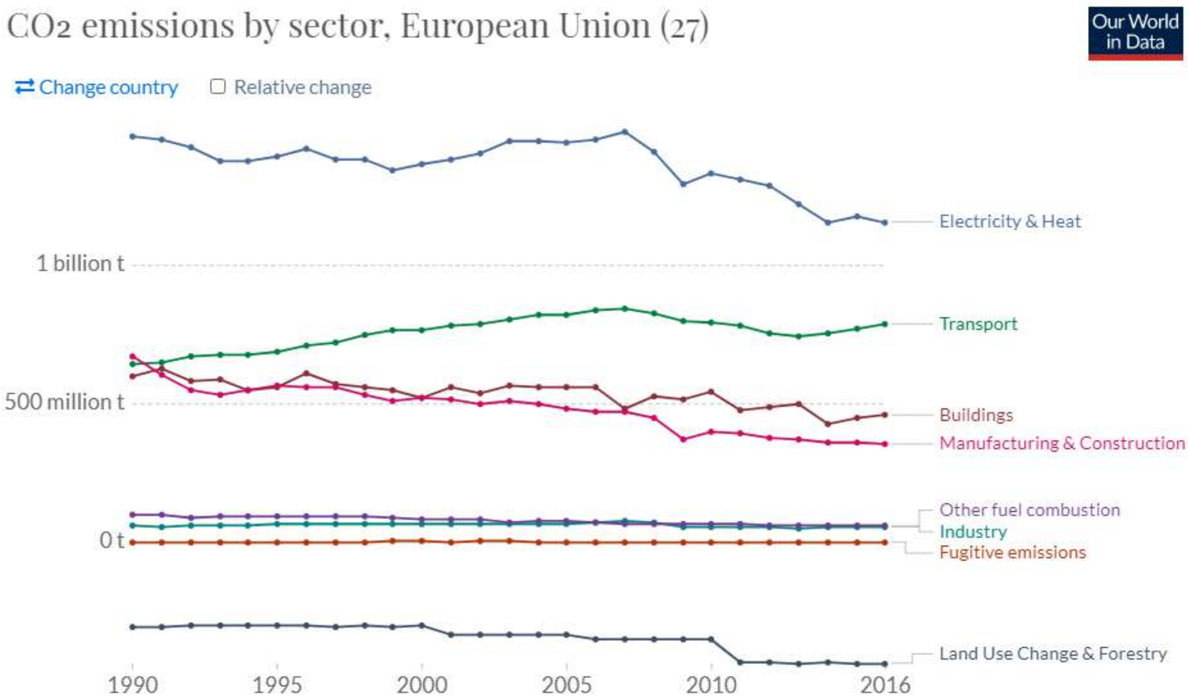

Figure 28: CO2 Emissions by sector, Europe

[57] https://ourworldindata.org/emissions-by-sector#annual-co2-emissions-by-sector

In chapter 4, where we will discuss the vectors of the automotive development and the technological developments that are taking place in terms of product and process, we will deal with the impacts of electric and hydrogen cars, trying to deepen also how much the supply impacts in its whole chain. This will be possible because the relative modernity of technologies concerning new means of transport, allows us to find very recent data.

Nitrogen oxide (NOx**):** Composed of nitric oxide (NO) and nitrogen dioxide (NO2), and unlike CO2 which is not toxic to humans, nitrogen oxide creates health problems.
Transport & Environment Federation estimates that NOx is responsible for 79,000 deaths each year in Europe. Furthermore, once emitted, it creates compounds that can acidify the air, causing acidification and eutrophication of water, which is a process that increases the presence of algae in watercourses, reducing the gas exchange between water and air, making this environment inhospitable to living beings.
It is estimated that road transport is responsible for 70% of the excessive NO2 concentration in the air. This chemical compound is the reason for the recent war on diesel engines due to the fact that while diesel cars on average emit less CO2 than petrol cars, they emit more NOx.
This is due to the fact that diesel engines reach higher temperatures, and this tends to favor the chemical reactions underlying NOx production.
Moreover, the so-called Diesel Gate broke out in September 2015, when Volkswagen altered the laboratory results to bring Diesel Euro 6 cars within the prescribed limits, using software that altered the control unit during type-approval and lowered performance, resulting in the type-approval of cars that exceeded the prescribed limit by up to 40 times.
On this basis, the methods for testing emissions have changed, with road tests replacing the laboratory test introduced by the Euro 6d-temp diesel legislation: In this test, the difference between the emissions measured in the laboratory cycle (NOx limit 60 mg/km for petrol and 80 mg/km for diesel) and the road cycle can be up to 110% (NOx limit 126 mg/km for petrol and 168 mg/km for diesel).
From January Euro 6d stipulates that the difference between WLTP emissions (on the road) and those measured in the RDE test (laboratory) may not exceed 50% (limit for NOx 90 mg/km for petrol and 120 mg/km for diesel). For the sake of completeness, it should be made clear that although public opinion is clearly against diesels, there are

technologies that seem to have lower NOx values than required, such as the Mercedes engine developed in conjunction with Bosh, gave on-road emission values of between 38 and 41 g/km.

This is particularly interesting because, despite this, a number of states are already starting to ban the production of diesel cars, as is the case in the UK where, from 2030, new diesel cars can no longer be approved. It is unclear what difference is being made between the future of diesel and petrol cars, which seem to have very similar polluting effects.

Particulate Matter (PM): The air contains particulate matter, which can be of natural or anthropogenic origin, and its composition varies greatly (heavy metals, hydrocarbons, dioxins, sulphates, nitrates, ammonium).

What determines the real danger of these dusts is their size: if they are larger than 10 microns they are normally blocked at the beginning of the respiratory system, but if they are smaller, they are able to penetrate the respiratory system. In particular, if they are smaller than 2.5 microns, they can reach lungs, while even smaller dusts in the nanometer range then atomic and molecular measurements can enter cells and even create DNA mutation.

According to the Italian Ministry of Health, these dusts are associated with respiratory diseases such as asthma and bronchitis for low exposures, while chronic exposures can lead to respiratory tract cancer. From Euro 4 cars onwards, a solution seems to have been found through the implementing of filters, called FAP or DPF, capable of trapping fine particles.

FAP or DPF filters are inserted to direct-injection diesel or petrol engines in order to solve the emission of more particulate matter. This filter traps dust and, when high temperatures are reached, ignites and charcoals it. Despite this, the problem remains since Euro 4 without FAP are still circulating. Anyway it is planned to banned Euro 4 cars without FAP in 2021.

It is worth noting that passenger and commercial vehicles have a significant, but not major, influence on particulate emissions.

A very high source of emissions are boiler heating systems for private and commercial use.

Rarely we hear how a simple object like a boiler affects our health, and that producers should invest in reducing emissions. This is important because it shows the role of institutions and the media in accelerating the process of reducing environmental impacts in various sectors.

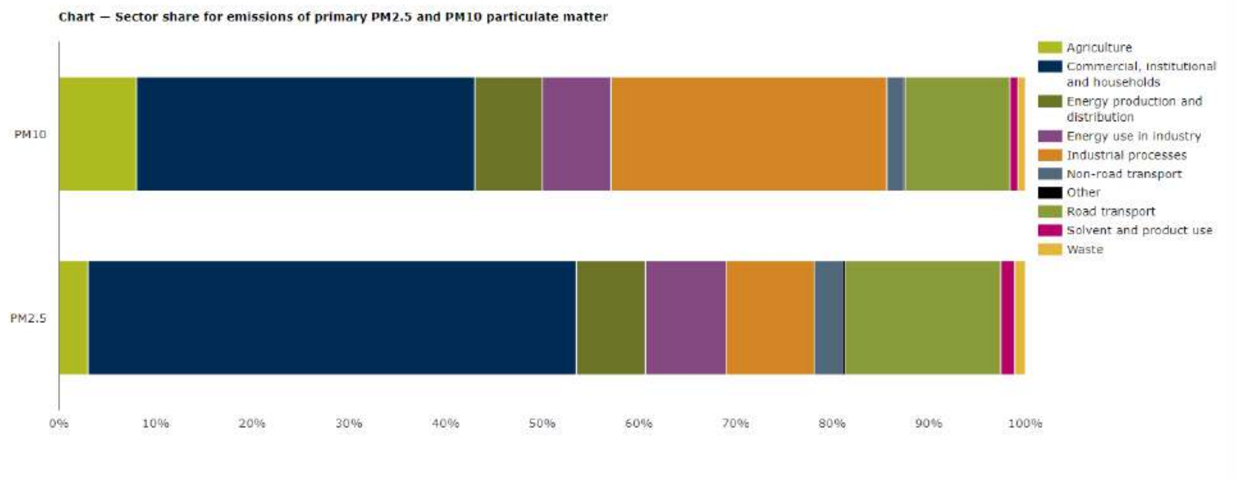

Figure 29: Sector share of emission of PM 2.5 and PM 10 [58]

Co2, NOx and PM are not the only ones emitted, but because of their presence and hazardousness, they are the ones that have been most studied in deep and delimited by legislation, which indicates maximum emission limits.

2.3 Low environmental impact technologies and barriers of adoption

As will be seen in chapter 4, advancing technology is making it possible to adopt cars whose systems do not emit substances that are harmful to the environment and to living beings.

Until a few years ago, these vehicles were only prototypes that were exhibited at trade fairs, as they did not yet have the characteristics to be adopted in real conditions. In just a few years, stringent regulations and farsightedness of some companies focused on

[58] https://www.eea.europa.eu/data-and-maps/daviz/sector-split-of-emissions-of-4#tab-chart_1

reducing environmental impact, have made possible to develop skills that are now spreading among all manufacturers.
Technologies that appear to be the most promising, and which will be explained in more detail in Chapter 4, are *Battery electric vehicles (BEVs)* and *Fuel cell electric vehicles (FCEVs),* the so-called hydrogen cars, which also represent the testing ground for developing technologies to be applied to goods transport vehicles, which, as will be seen, are more complex to convert essentially because of weight issues.
The adoption of these technologies, in particular BEVs, intended as a total replacement for the previous technology (i.e. internal combustion engines), could encounter barriers when it comes to mass adoption. Indeed, although these types of cars seem to be within everyone's reach because of the attention they receive, in reality they are only used by a small percentage of people, not so much for economic reasons but for infrastructure problem.

2.3.1 Infrastructure problem

The infrastructural problem arises when cars need to be recharged by plugging them into a specific power outlet capable of recharging the car's battery. This necessarily requires the development of a network of energy supply points capable of supplying the ever-growing car fleet.

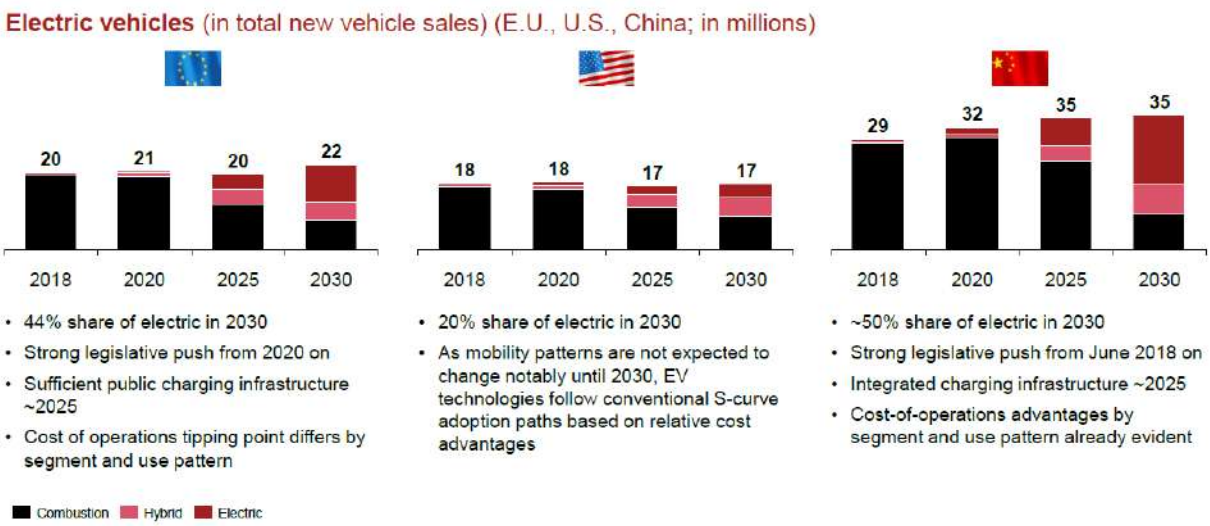

Figure 30: Millions of vehicles by type [59]

[59] PWC, Challenges and Trends in the Automotive Industry, 2019, pag. 10

In literature, Hybrid cars are referred as PHEVs (Plug-in Hybrid Electric Vehicles) and unlike BEVs, they also have a normal combustion engine in addition to the electric motor, which kicks in when the battery is flat. The average range of these cars is 40 km.
The graph shows that there is a clear trend of growth in the adoption of newly designed vehicles, which would guarantee a gradual reduction in emissions, and this growth must be supported at an infrastructural level, essentially through the development of public charging stations and through the management of charging from private property.

One of the first aspects to consider is the type of public charging stations. in Europe there are four types of charging stations:

1. Single phase AC chargers (3-7 kW): 7 to 16 hours;
2. Tri-phase AC chargers (11-22 kW): 2 to 4 hours;
3. Fast DC chargers (50-100 kW): 30-40 minutes;
4. Ultra-fast DC chargers (above 100 kW): 10-20 minutes or less.

The charging time depends on the size of the battery and the capacity of the charging point to deliver energy. This is extremely important, because in addition to the number of charging points, the ability to recharge the car quickly is also important for accelerating the adoption of electric cars.
Speed is strategic, because on one hand it allows more cars to be charged in an hour, reducing the number of charging points needed, and on the other hand it helps to increase the uptake of electric cars, as long charging times become a constraint for people that is difficult to accept.
Of course, there are situations where users have no problem with long charging times, such as at charging stations outside shopping centers and restaurants, but in these cases the reverse problem often occurs, i.e. cars are left charging for longer than necessary, making it impossible for other users to recharge their cars.
The graph below shows the distribution and type of charging points in the various European countries. The majority of these provide between 11 and 22 KW, and the charging times are between 2 and 4 hours.

The development and distribution of fast chargers becomes a lever on which to work to stimulate the purchase of electric cars.

In addition, it is also clear that Europe lacks a homogeneous distribution between the various countries, which does not contribute to the spread because (i) those who live in countries with a poor infrastructure are clearly not encouraged to buy, and (ii) also affects those who travel between countries and need to be able to recharge their cars.

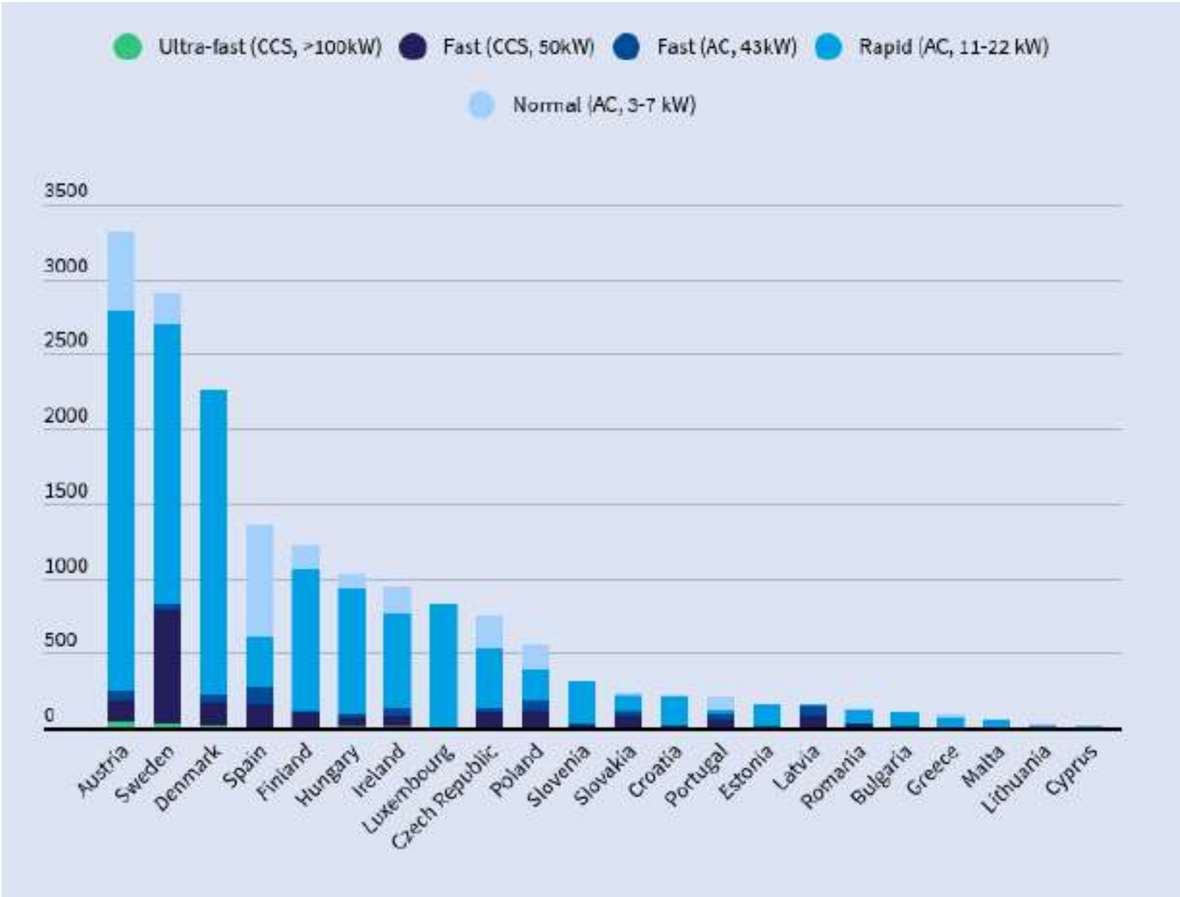

Figure 31: Distribution and type of Chargers [60]

In addition to speed, the number of charging points is obviously important, and the growth in the spread of electric cars and charging points must go hand in hand.

Obviously, this element is also related to the size of the territory of each country, and in the following graph you can get a better idea of the matter by looking at the amount of petrol stations per 100 km of TEN-T (Trans European Transport Network), which gives

[60] Tranport & Environment, Recharge Eu: how many charge point will be Europe and its member states need in 2020s, 2020, pag 16

an index not only of national distribution but also of how well equipped a country is to guarantee maximum European commercial functionality.

This is because these EU corridors ensure through their linearity the possibility to connect what are considered to be the most strategic areas both at urban and commercial level.

In a future in which a large number of electric vehicles, including freight transport, are expected, states that do not keep pace with infrastructure development are slowing down not only the state-wide deployment of the newly developed vehicles, but also at EU level.

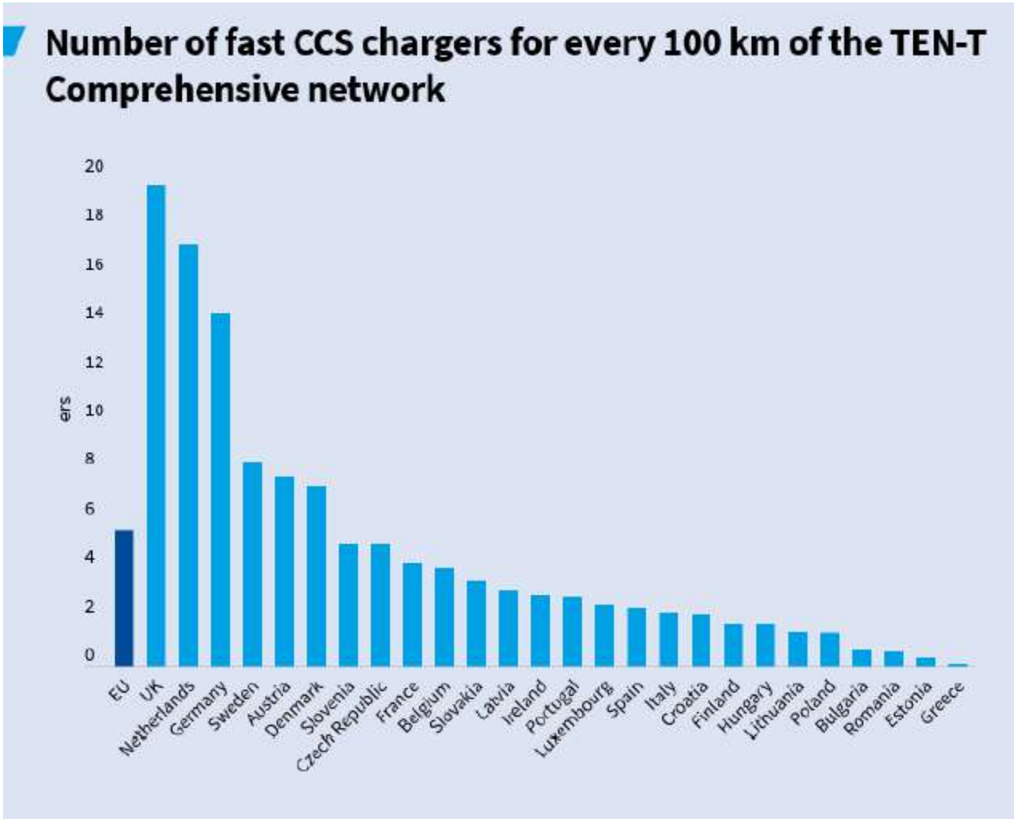

Figure 32: Distribution of fast CCS chargers for every 100 Km of TENT-T [61]

According to Jochem et al. (2019), strategic positioning emerges several times as a lever to act on to ensure a fast and massive adoption of electric cars. The main node is to ensure the presence of Fast Charging stations (FCS) on the highway network.

According to Lee and Clark (2018) "*without an accessible infrastructure that can re-charge an EV in a reasonable period of time, most motorists will be unwilling to purchase one, even if it is cheaper and its performance is better. Admittedly, the risk of being stranded without*

[61] Tranport & Environment, Recharge Eu: how many charge point will be Europe and its member states need in 2020s, 2020

power is small, but it is one that today's motorists have not faced in the vehicles that they have driven throughout their lifetimes" [62]

One of the main aspects that drivers look at in electric cars is the range in kilometers, because this determines the freedom of movement without having to look for a recharging point, which, as we will see below, varies in time depending on the amount of current provided by the charging station.

On average, electric cars today have a range of 300 km, with peaks of 600 km for some models such as Tesla Model S. For everyday life, these are reasonably high mileages, but they are not enough for people who need to travel long distances.

Since long distances occur normally on highways, this is why Jochem et al. (2019), focused on the importance of developing this infrastructure.

In their study[63], they tried to estimate the number of FCS (Fast Charging Stations) needed in Europe. France, Germany, the Benelux countries, Switzerland, Austria, Denmark, the Czech Republic, and Poland are the countries considered during their study.

In addition, they considered northern Italy, as the Italian motorway network connects with some of the above-mentioned states.

The results of this study are that cars with a range of 150 km, it would be sufficient to install 314 FCSs throughout the highway and they should be located in strategic areas in relation to the affluence of the motorway network.

Furthermore, individual charging points should be increased in relation to the increase of the electric car fleet over the years.

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[62] Lee H., Clarck a., Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption, 2018, Cambridge, pag 17

[63] Jochem P., Szimba E., Reuter-Opperman M., How many fast-charging stations do we need along European highways?, Hertzstr Germany, 2019

Country	Model Input						Model Output			
	Mileage 2020 [billion pkm]	Mileage 2030 [billion pkm]	PEV share 2020	PEV share 2030	Electricity Demand 2020 [GW h/a]	Electricity Demand 2030 [TW h/a]	No of FCS 2020 (avg. no. of points/ FCS)	No of FCS 2030 (avg no. of points/ FCS)	Electricity demand per FCS 2020 [MW h/FCS/a]	Electricity demand per FCS 2030 [GW h/FCS/a]
Germany	915	922	1%	10%	183	1.84	128(5)	128(20)	1430	14.4
Be-Ne-Lux	280	301	1%	20%	56	1.20	22(5)	22(25)	2545	54.7
France	768	849	1%	15%	153.6	2.55	104(5)	104(30)	1477	24.5
Switzerland	92	98	1%	15%	18.4	0.29	12(5)	12(8)	1533	24.5
Austria	78	84	1%	15%	15.6	0.25	15(5)	15(8)	1040	16.8
Czech Republic	73	84	1%	10%	14.6	0.17	10(5)	10(2)	1460	16.8
Poland	355	401	1%	10%	71	0.80	17(5)	17(2)	4176	47.2
Denmark	53	56	1%	15%	10.6	0.17	6(3)	6(3)	1767	28.0

Figure 33: Estimate of FCS needed [64]

In the columns entitled "No of FCS 2020" and “No of FCS 2030”, the number of individual charging points required at each station is shown in brackets.

This study was carried out by trying to optimize the necessary infrastructure, anticipating peak times of passing motorists, and at the same time, optimize earnings.

This could be a limit because maximizing the use of charging points could create waiting situations for recharging vehicles, and this leads to a low service, which in turn would reduce the number of drivers willing to use electric cars.

In order to avoid such problems, it is necessary to have a sufficient number of charging points so that saturation is not reached even at peak times.

The positive aspect of this research, however, is that it has given a minimum order of magnitude necessary to guarantee an infrastructure capable of meeting the needs of motorists travelling on highways.

The ability of institutions to strategically plan charging points will also serve in the future to ensure the possible adoption of new low-impact technologies, not only for cars but also for transport.

This will be explored in more detail in Chapter 4, trying to highlight the reasons why the uptake of electric power in transport is lagging behind, and what the drivers for development might be.

Another important aspect to be taken into account at macroeconomic level is the need for institutions to succeed in making strategic and coherent long-term choices.

[64] Jochem P., Szimba E., Reuter-Opperman M., How many fast-charging stations do we need along European highways?, Hertzstr Germany, 2019, pag 126

The changes that are taking in place in the road transport sector have the potential to reverse a trend that is leading to the destruction of our environment.

Connected to this statement, interesting, and at the same time worrying, is a study by Transport & Environment, which states that in order to achieve zero emissions in 2050 as envisaged by the European Union, the following electric cars should circulate (nowadays there are 1.3 million):

- 14 million in 2025
- 44 million in 2030

At the same time, in order to reach the infrastructure level, the following charging points need to be developed:

- 1.3 million by 2025
- 2.9 million in 2030

One of the problems that emerges is that these targets diverge from those required by today's emission reduction policies, which have a limit of 95 g/km today and a target of 50 g/km in 2030.

In order to meet these targets, it is estimated that the following cars and charging points are needed:

Electric cars

- 13 million in 2025
- 33 million in 2030

Charging points:

- 1.2 million by 2025
- 2.2 million in 2030

However, pursuing the second target would create a gap with the growth pathway that would have to be followed to achieve zero emissions in 2050, which is worrying because it would mean arriving late at the target.

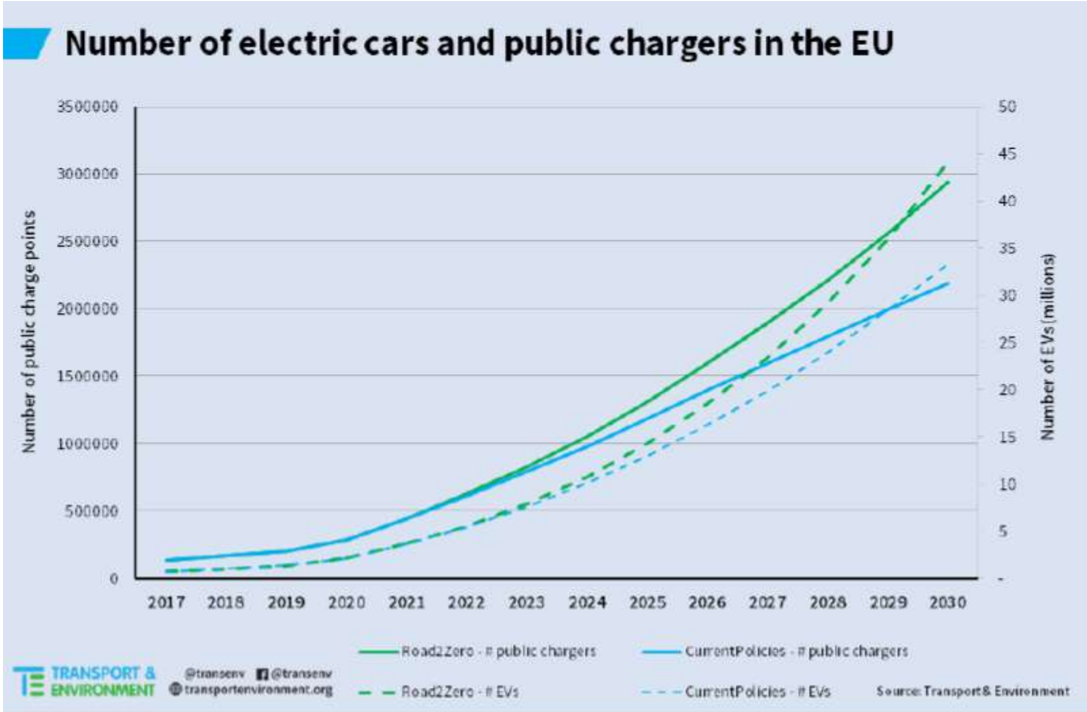

Figure34; Divergence of objectives and targets [65]

The graph makes clearer the divergence between long-term zero-emission targets and medium-term emission targets, and again makes clear the importance of simultaneously developing vehicle technology and the infrastructure needed to ensure its adoption.
In this section we have focused on the European market, as we will also concentrate on green deal legislation. However, we would like to stress that the dynamics outlined above also occur in other contexts, as they are aspects that are naturally related to the adoption of electricity.

2.3.2. Power Generation

A further critical issue in the uptake of electric comes from the fact that producing zero-emission cars makes no sense if electricity is generated from non-renewable sources such as coal and fossil fuels.

[65] Tranport & Environment, Recharge Eu: how many charge point will be Europe and its member states need in 2020s, 2020, pag 25

This would simply mean shifting the production of the emissions outlined above upstream, which means that the technological and infrastructural effort must also take place at the level of energy production.
In addition, in order to respond to the growth in energy due to the increase in world population, which will be discussed in more detail later in this chapter, it is estimated that there will be an increase in energy generated over the next 50 years of almost three times. This is as if the equivalent of the energy used in 2020 by China were added to the world's demand every eight years, which gives some idea of the scale of the growth.
It is also estimated that 70% of this increase in energy demand will come from increasing global electrification, while the remaining 30% (14000 terawatt-hours equivalent to about half of all electricity generated in the world today) will be used to be converted into other energy sources.
This 30% is particularly important in the decarbonisation plan, because electricity has certain limitations, especially in long-distance transport, both on wheels and also by sea and air, in which case electricity is used to produce other energy sources such as hydrogen. This will be discussed shortly in section 4.
The scenario derived from the study by the international energy agency demonstrate that thanks to the use of renewable energies, but also of coal-fired and nuclear plants, by 2070 we will be able to produce energy without emitting significant levels of CO_2.
As technology advances, it is possible to produce energy from non-renewable sources without emitting CO_2 in the air. This is possible through systems that capture and store the CO_2 produced. Such systems are called CCUS carbon capture utilisation storage.
Nowadays, there are several experimental projects on how to use CO_2 to avoid storage problems, many of which involve chemically attaching CO_2 molecules to other molecules to create polymers for the construction industry or attaching them to microalgae to convert into methanol for use as fuel.

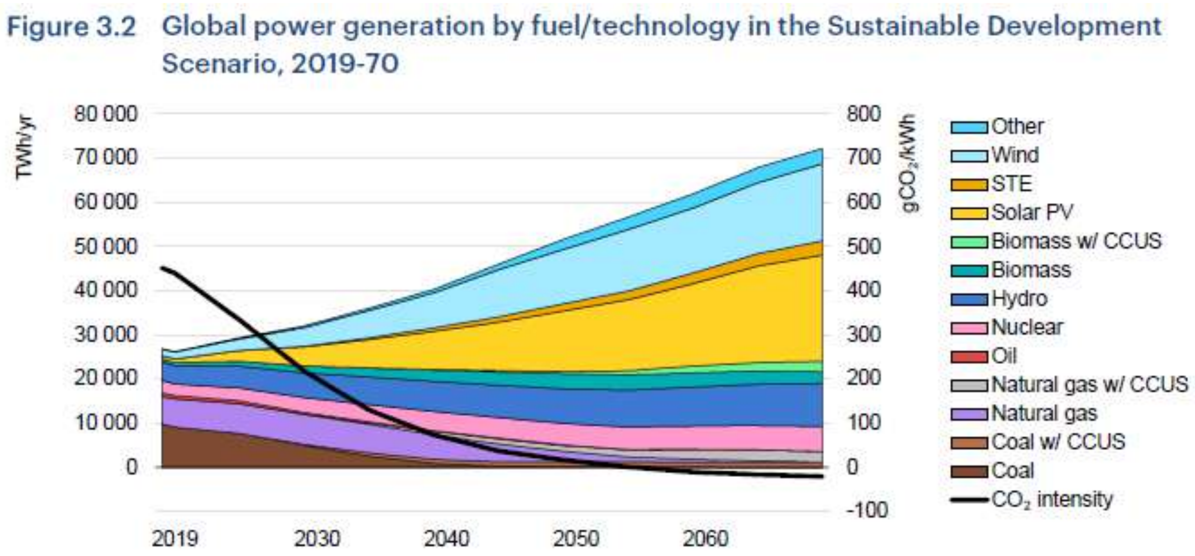

Figure 35: Global power generation and CO2 emission [66]

The graph shows the distribution of the expected sources and how they will develop over time, as well as the estimated CO2 emissions.

The automotive industry will also benefit from this scenario, with research and development efforts supported by upstream production of low-emission energy.

A further critical issue is identified in newly built plants producing energy from non-renewable sources, which are expected to continue producing until they decay, which is a major problem in reducing environmental impact. In particular, this issue concerns China since it has a large number of newly built coal-fired power plants.

It is estimated that this would lead to the production of around 4.5 Gt CO2 per year until 2050, and to limit these emissions, institutions need to set limits so as to stimulate companies to adopt solutions, which, moreover, from a technological point of view already exist. These solutions relate primarily to the use of CCUS carbon capture utilisation storage, associated with a conversion of the power stations that can be done either to use biomass or ammonia as fuels.

[66] Tranport & Environment, Recharge Eu: how many charge point will be Europe and its member states need in 2020s, 2020, pag 129

These are not just theoretical solutions but solutions that are already technically adopted.

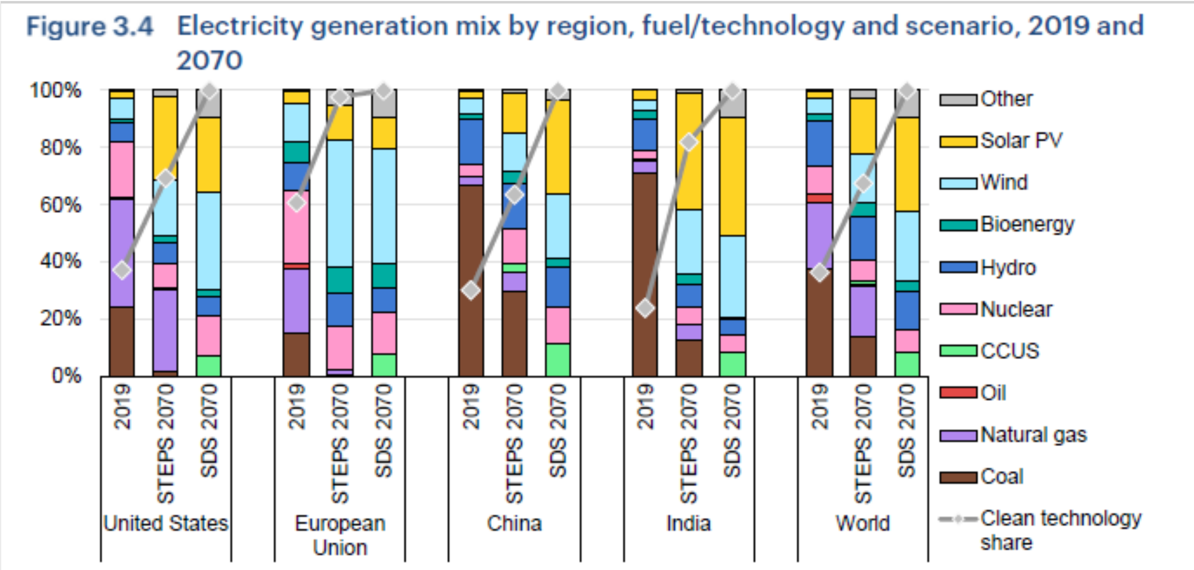

Figure 36: Differences between Stated Policies Scenario (STEPS) and Sustainable Development Scenario (SDS) [67]

From the graph it is possible to observe how much the future scenario changes in relation to the adoption or not of regulations able to stimulate the use of renewable energies. Observing the scenario of the European Union it is possible to understand how strong the impact of the green deal is, but this dynamic must be adopted by all states, especially in developing countries, otherwise there is the risk that the time taken will be greater than that available to reduce the damage that we have.

As will be seen later in this thesis, among the various renewable energy sources, hydrogen will play a key role in decarbonization in the transport sector.
As discussed in Chapter 4, hydrogen can be produced using different energy sources, and the amount of emissions depends on these.
Currently, only 0.1% is derived from electrolysis, which consists of splitting H20 atoms. Electrolysis is the greenest way to produce hydrogen since it derives from water.
This low percentage is mainly due to the fact that the energy required for electrolysis is particularly high with a high loss of efficiency, but it is estimated that as the cost of

[67] Tranport & Environment, Recharge Eu: how many charge point will be Europe and its member states need in 2020s, 2020, pag 131

electricity from renewable energy decreases, interest in and production of hydrogen will increase.

Today, production is around 1.5 GW/year, while it is estimated that this will rise to 60 GW/year in 2070, with the price dropping from $850-1100 per kilowatt to $300 in 2050. Furthermore, it will be important for the world's economic equilibrium: to produce hydrogen, it is necessary to obtain large quantities of energy from renewable sources, and this can become an element in favour of those states that, due to the orography of their territory, are able to implement infrastructures suitable for production.

For example, areas such as Africa where it will be possible to obtain large amounts of energy from solar and wind sources, it will be possible to produce hydrogen at low cost. Anyway, a key aspect is that hydrogen unlike electricity can be easily stored and transported.

This makes the resource saleable on the world market.

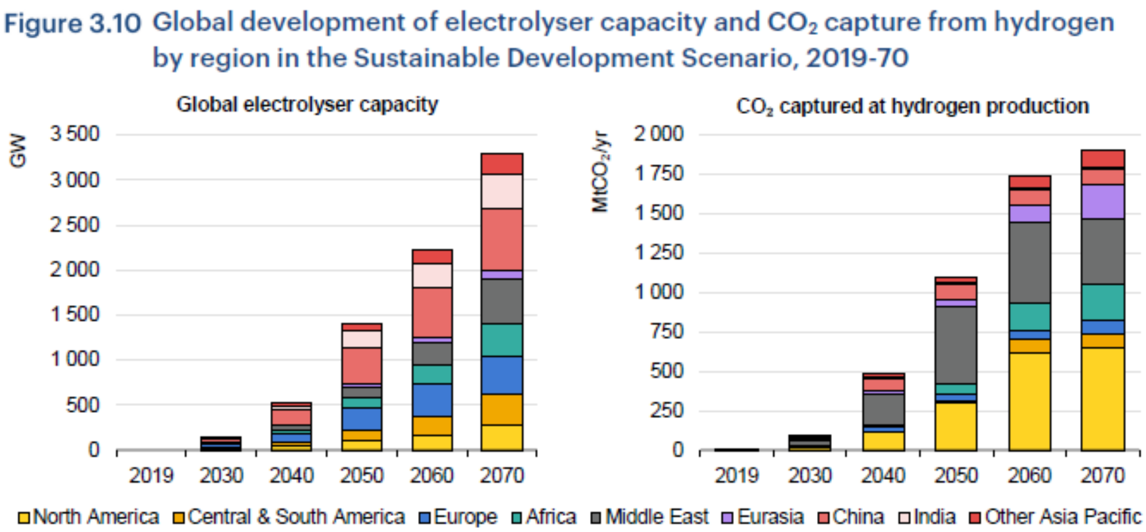

Figure 37: Global development of electrolyser capacity [68]

The graph shows what the production of an extremely strategic resource such as hydrogen is expected to be, especially for transport.

This strategic nature is due to the fact that hydrogen used as a fuel has certain characteristics that make it interesting to use in a complementary way to electric technology.

[68] Tranport & Environment, Recharge Eu: how many charge point will be Europe and its member states need in 2020s, 2020, pag 143

These aspects will be discussed in more detail in chapter 4, but we would like to mention that hydrogen powered vehicles do not have the recharging and range issues of electric cars, and refuelling times are similar to those needed to refuel petrol or diesel cars.
This has already led to the production of some hydrogen cars, but according to some studies, the real advantage comes from using the two technologies together by equipping cars with both a hydrogen tank and electric batteries.
This is not much because of the ever-increasing autonomy of batteries, but because reducing the size of batteries means reducing disposal problems, so equipping cars with a small battery for medium distances and a hydrogen tank for longer distances seems to be a theoretical optimization.
Where there seems to be less doubt, however, is the fundamental importance of hydrogen in vehicles for transporting goods or people over long distances, such as aircraft, ships and trucks.
For heavy goods vehicles, there seems to be a limit to the use of electric vehicles, as they are currently unable to provide autonomy for energy-intensive vehicles.
Instead, ammonia and synthetic hydrocarbon can be produced from hydrogen, which can be used as fuel for heavy vehicles. They also have the advantage of high energy density, making them storable in small spaces, which is extremely important.
In addition, being in a liquid state, the existing infrastructure for normal fuels can be used. The reason why there is no prospect of automotive use is the high cost of production.

2.3.3 Demographic aspects

If in the previous section Europe was used as benchmark, in this section we want to widen the viewpoint again to the global context.
From our position as European citizens we find ourselves in a situation that perhaps does not allow us to fully understand the fact that we are in a context of mature phase in which after long periods of economic development made without regard to environmental impact, we are now in a phase in which attention to environmental aspects is increasingly high.
At the governmental level there is a kind of ease in this as the context allows not to have too many highly unpredictable variables, the socio-economic context is quite stable, the

demographic growth is quite limited, and this allows to forecast the future on the basis of reliable data.

Africa and Asia are tumultuous countries from a demographic, social and economic point of view, and in many areas the need to create wealth and to develop economy comes before the need to protect the environment.

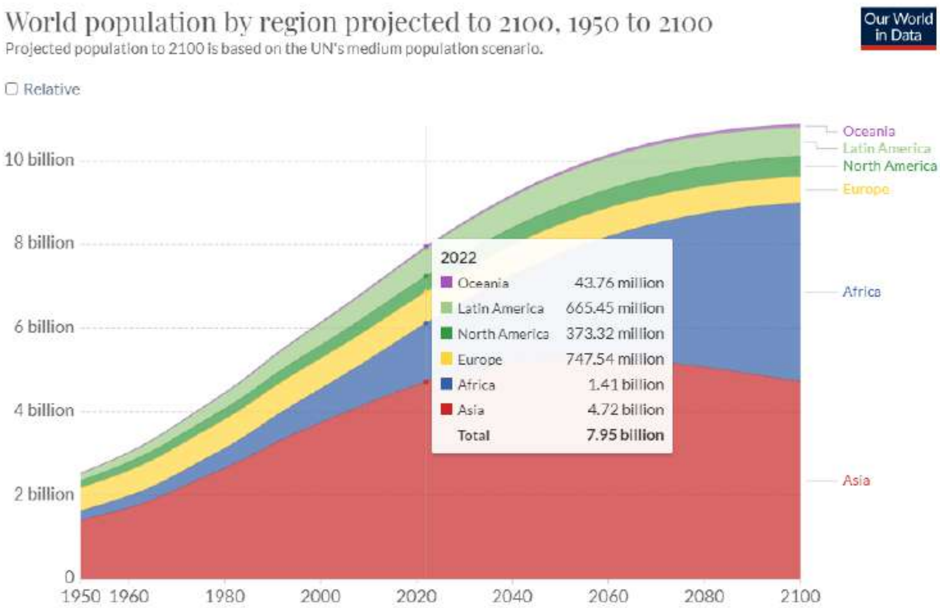

Figure 38: Word Population by region projected [69]

By looking at this graph, we can better understand the magnitude of changes that will take in place in the future. Although population growth has slowed down, it is set to continue, and if this growth is not matched by attention to environmental issues, the state of the earth will worsen.

According to the International Energy Agency, global primary energy demand reached 14 400 million tons of oil and oil equivalent in 2019, 45% higher than in 2000.

We should also remind that in 1800 the world population was around 1 billion and today we are 7.7 billion.

Total primary energy demand (TPED) is linked to GDP growth, because the richer a geographical area becomes, the more energy is required to fuel further growth and prosperity.

[69] https://ourworldindata.org/region-population-2100

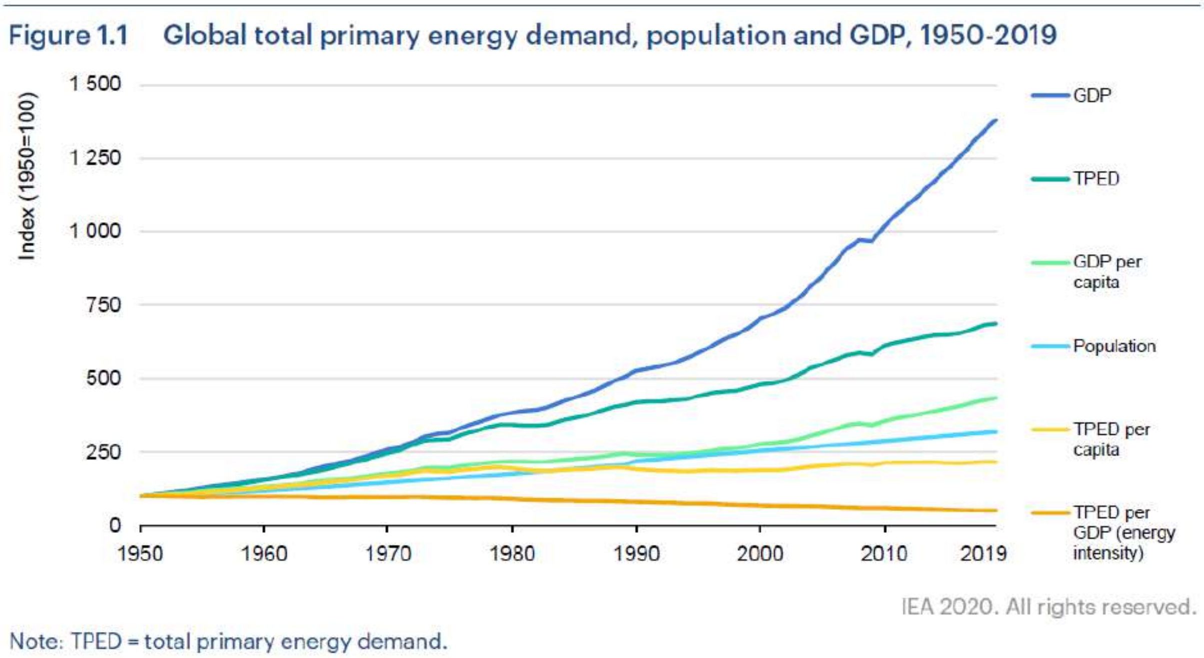

Figure 39: Global total energy demand, population and GDP [70]

If, as mentioned at the beginning of this section, wheeled means of transport have been one of the key components in the development of entire continents, this dynamic will also be repeated for developing areas.

According to the International Energy Agency, the number of kilometres travelled per capita will double between 2019 and 2070 and there will be a 60% increase in cars.

It is clear that it will not be possible to wait for developing areas to follow the steps taken in developed areas, but that there will have to be an uptake of zero-emission cars, but more generally of green technologies, much more quickly than in the past.

According to the International Energy Agency, a sustainable development model would make it possible to significantly reduce CO2 emissions by 2070. However, this requires that emerging economies succeed in rapidly developing infrastructures that encourage the use of low environmental impact vehicles.

[70] International Energy Agency IEA, Energy Technology 2020 Perspectives, 2020, pag. 36

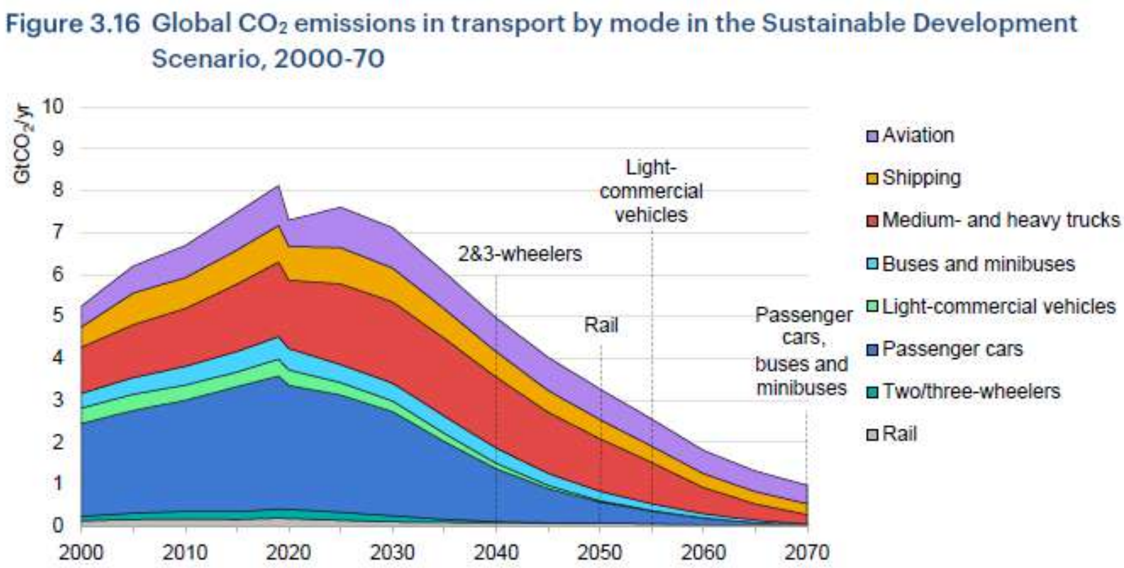

Figure 40: Global CO2 emissions scenario [71]

The dotted line in this graph, indicates the year in which any given transport model is expected to stop using energy derived entirely from fossil fuels.

This demographic analysis is necessary in order to understand how much the future of the automotive industry will impact our environment. We often have the illusion of thinking that the adoption of zero-emission vehicles can quickly solve the problems of our world, and this illusion perhaps derives from the concept of 'world' to which we often refer, thinking only of the developed part of the world.

The question then arises, will the initiatives that are being implemented be sufficient to reduce the environmental impact, or will it be necessary to start thinking about how to accelerate the technological curve in developing countries as well?

It is neither ethically correct nor environmentally sustainable to think that a world in which wealth is concentrated in a small area of the world is a sustainable scenario.

Finally, it is clear that what is often seen as the simple technological advancement of a product such as a car, hides behind it complex logics not only from a technological but also from a human point of view.

This leads one to think that while institutions and companies must act to encourage the acceleration of the technological curve, it is also necessary to act to increase public awareness of issues that are undoubtedly on the agenda but are often treated too superficially.

[71] Tranport & Environment, Recharge Eu: how many charge point will be Europe and its member states need in 2020s, 2020, pag 153

3. Regulatory's Plan of Action

3.1 Origin and features of Environmental policy

Even though the environment issue seems due to disruptive attitudes started from the second half of the 20th century, the history of humanity so far is not only a history of class warfare, but also a history of environmental catastrophes. The Romans, for example, had large parts of the Mediterranean forests cut down without a second thought. The supposedly nature-loving Indians in North and South America wiped out numerous animal species using exterminated numerous species of animals with sometimes cruel hunting methods, and the European cities in the Middle Ages were mostly stinking, rubbish-strewn and rat-infested cesspools. Nevertheless, it can and must be assumed that with the industrialization that began in England around 200 years ago, humanity entered into a new stage.

From the beginning, this phase has been accompanied by enormous environmental pollution in the vicinity of industrial plants. But more than the ecological question, the social question moved people's minds in this period. The real take-off into a global industrial and service society came with the end of World War II. World production and trade, if not the population itself, have grown exponentially, and in both capitalist and socialist countries progress has largely been equated with an increase in social product.

The "modern" environmental problem has essentially been discovered in the 1960s and mostly by scientists in the United States of America: the biologist Rachel Carson[72] predicted the negative effects of techniques in agriculture well in advance of the times, and was the first that warned about the damage inflicted on nature by the use and indiscriminate abuse of chemical insecticides like DDT and synthetic organic compounds, and about the phenomenon of deforestation and the uncontrolled intervention of man on the environment.

Paul Ehrlich denounced the population explosion, namely the number of people on earth was spiraling out of control.[73]

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[72] Carson R., Silent Spring, Houghton Mifflin Company, Boston, 1962
[73] Ehrlich, Paul R. The Population Bomb. Ballantine Books, New York, 1968.

The ecologist Garrett Hardin conjured up the "tragedy of the commons" focusing on the freedom to procreate. The unlimited increase in terms of numbers of human beings on Earth, would involve an excessive exploitation and, in extreme cases, an irremediable deterioration of natural resources.[74]

and Donella and Dennis Meadows used computer simulations to draw attention to the limits of growth. They stated that if the rate of population growth, of industrialization, of pollution and food production increase indistinctly, the limits of development on this planet will be reached at an unspecified time within the next hundred years. The most likely result will be a sudden and uncontrollable decline in population and industrial capacity. The state of global equilibrium should be designed so that the needs of every person on earth are met, and that each has an equal opportunity to realize their human potential. [75]

As counterpoints, as it were, to the naïve-optimistic belief in progress, these works found a broad response among the US public and led to the first high point of the environmental movement on "Earth Day" in April 1970.

This warning calls came into Europe with a certain delay. Originally, the founding Treaty of the European Economic Community (EEC), the so-called Treaty of Rome signed in 1957, did not provide any form of legislation for environmental protection. Indeed, in that phase, the contracting parties did not consider an environmental policy as a necessary common since the danger was not yet tangible and other policies on agriculture and industry were considered as much more urgent.

Transboundary pollution, particularly in the form of acid rain, led Sweden to propose in 1968 an international conference to address global environmental problems. In announcing the 1972 UN Conference on the Human Environment in Stockholm (the “Stockholm Conference”), the UN General Assembly stated that the “main purpose” of the conference was to serve as a practical means to encourage and provide guidelines for action by Governments and international organizations designed to protect and improve the human environment.[76]

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[74] Hardin G., The Tragedy of the Commons, Science 162, no. 3859, 1968, 1243-248.

[75] Meadows, Donella H., The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind, Universe Books, New York, 1972

[76] Brisman A., Stockholm Conference, Chatterjee D.K. (eds) Encyclopedia of Global Justice. Springer, Dordrecht, 1972. https://doi.org/10.1007/978-1-4020-9160-5_655

The UN Conference declared 26 principles by placing environmental issues at the forefront of international concerns and marking the start of a dialogue between industrialized and developing countries on the link between economic growth, the pollution of the air, water, and oceans and the well-being of people around the world.[77]

Stockholm Declaration:

Principle 2:
"The natural resources of the earth, including the air, water, land, flora and fauna and especially representative samples of natural ecosystems, must be safeguarded for the benefit of present and future generations through careful planning or management, as appropriate."

Principle 6:
"The discharge of toxic substances or of other substances and the release of heat, in such quantities or concentrations as to exceed the capacity of the environment to render them harmless, must be halted in order to ensure that serious or irreversible damage is not inflicted upon ecosystems. The just struggle of the peoples of all countries against pollution should be supported."

Principles 9, 10 and 11:

"Environmental deficiencies generated by the conditions of under-development and natural disastersp ose grave problems and can best be remedied by accelerated development through the transfer of substantial quantities of financial and technological assistance as a supplement to the domestic effort of the developing countries and such timely assistance as may be required."

"For the developing countries, stability of prices and adequate earnings for primary commodities and raw

[77] https://www.un.org/en/conferences/environment/stockholm1972

materials are essential to environmental management since economic factors as well as ecological processes must be taken into account."

"The environmental policies of all States should enhance and not adversely affect the present or future development potential of developing countries, nor should they hamper the attainment of better living conditions for all, and appropriate steps should be taken by States and international organizations with a view to reaching agreement on meeting the possible national and international economic consequences resulting from the application of environmental measures."

In the face of new environmental emergencies and in the wake of the first United Nations conference on the environment, the European Council held in Paris in 1972 declared the urgency of establishing common environmental rules the and the importance of this matter in terms of economic expansion. More than 200 laws on the subject have entered into force since the settlement of the Community. These first acts were aimed mostly at the control and labelling of chemical and hazardous substances, at the protection of water surfaces, as well as at the monitoring of pollutants.

The first phases of European environmental policy are, therefore, characterized by a vertical approach, consisting in the adoption of ad-hoc sectoral interventions. Even though the interest on the pollution phenomenon started to grow, the existing problem wasn't totally covered and further actions for pursue lasting and sustainable development were necessary.

The Chernobyl nuclear disaster in 1986 was the catalyst for the peak of public mobilisation around environmental issues. The explosion of the nuclear reactor near Kiev confirmed the worst fears and was an impressive proof of how quickly and distant events can affect our everyday lives.

In 1987, the Single European Act introduced into the Community Treaty a new title dedicated to the environment, thus giving this policy a formal legal basis and at the same time setting three main objectives on the subject: which constituted the first legal basis for a common environmental policy aimed at safeguarding the quality of the environment, protecting human health and ensuring the rational use of natural resources.[78]

In national and international surveys conducted between 1986 and 1990, environmental protection was often at the top of the list of problems considered urgent by the population.

The end of the Cold War and the East-West confrontation fundamentally changed the world political situation in 1989-1990.[79]

In 1992 the United Nations Framework Convention on Climate Change (UNFCCC) establishes the basis for international cooperation to fight climate change. More than 100 Heads of State met in Rio de Janeiro, Brazil, for the first *Earth Summit* with the general goal of limiting the average increase in global temperature and the resulting climate change. The agreement, which entered into force on March 21, 1994, aimed at stabilizing the atmospheric concentrations of greenhouse gases to a level that prevents dangerous anthropogenic interference with the Earth's climate system. It did not place mandatory limits on greenhouse gas emissions for individual nations, therefore it was a non-binding legal agreement, instead it included forecasts of updates, called protocols, that would set emission reduction targets. For the purposes of the agreement and the communication on its implementation, in particular Annex I countries (industrialized countries), must send regular reports listing the policies and measures adopted for the reduction of greenhouse gas emissions.

In 1997 more than 160 countries signed the Kyoto Protocol at the UNFCCC COP3. Unlike the first Earth Summit, the Kyoto Protocol was the first legally binding agreement in the world to reduce greenhouse gas emissions. Developed Countries (Annex B) pledged to reduce their total emissions by at least 5% in an initial commitment period (between 2008 and 2012) compared to 1990 levels. For all member countries of the European Union, the Kyoto Protocol establishes an 8% reduction in greenhouse gas emissions compared to 1990.

In 2000, the European Commission Established the European Climate Change Programme (ECCP) to build a cut-co2 emission-strategy. The first ECCP put in place the Kyoto Protocol measures in an extensive range of policy sectors. The main working groups were Energy,

[78]https://www.europarl.europa.eu/factsheets/it/sheet/71/politica-ambientale-principi-generali-e-quadro-di-riferimento

[79] Preisendörfer P., Diekmann A., Umweltprobleme, Handbuch soziale Probleme, Albrecht, Wiesbaden, 2012

Transport, Industry and Agriculture. With the second ECCP in 2005 the Eu Commission explored further cost-effective policies and measures to reduce Co2 Emission through additional working groups like aviation, Co2 and cars, carbon capture and storage.

8 years after the Kyoto Protocol, at COP21 in 2015, the first legally binding universal agreement on global climate has been adopted in Paris, to be implemented starting from 2020. The Paris agreement established a global action plan that address climate change through a deeper emission reduction commitment from all countries, both developed and developing.

Through the Paris agreement, 192 countries (accounting for 97 percent of global greenhouse gas emissions) have submitted their climate pledges and they agreed:

1. To keep the average global temperature increase well below 2°C compared to pre-industrial levels as a long-term goal;
2. To limit the increase to 1.5 ° C, as this would significantly reduce the risks and impacts of climate change;
3. To ensure that global emissions peak as soon as possible, while recognising that it will take longer for developing countries to reach their maximum level;
4. Achieve rapid reductions thereafter according to the best available scientific knowledge, so as to achieve a balance between emissions and removals in the second half of the century.[80]

Furthermore, they have agreed to strengthen the ability of societies to address the impacts of climate change and provide developing countries a continued and increased international support for adaptation.

Article 9:

"Developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation in continuation of their existing obligations under the Convention."

[80] https://ec.europa.eu/clima/policies/international/negotiations/paris

In fact, in order to achieve their goal, governments agreed to meet every 5 years to assess collective progress towards the long-term goals and inform the parties to update and improve their nationally contributions, also known as *global stocktake* process. They must also report to other Member States and the public on what they are doing to achieve climate action and report progress towards their commitments under the agreement through a robust system based on transparency and accountability.

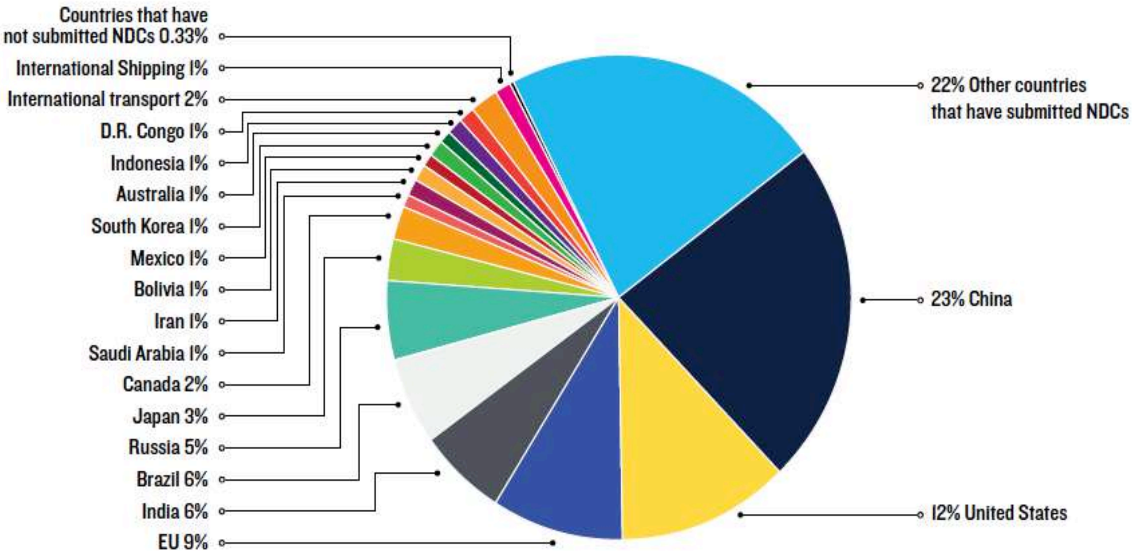


Figure 421: Share of greenhouse gas emmission by countries with climate targets[81]

Another essential element of the Paris Agreement related to (i) Climate Finance, (ii) Technology Transfer and (iii) Capacity-building support:

i. Climate Finance "*refers to local, national or transnational financing—drawn from public, private and alternative sources of financing—that seeks to support mitigation and adaptation actions that will address climate change".* For this purpose, the UNFCCC facilitated the provision of climate finance through financial mechanisms like the Global Environment Fund (GEF) and the Green Climate Fund (GCF) and other two special funds like the Special Climate Change Fund (SCCF), the Least Developed Countries Fund (LDCF) and the Adaptation Fund (AF).

[81] Natural Resource Defense Council

ii. Technology Transfer means that all countries are required to promote and cooperate in the development and transfer of technologies that reduce emissions of GHGs. Namely, they have to facilitate the transfer, or access, of climate technologies to other parties, particularly developing countries.

iii. Capacity building is about "enhancing the ability of individuals, organizations and institutions in developing countries and in countries with economies in transition to identify, plan and implement ways to mitigate and adapt to climate change" since not all countries are equipped of knowledge, public support, tools, political know-how and scientific expertise.

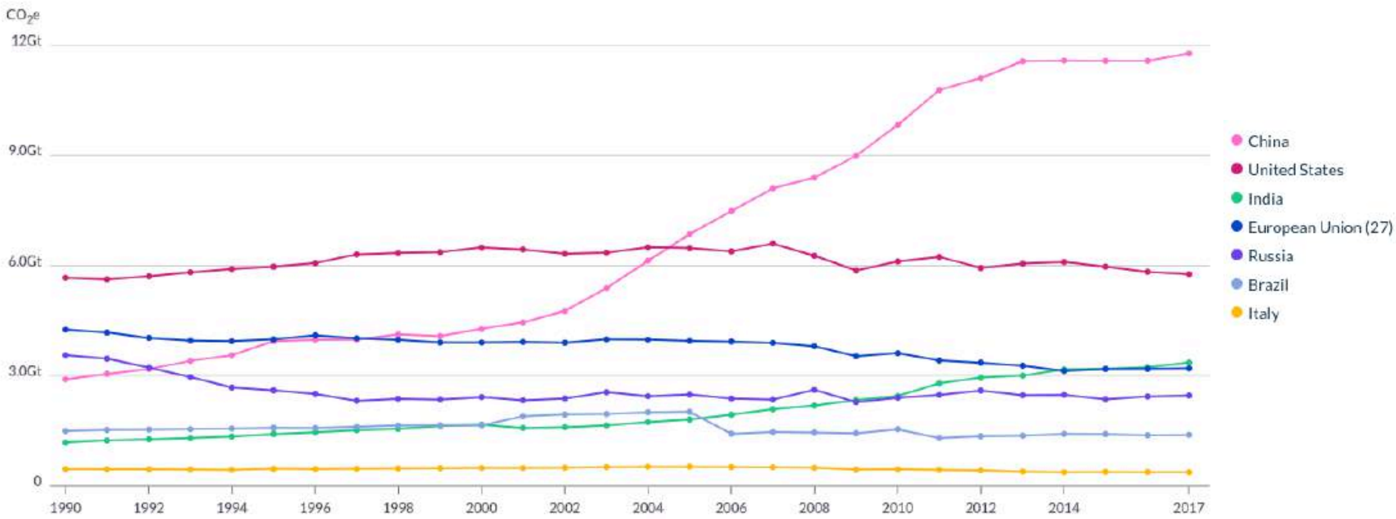


Figure 422: Global Historical Emissions - 7 Countries selected, from 1990 to 2017[82]

[82] Climate Watch Data

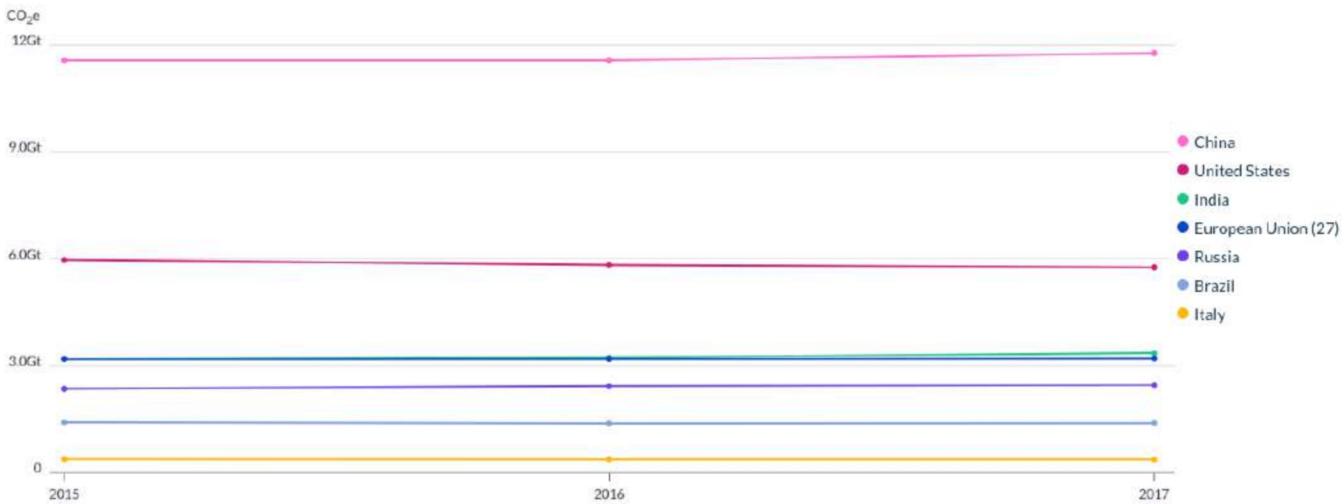


Figure 423: Global Historical Emissions - 7 Countries selected, 2015 to 2017

Despite the commitment of all states, the Intergovernmental Panel on Climate Change (IPCC), a scientific body of the United Nations, issued a dire climate warning in October 2018: greenhouse gas emissions are accelerating, and we are on the brink of a series of increasingly intense climate events that will endanger life on the planet.

Most scientists say that the Paris agreement will not be enough to prevent the global warming and if it happens, the earth will suffer devastating consequences, like heat waves, drought and floods, rising seas, ocean changes, artic ice thaws and species loss[83].

The IPCC report explained why is necessary and even vital to maintain the global temperature increase below 1.5°C versus higher levels showing the development impacts at 1.5°C and 2°C by finally asking for synergies and tradeoffs of mitigation and adaptation with the Sustainable Development Goals (SDG). Meanwhile in Europe, the EU environmental policy is based on Articles 11 and 191-193 of the Treaty on the Functioning of the European Union. The fight against climate change is an explicit objective of EU environmental policy while sustainable development is a general objective for the European Union, which is committed to ensuring "*a high level of protection of the environment and the improvement of its quality*" (Article 3 of the Treaty on European Union).

[83] Maizland L., Global Climate Agreements: Successes and Failures, Councilon Foreign Relations, 2021

TFEU - Article 191 (ex Article 174 TEC)
"*1. Union policy on the environment shall contribute to pursuit of the following objectives: preserving, protecting and improving the quality of the environment, protecting human health, prudent and rational utilisation of natural resources, promoting measures at international level to deal with regional or worldwide environmental problems, and in particular combating climate change….*"

After the Paris Agreement and the IPCC report, in December 2019, the European Commission presented the "Green Deal", a programme for more climate and environmental protection in the EU area. Sustainability became an important concern also for the European economy but whether these comprehensive goals and targets will result in a growth strategy for European companies, as promised by the EU Commission, depends crucially on the concrete implementation of the measures individually and entrepreneurially.

3.2 The European Green Deal

Many studies and statements on green programmes focus on climate and energy issues, but a Green Deal encompasses more than a response to climate change, it must promote eco-industries with a clear vision of greening the economy.
Based on the Eurostat/OECD definition of eco-industries, we define a Green Deal as a targeted government investment in *"activities which produce goods and services to measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems. This includes cleaner technologies, products and services that reduce environmental risk and minimise pollution and resource use"*[84].

In 2010 the European Commission adopted the Europe 2020 strategy for a smart, sustainable and inclusive growth, which will be triggered by greater innovation and by managing our resources more efficiently. This goal introduces the concept of eco-

[84] OECD/Eurostat, The Environmental Goods and Services Industry – Manual for Data Collection and Analysis, 1999

innovation proposed by the EU Commission, which states that eco-innovation "*refers to all forms of innovation – technological and non-technological – that create business opportunities and benefit the environment by preventing or reducing their impact, or by optimising the use of resources. Eco-innovation is closely linked to the way we use our natural resources, to how we produce and consume and also to the concepts of eco-efficiency and eco-industries. It encourages a shift among manufacturing firms from "end-of-pipe" solutions to "closed-loop" approaches that minimise material and energy flows by changing products and production methods – bringing a competitive advantage across many businesses and sectors."*[85]

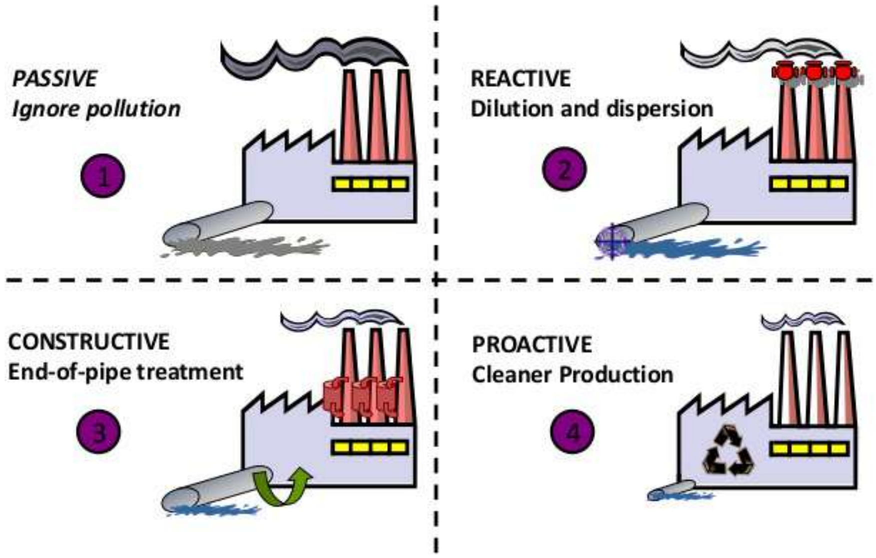


Figure 424: Background responses to pollution

The "*end of pipe*" or end-of-cycle technologies owe their definition to the fact that they intervene on the treatment of pollution after it has been produced, thus acting downstream of the production process: the gaseous emissions abatement plants and the treatment of biological or chemical-physical waste are an example[86].

While closed-loop approach in supply chain refers to all forward logistics in the chain (like procurement of materials, production and distribution) as well as the Reverse Logistics

[85] Interreg Europe, A Policy Brief from the Policy Learning Platform on Environment and resource efficiency, 2019
[86] GEMET - Environmental thesaurus

to collect and process returned (used or unused) products and/or parts of products in order to ensure a socioeconomically and ecologically sustainable recovery.[87]

From this definition we can state that one way to respond to the environment issue is implementing a circular economy, namely a model of production and consumption that involves sharing, lending, reusing, repairing, reconditioning and recycling existing materials and products for as long as possible. This transition promotion could also deal with the waste production occurring in the EU which accounts more than 2.5 billion tons of waste every year.

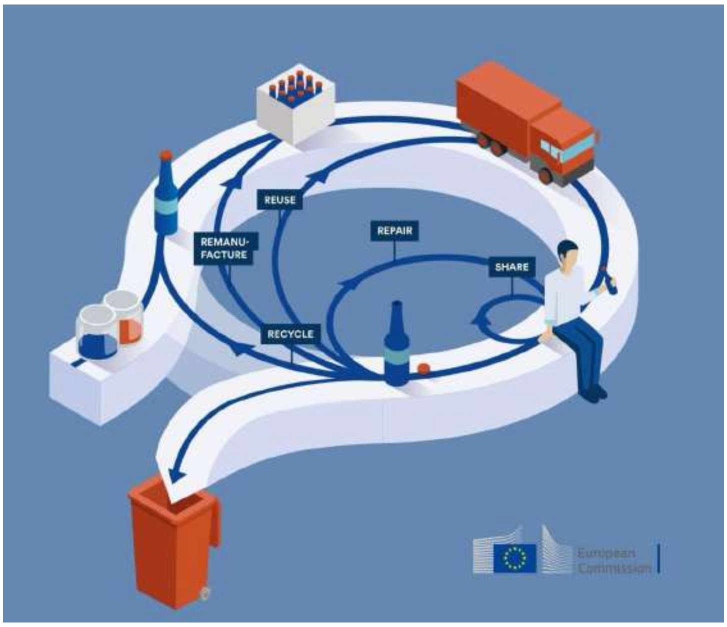


Figure 425: EU Circular Economy Action Plan, 2015

We have seen in the previous chapter that during the Paris Agreement in 2015, the international community committed itself to restricting global warming to well below 2°C, if possible, below 1.5°C compared to the pre-industrial level. From the beginning of its mandate in December 2019, the new European Commission headed by President Ursula von der Leyen declared climate policy a top priority[88].

On the way to a climate-friendly economy, the European Union relies on overarching target formulations, EU-wide measures and binding national climate protection targets.

[87] Kumar N et. al., Closed Loop Supply Chain Management and Reverse Logistics - A Literature Review, International Journal of Engineering Research and Technology, volume 6/nr. 4, 2013, pp. 455-468.
[88] Siddi M., The European Green Deal: Assessing its current state and future implementation, 2020

In December 2019, the heads of state and government of the EU committed themselves to the goal of climate neutrality by 2050.

By 2050, all greenhouse gas emissions in the European Union should be avoided as far as possible. The remaining emissions must be offset by processes that remove greenhouse gases from the atmosphere, especially sustainably managed forests and soils. With the European Green Deal, the European Union is showing that it continues to play an international pioneering role in climate protection.

In December 2020, the EU heads of state and government agreed to raise the EU climate target for 2030 from the current level of at least 40 to at least 55 percent compared to 1990. According to this, EU-internal greenhouse gas emissions should decrease by at least 55 percent by 2030 compared to 1990. The agreement was based on the proposal of the European Commission, which was published in September 2020 as part of the so-called *Climate Target Plan 2030* together with a detailed impact assessment. At the environmental council on December 17th, it was also decided that the new EU climate target for 2030 will be submitted to the United Nations as an updated EU climate protection contribution in 2020, as provided for in the Paris Agreement. In order to implement the EU's new, and more ambitious, 2030 climate target, the EU Commission will present a series of legislative proposals in 2021 to adapt the existing EU climate and energy legislation.

The European Green Deal (EGD) is the EU Commission's new key project. It is a comprehensive growth strategy for a climate-neutral and resource-saving economy. The overarching goal of the EGD is EU-wide greenhouse gas neutrality by the year 2050. Europe would thus be the first climate-neutral industrial region in the world. On 11 December 2019, the Commission presented a communication with its ideas for the Green Deal and a comprehensive work program for the further development of EU policies in this regard. The European Green Deal shows how a sustainable transformation can succeed: its measures are versatile. They range from climate, environmental and biodiversity protection to mobility and industrial policy to specifications in energy, agricultural and consumer protection policy.[89]

The figure below illustrates the various elements of the Green Deal:

[89] EU Commission, The European Green Deal, COM(2019) 640 final, Brussels, 2019

As an important part of the European Green Deal, the EU Commission presented its proposal for a European climate law on March 4, 2020. This is intended to stipulate the goal of Union-wide greenhouse gas neutrality by 2050 and thus offer authorities, companies and citizens planning security and serve as a guide. In addition, the EU Climate Act is also intended to legally anchor a new climate target for 2030, regulate measures for successful adaptation to climate change and regular progress monitoring, and ensure public participation on the way to climate neutrality in 2050. The negotiations on the EU climate law between the European Parliament and the member states are expected to be concluded in the first quarter of 2021.

3.3 Vehicles Emission Standard

After making an excursus on the regulatory framework that has been put in place to stimulate the reduction of the environmental impact, we will try to understand how the automotive sector implement these regulations to try to limit the environmental problems.
This analysis will focus on the European context as it would be firstly too complex to analyze the case applied in every single world area, but also because Europe in many situations has proved to be at the forefront in trying to limit the environmental impact.
This effort comes both from institutions, which ultimately implemented the Paris Agreement through the Green Deal, but also from European car manufacturers.

The regulatory framework aims to regulate mainly two areas:

1. Limitation of greenhouse gas production
2. Reduction of the pollutants emission

We will now try to analyze in detail these two macro-areas of regulatory intervention but before explaining in detail the limits imposed by the regulations it is necessary to deal with the issues concerning the methods through which these emissions are monitored.

3.3.1 Emission standard calculation

The methodology by which the emissions exhaled by vehicles are measured is often treated as a secondary aspect, but in reality, it represents a fundamental element. This is also due to scandals such as *Dieselgate*, which has brought to light irregularities perpetrated by car companies, but also the weakness of the measurement parameters and methodologies.
In fact, in 2018 the new WLTP (Worlwide Harmonized Light Vehicles Test Procedures) homologation method came into force, which replaced the previous NEDC (New European Driving Cycle) procedure.

The goal of WLTP is to reproduce in a more faithful way the real conditions of use of a vehicle, this is because the parameters established by the NEDC had proved unsuitable to reproduce the real conditions of use and therefore the real emissions which very often were very greater than stated.

Figure 426: Adoption of the WLTP[90]

The WLTP protocol is adopted by the 28 countries indicated in blue while the countries indicated in light blue (China, Japan, South Korea, Russia, India and the United States) use methodologies inspired by WLTP procedures.

This makes us understand once again how the European Union is at the forefront of policies aimed at reducing emissions.

[90] https://www.alpinecars.com/en/wltp/

To avoid values distortion, the WLTP was therefore invented, which introduced new test methodologies:

- ISC: this is a sample test carried out in mechanical workshops on used cars that must not be more than 5 years old or have 100,000 km. The goal is to assess the harmful emissions of carbon monoxide, nitrogen oxides and hydrocarbons.
  This test is used to monitor that the OBD (on board) emission control systems work even after a certain number of years. It is useful to know that new generation cars adopt systems to monitor that the anti-pollution systems such as the particulate filter are in good conditions and that they work efficiently, otherwise alerts are issued to indicate to the driver of the vehicle that anomalies are present, and it is necessary intervene with professionals to restore normal functioning.

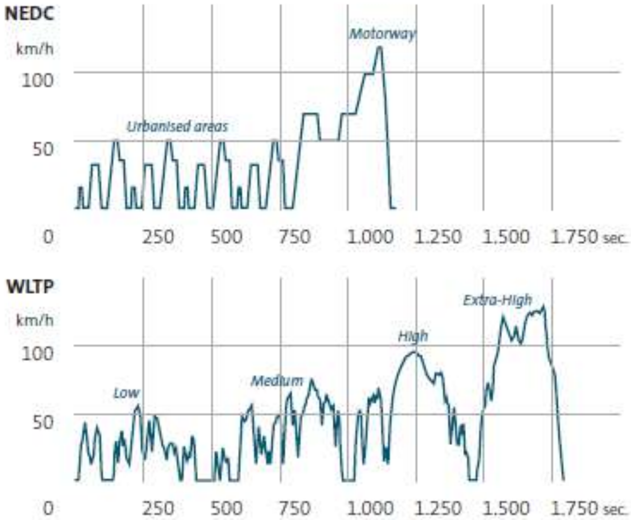
- EVAP: this test is used to measure the emissions from fuel evaporation when cars are off. The test measures the evaporations from the tank over a period of 48 hours at a temperature of 35°C, which must not exceed 2gr / 48 hours.

- RDE, this test is perhaps the most important as it assesses the actual emissions in road use and allows you to study the real behavior of the vehicle. Thanks to PEMS systems (Portable Emissions Measurement System) it is possible to measure CO2, NOx and particulate matter emissions (P 10, PM 2.5).

Figure 427: PEMS Bosh[91]

[91] https://www.bosch.com/stories/real-driving-emissions/

In addition, the test parameters through which the emissions of the models are being tested in view of being placed on the market have also changed.



	NEDC	WLTP
Starting temp.	cold	cold
Duration	1.180 sec.	1.800 sec.
Idle time	25 %	13 %
Distance	10.966 m	23.274 m
Phases	2 phases: Urban and long-distance trip	Up to 4 phases: "Low", "Medium", "High" and "Extra-High"
Speed	mean: 34 km/h – maximum: 120 km/h	mean: 47 km/h – maximum: 131 km/h
Acceleration	mean: 0,50 m/s^2 – maximum: 1,04 m/s^2	mean: 0,39 m/s^2 – maximum: 1,58 m/s^2
Influence of extra features	Currently not included	Special equipment is included (weight, aerodynamics)

Figure 428: Comparasion NEDC/WLTP[92]

By observing figure 3 it can be seen how the WLTP standard, compared to NEDC, tries to reproduce a greater number of conditions.

First of all, the test time passes from 20 to 30 minutes, this allows you to observe the car at regulated temperatures and on a greater number of conditions, the static time is reduced to 13%.

[92] Volkswagen Group, A new Standard, 2017, pag 4

This part, according to some, represents a delicate element, as it reproduces the conditions in the city less faithfully, in fact, especially in winter, short journeys at low speeds do not allow the car to reach the ideal operating temperature, and this tends to reduce the efficiency of the FAP / DPF (particulate filter) systems. Even though it could represent a critical element of the WLTP considering the NEDC, in absolute terms they are very low values, therefore the WLTP can be compared to NEDC on this aspect.
On the other hand, the distance traveled is greater, like the average speed and the top speed. With the NEDC parameters only speeds of 120 km/h were reached which is absurd if you consider that in countries like Italy on the motorway it can travel at 130 km/h.
Finally, tools such as air conditioning and heating are activated to understand their impact on consumption.
It is clear from this comparison how the adoption of WLTP is able to guarantee tests capable of reproducing real consumption in a better way.
More importance was given to the difference between the two types of tests, since those regulations on reducing emissions were first based on NEDC and then used the WLTP as a reference, as it was found that the parameters used in laboratory tests, gave false data compared to reality.

3.3.2 Reduction of greenhouse gasses

The European Union, in transposing the regulations deriving from the Kyoto Protocol and following the Paris Agreement, has applied the legislation to achieve the reduction of the CO_2 level emitted. This was made through two steps:

1. 2013-2020 target to reduce CO_2 emissions by 20% compared to 1990 values
2. 2021-2030 40% reduction compared to 1990 emissions

In addition to the transposition of international regulations, Europe has set for itself the goal of reaching the zero-emissions target produced by the transport sector by 2050.
This proves how much the European Union represents one of the reference benchmarks worldwide.

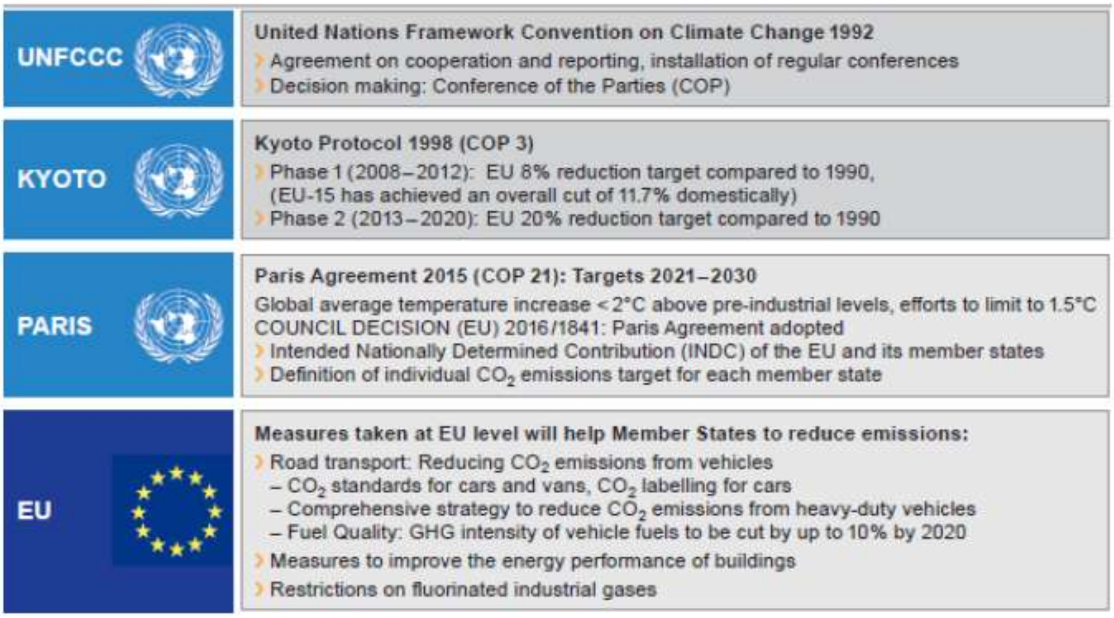


Figure 429: Main International agreements[93]

3.3.2.1 CO2 emission limit based on NEDC until 2020

Regulation (EC) No. 443/2009 regulates the CO2 emissions average for each passenger car manufacturer (M1) recorded in Europe each calendar year.

Regulation (EC) No. 510/2011 instead regulates CO2 emissions for light commercial vehicles (N1).

From 2009 to 2020 for car vehicles and from 2011 for light commercial vehicles, the emissions target (figure 3) for each individual vehicle varies according to the weight, and the curve is defined by the following formula:

CO2 = Target + a x (M - M0)

The parameters are those indicated in figure 2, where M0 is the average weight of the European car fleet in the previous three years.

[93] CPT Group, WorldwideEmission Standards andRelated Regulations Passenger Cars / Light and Medium Duty Vehicles, 2019, Regensburg, pag 1

While M represents the mass in kg of the vehicle for which the emissions target must be calculated.

By taking the weighted average of all vehicles registered for sale during the calendar year, the average emissions produced by the individual car manufacturer are obtained.

Vehicle type	Years	a	Target	M0
		g/km / kg	g/km	kg
Passenger Cars	2012-2015	0.0457	130	1372
	2016-2018	0.0457	130	1392.4
	2019	0.0457	130	1392.88
	2020	0.0333	95	1392.88
Light Commercial Vehicles	2014-2017	0.093	175	1706
	2018	0.093	175	1766.4
	2020	0.096	147	1766.4

Figure 30: Limit curve parameters[94]

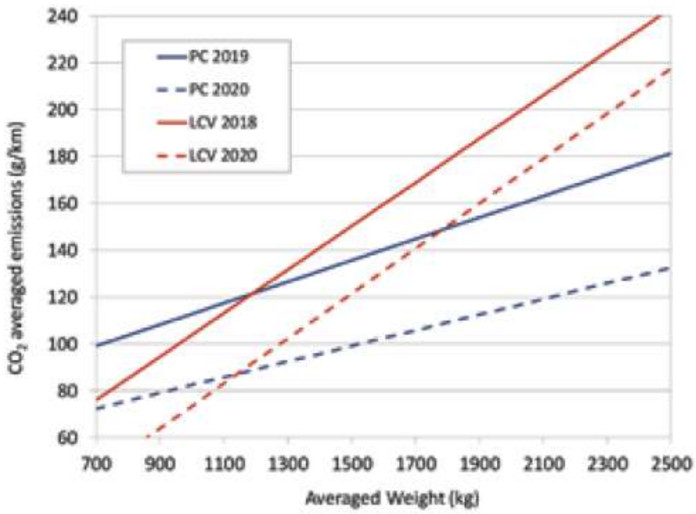


Figure 31: CO2 Emission Limit Curve[95] PC= passenger Cars, LCV=Light Commercial Vehicles

As summarized in Figure 5, the first limit was 130 g CO2 / Km for passenger cars and 175 g CO2 / Km for light commercial vehicles considering the period from 2012 to 2015 Since 2020 the regulation (EC) 333/2014 has defined the emission target 95 g CO2 / Km for passenger cars and the regulation (EU) No 253/2014 the target of 147 g CO2 / Km for the light commercial Veichles .

[94] Delphi Technologies, Worldwide emissions standards, Passenger cars and light duty vehicles, 2019, pag 79
[95] Delphi Technologies, Worldwide emissions standards, Passenger cars and light duty vehicles, 2019, pag 79

In this calculation it is also necessary to consider the presence of "super credits" or "green credits" which are attributed if the car manufacturer registers cars with emissions lower than 50 g CO2 / Km for sale.
These cars are included in the calculation of the emission weighted average and each vehicle is calculated twice in 2020, 1.67 in 2021, 1.33 in 2022 and 1 from 2023 onwards.
This reduction during the period from 2020 to 2022 is limited to 7.5 g CO2 / Km.
This aspect is particularly important because companies that have an excess of these super credits can sell them to other companies, if we consider the fact that producers who do not respect the emission limits incur financial fines, which are calculated on the number of g / km above the curve, multiplied by the number of vehicles sold by the manufacturer during the year:

- 2012/2018: 5 euros for the first gram, 15 euros for the second, 25 euros for the third and 95 euros for the fourth and the following excess grams.
- 2019 onwards: 95 €/gr excessing the limit.

It is understood how fines can reach considerable sums, and the ability to purchase green credits from other companies represents the possibility of limiting the economic impact, which on the other hand represents a disincentive to effort.
It should also be added that although the WLTP was introduced in 2017, this procedure was not used from 2017 to 2020, but with a series of parameters defined CO2MPASS, the CO2 emissions measured in WLTP were converted into NEDC.
In 2020, both WLTP and NEDC values were used with the aim of establishing the 2021 targets.
This was done in several steps in order to ensure a smooth transition from the NEDC procedure to the WTPL.

3.3.2.2 CO2 Fleet Target 2021 to 2024

Starting in 2021, each producer has individual CO2 emissions targets based on WLTP measurements.
Using the data obtained in 2020, each manufacturing company obtains a new CO2 emissions reference target based on the correlation between NEDC and WLTP, which is calculated as follows:

"WLTP specific reference target = WLTP 2020 CO2 *(NEDC 2020 target/ NEDC 2020 CO2)

- *WLTP 2020 CO2 = averaged CO2 emissions in 2020 obtained on WLTP,*
- *NEDC 2020 target = 2020 fleet specific emission target of the OEM,*
- *NEDC 2020_CO2 = averaged CO2 emissions in 2020 calculated on NEDC.*

Specific emissions for the single producer are instead calculated as follows:

Specific emission target = WLTP reference target + a [(Mø - M0) - (Mø**2020* **- M0,2020***)]***

- *a =coefficient defined for the year 2020 in table on previous page,*
- *M0 = reference mass for the specific calendar year, for 2021 it is the same mass as 2020.*
- *M0,2020 = reference mass for 2020 defined in table on previous page,*
- *Mø = manufacturer's averaged mass in the specific calendar year,*
- *Mø2020 = manufacturer's averaged mass registered in 2020."*[96]

[96] Delphi Technologies, Worldwide emissions standards, Passenger cars and light duty vehicles, 2019, pag 80

3.3.2.3 CO2 Fleet Target 2025 to 2030

In 2018, the European Parliament established that the new emission targets would be established in relation to the reference value for 2021 and a decrease of:

- 15 % in 2025 and 37,5% in 2030 for passengers cars
- 15% in 2025 and 31 % in 2030 for light commercial vehicles

"A CO2 reference value for 2021 is calculated for each OEM, as follows:

Reference value2021 (i) = WLTP 2020_CO2 measured * (NEDC 2020 fleet target/ NEDC 2020_CO2) + a · (M Ø2021 – M 02021)

- *WLTP 2020_CO2_measured = the averaged CO2 emission measured by the manufacturing company in 2020,*
- *NEDC 2020 fleet target = 95 g CO2/km for Passenger cars (PC) ; 147 g CO2/km for Light commercial vehicles (LCV) ,*
- *a =the coefficient 0.0333 for PC; 0.096 for LCV,*
- *M Ø2021 = the manufacturer's averaged mass in running order registered in 2021,*
- *M 0,2021 = the averaged mass in running order of all new vehicles registered in 2021.*

From 2025, a single WLTP emissions target for the European fleet will be used for all OEMs (car manufacturers) calculated on the average of the 2021 Reference Value:

EU Fleet wide target 2025/2030 (Σ Reference value 2021 (i) · N(i) / Σ N(i)) * (1 - reduction factor 2025/2030)

- *N(i) = number of vehicles sold by OEM (i) in 2021,*
- *reduction factor2025 = 0.15,*
- *reduction factor2030 = 0.375 for PC; 0.31 for LCV.*

While the target for each individual producer will be calculated as follows:

Specific emissions reference target 2025/2030 = EU Fleet wide target 2025/2030 · (TM – TM 0)

- *TM = manufacturer's averaged test mass of vehicles sold in the calendar year*
- *TM0 = EU averaged test mass of all vehicles registered in the calendar year*

Each manufacturer will have to stay below the defined target, if exceeded the manufacturer will have to pay 95 euros per CO2 / km gram in excess for all cars sold during the year.
This calculation includes super credits which modify the target as follows:

Specific emissions target 2025/2030 = Specific emissions reference target 2025/2030 · ZLEV Factor

The ZLEV factor has a max value of 1.05 and a min value of 1.0 and is defined as 1+y-x. The parameter y takes into consideration the share of low (< 50 g CO2/km) and zero emissions vehicles in the fleet according to a specific formula based on actual CO2 emission of the vehicle. x is the benchmark for low and zero emission vehicles sales target, set at 15% for the years 2025 to 2029, and 35% for PC and 30% for LCV for the years 2030 onwards."[97]

3.3.3 Reduction of the pollutant's emission

In the previous part we have seen that the legislation aimed at reducing the greenhouse gases produced by the automotive sector, especially those concerning CO2 which is considered the most impacting element.
CO2 does not impact on air quality, but impacts on global warming, there are other substances instead, already exposed in chapter two that are responsible for the quality of the air and even in this case the legislation intervenes to try to reduce emissions.
In this section we will discuss about these aspects.

[97] Delphi Technologies, Worldwide emissions standards, Passenger cars and light duty vehicles, 2019, pag 81/82

From September 1 2019, the legislation that requires all approved cars to comply with the limits of the 6D Temp came into force, which represents the most recent legislation in terms of emissions of harmful substances such as Particulate Matter (PM) and Nitrogen (Nox), which have been explained in detail in chapter 2.
The Euro 6D Temp standard is the evolution of the Euro 6C standard, which entered into force on 1 September 2017 and provided for the NOx limit of 0.8 mg / km for Diesel cars and 0.6 mg / km for petrol cars.
While for both types of engine the PM production limit is 0.005 g / km, but on this aspect the legislation has undergone minor changes over time, in fact it has focused on NOx emissions.
The difference between Euro 6C and Euro 6D Temp, concerns the methodologies used to measure emissions.
For the Euro 6C the use of the parameters assigned by the WLTP was expected but through laboratory tests on the test bench.

Figure 32: WLTP test in the laboratory

Regarding the Euro 6D Temp, instead, it is required that the parameters established by the WLTP protocol are carried out in real RDE conditions of use with the use of PEMs (explained in paragraph 3.3.1).

This is a strong paradigm shift because it determines the obligation for manufacturers to assess the real emissions of harmful substances.
To allow manufacturers to adapt to the new system, the limits of 0.6 for petrol cars and 0.8 for diesel have been maintained, but a multiplicative compliance factor has been added that makes the limit wider:

- **Factor 2.1** = until September 2019 petrol cars tested on RDE parameters could emit 126 mg / Km and Diesel cars 168 mg / Km;
- **Factor 1.43** = From 2020 petrol has a limit of 85.8 mg / Km and diesel 114.4 mg / Km, which has made the Euro 6 D pass from Temp (temporary) to 6D Standard.

According to Transport & Environment, the objectives established by the Euro 6D standard are not in line with the objectives of the European Union contained in the Green Deal.
This is because it is believed that the technological level would allow emissions to be lowered up to ¼ compared to the 0.8 mg / Km envisaged by the Euro 6 C, but with the Euro 6D standard the limits have even been raised as just seen.
Furthermore, it is believed that many of the harmful substances emitted into the air are treated in a marginal way, first of all the PMs smaller than 23 nm which are also able to determine DNA modifications. To date are completely unregulated since the FAP and DPF filters do not stop particles of this size.

It is therefore clear how the Paris Agreement and the transposition of the European Union through the Green Deal are contributing to reducing the environmental impact and making the European area at the forefront of the environmental challenge.

4. Operational Execution

After discussing the environmental issues associated with the production and usage of motor vehicles, we will proceed with the understanding of real initiatives that car manufacturers are implementing firstly to adapt to the legislation and secondly to try to reduce the environmental impact. At the end we will see what are the technological and organizational vectors that are related with the green development and transition.
In the first chapter we will try to explain why the supply chain plays a fundamental role in achieving the limits imposed by institutions and what are the objectives set by the companies themselves.

4.1 Green Supply Chain Management

One of the disciplines able to offer concepts that have a practical implication in the optimization of business operational processes with the aim of reducing the environmental impact, is undoubtedly the business discipline normally defined as Supply Chain Management, which finds in the addition of the adjective "*green*" a new way of using concepts and tools focusing not only on maximizing company profits but on protecting the environment.
First of all, it is necessary to clarify what Supply Chain Management is and to do this we can start from the definition given by the Council of Supply Chain Management, which represents one of the most authoritative research, training and dissemination bodies in this matter:

"Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies.
Supply chain management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a

cohesive and high-performing business model. It includes all of the logistics management activities noted above, as well as manufacturing operations, and it drives coordination of processes and activities with and across marketing, sales, product design, finance, and information technology."[98]

This definition hides the set of complexities that the corporate world has within it. Companies are living-systems and to continue to operate during their lifecycle, they need to move in relation to the context, implement relationships with it and with the players who are part of it.

The survival and success of the company depend on the ability of the management to understand that a company, especially in a dynamic context such as today, is not only a set of tangible assets but is the result of the flow of information, materials, financial resources, human resources and capital.

Elements and resources which, however, not only move within the physical and legal boundaries of the company, but which must be managed to create relationships with the external environment.

The need to pay attention to the supply chain and use it as a competitive lever derives from changes in the context due to the tendency to globalize business, the emphasis on competition based on quality and time, and the presence of increasingly demanding customers.

The development of technology and the exponential increase in computational capacity, on one hand, help companies to increase business performance, but on the other hand increase competition, triggering an escalation of technological improvements followed by ever faster technological obsolescence. In such context, the supply chain plays a primary role as the increasingly extreme specialization leads companies to focus on their core business, looking outside for companies with parallel and synergistic skills thanks to which it is possible to offer better and better products and services. In this aspect it is possible to notice one of the fundamental differences between logistics and supply chain, as the first refers to the management of the flows of goods and components, while the supply chain in addition to the handling aspect, has a strong internal relational component between companies.

98 https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx

The Supply Chain Management therefore offers the tools to analyze and understand the value proposition by providing managers with a new way of interpreting relationships with companies, which should not be seen as mere suppliers of materials and components but become suppliers in the first place of know how.
Ideally, transforming the supply chain into a value chain, where the various participating companies collaborate in order to be able to offer end customers products that are increasingly advanced and better than the competition. Competition therefore shifts from competition between companies to competition between networks.
After giving the definition of Supply Chain Management, as a second step, we will try to understand what the Green Supply Chain (GSCM) is and how it is characterized
As previously indicated, the companies that are part of the Supply Chain collaborate in order to create greater value for the end user. To do this, companies analyze trends to try to understand what the preferred elements are.In the automotive world this is particularly clear when observing the competition between car manufacturers, which carefully plan the range offered to attract specific types of buyers.
If you look at the range that the various brands offer, you will notice how companies try to cover all automotive segments with at least one model, and for each model various configurations are offered. Behind these choices there are extremely in-depth market studies, whose purpose is to maximize sales on one hand and corporate profits on the other.
In recent years, however, an important variable has taken over that car manufacturers must pay attention to, namely environmental sustainability related to car production.
On one hand, in fact, as indicated in the previous chapters, this attention to these aspects derives from regulatory obligations, but on the other hand, buyers are increasingly paying attention to the environmental sustainability when they buy a product. This sensitivity to these issues therefore becomes a marketing lever for companies which must organize themselves to offer products with an ever lower environmental impact.
So if until recently companies configured their supply chain with the aim of maximizing corporate profits, now the supply becomes the pivotal point on which to act, to comply with the regulations aimed at protecting the environment. This determines the birth of Green Supply Chain Management. This duality of objectives gives a huge boost to research into environmental protection because the economic impact of the automotive sector in

terms of supply chains is extremely important and drives both car brands and parts manufacturers to invest in research and development to comply with regulations and to accelerate the learning curve. This has an impact on all companies in the supply chain who have to maintain the standards required by the leading companies that market cars.
Furthermore, consider that many of the components that are used in the automotive industry are also used in other industries, and consequently, the stimulus given by car manufacturers to their component suppliers affects other industries both in direct and indirect terms.
It is therefore clear how the discipline of Green Supply Chain Management can contribute to solve environmental problems.
Now that the external perimeter has been delimited, we will try to understand in more detail what the practices related to the Green Supply Chain Manage discipline are.

4.1.1 Green Purchasing

As previously indicated in a dynamic and complex context such as today, where specialization reaches high levels, companies, in order to offer competitive products, must organize themselves by creating networks of companies.
Companies that have among their goals reducing their environmental impact, must be able to choose suppliers capable of supporting them in achieving this goal.
The choice of suppliers therefore becomes a strategic element: to be able to protect the environment and achieve profit at the same time, the need of collaboration becomes fundamental because if the philosophy and intentions are aligned, companies can achieve profit in an ethical way.

The aspects to be taken into consideration when choosing suppliers are the following:

1. **Choose environmentally certified suppliers:**
   The EMS (*Environmental Management System*) is a framework that helps companies plan and evaluate their environmental objectives so companies can understand what are the areas in which they can act to limit their environmental impact. The best-known EMS is ISO 14001 which sets the requirements for an environmental management system of an organization. It is part of the ISO 14000 series of standards

developed by the Technical Committee ISO / TC 207. This standard can be used for a certification, for a self-declaration or simply as a guideline to establish, implement and improve an environmental management system. Organizing according to the provisions of the ISO 14001 standard allows those companies that supply components to find new market opportunities and, at the same time, allows those looking for suppliers to select faster those that may have the necessary environmental sustainability characteristics.

2. **Check supplier requirements:**

   Although the ISO 14001 certification allows to accelerate the process of selecting the suppliers that make up the Green Supply Chain, it is still necessary carrying out direct checks.

   In this way, companies are ensured that what is certified corresponds to reality: sometimes this point is taken for granted, but cases in which large companies have had to answer for the environmental and ethical irregularities of their suppliers are not rare.

   This aspect is important because companies in charge of value creation, which are normally those who then sell the final product or service to consumers, given their position and contractual strength, have the ethical responsibility to influence the choices of their suppliers. Think, for instance, Apple, how many times it had to answer for the actions of its suppliers as illegal from a legal or ethical point of view.

3. **Use the level of environmental sustainability as a factor when choosing suppliers:**

   Although companies have to be charged of their social impact and role, it is also true that when business profit fails, the reason why companies exist also fails.

   Pursuing environmental sustainability has a cost, on average higher than developing products and processes that do not take this aspect into consideration, and especially in the short term the cost difference is sometimes high. For companies, therefore, choosing the suppliers of goods and services that guarantee certain environmental standards often also corresponds to higher purchase costs, which therefore requires careful consideration of the choices. These choices require a correct balance because pursuing environmental sustainability cannot always be done at the expense of profit, especially when it comes to listed companies, which in a certain way are correlated with investors' expectations. To reduce the impact and ensure business survival, it is important to gradually develop a Green Supply Chain.

4.1.2 Internal Environment Management

The Internal Environmental Management represents the creation of procedures by the company itself to regulate itself and give itself guidelines to follow with the aim of contributing to the reduction of the environmental impact.

Even though this aspect is very difficult to standardise and every company must design its own plans and timelines, however, it has some prerequisites necessary for operation:

1. **Support from top and middle management:**
   This commitment must first of all be perceived and formalized in its guidelines by the top management, this is important for developing awareness and commitment by the employees.

2. **Facilitate communication between various departments:**
   All business departments must perceive the importance of these dynamics and above all they must communicate and collaborate to succeed and develop concrete solutions. In the following, when it comes to product development, it will be better understood how fundamental organizational interdependencies are to guarantee the development of successful initiatives.

3. **Adopt an EMS:**
   As discussed in the previous paragraph, companies need guidelines to establish how to change their processes in order to become green companies and the adoption of an EMS such as ISO 14001 can represent a framework.

4.1.3 Green Distribution

Distribution, understood as the handling of goods and products in order to move goods where they are needed, represents one of the components with a strong impact on the environment.
Globally, it is estimated that passenger cars impact 2.8 gigatons of CO2 (where one gigaton equals 1 billion tons) while wheeled freight vehicles are estimated to impact 3.7 gigatons per year. It is understood that although media attention and technological development are focused on passenger cars, road freight transport has an even greater impact. The problem is also due to a lack of short-term technical solutions as existing technologies such as electric motors still fail to guarantee the driving force required to move vehicles weighing almost 20 tons at competitive prices. Also consider that as weight increases, the power required increases more than proportionally, as emissions increase more than proportionally.
This can also be seen from an analysis made by PwC on the impact of wheeled transport in Germany, which shows that the vehicles defined as heavy duty, i.e. those weighing more than 15 tons, despite having cumulatively only 39% of the total kilometers traveled, impact on emissions by 66%. Europe has already established a timeline, which provides for a reduction in emissions from heavy duty vehicles of 15% by 2025 and 30% by 2030. To be able to achieve these results, technologies are being developed, which can be summarized as follows:

1. **Conventional combustion engine trucks (SYT)** vehicles that are powered by Synthetic fuel, which is a liquid fuel derived from biomass or natural carbon dioxide.

2. **Purely battery electric truck (BET)** electric motor vehicles with an energy storage battery.

3. **Hydrogen powered fuel cell trucks (FCT)**: vehicles powered by hydrogen, which is converted into electricity that powers the electric motor.

4. **Overhead catenary hybrid trucks (CAT)**: a homologous system to the one that is used in certain situations by trains or trams, which connect to the electricity grid that is located on the cables above the rails.

Each technology has pros and cons, summarized in the following graph, consider that ICE represents the normal internal combustion vehicles that we are used to seeing every day:

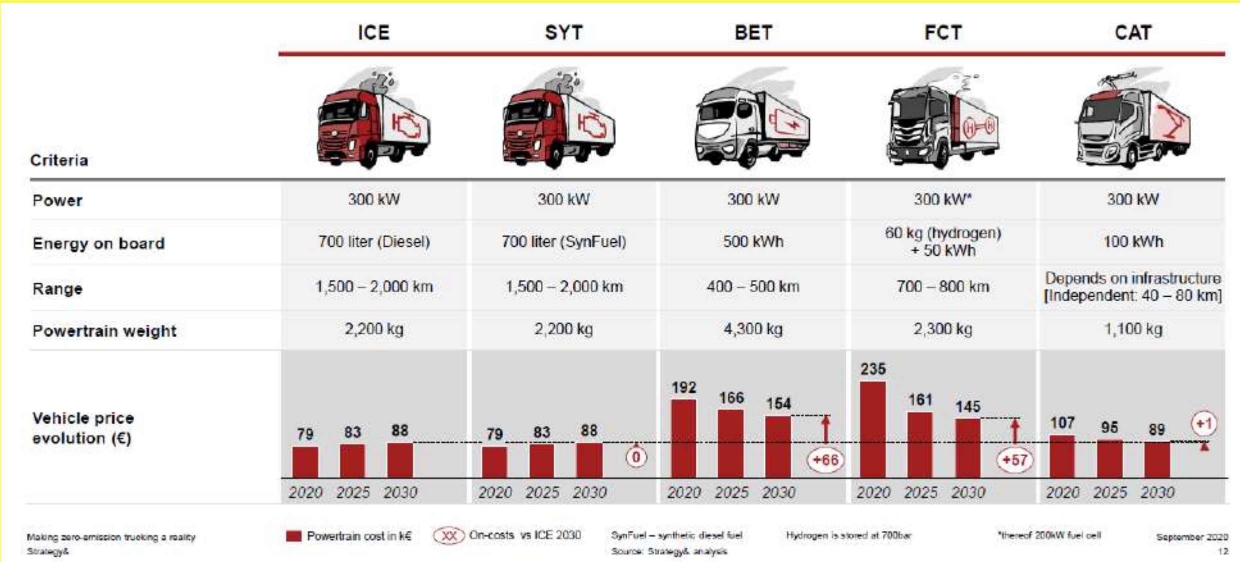
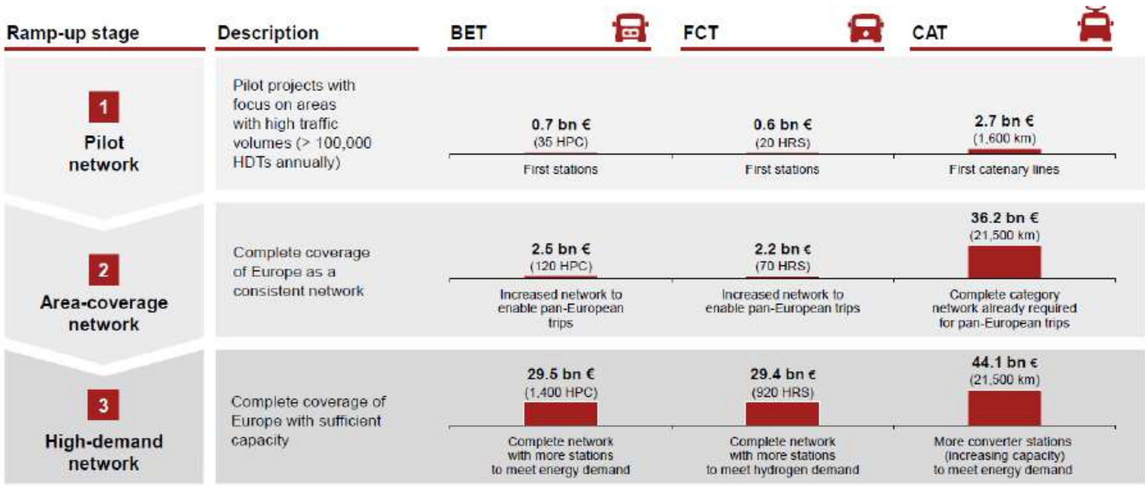


Figure 54: main characteristics of the various technologies

Choosing which is the most promising technology is a challenge and a huge bet for the whole market, as the choice of the technology to use also requires the development of the related infrastructures, and from the following graph you can understand what investments are necessary to test these technologies and to virtually develop them across Europe.



These huge figures can potentially help to solve environmental problems, but given the number of resources required, it is necessary to make the correct choices immediately.
In a certain way, cars are therefore representing a sort of test to acquire more information and technologies to be applied in the world of road transport.
Despite this, companies still have room for maneuver to limit the impact of transport in a short time before the development of technologies allows more radical and impactful initiatives.
This margin leverages the optimization that can be sought with initiatives such as:

1. Increase the utilization rate of vehicles;
2. Optimize loads through product and packaging planning that ensures better use of space;
3. Structuring warehouses and offices in order to reduce and optimize the overall length of all journeys;
4. Fill the vehicles even on return journeys.

These initiatives must be pursued not only by developing the know-how internally but also by making use of the skills of logistics companies, which are specialized in optimizing these aspects, and this makes us understand once again how important collaboration between companies can bring benefits for all.

4.1.4 Green Packaging

Each element plays a fundamental role in this battle for the protection of the environment, and almost every product, transported or sold, corresponds to its packaging.

Companies must also work on this variable by developing initiatives capable of rationalizing the production and disposal of packaging:

1. Maximize recycling
2. Reuse packaging whenever possible
3. Reduce the amount of wrapping

4.1.5 Reverse Logistcs

Reverse logistics concerns all the return handling of goods, components and finished products.

If on one hand logistics has the role of getting the goods to the end user, in a context of rationalization of resources and circularity of the economy, logistics also takes on the role of returning the goods to the manufacturing companies or their partners to reuse as much material as possible in recycling processes.

As will be seen later this is particularly true in the automotive sector where, by law, manufacturers are obliged to take charge of the vehicles at the end of their life.

As will be seen later in this industry, recycling must not be understood only as the destruction and reuse of the material obtained but there are various ways to restore life to an asset or its parts, such as the reuse of low wear, or the down-cycling of components that degrade during their life but still have sufficiently high standards to be used in other goods.

4.1.6 Green Production

Production is a process with a high environmental impact and energy expenditure.

This determines that companies must focus much of their energies on optimizing production through:

1. **Reduction of the energy required for production processes:**
   Invest in and encourage the use of recent technologies and the development of products designed with a focus on reducing the energy required during production.

2. **Direct or indirect use of energy deriving from renewable sources:**
   Companies must prefer the use of energy from renewable sources, to do this companies can for instance implement proprietary infrastructures such as photovoltaic systems. Anyway institutions must also provide the infrastructure necessary to reduce emissions, for example the exploitation of hydroelectric energy is unthinkable that it will be implemented by companies, but it must be a context design that makes it possible. In a supply chain logic, the reduction of the impact of production must also be done through the choice of suppliers who are located in geographical areas that make greater use of renewable energy, we will see this how much impact in percentage terms on the total emissions, has an electric car during its entire life cycle.

4.1.7 Green Design/ Design of new product

The final goods produced by companies have a great environmental impact and to make them eco-sustainable, companies strive to rethink them in order to reduce the impact they have throughout their life cycle, from production to recycling.
Often this component is also the center and the hub on which all business processes converge, and an eco-sustainable design requires the intervention of all company departments. The paradigm shift becomes important, which requires that the impact of the assets must be evaluated throughout their life cycle, from production to use and management of the asset at the end of its life. Given its fundamental importance in the automotive industry, green design will be dealt with in detail in the next paragraph, trying to investigate which are the most important initiatives in reducing environmental impact.

4.2 Green design of passenger cars

When it comes to automotive, the first element that comes to mind is obviously the car, which although it is not the only element on which companies intervene in this path of environmental improvement, is undoubtedly the one that is having the greatest changes. It is therefore right to understand in detail the changes that are taking in place, dedicating a good part of the chapter to this aspect.

First of all, in order to comply with sustainability standards, car manufacturers cannot limit themselves to considering only the emissions reduction aspects of cars during use, but must also consider pollution reduction throughout the car's life cycle. Therefore, a *green design* approach requires taking into account and optimising various aspects, including: the choice of raw materials and components with a low environmental impact, the impact of production technologies, emissions during the vehicle's life cycle and finally the procedures for recycling the vehicle at the end of its useful life.

The choices that are made to reduce impact during the life cycle have a strong impact on all business processes, and each choice is related to various business aspects, so the approach that companies adopt is to analyse the complexity of the system, moving the individual variables to achieve total optimisation.

The areas that most influence the impact that cars have during their life cycle are: the type of vehicle and its characteristics such as weight and aerodynamics, the propulsion system which can be the conventional internal combustion system, or alternative propulsion systems, in particular hybrid or electric cars, and finally there are the choices made in relation to production technologies and the choices in terms of materials and recycling.

We will try to deal with these elements clearly. Although many of these aspects are complex and fall within the technical field, it is useful to try to understand them.

In times when fuel consumption was not a sensitive issue for society, car manufacturers were building their cars trying to produce more and more performing and aesthetically appreciated vehicles on the market. Now that attention to environmental impact is one of the key elements, companies' research focuses on maintaining high performance and aesthetics by improving aerodynamics and reducing weight. This is because these two elements, as we will see shortly, are the most important determinants of a vehicle's fuel consumption.

4.2.1 Impact of aerodynamics on emissions

The shape that is given to the bodywork of a vehicle is extremely important in order to achieve the trade-off between maximising profits and protecting the environment, since, clearly, the aesthetic appearance of a vehicle is an element that buyers look at when purchasing a product, but it is also true that the shape of the car has a huge impact on energy consumption, since it determines its aerodynamics, which indicates the level of the vehicle's ability to cut through the air.

The aerodynamic level of a vehicle is indicated by the cx coefficient, which in physics measures the aerodynamic resistance of a body moving through a fluid. Translated into practice, to measure the resistance encountered by a car as it travels along a road and clears the air, it is necessary to calculate the cx by multiplying it by the frontal surface area of the car. However, since this is only an approximation, car manufacturers use modern wind tunnels to calculate the real resistance of the wind to the car as it moves forward. The lower the CX, the more aerodynamically efficient the car.

To better understand this aspect, consider that, as Bellmann et al. indicate, 53% of the energy produced by an engine is used to overcome the resistance given by the air as it passes through the vehicle, while 32% of the engine's power is used to overcome the friction created between the tyres and the road surface.

This illustrates the importance of improving aerodynamics, since 85% of the force produced by the engine is used to combat air and ground resistance, while only 9% is used by other car's components, such as the electronics components, and 6% is lost in friction in the transmission system. Also consider that a 15% reduction in aerodynamic resistance at a speed of 55 mph (88.5 km/h) results in a fuel saving of between 5 and 7%.

To understand the importance of what might seem like small percentages in terms of energy savings, consider that according to Belmann et al. a reduction in fuel use of 1% of the world's car fleet, results in fuel savings of approximately 245 million US gallons, which when converted to litres equates to a saving of 927 million litres.

Now that we understand how the shape of a car impacts on emissions, it is right to understand how car manufacturers address this issue.

The pivotal element around which the optimisation of the aerodynamic aspects of a vehicle revolves is the wind tunnel, which is basically a large tunnel that, with the aid of powerful engines, manages to create air flows capable of reproducing the friction created between a solid object (which can be a car, an airplane, a bicycle, etc.) and the air.

Figure 55: Wind tunnel, Fca group, Orbassano.

In a nutshell, the wind tunnel is able to faithfully reproduce the air flows that are created while the car is in motion, the car is placed on a rotating platform capable of reproducing the dynamic aerodynamic impact, making the car turn and reproducing the rotation of the tyres and the flow of the road, thus reproducing real driving conditions.
In addition, these tests are also carried out at different temperatures in order to simulate the change in air density due to the change in temperature.
Once the effect of air on the vehicle has been simulated, the aerodynamic impact is measured using a scale on which the car is placed, which is able to measure extremely small weight variations. For example, the FCA wind tunnel can measure variations in the order of 50 g, which is an extremely small number if you consider the weight of a car.
The measured weight change then indicates how much the car is "pressed" to the ground during air penetration, the lower this index is the more aerodynamic the car is.

At this point, having clarified how much the shape of a car impacts on its operation and environmental sustainability, it is also clear how complex vehicle design is and that communication between the various company departments is fundamental to achieving that trade-off between design as aesthetics and design as functional form.

4.2.2 Importance of weight on emissions

Having explained the importance of the aerodynamic component, we will now discuss the impact of weight on emissions.

The reason for the impact of weight on consumption is simple physics: the greater the mass of an object, the greater the energy needed to move it.

The weight of cars, for the average customer, is not a factor that is taken into account when making a purchase, as the driver does not perceive the engine effort needed to move the mass of the vehicle, but think instead of what happens in a sport like cycling, where the driving energy comes from human effort: for decades, the bicycle industry has been trying to reduce the weight of bicycles by changing the materials used to make frames from steel to aluminium, carbon fibre and titanium, but it also works on the development from the shape of the components to file away every possible gram. For cyclists the importance of reducing weight is a necessity because they perceive the effort required to move a heavier vehicle, but also as motorists we should consider the price we pay for moving heavy vehicles, which takes the form of damaging our most important asset: the environment.

The weight has a huge impact on emissions to the extent that, according to the FIA International Automobile Federation, a weight reduction of 380 kg would result in a 40% reduction in emissions.

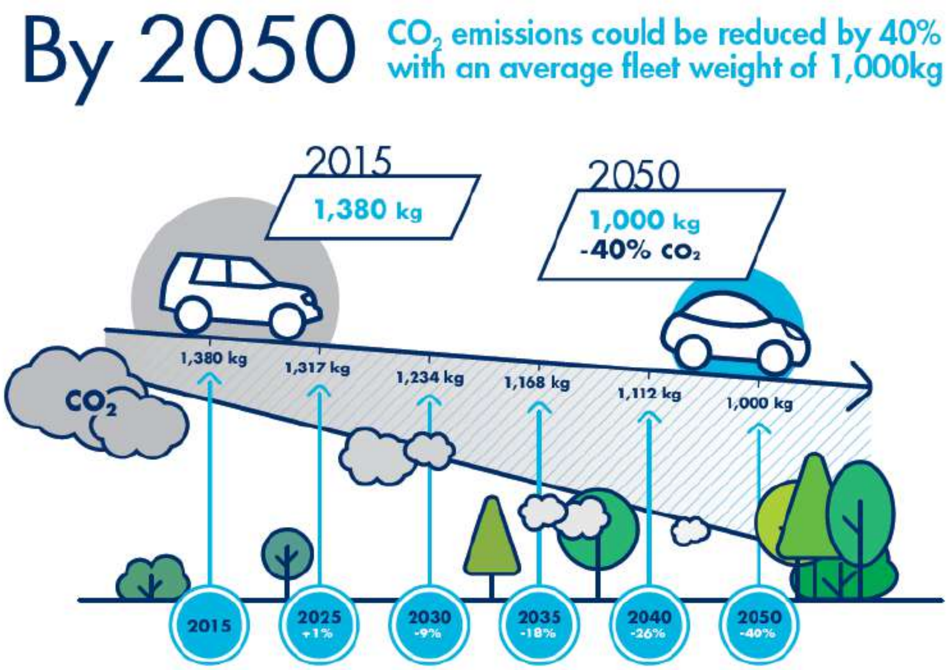


Figure 56: impact of weight on emissions.[99]

Companies therefore attach great importance to the type of materials used, especially for the construction of the chassis and the bodywork.

The materials that have a positive impact, without affecting the rigidity and durability of the machine, are composite materials such as HSS, which is a very resistant steel but lighter than the steel traditionally used, carbon, which is too expensive and not suitable for mass processing, and aluminium.

With the use of aluminium, Norman B., estimates a maximum weight reduction of 33%, while with HSS a weight reduction of 20% could be achieved.

In addition, according to the non-profit organisation Transport and Environmental, the use of aluminium in car production is a cause for concern: *"a mass saving of 100kg can deliver an average saving of 5.4gCO2/km on a vehicle powered with a conventional internal combustion engine (ICE).48 However, light-weighting allows many further design optimisations that can lead to better CO2 emission improvements. Indeed, smaller parts can be fitted to the vehicle, such as the powertrain, as less power is needed from the engine for the same level of performance, as well as less energy to cool it down; the gearbox has less torque to deliver to the wheels; but also non-powertrain parts, such as brakes, suspensions,*

[99] Federation Internationale de l'automobile, How less heavy vehicles can help cut CO2 emissions, 2020

etc. For the same mass reduction of 100kg with an optimised powertrain, the European Aluminium Association's CO2 average saving estimation goes up to 6.9gCO2/km. The increase in average mass has contributed to around an 8.5g/km increase in CO2 emissions overall."[100]

On the face of it, the choice would seem to lean towards the use of aluminium, but one must also take into account the impact on the whole life cycle, and the fact that the production of aluminium requires more energy and is less recyclable.

As can be seen from the analysis of Jarod C. et all *"GHG emissions ratios of a base material (row) replaced by another material (column) on a weight basis, i.e., 1 kg of cast iron replaced with 1 kg of steel has a GHG emissions ratio of 4.11 (g CO2e/kg)/(g CO2e/kg)."*[101]

Replaced Material \ Replacing Material	Cast Iron	Cast Aluminum	Steel	HSS	AHSS	Glass Fiber	Wrought Aluminum	Magnesium (w/o SF_6)	Magnesium (with SF_6)	Carbon Fiber
Cast Iron	1.00	2.84	4.11	4.11	4.11	5.66	10.31	13.30	52.98	21.31
Cast Aluminum	0.35	1.00	1.45	1.45	1.45	1.99	3.63	4.68	18.64	7.50
Steel	0.24	0.69	1.00	1.00	1.00	1.38	2.51	3.24	12.90	5.19
HSS	0.24	0.69	1.00	1.00	1.00	1.38	2.51	3.24	12.90	5.19
AHSS	0.24	0.69	1.00	1.00	1.00	1.38	2.51	3.24	12.90	5.19
Glass Fiber	0.18	0.50	0.73	0.73	0.73	1.00	1.82	2.35	9.37	3.77
Wrought Aluminum	0.10	0.28	0.40	0.40	0.40	0.55	1.00	1.29	5.14	2.07
Magnesium	0.08	0.21	0.31	0.31	0.31	0.43	0.78	1.00	1.00	1.60
Carbon Fiber	0.05	0.13	0.19	0.19	0.19	0.27	0.48	0.62	2.49	1.00

Figure 57: CO2 Emissions Ratio of different materials

The CO2 emitted in the production of HSS is the same as in the production of steel (1.00), but the reduction occurs during the use of the machine as it is less heavy.

The same applies in terms of the energy required to produce the material:

"Primary energy ratios of a base material (row) replaced by another material (column) on a weight basis, i.e., 1 kg of cast iron replaced with 1 kg of steel has an energy use ratio of 1.32 (GJ/kg)/(GJ/kg), or 1.32."

[100] Transport & Environment, CO2 EMISSIONS FROM CARS: the facts, 2018, pag.31

[101] Jarod C. et al., Impacts of Vehicle Weight Reduction via Material Substitution on Life-Cycle Greenhouse Gas Emissions, 2015, Argonne, pag. 3/4

Replaced Material \ Replacing Material	Cast Iron	Cast Aluminum	Steel	HSS	AHSS	Glass Fiber	Wrought Aluminum	Magnesium	Carbon Fiber
Cast Iron	1.00	1.18	1.32	1.32	1.32	2.78	4.01	5.43	9.35
Cast Aluminum	0.85	1.00	1.12	1.12	1.12	2.36	3.40	4.60	7.92
Steel	0.76	0.89	1.00	1.00	1.00	2.11	3.04	4.11	7.08
HSS	0.76	0.89	1.00	1.00	1.00	2.11	3.04	4.11	7.08
AHSS	0.76	0.89	1.00	1.00	1.00	2.11	3.04	4.11	7.08
Glass Fiber	0.36	0.42	0.47	0.47	0.47	1.00	1.44	1.95	3.36
Wrought Aluminum	0.25	0.29	0.33	0.33	0.33	0.69	1.00	1.35	2.33
Magnesium	0.18	0.22	0.24	0.24	0.24	0.51	0.74	1.00	1.72
Carbon Fiber	0.11	0.13	0.14	0.14	0.14	0.30	0.43	0.58	1.00

Figure 48: Energy ratio in Joule

Companies must therefore analyse the impact of the materials chosen, throughout the life of the car to understand which choice can optimise the reduction of emissions, but beyond this it is clear how the community and the environment can benefit from research directed towards reducing the weight of cars.

Although this is clear, however, if you look at the data on the weight of new cars, something seems to be wrong with this equation.

According to a study published by the European Environment Agency *"After a steady decline from 2010 to 2016, by almost 22 grams of CO2 per kilometre (g CO2/km), average emissions from new passenger cars increased in 2017 and in 2018 (by 2.8 g CO2/km in total). According to provisional data, the upward trend continued with an additional increase of 1.6 g CO2/km in 2019, reaching 122.4 grams of CO2 per kilometre. This remains below the target of 130 g CO2/km that applied until 2019 but well above the EU target of 95 g CO2/km that phases-in this year.*

The reasons for the increase in car emissions include the growing share of the sport utility vehicle (SUV) segment.

About 38 % of new car registrations were SUVs. Compared to other cars in the same segment, SUVs are typically heavier and have more powerful engines and larger frontal areas – all *features that increase fuel consumption. The majority of new SUVs registered were powered by petrol, with average emissions of 134 g CO2/km, which is around 13 g CO2/km higher than the average emissions of other new petrol cars."*[102]

According to the International Energy Agency, SUVs consume about a quarter more energy than the average car, which has led to an increase in global demand for fuel of 3.3 million barrels a day from 2010 to 2018, while other types of car have seen a decrease in demand over the same period, as efficiency improvements in small cars have saved about 2 million barrels a day.

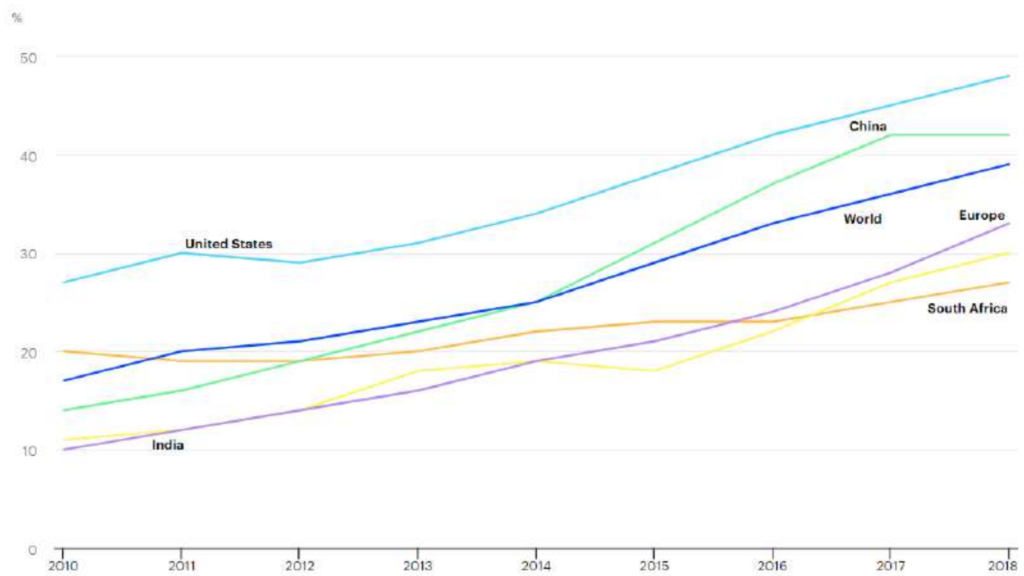


Figure 59: Share of SUVs in total car sales in key markets, 2010-2018 [103]

These figures are impressive and it is necessary to understand the reasons for this increase in weight, why car manufacturers have continued to offer heavier and heavier models despite the limits imposed, and why, according to figures made available by the Transport and Environment organization, this trend has been going on for at least 20 years.

[102] https://www.eea.europa.eu/highlights/average-co2-emissions-from-new-cars-vans-2019
[103]https://www.iea.org/commentaries/growing-preference-for-suvs-challenges-emissions-reductions-in-passenger-car-market

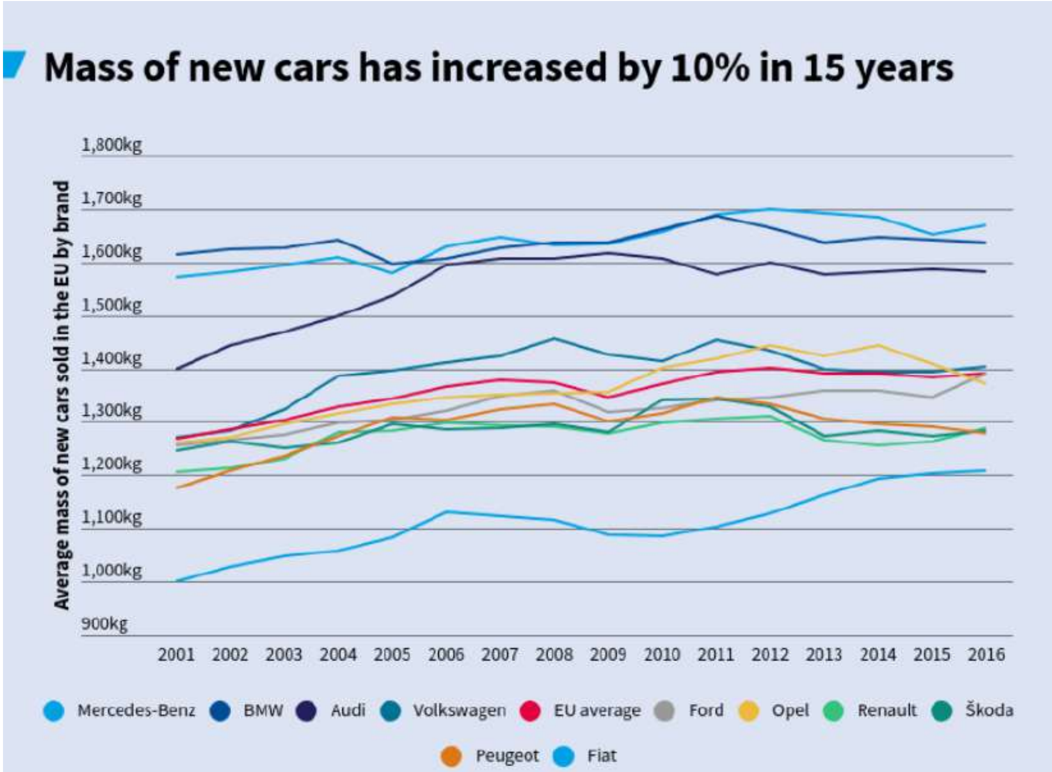


Figure 60: Increased weight of cars[104]

With modern safety standards, even the lightest cars guarantee enormous shock-absorption capacity. Modern cars tend to “crumple” even for not particularly powerful accidents and this suggests this makes people think that the passenger has suffered serious damage, in reality, the opposite is true, because it is the vehicle that should absorb the impact and not the passenger.

Despite this, as a matter of physics, larger cars tend to guarantee greater safety in the event of an accident, as the greater distance between the start of the hood and the people in the passenger compartment guarantees greater shock absorption capacity.

As can be seen from the graph below, deaths decrease as car size increases (mass and weight are correlated).

But it is also interesting to note that the curve is much flatter in recently produced cars, showing how technology has decoupled size and safety.

[104] Transport & Environment, CO2 emissions from the cars: the facts,2018, pag.31

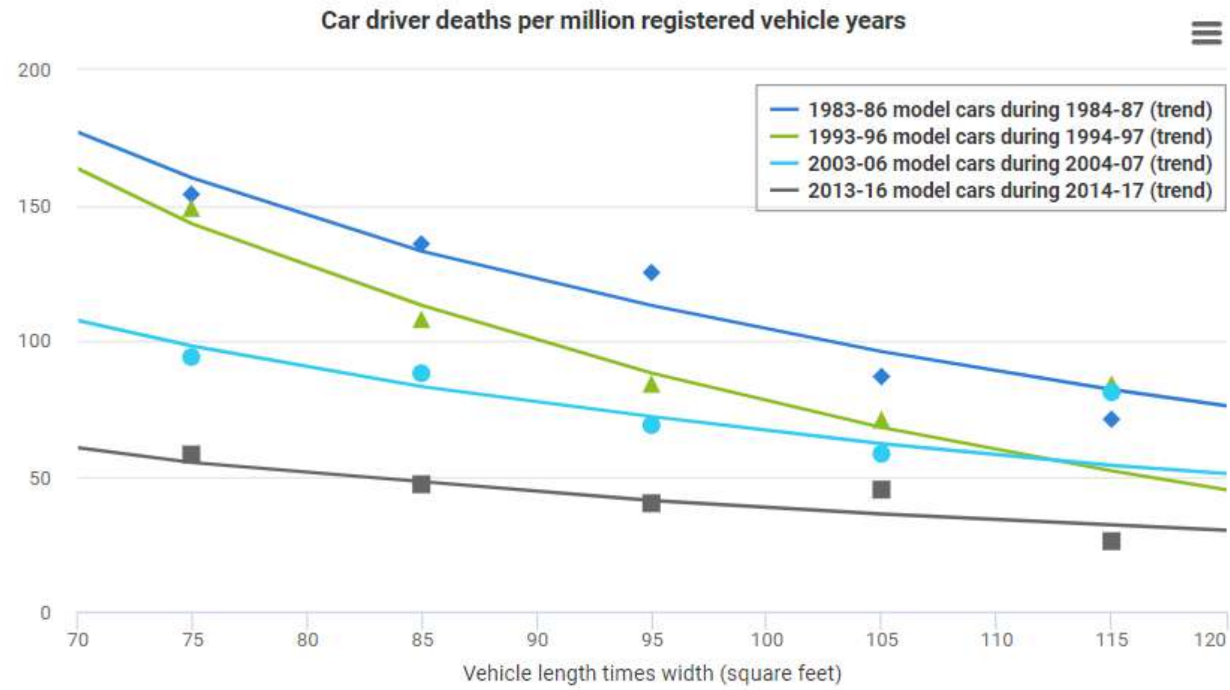


Figure 61: Car driver death per million[105]

On the other hand, the excessive weight of cars is paradoxically becoming a safety problem, according to the IIHSI Insurance Institute for Highway Safety: *"weight is important when two vehicles collide. The bigger vehicle will push the lighter one backward during the impact. That puts less force on the people inside the heavier vehicle and more on the people in the lighter vehicle.*

IIHS demonstrated the role of size and weight in a series of crash tests in 2019, pairing a midsize SUV and small car made by Kia and a large car and minicar made by Toyota in collisions with each other. Both of the smaller vehicles, the 2018 Kia Forte and 2018 Toyota Yaris iA, had good ratings in the five IIHS tests relevant to driver protection, but they performed poorly in collisions with the larger vehicles. Improvements in crash protection have made vehicles of all sizes safer, but bigger vehicles are still safer than smaller ones even with those improvements."[106]

The size of the cars and consequently the weight could therefore be justified by safety, but it should also be considered that there is an incompatibility in terms of safety between cars of very different sizes because in the event of an accident between a small car and an

[105] https://www.iihs.org/topics/vehicle-size-and-weight
[106] https://www.iihs.org/topics/vehicle-size-and-weight

SUV, the occupants of the small car absorb a greater amount of force. In fact as stated by the IIHS *"the bigger vehicle will push the lighter one backward during the impact. That puts less force on the people inside the heavier vehicle and more on the people in the lighter vehicle."*[107]

It is therefore a question of safety and consumption, but also of ethics, since it is as if the ability to buy bigger cars tends to correspond to the ability to buy safety.

According to Kahane (Kahane 2012), one approach to respect safety and reduce emissions at the same time is to reduce the weight difference between heavier and lighter cars by lightening the heaviest ones.

A reduction of 100 pounds (about 45 kg) in both categories would lead to a 1.6% increase in fatalities if cars weighing less than 1400 kg were included in the reduction.

Safety therefore proves to be an important element to be taken into consideration in weight reduction.

Another important element is also the aesthetic element and the fact that cars tend to be an element that defines the social status of individuals, these two aspects tend to determine an element of people's preference for SUVs.

This proves that SUVs steal market shares from other segments which, for the same amount of space and equipment, are able to guarantee a lower weight.

This segment is that of stationwagons, which for years represented the premium segment of car manufacturers and, thanks to its aerodynamic shape and lower height, guaranteed lower weights and consequently lower emissions.

This shows how an extremely rational segment that combines safety, space, comfort and low emissions is losing market share in favour of SUVs.

[107] https://www.iihs.org/topics/vehicle-size-and-weight

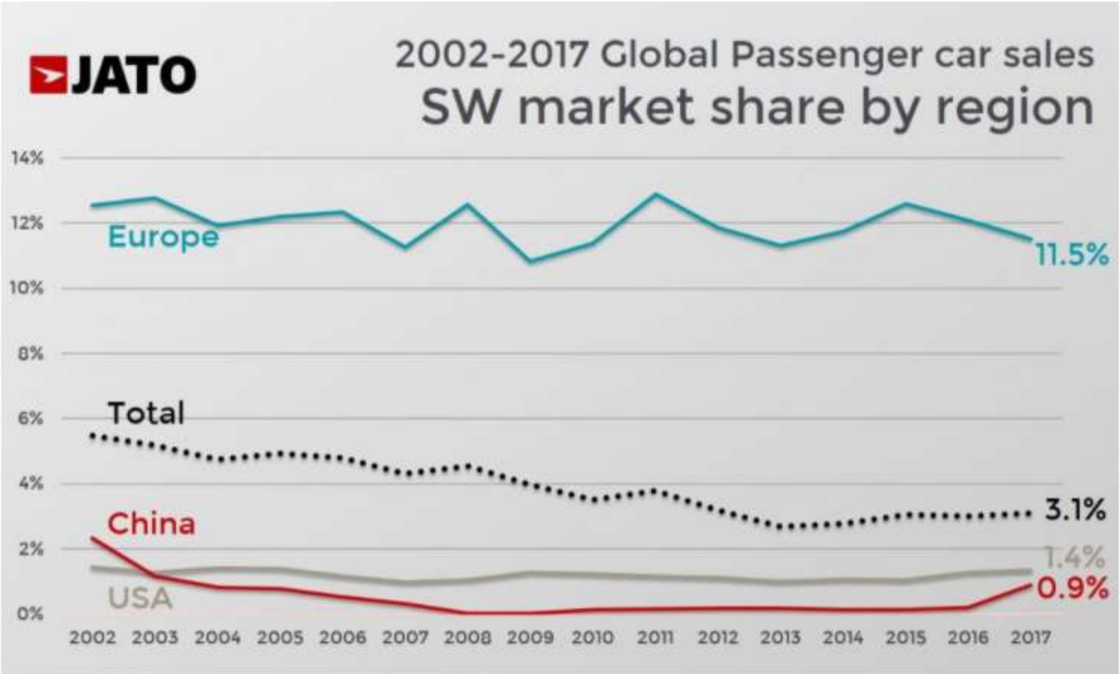


Figure 62: Stationwagon market share[108]

But the element that seems to have the greatest impact on the choice of manufacturers to reduce the weight of cars, is the European legislation on how to identify the maximum CO2 emissions emitted by cars.

As explained in chapter 3, from 2020, regulation (EC) 333/2014 sets a target for passenger cars of 95g CO2/Km, compared to the previous target of 130g CO2/Km. While for light commercial vehicles the limit was set at 147g against 175g of the previous target. These targets are to be assessed on the average of the entire fleet of cars sold, which means that car manufacturers can produce cars that emit more, as long as the average is 95g CO2/km.

Another element to be taken into account is the presence of Super-Credits issued for cars that emit less than 50 g CO2/Km, which as folded above represents additional room for manoeuvre for companies that find themselves able to exceed the 95 g average.

Although the average emission is important, a target is set for each individual vehicle, which is related to the mass of the vehicle. This parameter takes into account the evolution of the average weight of cars, e.g. from 2016 to 2020 the reference mass went from 1392.4 kg to 1379.88. This target is based on the limit value curve which is described

[108] https://www.jato.com/station-wagons-are-disappearing-but-wait-theres-hope/

in chapter 3 and implies that heavier vehicles can emit more CO_2 than lighter cars while maintaining the required average emissions. For the sake of completeness, also take into consideration how the position of the total emissions of the individual producing companies is calculated with respect to the limit value curve.
The emissions of all cars registered for sale by the individual car manufacturer during the calendar year are averaged.
The emissions of individual cars are instead calculated with the following formula:

From 2016 until 2019

Passenger cars:

Specific Emission Target = 130 + a x (M – M0) [g CO_2/km]

a=0.0457; M= mass of vehicle in kilograms [kg]; M0= 1392.4 kg

Light Commercial vehicles:

Specific Emission Target = 175 + a x (M – M0) [g CO_2/km]

a=0,093; M=mass of vehicle in kilograms [kg]; M0=1766.4 kg

From 2020:

Passenger cars

Specific Emission Target = 95 + a x (M – M0) [g CO_2/km]

a=0.0333; *M*= mass of vehicle in kilograms [kg]; *M0, 2020*= 1379.88

Light Commercial vehicles:

Specific Emission Target = 147 + a x (M – M0) [g CO_2/km]

a=0,096; M=mass of vehicle in kilograms [kg]; M0, 2020=1766.4 kg

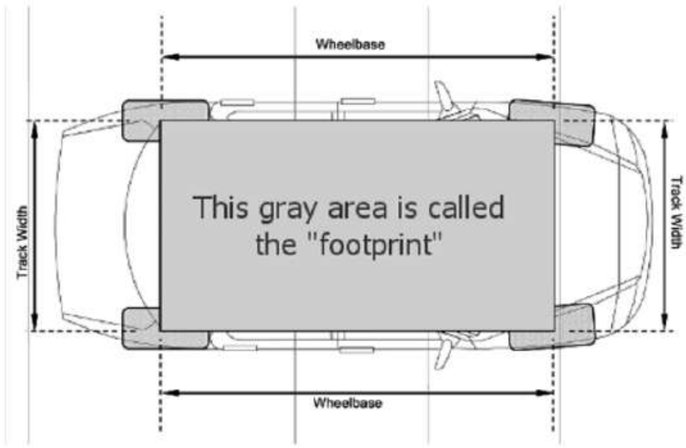
However, many authors complain that using mass as a criterion for setting the emissions target for each individual vehicle is not a sufficient incentive for companies to reduce weight and therefore emissions. The higher the weight, the higher the target emissions for each individual car model, even though the established average of 95g/km does not guarantee that companies will make every effort to minimise their impact even beyond the stated limits, as small cars are used to lower the average emissions, and allowing SUVs to pollute more.

It should also be remembered that for companies that do not reach the limits there is also the possibility to make agreements with other car manufacturers to "buy" the so-called *green credits.*

If one thinks carefully about what has just been said, establishing an average and allowing the purchase of green credits from virtuous companies allows less environmentally oriented car manufacturers to continue to produce higher emissions than established, thus achieving the stable average but not the best value that technology would allow.

Basically, the legislation is "satisfied" with reaching a value established at the table and does not aim to reach the best achievable value.

Instead, these authors propose to use the Footprint-based target system, which envisages using the footprint as a criterion instead of the mass, i.e. the square meters of the machine (against the mass which basically refers to kg and therefore correlates to cubic meters).



According to the International Council on Clean Transportation, this would be a greater incentive to reduce the weight of cars. By setting strict limits, car manufacturers would have to work on the height of their cars to maintain their interior comfort, since they would not be able to intervene on length and width. This would clearly put SUVs at a disadvantage. SUVs are not fuel-efficient vehicles because they are taller and heavier, and therefore less efficient, with the same interior space. Furthermore, this would impact on aerodynamics by creating a synergy between shapes and weight, further reducing emissions.

To better understand this concept, look at this example of the Volkswagen Passat, the German station wagon which is the second best-selling model in the history of the German group after the Golf, but which is increasingly losing market share to SUVs.
The dimensions of the Passat are 4,773 mm long x 1,832 mm wide with a boot capacity of 639 litres in the normal configuration, all for 1474 kg, and a petrol engine 1.5 with 150 hp and 144g $CO2$/Km, or diesel 2.0 with 150 hp and 129g $CO2$/Km. If you compare it with the Touareg, the largest SUV proposed by Volkswagen, which however has dimensions very close to the Passat: 4,878 mm long (+10 cm) x 1,984 (+15 cm) mm wide with a boot capacity of 610 litres (-29 litres) in the normal configuration, all this for 2092kg, and a 3.0 diesel engine with 231 hp and 209g $CO2$/Km.
It is therefore noticeable how a change of just a few outer centimetres translates into an extra 618 kg and 80 g $CO2$/km, which when you look at the regulations is an enormous amount.
Here we enter an almost ethical discourse, in that it is as if the greater ability to spend money could allow the purchase of cars that guarantee less protection of the common good "environment", leaving the limitation of overall damage to more rational cars.
A law based on the Footprint would therefore mitigate this problem because it would force manufacturers to reduce very elite but inefficient cars such as SUVs.

4.2.3 Importance of recycling and choice of materials

According to the European regulation 2005/64/EC, updated by the regulation 2009/1/EC, only vehicles can be sold in Europe if at least 85 % of their mass is reusable and/or recyclable, or if at least 95 % of their mass is reusable and/or recoverable. This is required for cars registered from 2008 onwards.
Furthermore, the previous legislation 2000/53/EC stipulates that car manufacturers are obliged to accept end-of-life vehicles without requiring any kind of payment from the owner and are also obliged to pay for the disposal and recycling of the car.
These two EU directives are the framework on the basis of which car sales in Europe must take place. Obviously, this regulatory framework differs in the rest of the world, but the fact that it is required for the approval of vehicles sold in Europe also affects manufacturers on other continents. By virtue of these regulations, there has been an

increase in the use of plastic components in cars, as plastics are characterised by being more easily recyclable.
According to Miller et al. (2014), the amount of plastics used in vehicles rose from 6% in 1970 to 16% in 2010 and was expected to reach 18% in 2020. This element has contributed not only to the increase in recyclability but also has an impact on the dynamics concerning the weight set out in the previous paragraph. In fact, the use of plastics also guarantees a reduction in weight, thus not only reducing the environmental impact of the vehicle at the end of its life, but also reducing emissions during its entire life cycle.
However, if you look at the legislation, you will see that it refers to the possibility of recycling, not to actual end-of-life recycling, which often finds obstacles in its actual implementation, even if theoretically feasible. In this regard, it should be observed what happens in the recycling of plastic materials, for simple and homogeneous materials such as, for example, bottles or food packaging; recycling is simple and immediate. In the world of automobiles, the issue is much more complex, as the types of plastics used are varied and heterogeneous, and they are also joined together with joints that make it difficult to divide them, making recycling complex.
An important distinction that needs to be made in relation to the types of plastics is between thermosets and thermoplastics. Thermosets are processed through the application of heat, and the bonds that are created between the molecules are extremely rigid, making it impossible to melt these plastics in order to recycle them. The only alternative is to pulverize the pieces made from these materials and use these scraps as fillers for other industries, such as construction.
Thermoplastics, on the other hand, can be melted down, normally made into plastic pellets, which are then melted down and re-moulded. This process can be done many times but over time the material properties degrade. It is still possible to reuse them for purposes where the required properties are not particularly pronounced, this process is called down-cycling.
The fact that plastics of two types are often joined together means that they cannot be recycled while maintaining their intrinsic mechanical properties.
For example, according to Miller et al. on average, five different plastics are used in the seats, recycling them requires an increase in the time invested and the necessary machinery.

There are a number of alternatives that can be pursued to reduce this problem, the most interesting are the following four:

1. **Regenerate and reuse parts as spare parts:**
   Some parts, especially metal, such as the engine, transmission, radiator, alternator and steering column, given their high resistance, are recovered, overhauled and regenerated to be put back on the market. These parts have an attractive market as they are normally sold with a guarantee and are priced lower than the same new prices. Plastic components, on the other hand, are not normally overhauled and resold, but there is a parallel market, namely the sale at scrapyards, where private individuals and professionals look for used components in good condition.

2. **Orienting choices to encourage recycling:**
   As mentioned above, recycling faces obstacles due to the way plastics are used in cars and vehicles. This requires keeping the focus on recycling once the machine has reached the end of its useful life, choosing the plastics in order to limit their heterogeneity, however this variable is limited by technical aspects, as certain characteristics are required for certain components. that only certain plastics can offer.
   Another variable that can be pursued, however, is to provide for a rapid disassembly of car parts during the design phase, in relation to this we will see a real application of this methodology in the in-depth study dedicated to Toyota.

3. **Provide for Partnerships:**
   Another important step in reducing the environmental impact of disused cars is to provide for partnerships capable of reallocating car components.
   As discussed at the beginning, speaking of Green Supply Chain Management, companies must find the skills and resources outside of their legal boundaries that can maximize business objectives, and recycling must also be among these objectives.
   For example, this strategy was applied by BOEING and BMW[109], which thanks to a partnership managed to operate a win-win logic, Boeing disposing of the carbon fiber

[109]https://www.press.bmwgroup.com/global/article/detail/T0135185EN/bmw-group-and-boeing-to-collaborate-on-carbon-fiber-recycling?language=en

present in its disused aircraft in a green way and BMW recycling this fiber by inserting it inside their cars. In addition, the use of carbon fibre guarantees a reduction in the weight of cars adopting it, thus reducing emissions. This is just an example, but the possibilities are varied, it is only up to companies to have a focus on the possibility of studying and creating partnerships of this type.

4. **Use of Bio-Plastics:**
   The use of bio-plastics in the modern economy is an increasingly present reality, and they represent an alternative to petroleum-based plastics. The two main characteristics of these components are Renewability and Biodegradability. The first characteristic is defined as the characteristic of a material to be derived from plant or animal sources and to have a sufficiently short production cycle. Unlike petroleum which is equally natural but has a process that takes millions of years. The second characteristic is defined as the ability of a material to disintegrate chemically and biologically. These materials have a much lower environmental impact than traditional plastics and are increasingly used in the automotive sector. Their only limitation at the moment is that they do not have the mechanical properties to be used in the construction of structural components, but they are especially used for interior components. These plastics will find increasing technical development when the use of petroleum-based plastics begins to be hampered by regulations.

4.2.4 Propulsion Systems and Environmental Impact

At this point in the thesis we will discuss the topic that is the central element on which the strategies of car manufacturers are being based in this historical period, i.e. new fuel and engine propulsion systems.

It is correct in relation to the subject of the thesis to try to give visibility to the technologies that seem most promising: **Electrically-chargeable vehicles (ECVs)** and in particular focusing on **Battery electric vehicles (BEVs)** cars that are fully powered by an electric motor, using electricity stored in an on-board battery that is charged by plugging into the electricity grid.

Fuel cell electric vehicles (FCEVs) are also propelled by an electric motor, but their electricity is generated within the vehicle by a fuel cell that uses compressed hydrogen (H2) and oxygen from the air. So, unlike ECVs, they are not recharged by connecting to the electricity grid. Instead, FCEVs require dedicated hydrogen filling stations.
The decision to analyse the impact of these technologies is due to the fact that, compared to classic internal combustion engines (diesel and petrol), these propulsion systems are the ones that, according to studies, seem to have a lower life cycle (LC) impact on the environment.

4.2.4.1 Battery electric vehicles (BEVs)

One of the most dubious aspects of the impact of electric cars is not related to CO2 emissions during the phases of use of the vehicle, as it is quite clear that they have a lower impact than cars with combustion engines, but rather the fact that, according to some studies, the environmental impact during the life of a car must take into account the emissions that are created to produce the electrical energy with which they are powered.
Another area of disagreement often arises in connection with the production and disposal of batteries, which have an impact on the eutrophication of fresh water.
Eutrophication of freshwaters indicates an excessive presence of plant organisms within the aquatic ecosystem, which is due to unnatural doses of nutrients such as nitrogen, phosphorus and sulphur.
The increase in the number of these plant organisms on the water surfaces results in a limited gas exchange and when these organisms die, excessive doses of ammonia and methane are created, causing the waters to become inhospitable to living organisms.
The production and incorrect disposal of batteries has an impact on this dynamic.
It has therefore tried to use recent sources that take these aspects into account, and based on these sources what emerges is an almost total superiority of electric cars in reducing environmental impact.
According to the Transport and Environment Association, for cars sold in 2020, an average-sized electric car will emit around 90g CO2/km throughout its life cycle, including upstream emissions in production, while the same diesel model will emit 234g CO2/km and petrol 253g CO2/km. Considering an average life of 225,000 km, this translates into 20 tons respectively, against 53 and 57 CO2.

These are average emissions, which however must be evaluated on several scenarios:

1. **Location of battery production:** the energy required in battery production is estimated at between 61 and 106 kgCO_2e/kWh, this consumption varies depending on where the production plant is located, with Sweden being the most efficient, deriving large amounts from renewable energy, and China and Poland using large amounts of coal.

2. **Location of use of the vehicle,** also in relation to the source of energy production, the impact of recharging the car battery changes.

If electricity is produced from renewable energies, as in the case of Sweden which makes extensive use of hydroelectric power plants, and the batteries are produced according to high standards, again as in the case of Sweden, this value drops to 11 tons of CO2.
In the worst-case scenario, that of battery production in China and use of the machine in Poland, the life cycle impact rises to 41 tonnes.
Even in the worst-case scenario, electric power is still 22% less impactful than diesel and 28% less impactful than petrol.
This shows that BEVs have the potential to reduce the environmental impact of the automotive industry, but to really maximise the impact of these technologies, governments need to invest in infrastructure that can generate energy from renewable sources, such as solar or hydroelectric power.

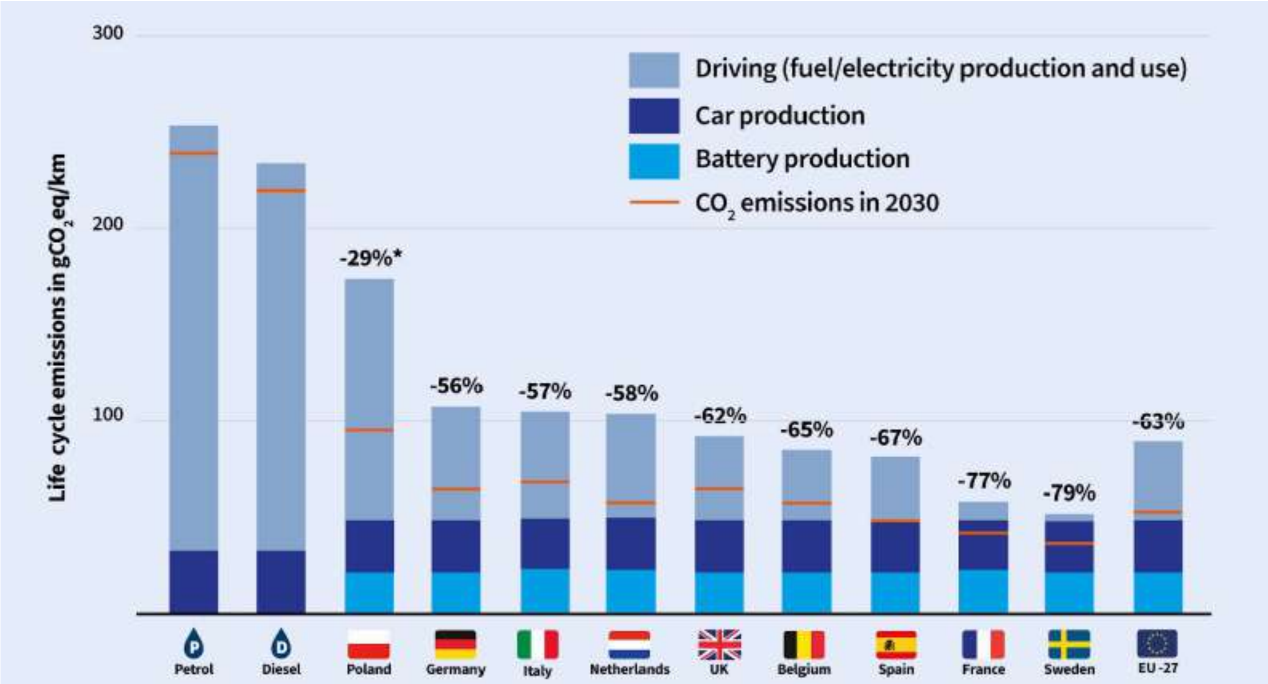


Figure 63: impact source of energy production[110]

In this graph you can see the analysis made by the Association for Transport and Environment, which gives a good idea of the high impact of the source of the electricity used to recharge cars, while the place of production of cars and batteries has been kept fixed at European values.

The percentage shown indicates the reduction in emissions from electric cars compared to internal combustion cars. In Poland, where the use of coal-fired power stations is still widespread, the reduction in emissions is 29%, while in Sweden the figure is 79%.

It is clear that it is important to see the electric car not only as a commitment of the car manufacturers, but that the whole ecosystem must support the development of its potential.

As mentioned above, another extremely important aspect to take into account when assessing the impact of electric cars throughout their life cycle is the eutrophication of water and the resulting toxicity to animals and humans.

What the scientific community is most concerned about is the disposal of batteries. It is estimated that by the end of 2030 there will be 400,000 tonnes of batteries in Europe that will have reached the end of their life.

[110] Transport & Environment, How clean are electric cars? T&E's analysis of electric car lifecycle CO_2 emissions, 2020, pag. 2 and pag. 18

There are already several projects that aim to understand how to reduce the environmental impact of such exhausted batteries, but what seems to be most promising today is the direct recycling of the cells inside the batteries.
In several pilot projects, these are recycled in the production of batteries for recharging stations or are used for down-cycling in the production of batteries requiring lower efficiency levels.
This aspect will be discussed in the chapter dedicated to Toyota, which has been applying such strategies for some time.
However, if the electric car is to become the vehicle of the future, companies and institutions alike will need to understand how best to limit the problem of eutrophication and toxicity, as electric cars currently have a greater impact than internal combustion engines.

4.2.4.2 Fuel cell electric vehicles (FCEVs)

The other low-environmental impact technology that has been talked about for several years now is the hydrogen car, which has also attracted a great deal of interest at a theoretical level, but unlike the electric car, which is now widespread throughout the world, the hydrogen car has a very low uptake despite the fact that there are approved and purchasable models: in 2018, 5233 of them were sold worldwide (Manoharan et al. 2020) remaining however a technology that could have a great impact in the future.
Electric cars are growing in popularity because of their great efficiency in converting energy into deadly force. One of their limitations is the range of the battery, which on average does not exceed 300 km, although there are cars that reach 600 km.
Hydrogen cars have complementary characteristics, as theoretically (because there are practically no refuelling points) the average range with a full tank of hydrogen is 500 km, but unlike electric cars they take a long time to recharge depending on the type of filling station (between 15 km and 300 km recharged in one hour depending on the kW).
Hydrogen cars have recharging times very similar to those of a classic diesel or petrol car. Despite this positive aspect, hydrogen-powered cars still encounter many limits to their deployment, first of all the production of hydrogen.

Although hydrogen is the element most commonly found in nature, it is not present in its pure form, i.e. the form needed to use it in cars, which means that hydrogen has to be produced.
The production we often hear about when talking about clean energy is electrolysis, i.e. the production of hydrogen (H) by splitting H2O.
The problem with this process is that it requires huge amounts of energy, and although it would be possible to obtain this energy from renewable sources and achieve green hydrogen, this is not yet the norm at present.
The alternative is to produce H from other sources, such as natural gas, biomass and fossil fuels.
Today's most common process for producing hydrogen for industrial purposes is the natural gas, whose molecules contain carbon and hydrogen, is used as the primary source. Hydrogen is used as an energy carrier and does not generate greenhouse gases, while the CO_2 generated in the production process is either emitted into the air or captured and stored.
In the first case, the hydrogen is called *grey hydrogen* and the associated carbon dioxide emissions are those of the production process, essentially equal to those of natural gas combustion. In the second case, the hydrogen is called *blue hydrogen* and the associated carbon dioxide emissions are very low or zero, depending on the percentage of CO2 produced.
Given the lack of development of this technology, it is difficult to find reliable data on the consumption of these cars during their life cycle, but what is clear is that in order for them to begin to have a positive impact on the environment and be competitive in the automotive world, institutions need to invest in infrastructure.
In Germany, for example, it has been estimated that developing the necessary network by 2030 would require an investment of 375 billion euros[111].
It must be considered, however, that while electricity is easier to implement in terms of infrastructure, as the electricity grid is already fully developed, it still requires large investments as the time taken to use the electricity columns is long for each user, while hydrogen would have dynamics very similar to those of normal fuels.

[111] https://www.deingenieur.nl/artikel/hydrogen-car-wins-over-electric-car

However, we must bear in mind that research in this field is progressing and that there are encouraging results, such as those announced by the Technion-Israel Institute of Technology, which has developed a technique to reduce the complexity of hydrogen production from water. It has also solved another major problem, which is that of efficiency: normal production techniques are very inefficient, since 25% of the energy used to produce hydrogen is lost during the process. With the new technology a level has been reached efficiency of 98.7%. To date, the country that seems to be most advanced in the production of hydrogen and its use is California, which already has 45 operational service stations, 134 in production and in 2020 has allocated 115 million dollars to add another 111 stations by 2027.

In addition, the law number 662 of 22 February 2019 of the California Senate prescribes that "*The bill would require that the renewable hydrogen percentage be increased to 44% by December 31, 2024, 52% by December 31, 2027, 60% by December 31, 2030, and would require that by December 31, 2045, 100% of the hydrogen produced or dispensed in California for motor vehicles be either renewable hydrogen or clean hydrogen produced using zero-carbon resources.*"[112]

It is clear that although hydrogen is developing at a slower pace than electric power, it is a technology that could have a positive impact on reducing emissions.

4.2.5 Joint impact of all components

At this point, having made an excursus of various dynamics and choices that fall within the logic of improving environmental sustainability, it is fair to point out that many of the aspects discussed are interconnected. It would therefore be correct to deal with these aspects not by compartmentalisation, but always bearing in mind that every design and production choice has an impact on all the dynamics.

As mentioned above, weight and aerodynamics have a strong impact on emissions and fuel consumption, but they also have an impact on the level of autonomy of electric cars. Considering that the autonomy of these vehicles is one of the biggest barriers to purchase, as there is no sufficiently widespread recharging infrastructure, it is easy to see how increasing the autonomy could accelerate the rate of purchase of these cars.

[112] http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB662

For example, Tesla's SUV, the model X, which weighs 2526kg, and Tesla's model S, which weighs 2256kg, share the same 100kWh battery pack weighing 544kg. Obviously, the model S weighs 270kg less and is more aerodynamic, giving it a range of 652km compared to the 561km of the model X declared on the website.

So if we reverse the reasoning, the Model X, given its greater weight and aerodynamics, consumes more resources. Obviously, having an SUV is part of an important commercial strategy to encourage the use of electric cars, but if we think about the importance of autonomy in increasing sales, it is clear that weight is a fundamental variable.

It is also important to consider the importance of developing a supply chain that is geared towards achieving these objectives. For example, the importance of tyres: the heavier the car, the greater the tread wear, and thus the environmental impact. In addition, the greater the friction of the tyre, the greater the consumption of the car. Tyre manufacturers are therefore developing various projects to reduce rolling resistance and thus reduce environmental impact.

This is just one element of the various initiatives that exist in the automotive world, but it allows us to understand how much improvement is hidden in each individual component and how the development of a vehicle is equivalent to the joint development of each of its components.

The real impact will then come when the focus of the entire supply chain of car manufacturers is on reducing fuel consumption with radical approaches, as we see many cars that were designed as internal combustion cars and then converted to hybrid or electric versions.

They are undoubtedly a first step, but perhaps to maximise the reduction in emissions it will be necessary to wait for cars developed with a logic totally oriented towards the use of low-impact technologies.

5. Case study: Toyota Motors Corporation

The choice to treat Toyota Motor Corporation as a business case is not accidental. In the course of the paragraphs we will discover how this company has always been a revolutionary and innovative model for the entire sector and how Toyota has previously addressed the environmental issue through the implementation of its own model, the Toyota Production System. Ultimately, we will find out how Toyota had already offered sustainable alternatives to the market, even before the environmental issue was recognized as an internationally relevant problem.

"If you want to achieve long-term success, you cannot separate the development of people from that of the production system" Isao "Ike" Kato

5.1 Understand the Entity

With almost 85 years of existence, Toyota Motor Corporation is one of the world's best-known automobile manufacturers. With the introduction of *Just-in-Time*, Jidoka, Kaizen and Visualization concepts, Toyota not only revolutionised the entire automotive industry with the Toyota Production System, but also set an example for all industrial companies. In fact, the Toyota model as we know it today is the result of decades of development and refinement. But even on the threshold of the 21st century, the benefits derived from its basic techniques and management processes can be applied equally to other types of business operations.

5.1.1 History

Toyota's history began in 1867, when Sakichi Toyoda was born that year. The inventor, with 84 patents behind him, dedicated himself to a philosophy of uncompromising quality: always providing only the best for the customer. In 1890 he founded Toyoda Automatic Loom (now Toyota Industries Corporation, subsidiary of Toyota Motor Corporation), a company dedicated to the production of looms. The Toyota Motor

Corporation was officially founded in 1933 when Toyoda Automatic Loom opened an automobile subsidiary. It was headed by Kiichiro Toyoda, Sakichi's son.

In 1935, Sakichi Toyoda, built the foundations and defined the 5 Main Principles for his company to follow, which would later be formalised and become the guiding principles for every Toyota worker:

1. Always be faithful to your duties, thereby contributing to the Company and to the overall good.
2. Always be studious and creative, striving to stay ahead of the times.
3. Always be practical and avoid frivolousness.
4. Always strive to build a homelike atmosphere at work that is warm and friendly.
5. Always have respect for God and remember to be grateful at all times.[113]

Figure 64: Mr. Sakichi Toyoda and the 5 main Principles

Toyota decided to devote itself entirely to the production of small cars in order to avoid direct competition with American manufacturers. In 1936, Toyota produces its first car, the Model AA. The strategy to distinguish itself from the competition leads the company to a remarkable growth until during the Second World War, the production of cars is suspended in order to favour models intended for the army. In the meantime, Toyota merges several related companies, including Toyoda Machine Works, Ltd, Toyota Auto Motor Company in 1941 and Toyota Auto Body Ltd. in 1945. Toyota car production restarted in 1947 with the SA, a model distinguished by its four-cylinder engine (1.0 with 27 hp), four-wheel independent suspension and aerodynamic bodywork. The Japanese economy suffered from high inflation in those years. The money supply was drastically

[113] http://www.toyota.com.cn/company/vision_philosophy/guiding_principles.html

limited, purchasing power was significantly weakened and demand was suppressed. Surviving the crisis, Toyota recovered in 1950 when it supplied 5,000 vehicles to the US Army for the Korean War and when it offered the first BJ off-roader to the market in 1951. The 1950s were crucial years for Toyota's internal formation. Given the high technical and economic standards of rival American car manufacturers, the company sent its executives, including Taiichi Ohno, to visit the United States to study Ford Motor Company's production methods. What impressed Taiichi Ohno most there, however, were the American supermarkets. He noticed how customers always took only what they needed from the shelves at a given time, and how quickly and precisely stocks were replenished. Ohno realised that a supermarket is basically nothing more than a well-managed warehouse whose receipts of goods correspond as closely as possible to the issue of goods and which has no room for long-term storage. Once they had absorbed the know-how and innovative production technologies of the American plants, they returned to Japan and began to develop various concepts including *Kanban.* Sakichi Toyoda's philosophy of satisfying the customer with the best possible product was maintained and promoted by his son and his successors. Only the best materials were used, and meticulous attention was paid to the most careful workmanship. The production systems were continually improved, the processes refined, the employees more involved. This development culminated in the Toyota Production System. Toyota is not only a supplier but also an employer, manifesting itself in social life: this ranges from working in local communities to promoting educational and cultural programmes, international exchanges and research programmes.

In 1957, Toyota exported the Toyopet Crown, sedan or station wagon, to the United States for the first time, with petrol and diesel engines ranging from 1.5 to 1.9 litres. While sales of the Toyopet Crown were not as high as Toyota had hoped, the Crown was discontinued in 1961 due to its high price and lack of power compared to the competition. The Corolla was the first imported vehicle that was designed specifically for the American market and was a great success, especially as it was recognised as a reliable and high-quality vehicle. With the Corolla, the company was able to set the standard for the Toyota name and build its reputation. By 1967, sales of the Corolla made Toyota the third best-selling import brand in the United States. Since its release in 1966, the Corolla has become the world's best-selling car with over 30 million units sold in more than 140 countries.[114]

The 1960s were years of expansion for the company, which led to global recognition in the 1970s and 1980s. The company took its current name in 1982, when Toyota Motor Company was merged with Toyota Motor Sales Company, Ltd. Two years later Toyota partnered with General Motors Corporation to create New United Motor Manufacturing, Inc. a dual-brand manufacturing facility in California, where Toyota began U.S. production in 1986.

The company experienced significant growth (ethical and economical) in the 21st century.

The originally issued in 1992 and then revised in 1997, Guiding Principles, were the milestone of what is now known as "Toyota Way".

The company set the follow 7 guidelines in order to achieve sustainable development:

"1. Honor the language and spirit of the law of every nation and undertake open and fair corporate activities to be a good corporate citizen of the world.
2. Respect the culture and customs of every nation and contribute to economic and social development through corporate activities in the communities.
3. Dedicate ourselves to providing clean and safe products and to enhancing the quality of life everywhere through all our activities.
4. Create and develop advanced technologies and provide outstanding products and services that fulfill the needs of customers worldwide.
5. Foster a corporate culture that enhances individual creativity and teamwork value, while honoring mutual trust and respect between labor and management.
6. Pursue growth in harmony with the global community through innovative management.
7. Work with business partners in research and creation to achieve stable, long-term growth and mutual benefits, while keeping ourselves open to new partnerships."[115]

This thanks to its market innovations: its luxury brand Lexus in 1989 and the world's first mass-produced hybrid-powered vehicle, the Prius XW10, in 1997. With four doors and a

[114] https://www.philwrighttoyota.com/history-of-toyota.htm
[115] https://global.toyota/pages/global_toyota/company/vision-and-philosophy/code_of_conduct_001_en.pdf

1.5 litre petrol engine combined with an electric unit, the Prius won the prestigious "Best engine of the year" award in 1999. In the same year, Toyota was listed on the London Stock Exchange and on the New York Stock Exchange. In 2000 the company offered the car of the year, Yaris XP10. The company continued to expand into new markets, unveiling the world's first luxury hybrid vehicle, the Lexus RX 400h, in 2005. However, the company subsequently faced significant financial challenges: the sales slump resulting from the 2008 global financial crisis and after facing an international safety recall of more than eight million vehicles in 2010, which temporarily halted production and sales of many of its flagship models. Today Toyota has assembly plants and distributors in many countries. In addition to automotive products, its subsidiaries produce tyers and materials in cork, steel and synthetic resins, automatic looms and cotton and wool items. Others are involved in real estate, prefabricated housing units and the import and export of raw materials.[116]

Today the company has 29 office locations across 22 countries[117]:

1. **Japan**: Toyota (HQ), Nagoya City, Tokyo.
2. **United States**: Hialeah (FL), Honolulu (HI), Plano (TX)
3. **Austria**: Wien
4. **Belgium**: Brussel
5. **Bulgaria**: Sofia
6. **Canada**: Toronto
7. **China**: Beijing, Changchun Shi, Chengdu Shi, Tianjin
8. **Colombia**: Bogotá
9. **Costa Rica**: San José
10. **Czech Republic:** Praha
11. **Denmark:** Søborg
12. **Finland:** Vantaa
13. **France:** Vaucresson
14. **Germany:** Köln
15. **Malaysia:** Shah Alam
16. **New Zealand:** Palmerston North
17. **Pakistan:** Karachi
18. **Panama:** Panamá
19. **Russian Federation:** Moskva
20. **Trinidad and Tobago:** Barataria
21. **United Arab Emirates:** Dubai
22. **United Kingdom:** E

[116] https://www.toyota-global.com/company/history_of_toyota/75years/
[117] https://craft.co/toyota/locations

5.1.2 Toyota production system

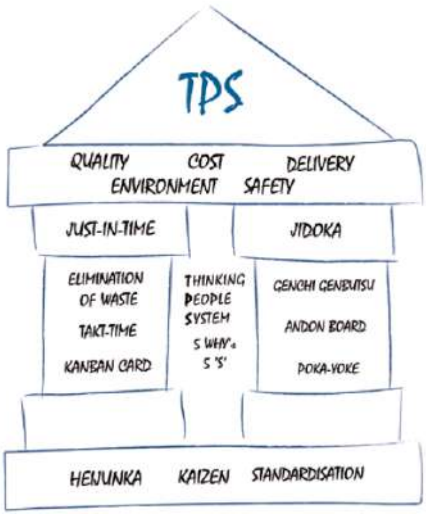


Figure 65: The TPS model

The Toyota Production System (TPS) is the most efficient production system known in the world, a model that almost all car manufacturers try to imitate. The system was developed within Toyota, in particular by Sakichi Toyoda, Kiichiro Toyoda and Taichii Ohno. Its secret is the careful organisation of work, high efficiency and strict quality. The aim is to produce a very high-quality product for the lowest possible price, i.e. to exploit the available resources in the most productive way possible so as to drastically increase the productivity of the factory and consequently increase profits by reducing costs and eliminating what is superfluous. When Toyota adopted the new production philosophy in the 1950s, it was a revolution similar to Henry Ford's introduction of the assembly line. The basis of TPS is the principle of continuous improvement of standards, called *Kaizen,* that leads to the progress of the production process every day. The Toyota model is a production system that completely eliminates what is superfluous in production in order to reduce costs. It impacts on every aspect of the organization and incorporates a common base of values, knowledge and procedures and enables employees to optimize quality, continuously improving processes and avoiding the waste of natural, human and corporate resources. Employees are assigned clearly defined responsibilities at each stage of production and each team member is encouraged to strive for improvement. The extraordinary results achieved using this production approach have led to TPS becoming established worldwide, being referred to as Lean Production. The essence of TPS is substantially contained in the Just in time principle, also known as JIT, according to which the aim is to produce "the type of pieces that are needed, for the moment they are needed and in the quantity in which they are needed" and therefore to obtain a lean and efficient production flow, aimed at eliminating all waste, in this way there are zero stocks and zero waste. The Toyota Production System goes beyond principles that relate only to production processes. It extends to the whole organisation: marketing and sales, administration, product development and management. All employees are treated equally, regardless of their position.

Kaizen, Jidoka, Just-in-time, Heijunka, Visualisation, Takt-time, Standardisation, are just few main concepts on which the Toyota Production System is based.

Kaizen leads the company to continuous improvement, almost to the point of being dissatisfied with the current solution and for this reason, constantly looking for possible improvements in quality and performance. This enables the continuous raising of production standards. In other words, it means that all team members throughout the organisation continuously look for ways to improve operations, and this improvement process is supported at all levels of the organisation. Furthermore, *Kaizen* requires clarity about what is to be achieved, i.e. the formulation of clear objectives and targets for improvement. So it is mainly about a positive attitude, focusing on what needs to be done rather than what can be done. It requires that all improvements are carefully examined for logic and benefit before implementation. The concept of "5 Why Questions" was developed for this purpose: every planned improvement must be examined at five levels with the question "Why?" so that there is real clarity about its rationale and value. This reduces the risk that changes are made without sufficient reason.

Defects and errors cost energy to eliminate, it does not add any value, and for this reason, Toyota developed the *Jidoka* concept. *Jidoka* means to stop the assembly process if any defect occurs and to address it promptly. This ensures that any quality defect is detected and corrected at the point of origin. In practice, any employee who finds a defect on the vehicle will stop the assembly line to prevent the defect from being passed on. Quality checks are carried out at every stage of the production process and as soon as a defect or fault is detected, an appropriate solution is sought immediately, even if this means stopping production temporarily.

Just-in-time production is a concept of orientation to current demand. It amounts to inventory reduction, which can lead to unnecessary costs and wasted resources. The aim is to meet customer requirements in an efficient and timely manner by aligning all production activities to actual market demands. Just-in-time production is based on finely tuned processes in the assembly flow, using only the quantities of parts that are actually needed, when they are needed. At the base of the Just-in-time processes, stands the *Heijunka* concept, i.e. eliminating irregular workloads, called *Mura*, balancing the quantities, allowing a regular, continuous and efficient production flow: always producing what is required, when the there is a question. This concept differs from mass production, where large quantities of a single product are often produced without reference to actual demand. This also leads to the elimination of labor overload or strenuous work which can lead to safety and quality problems. Waste, called *Muda*, is anything that does not add value, and does not only refer to waste but also to inefficiencies such as overproduction, excessive inventory, rework and unnecessary movement, processing and waiting. The *Visualization* principle, on the other hand, is based on providing everyone with the same amount of information on the status of the production process and on the parts in stock that are clearly visible to all at all times, in order to respond quickly to potential problems and work as a team. This must be done for every employee category, from an assembly line machine operator to an engineer, from maintenance to a foreman. This is because everyone has to see the same picture and have a clear state of the process at all times.

Takt time is the rate of customer demand, i.e. what the market needs. It describes a work cycle that meets a customer's demand and the importance of synchronising the work cycle with demand is to avoid under- or over-production.

Standardisation on one hand ensures a consistently high level of quality, and on the other hand, by maintaining a constant pace of production, it provides a benchmark for continuous improvement.[118]

[118] https://global.toyota/en/company/vision-and-philosophy/production-system/

5. 2. Financial Performance Analysis 2020

On 11 June 2020, the general shareholder's meeting, approves the consolidated financial statements for the period from 1 April 2019 to 31 March 2020[119].

5.2.1. Balance Sheet

The company's consolidated balance sheet and main financial indicators are shown below:

Toyota Motor Corporation: BALANCE SHEET

Annual			
JPY	**FY, 2018**	**FY, 2019**	**FY, 2020**
Cash	3.1t	3.6t	4.2t
Accounts Receivable	2.2t	2.4t	2.1t
Prepaid Expenses	833.8b	806.0b	1.2t
Inventories	2.5t	2.7t	2.4t
Current Assets	18.2t	18.9t	18.6t
PP&E	10.3t	10.7t	24.5t
Total Assets	50.3t	51.9t	52.7t
Accounts Payable	2.6t	2.6t	2.4t
Short-term debt	5.2t	9.6t	9.9t
Current Liabilities	17.8t	18.2t	17.9t
Long-term debt	10.0t	10.6t	10.7t
Non-Current Liabilities	12.6t	13.1t	13.5t
Total Debt	15.2t	20.2t	20.6t
Total Liabilities	30.4t	31.4t	31.4t
Common Stock	397.1b	397.1b	397.1b
Additional Paid-in Capital	487.5b	487.2b	489.3b
Retained Earnings	19.5t	22.0t	23.4t

[119] https://global.toyota/pages/global_toyota/ir/financial-results/2020_4q_summary_en.pdf

Quarterly								
JPY	**Q1, 2019**	**Q2, 2019**	**Q3, 2019**	**Q1, 2020**	**Q2, 2020**	**Q3, 2020**	**Q1, 2021**	**Q2, 2021**
Cash	3.0t	3.2t	3.2t	3.8t	4.0t	3.8t	6.8t	5.5t
Accounts Receivable	2.1t	2.2t	2.1t	2.2t	2.2t	2.1t		
Prepaid Expenses	924.5b	909.6b	937.9b	935.7b	872.7b	1.3t		
Inventories	2.5t	2.6t	2.6t	*2.7t*	2.6t	2.4t	2.4t	*2.7t*
Current Assets	18.0t	18.5t	17.8t	19.3t	19.0t	19.3t	20.4t	21.1t
PP&E	10.5t	10.7t	10.6t	10.5t	10.6t	10.7t	10.7t	10.7t
Total Assets	51.0t	52.5t	51.1t	52.1t	52.2t	53.8t	55.9t	56.5t
Accounts Payable	2.4t	2.4t	2.3t	*2.5t*	2.5t	2.3t		
Short-term debt	9.8t	9.8t	9.8t	9.6t	9.7t	10.0t	11.4t	11.4t
Current Liabilities	17.8t	18.0t	17.8t	17.9t	17.9t	18.1t	18.9t	19.7t
Long-term debt	10.4t	11.1t	10.4t	10.5t	10.3t	10.9t	12.6t	12.2t
Non-Current Liabilities	13.1t	13.8t	13.0t	13.5t	13.3t	14.1t	15.5t	14.9t
Total Debt	20.2t	20.9t	20.2t	20.1t	20.0t	20.9t	24.0t	23.6t
Total Liabilities	30.9t	31.8t	30.8t	31.4t	31.2t	32.3t	34.4t	34.7t
Common Stock	397.1b	397.1b	397.1b	397.1b	397.1b	397.1b	397.1b	397.1b
Additional Paid-in Capital	487.7b	487.4b	487.4b	488.1b	491.1b	487.4b	504.5b	504.5b
Retained Earnings	20.9t	21.5t	21.5t	22.3t	22.9t	23.4t	22.1t	22.6t
Total Equity	19.6t	20.2t	19.8t	20.2t	20.5t	21.0t	21.5t	21.8t

Fiscal Year	Financial Indicator					
	Operating income return on revenues	Pretax return on revenues	Pretax return on capital	Return on assets (R.O.A.)	Return on equity (R.O.E.)	Shareholders' equity ratio
FY2020	8.2%	8.5%	4.8%	4.0%	10.4%	38.1%
FY2019	8.2%	7.6%	4.4%	3.7%	9.8%	37.3%
FY2018	8.2%	8.9%	5.2%	5.0%	13.7%	37.2%
FY2017	7.2%	7.9%	4.5%	3.8%	10.6%	35.9%
FY2016	10.0%	10.5%	6.3%	4.9%	13.8%	35.3%

* Financial figures are based on U.S. GAAP (Generally Accepted Accounting Principles)

5.2.2. Income Statement

The Income Statement is shown below:

Toyota Motor Corporation: INCOME STATEMENT

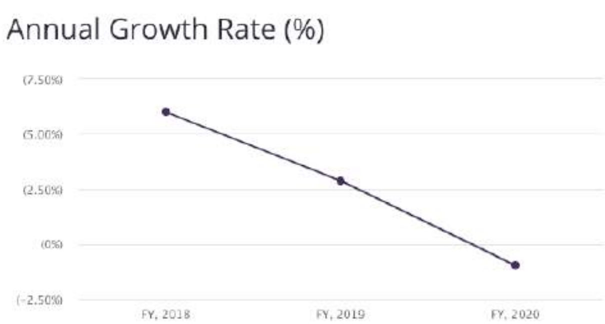
Annual			
JPY	**FY, 2018**	**FY, 2019**	**FY, 2020**
Revenue	29.4t	30.2t	29.9t
Revenue growth, %	6%	3%	-1%
Cost of goods sold	23.9t	24.8t	24.5t
Gross profit	5.5t	5.4t	5.4t
Gross profit Margin, %	19%	18%	18%
General and administrative expense	3.1t	3.0t	3.0t
Operating expense total	3.1t	3.0t	3.0t
EBIT	2.4t	2.5t	2.4t
EBIT margin, %	8%	8%	8%
Interest expense	27.6b	28.1b	32.2b
Interest income	179.5b	225.5b	232.9b
Pre tax profit	2.6t	2.3t	2.6t
Income tax expense	504.4b	659.9b	683.4b
Net Income	2.6t	2.0t	2.1t
EPS	832.8	645.1	729.5

Financial results

As already seen in paragraph 1.3.1 in chapter 1, for the year 2020, the world economy has shifted from a trend of moderate expansion to a sharp slowdown due to the effects of trade frictions and the impact of Covid-19 spreading from China to North America, Europe and Asia.

Since Toyota Financial Statement refers to the period 1st April 2019 - 31st March 2020, the results were lowly impacted by the pandemic, we should wait to the next Financial Statement (FY2021) to see the real impact of Covid-19 on the company.

Toyota Motor Corporation revenue decreased from ¥30.2 trillion in 2019 to ¥29.9 trillion in 2020, a (1.0%) decrease.



Due to the effects of the global rollout of Covid-19, operating income for the year 2020 decreased by ¥160.0 billion, which is mainly attributable to the decrease in consolidated vehicle unit sales. There is a decrease in depreciation expenses of ¥173.2 billion, this is also due to the changing of the depreciation method of the parent company and Japanese subsidiaries to the straight-line method, effective 1 April 2019.

Changes in net income attributable to Toyota Motor Corporation include a loss of ¥38.1 billion, which is attributable to the effect of unrealised gains (losses) on equity securities in FY2020.

Quarterly								
JPY	**Q1, 2019**	**Q2, 2019**	**Q3, 2019**	**Q1, 2020**	**Q2, 2020**	**Q3, 2020**	**Q1, 2021**	**Q2, 2021**
Revenue	7.4t	7.3t	7.8t	7.6t	7.6t	7.5t	7.7t	6.8t
Cost of goods sold	6.0t	6.0t	6.3t	6.2t	6.3t	6.1t	6.3t	5.6t
Gross profit	1.4t	1.3t	1.5t	1.4t	1.4t	1.4t	1.5t	1.1t
Gross profit Margin, %	19%	18%	19%	19%	18%	19%	19%	17%
General and administrative expense	691.9b	736.1b	777.3b	694.1b	692.7b	741.5b	711.5b	642.1b
Operating expense total	691.9b	736.1b	777.3b	694.1b	692.7b	741.5b	711.5b	642.1b
EBIT	682.9b	579.2b	676.1b	742.0b	662.4b	654.4b	740.6b	506.1b
EBIT margin, %	9%	8%	9%	10%	9%	9%	10%	7%
Interest expense	3.4b	9.2b	8.9b	4.4b	10.5b	3.5b	10.0b	23.2b
Interest income	87.9b	26.0b	65.6b	74.4b	51.8b	66.6b	114.8b	168.0b
Pre tax profit	813.9b	572.8b	177.0b	841.8b	741.7b	932.3b	118.2b	610.6b
Income tax expense	246.2b	188.8b	6.1b	249.6b	225.0b	265.9b	31.2b	128.8b
Net Income	684.2b	481.2b	203.1b	701.7b	613.1b	763.9b	149.4b	481.7b
EPS	222.3	200.2	62.1	237.2	207.6	260.6	56.9	166.7

Toyota Motor Corporation revenue breakdown by business segment is structured as follow: 53.4% from Automotive, 43.6% from Financial Services and 3.0% from all other businesses while the breakdown by geographic segment is divided as follow: 43.4% from Japan, 28.1% from North America, 8.9% from Europe, 14.1% from Asia and 5.6% from all other regions.

Segment operating results 2020:

FY2020 (As of and for the year ended March 31, 2020)

(Yen in millions)

	Automotive	Financial Services	All Other	Inter-segment Elimination and/or Unallocated Amount	Consolidated
Net revenues:					
Sales to external customers	26,834,485	2,170,243	925,264	—	29,929,992
Inter-segment sales and transfers	29,029	20,316	579,286	(628,631)	—
Total	26,863,514	2,190,559	1,504,550	(628,631)	29,929,992
Operating expenses	24,811,168	1,898,376	1,407,895	(630,316)	27,487,123
Operating income	2,052,346	292,183	96,655	1,685	2,442,869
Assets	18,754,728	24,858,837	2,023,111	7,043,760	52,680,436
Investment in equity method investees	3,711,151	61,852	180,425	137,362	4,090,790
Depreciation expenses	824,777	743,710	36,896	—	1,605,383
Capital expenditure	1,454,142	2,062,718	71,554	14,818	3,603,232

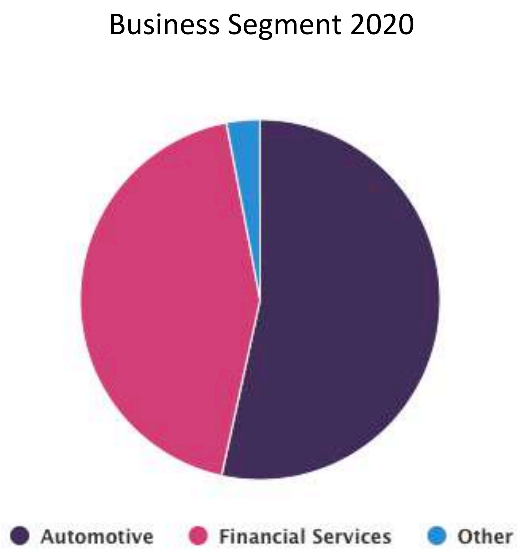
Note: Unallocated corporate assets included under "Inter-segment Elimination and/or Unallocated Amount" for FY2019 and FY2020 are 9,329,020 million yen and 8,630,468 million yen, respectively, and consist primarily of funds such as cash and cash equivalents, marketable securities and portion of security investments held by the parent company.

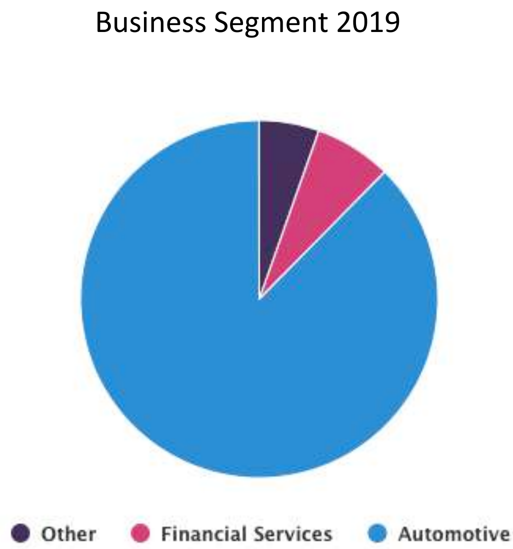
	FY, 2020	FY, 2019	FY, 2018
Automotive	26.86 t	27.08 t	26.4 t
Financial Services	21.91 t	2.15 t	2.02 t
Other	¥1.5 t	¥1.68 t	¥1.65 t

Automotive: Net revenue for automotive operations decreased ¥215.5 billion (-0.8%), to ¥26,863.5 billion in FY2020 compared to FY 2019. However, operating income increased by ¥13.4 billion (+0.7%), to ¥2,052.3 billion in FY 2020 compared to FY 2019. The increase in operating income was mainly due to cost reduction efforts as well as lower expenses and expense reduction efforts.

Financial Services: Net revenue from financial services operations increased by ¥37.0 billion, or 1.7%, to ¥2,190.5 billion in FY2020 compared to FY 2019. However, operating income decreased by ¥30.6 billion, or 9.5%, to ¥292.1 billion in fiscal 2020 compared to fiscal 2019. The decrease in operating income was mainly due to the increase in expenses related to credit losses in financial subsidiaries.

All other businesses: Net revenue for all other activities decreased by ¥171.8 billion, or 10.2%, to ¥1,504.5 billion in FY2020 compared to FY 2019, and operating income decreased by ¥8.8 billion (-8.4%), to ¥96.6 billion in FY2020 compared to FY 2019.





Compared to 2019 the main difference is the gain of revenues portions in favor to the financial sector. This is mainly due to a trend change in purchasing methods, the idea of buying a car is gradually replaced by get it through a leasing or rental.

Geographic segment 2020:

FY2020 (As of and for the year ended March 31, 2020)

(Yen in millions)

	Japan	North America	Europe	Asia	Other	Inter-segment Elimination and/or Unallocated Amount	Consolidated
Net revenues:							
Sales to external customers	9,522,905	10,416,582	3,138,755	4,828,635	2,023,115	—	29,929,992
Inter-segment sales and transfers	6,938,616	222,166	222,123	510,021	89,387	(7,982,313)	—
Total	16,461,521	10,638,748	3,360,878	5,338,656	2,112,502	(7,982,313)	29,929,992
Operating expenses	14,893,543	10,368,119	3,210,333	4,967,657	2,021,778	(7,974,307)	27,487,123
Operating income	1,567,978	270,629	150,545	370,999	90,724	(8,006)	2,442,869
Assets	17,517,032	18,012,336	4,192,858	5,241,588	2,837,944	4,878,678	52,680,436

Note: 1.Unallocated corporate assets included under "Inter-segment Elimination and/or Unallocated Amount" for FY2019 and FY2020 are 9,329,020 million yen and 8,630,468 million yen, respectively, and consist primarily of funds such as cash and cash equivalents, marketable securities and portion of security investments held by the parent company.
2."Other" consists of Central and South America, Oceania, Africa and the Middle East.

	FY, 2020	FY, 2019	FY, 2018
Japan	¥16.46 t	¥16.63 t	¥16.02 t
North America	¥10.64 t	¥10.82 t	¥10.57 t
Europe	¥3.36 t	¥3.24 t	¥3.19 t
Asia	¥5.34 t	¥5.51 t	¥5.15 t
Other	¥2.11 t	¥2.33 t	¥245.4 b

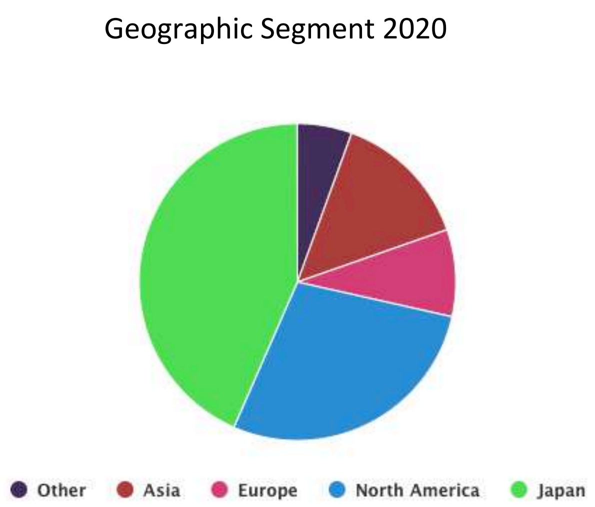
Japan: Net revenue in Japan decreased by ¥163.8 billion (-1.0%), to ¥16,461.5 billion in FY2020 compared to FY2019, and operating income decreased by ¥123.6 billion (-7.3%) to ¥1,567.9 billion in FY2020 compared to FY2019. The decrease in operating income was mainly due to the effects of marketing activities and changes in foreign exchange rates.

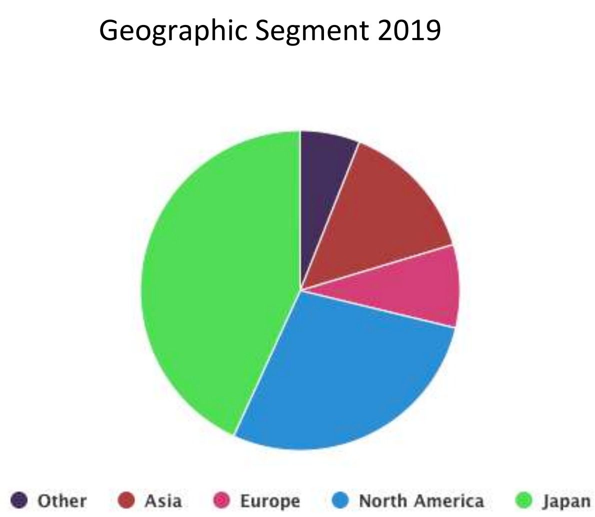
North America: Net revenue in North America decreased by ¥178.4 billion (-1.7%), to ¥10,638.7 billion in FY 2020 compared to FY 2019. However, operating income increased by ¥156.1 billion (-136.3%), to ¥270.6 billion in FY2020 compared to FY2019. The increase in operating income was mainly due to marketing efforts.

Europe: Net revenue in Europe increased by ¥122.0 billion (-3.8%), to ¥3,360.8 billion in FY2020 compared to FY2019, and operating income increased by ¥25.6 billion (+20.6%), to ¥150.5 billion in FY2020 compared to FY2019. The increase in operating income was mainly due to the increase in vehicle unit sales.

Asia: Net revenue in Asia decreased by ¥174.3 billion, (-3.2%), to ¥5,338.6 billion in FY2020 compared to FY2019, and operating income decreased by ¥86.4 billion, (-18.9%), to ¥370.9 billion in FY2020 compared to FY2019. The decrease in operating income was mainly due to the effects of changes in foreign exchange rates.

Other (Central and South America, Oceania, Africa and the Middle East): Net revenue in other regions decreased by ¥220.9 billion, (-9.5%), to ¥2,112.5 billion in FY2020 compared to FY2019, and operating income decreased by ¥0.3 billion, (-0.4%), to ¥90.7 billion in FY2020 compared to FY2019.





Vehicle Production by region:

	FY2019					FY2020				
	1Q (2018/4-6)	2Q (2018/7-9)	3Q (2018/10-12)	4Q (2019/1-3)	12 months ('18/4-'19/3)	1Q (2019/4-6)	2Q (2019/7-9)	3Q (2019/10-12)	4Q (2020/1-3)	12 months ('19/4-'20/3)
Vehicle Production (thousands of units)	2,199	2,184	2,262	2,340	8,985	2,311	2,236	2,146	2,126	8,820
(Japan) - including Daihatsu & Hino	1,003	1,004	1,099	1,203	4,309	1,134	1,122	1,066	1,091	4,413
[Daihatsu & Hino]	[257]	[257]	[290]	[292]	[1,096]	[265]	[275]	[277]	[292]	[1,109]
(Overseas) - including Daihatsu & Hino	1,196	1,180	1,163	1,138	4,676	1,178	1,114	1,080	1,035	4,406
[Daihatsu & Hino]	[133]	[162]	[161]	[141]	[598]	[124]	[155]	[138]	[127]	[545]
North America	517	447	435	442	1,841	499	456	434	418	1,807
Europe	168	159	173	180	679	174	143	182	176	674
Asia	402	449	429	402	1,682	386	413	366	357	1,522
Central and South America	82	93	96	82	353	86	69	76	62	293
Africa	28	31	30	32	121	33	32	22	23	110

In FY2020, Toyota has a drop in vehicles production, in particular during its first quarter. The change from 2019 amounts to 165,000 vehicles.

Figure 66: Annual Vehicle Production, 2016-2020[120]

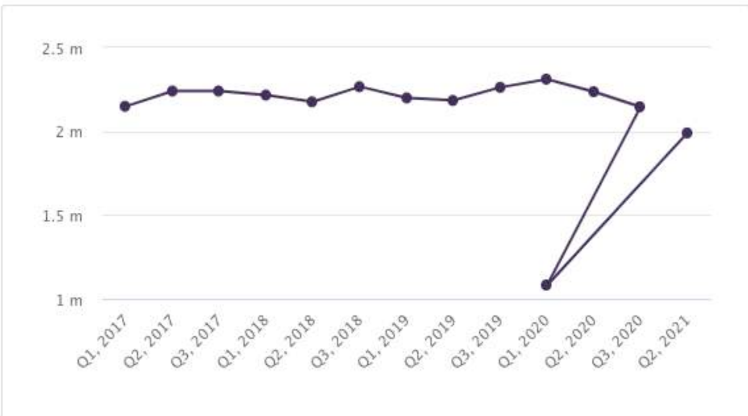


Figure 67: Quarterly Vehicle Production, 2017Q1-2021Q2[121]

[120] https://craft.co/toyota/metrics
[121] https://craft.co/toyota/metrics

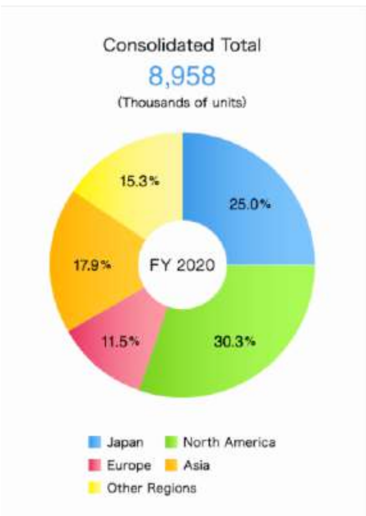
Vehicle Sales by region:

Vehicle Sales (thousands of units)	2,236	2,183	2,282	2,276	8,977	2,302	2,333	2,196	2,128	8,958
[First Half 6 months]					[4,419]					[4,634]
(Japan) - including Daihatsu & Hino	510	521	565	631	2,226	555	585	516	583	2,240
[Daihatsu & Hino]	[155]	[161]	[169]	[203]	[688]	[158]	[183]	[139]	[177]	[657]
(Overseas) - including Daihatsu & Hino	1,726	1,662	1,717	1,645	6,751	1,746	1,748	1,679	1,545	6,719
[Daihatsu & Hino]	[75]	[87]	[89]	[86]	[337]	[65]	[76]	[70]	[74]	[285]
North America	746	665	680	654	2,745	744	702	668	600	2,713
Europe	253	240	232	269	994	274	250	246	259	1,029
Asia	394	417	464	410	1,684	398	431	406	370	1,605
Central and South America	117	120	114	97	448	104	109	114	77	403
Oceania	72	74	66	60	272	66	64	63	69	262
Africa	48	50	54	48	200	54	63	43	48	207
Middle East	93	95	105	104	398	106	128	138	122	493
Other	2	2	2	2	8	2	2	2	2	7
Total Retail Unit Sales (thousands of units) [Toyota, Daihatsu and Hino]	2,616	2,677	2,707	2,602	10,603	2,709	2,745	2,685	2,317	10,457
Housing Sales (units)	1,892	4,808	2,656	5,777	15,133	2,164	4,821	2,610	—	9,595

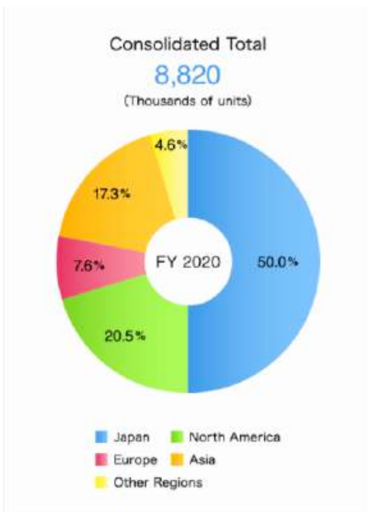
Fiscal Year	Financial Indicator					
	Operating income return on revenues	Pretax return on revenues	Pretax return on capital	Return on assets (R.O.A.)	Return on equity (R.O.E.)	Shareholders' equity ratio
FY2020	8.2%	8.5%	4.8%	4.0%	10.4%	38.1%
FY2019	8.2%	7.6%	4.4%	3.7%	9.8%	37.3%
FY2018	8.2%	8.9%	5.2%	5.0%	13.7%	37.2%
FY2017	7.2%	7.9%	4.5%	3.8%	10.6%	35.9%
FY2016	10.0%	10.5%	6.3%	4.9%	13.8%	35.3%

* Financial figures are based on U.S. GAAP (Generally Accepted Accounting Principles)

Vehicle Sales by Region 2020



Vehicle Production by Region 2020



5.2.3 Cash Flow

Toyota Motor Corporation: CASH FLOW

Annual			
JPY	FY, 2018	FY, 2019	FY, 2020
Net Income	2.6t	2.0t	2.1t
Depreciation and Amortization	1.7t	1.8t	1.6t
Cash From Operating Activities	4.2t	3.8t	3.6t
Purchases of PP&E	(1.2t)	(3.7t)	(3.6t)
Cash From Investing Activities	(3.7t)	(2.7t)	(3.2t)
Long-term Borrowings	(4.5t)	(4.4t)	(4.4t)
Dividends Paid	(690.7b)	(714.2b)	(684.9b)
Cash From Financing Activities	(449.1b)	(540.8b)	397.1b
Net Change in Cash	(449.1b)	486.9b	705.7b

Quarterly								
JPY	Q1, 2019	Q2, 2019	Q3, 2019	Q1, 2020	Q2, 2020	Q3, 2020	Q1, 2021	Q2, 2021
Net Income	684.2b	1.3t	1.5t	701.7b	1.3t	2.1t	149.4b	631.2b
Depreciation and Amortization	413.5b	865.3b	1.3t	398.4b	784.1b	1.2t	398.0b	810.6b
Cash From Operating Activities	824.0b	1.8t	2.9t	908.4b	2.1t	2.9t	673.3b	1.3t
Purchases of PP&E	(1.0t)	(1.9t)	(2.9t)	*(998.5b)*	(1.9t)	(2.8t)	(745.0b)	*(611.4b)*
Cash From Investing Activities	(1.0t)	(1.9t)	(2.3t)	(731.1b)	(1.5t)	(2.7t)	(337.6b)	(1.9t)
Long-term Borrowings	(907.3b)	(2.2t)	(3.3t)	(1.2t)	(2.2t)	(3.3t)	(1.3t)	(2.6t)
Dividends Paid	(381.4b)	(395.2b)	(713.9b)	(363.5b)	(383.5b)	(684.4b)	(349.9b)	(364.5b)
Cash From Financing Activities	157.0b	154.4b	(436.1b)	*40.6b*	(114.8b)	66.4b	2.3t	*2.0t*
Net Change in Cash	(52.0b)	163.2b	74.3b	184.0b	393.3b	225.1b	2.7t	1.4t
Interest Paid							101.5b	230.8b
Income Taxes Paid							204.0b	314.5b

Cash and cash equivalents and restricted cash and cash equivalents increased by ¥705.6 billion, (+19.0%), to ¥4,412.1 billion at the end of FY2020 compared to the end of FY2019. The increases or decreases for each cash flow activity compared to the previous fiscal year are as follows:

Cash flows from operating activities: Net cash flows from operating activities resulted in an increase in cash and cash equivalents of ¥3,590.6 billion in fiscal year 2020. Net cash provided by operating activities decreased ¥175.9 billion from ¥3,766.5 billion in fiscal 2019.

Cash flows from investing activities: Net cash flows from investing activities resulted in a decrease in cash and cash equivalents of ¥3,150.8 billion in FY2020. Net cash used in investing activities increased by ¥453.6 billion from ¥2,697.2 billion in FY2019.

Cash flows from financing activities: Net cash flows from financing activities resulted in an increase in liquidity of ¥397.1 billion in FY2020. Net cash provided by financing activities increased by ¥937.9 billion from ¥540.8 billion of net cash used in FY2019.

The consolidated cash flows by segment for the year 2020 are as follows:
Non-financial services: Net cash provided by operating activities was ¥2,506.8 billion, net cash used in investing activities was ¥1,445.7 billion and net cash used in financing activities was ¥1,005.2 billion.
Financial Services: Net cash provided by operating activities was ¥1,045.2 billion, net cash used in investing activities was ¥1,915.9 billion and net cash provided by financing activities was ¥1,651.9 billion.

5.3 Toyota Green Commitment and Endeavor

5.3.1 Green Technological Design

The change we are seeing today in the automotive world is driven by the need to reduce the impact on the climate.
Toyota in the automotive world is the company that has contributed most to driving the corporate and technological changes that are so tumultuous today. While most companies have only been offering alternative drive models to the market in recent years, Toyota presented the first hybrid car on the Japanese market as early as 1997: the Toyota Prius.
The project began in 1993, trying to imagine what cars of the 21st century would look like. The Japanese company's goal was to create a car that could improve fuel efficiency by 1.5 times, a goal that R&D chief Akihiro Wada pushed to a 2.5-fold improvement by implementing the first hybrid technology. [122]
In 1995, the prototype of the G21 was presented at the Tokyo Motor Show. It was powered by a 1.5 litre diesel engine mated to a continuously variable CVT gearbox (still in use in Toyota cars), which, by means of a conical mechanism, allowed the car to always travel at the right torque ratio.

[122] https://www.alvolante.it/news/toyota-prius-prima-ibrida-compie-20-anni-353813

To this system was added the first electric motor and the EMS energy management system, which allows the energy produced during deceleration and braking to be captured and used to recharge the electric motor.
This combination allows efficiency to be increased, using the high torque of the electric motor at low speeds to reduce fuel consumption and emissions, achieving a range of 30km/l, which at the time was around double the average vehicle efficiency.
In 1997 the car was released on the Japanese market, but compared to the G21 prototype presented in Tokyo in 1995, the car was powered by a 1.5 petrol 1.5 kW hybrid engine instead of a Diesel engine.
The aerodynamics were studied to the point of achieving a Cd of 0.29 (explained in paragraph 4.2.1) which, when compared to the best-selling car in 2020, the Volkswagen Golf 8, with a Cd of 0.275, gives an idea of how accurate the aerodynamic study was at the time.
The electric motor was capable of delivering 30 kW, which when added to the petrol engine allowed the Prius to perform in line with cars of the time but with fuel consumption estimated at 28 km/l in the Japanese test cycle.
The car emitted only 120 g/km of CO_2, a very low value in 1997 that would have been in line with the anti-pollution regulations in Europe until 2019, which were 130 g/km (paragraph 3.3.2.1).
An extraordinary car for its time, but also because it is the project that was the basis for the hybrid and electric cars that are now welcomed by the market as revolutionary innovations, but which actually have their origins in a car from almost 25 years ago and in the forsight of a company that has always been attentive to the environmental impact of its products.

Figure 58: Toyota Prius 1st generation

This car has undergone many evolutions over the years but has always embodied the conceptual urge to minimise environmental impact, and to do this the aesthetics have always been characterised by lines designed to minimise cx, so much so that Toyota says the car is "designed by the wind".
In addition, it is the car in which you would normally find the maximum technology developed by the Japanese manufacturer.

Figure 69: Toyota Prius 4th generation

5.3.2 Technologies developed

Toyota at company level is recognised not only for the products it produces and sells, but also for the philosophy with which the company is run.

As we have seen previously, the company is often cited for having initiated lean management, whose philosophy is based on reducing waste while continuously improving processes and products.

The internalisation of these philosophies has led the Japanese company to approach the automotive market as an innovation leader, prototyping and marketing a variety of technologies.

These types of technologies are expressed in four different drive systems that are applied to various car models, from which the end user can choose according to his or her needs:

Full Hybrid Toyota

This technology is the one that was first introduced in the Prius, and then became a feature of Toyota products for many years.

Basically, cars equipped with this propulsion system have three engines, a classic internal combustion engine powered by petrol, an electric engine which acts as a starter motor and another electric engine which acts as the actual engine.

Figure 70: Hybrid System

The special feature of this system is the way in which the electric motor is powered, since it is driven by a lithium battery located under the rear seats whose power varies, depending on the size of the car, from 59 kW for the Yaris up to 134 kW for the Highlander. However, the battery is not recharged by plugging it into a mains socket, as is the case with electric cars, but is recharged by storing the energy created during braking and deceleration.

This technological solution is also seen in F1, where the KERS Kinetic Energy Recovery System is used, which allows energy to be accumulated from braking and then used as incremental power for the engine.

This system is extremely interesting and rational, as it prevents the energy created during braking from being dissipated in the form of heat but is crammed into the battery as energy.

Hybrid cars use two types of braking, in the case of sudden braking (normally used in dangerous situations) the car behaves like a classic car, and braking takes place thank to the tightening of the brake calipers, but in the case of gradual braking (the one used on

most occasions to slow down the car) the electric motor exerts a resistant force on the wheel axle, which acts as a generator of energy that is transferred to the battery.
On the one hand, this aspect guarantees a longer duration of the brakes and therefore lower maintenance costs for the user, on the other hand it reduces the metals emitted into the air by the brake pads due to the friction generated by braking. This has a triple benefit, reducing particulate matter (fine dust), lowering maintenance costs and reducing energy waste.
Another interesting element is the fact that, thanks to the way the propulsion system is designed, the electric motor and the combustion engine can work together, either only the electric motor or only the combustion engine.
This is the big difference from many cars sold on the market as hybrids but which are in fact Mild Hybrids. This type of cars is equipped with a small electric motor, which cannot work autonomously and gives very little support to the combustion engine during restarts.
Toyota's full hybrid cars make the three engines work together, thanks to a Planetary Gear, which is a simple and particularly robust gear that eliminates clutches, torque converters, transmission belts and other elements subject to wear, breakage and replacement. [123]
This is an advantage for the user who incurs a low probability of breakage and also because the lack of some components lowers the maintenance costs of the car throughout its life.
Thanks to the way in which it is conceived, the Full Hybrid system guarantees low fuel consumption, performance equal to that of internal combustion cars, low maintenance costs and low probability of breakage.
If you also consider the fact that, apart from the incremental improvement, the system has remained unchanged since its conception in 93', we understand how reliable this technology is and it is surprising how many manufacturers are only starting to offer similar propulsion systems in recent years.

[123] https://www.toyota.it/hybrid/come-funziona-sistema-full-hybrid-electric-toyota

Plug-in Hybrid Electric

Another interesting technology developed by Toyota and technically derived from the full Hybrid is the Plug-in Hybrid Electric.
In contrast to the technology explained above, cars equipped with this technology have a much larger battery which is not only recharged by regenerative braking, but also by plugging it into a specific power socket.

Figure 71: Charging point detail

Charging times are variable:

- 10 h in the classic 10 A household power socket
- 2.5 h in standard columns
- 30 minutes in fast-charging stations

Cars equipped with this technology operate in the same way as Full Hybrids, the main difference is that they are able to run fully electric with a maximum range of 75 km.
This mileage may not seem like much, but for daily use it meets the needs of many users, and it is very important to consider the fact that these cars, once the battery is discharged, switch to Full Hybrid mode running, pushed by the heat engine and supported by the electric motor recharged by regenerative braking.

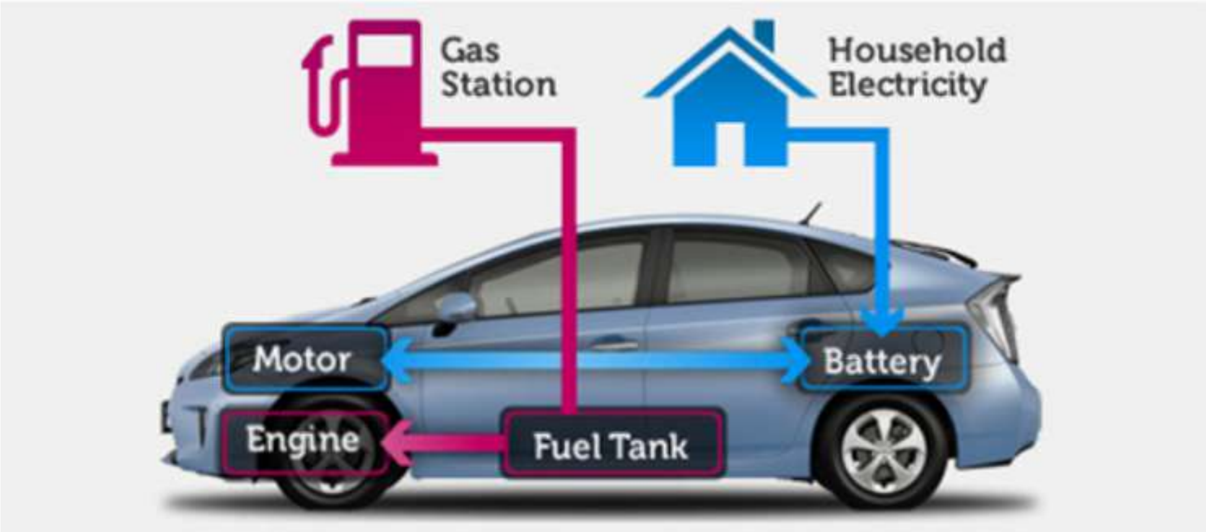


Figure 72: Toyota Plug-in scheme

This detail is of enormous importance if one considers what was said in section 2.2.3.1 about infrastructure issues.
In chapter 2 it was explained how one of the main limits to the adoption of electric cars is the problem concerning the km of autonomy and the charging times in the columns, we saw how electrifying the road network to allow fast charging of electric cars has costs huge at the state level. Costs that are slowing down the implementation of an adequate number of charging stations able to guarantee users to always be able to recharge their car in a short time, this becomes a limit to the spread, because buyers need high autonomy and the safety of to be able to recharge quickly.
In this way, a vicious circle is created: on the one hand, institutions are slowing down investment in infrastructure because the electric car fleet is still small, and on the other hand, there are few buyers willing to tie themselves to a technology not supported by adequately widespread infrastructures.
The result is a slowdown due to the failure to reach the critical mass necessary to trigger a virtuous circle.
Plug-in technology is extremely interesting in this context, as users on day trips can run electric, while in the case of longer distances they can run using the full hybrid technology, without running the risk of ending the autonomy of the car using the gasoline as fuel.
The versatility of these cars fits in perfectly with today's infrastructure situation, as in standard use they greatly reduce emissions thanks to an electric range sufficient to meet

the needs of the average user, while at the same time meeting the need for high autonomy due to the scarcity of recharging points.
Also consider the fact that one of the barriers to the adoption of electric cars are the recharging times, as users cannot always afford to wait for the car to recharge, plug-in cars bypass this obstacle as refueling is the classic at the petrol pump.
It is clear how this technology could be useful to foster the electrification of the world car fleet in a gradual but immediate way, because as shown in section 4.2.4.1 electric cars seem to be able to reduce the impact on the ecosystem but their mass adoption is encountering too many obstacles.
Instead, plug-in cars would be adoptable with minimal and gradual investment in infrastructure and would not require users to change their habits, which would ensure an immediate impact on emissions without the need to wait for the development of an adequate infrastructure network.

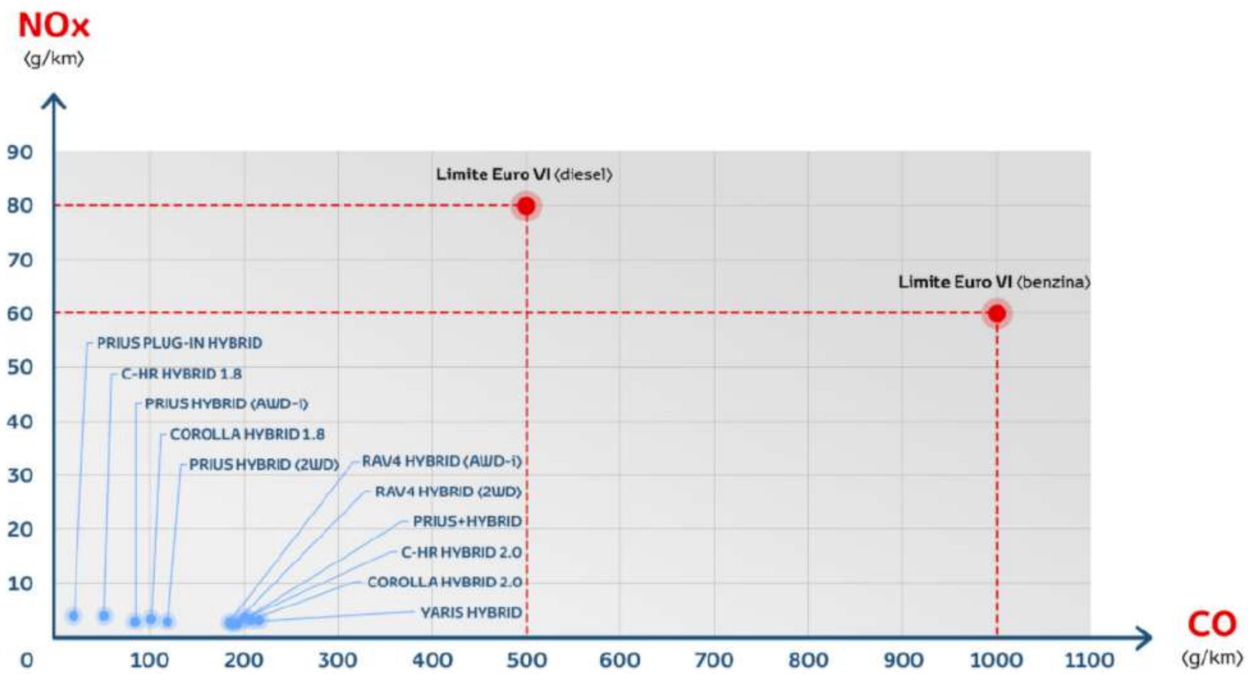


Figure 73: Toyota data, refer to the limit value (NOx and CO) set by law for Euro 6. Values measured with the WLTP test procedure.[124]

[124] https://www.toyota.it/hybrid/sfida-ambiente-salute#nox

From the graph above it can be seen that the Prius plug-in, which together with the Rav4 Plug-in is the only plug-in model sold in Italy, has Co and Nox emissions values close to zero.

It is important to note that these values refer to WLTP tests, which as explained in chapter 3 refer to the most recent legislation which aims to reproduce the real cycle of use.

Toyota Hydrogen Fuel Cell Electric

Full Hybrid technology is now the distinctive element of Toyota and the result of the organizational practices and philosophy that guide the company, an extremely tested and guaranteed technology of which the Plug-in is the refinement.

The Hydrogen Fuel Cell, on the other hand, represents Toyota's attempt to make the future present, cars equipped with this technology are those which are defined as hydrogen cars.

As explained in paragraph 4.2.4.2, these cars are equipped with a pressure tank in which a quantity of hydrogen is crammed in such a way as to reach 500km of autonomy. Unlike electric cars, where recharging times are at least 30 minutes, hydrogen cars take about 5 minutes to fill up.

This technology, as explained in chapter 2 and 4, is extremely promising but the infrastructures are at a lower stage of development than the electric one.

Toyota, however, shows its belief in hydrogen and has not just presented prototypes and designes at car shows, but has industrialized and commercialized a car that is the test bed of all hydrogen technology, the Mirai.

Figure 74:Toyota Mirai

This car has an extremely important role in the development of this technology, because it has demonstrated the feasibility of using hydrogen as a fuel for human transport, but also because it acts as a test bed for perfecting the technology and then transferring it to freight transport

In fact, it is thought that the main role of hydrogen will be in freight transport as it will take a long time for electric power to achieve the autonomy and propulsion power needed to move heavy vehicles. Electric power is not suitable for long-distance vehicles such as ships and aircraft, while hydrogen's intrinsic qualities mean that it can be compressed and packed into large quantities in relatively small spaces.

Figure 75: Infotainment detail

Based on the expertise gained from the feedback received from the marketing of the Mirai, Toyota recently announced that from 2021 it will begin marketing a fuel cell module designed for the B2B market.

Companies wishing to produce hydrogen vehicles will be able to take advantage of the expertise developed by Toyota and purchase a hydrogen propulsion system that is already developed and functioning.

"These modules are designed to be extremely versatile and to meet different needs:

- *The new module has a wide voltage range (400 to 750 V) and can be connected directly to an existing electrical system equipped with motor, inverter and battery, etc., thanks to an integrated and dedicated FC power converter, thus facilitating the development and production of FC products. Furthermore, the modularity of the system makes it more practical.*
- *The four versions can be combined according to application needs (available space and required output power).*

- *Its modularity eliminates the need to install and connect the different FC components individually. It also makes installation easy as it integrates and reduces the number of connection points to a device. "*[125]

Toyota full Electric

The latest technology offered in the Toyota range is the all-electric propulsion system. However, if you look at the company's website, you will notice that only one electric vehicle is sold, the Toyota Proace, which is a medium-sized Van with a range of about 300km.

Figure 76: Toyota Proace

This is a strange choice, because while competitors are starting to include several fully electric models in their range, Toyota which is one of the companies with the greatest expertise in electrified vehicles and battery development does not offer any model for passenger transport.
The reason for this choice is found in the words of the president of Toyota and the Japan Automobile Manufacturers Association, Akiro Toyoda, who at a press conference said that

[125] https://www.toyota.it/mondo-toyota/news-eventi/2021/modulo-compatto-celle-combustibile-idrogeno

the move towards electric power is being done indiscriminately without thinking about the consequences that it would have.
According to Toyota's chief executive, creating the necessary infrastructure in Japan would require an investment ranging from 165 to 438 billion euros, and this would also lead to the collapse of the automotive industry's business system with consequent loss of millions of jobs.
Toyoda also stated that the car has always been an affordable vehicle but switching to electric power too quickly would make cars an elitist medium for the few. From these words it is clear that the Japanese company does not believe in the adaptability of electric cars in the short term, but probably believes that a gradual adoption through the use of Hybrid Plug-in vehicles could maximize the environmental benefits in a short time, paving the way for road to electric.
Whether this view is correct is not easy to say, but it remains clear that we are trying to obtain the maximum reduction in consumption through electricity, but in the meantime we continue to use high-emission vehicles, when hybrid technologies exist to immediately reduce the environmental impact of cars.

5.3.3 Life Cycle Impact

The commitment of the Japanese company is not limited to the development of low environmental impact cars but extends by trying to limit the impact throughout the life cycle from design to disposal. Fundamental importance is given to recycling which is maximized in the design phase, Toyota tries to design the components and cars so that once the end of their life cycle is reached, as much quantity as possible can be recycled.
In 1998 Toyota was the first car company to introduce ISO14001 in its design and development area, followed by the "Eco-VAS" in 2005, a system of approach to design that takes into account the entire Life Cycle.
The ultimate goal that the company has set itself is to create a closed-loop recycling, in which each component is recycled and the same component is recreated.
Now we will list some of the practices that the Japanese company carries out to achieve this goal.

Design of components in order to facilitate their disposal

As indicated in chapter 4, one of the problems that limit the correct recycling of components in the automotive world is the fact that disassembling the parts takes too long and the resulting costs are unsustainable.
To prevent this from happening, during the design phase, the car and its components are designed to make it possible to quickly disassemble them.
All parts that comply with this objective are marked with a symbol indicating the fact that a quick disassembly mode is provided.

Figure 77: Easy to dismantle Mark

For example, for the battery pack of Full Hybrid and Plug-in cars, removal is expected to take place quickly without the need to disassemble other components, this is a strategic choice due to the fact that the substances contained in the batteries are extremely harmful to the environment, and it is necessary to favor its removal.
Quick disassembly is also provided for the instrument panel, which takes place simply by pulling the various parts with force, without the need to unscrew screws.
In addition, all the related wiring is removed by forcefully pulling the cables, which come out without being obstructed by other components, the cables are covered with green tape at the point where they must be pulled hard to facilitate their identification.

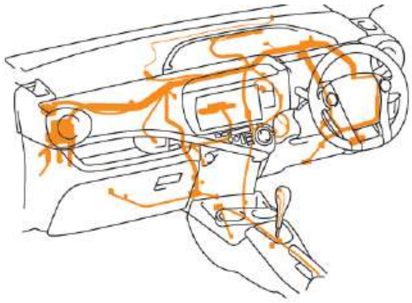


Figure 78:Wiring Scheme[126]

Figure 79: Stripped point[127]

Use of bio-plastics

In addition to how components are designed to promote recycling, Toyota tries to use plant-based components as much as possible.

In 2003, it was the first company to insert bio-plastics in a car, specifically in the Toyota Raum.

In 2011 it was the first company to use bio PET derived from sugar cane and in the same year it managed to reach 80% percent of ecological plastics in the interiors of the SAI model.

[126] Toyota, Vehicle Recycling, 2017, pag 7

[127] Toyota, Vehicle Recycling, 2017, pag 7

Recycling of components

The design choices and the choice of ecological materials must be accompanied by a recycling plan, otherwise the initiatives would only be good intentions with minimal implications in terms of environmental impact.

On this aspect too, Toyota demonstrates extremely detailed planning, proving that they do not limit themselves to designing cars that have low emissions during their use, but sell an entire system that can guarantee environmental protection.

What is surprising about this company is the fact that this approach is not a response to the latest environmental trends but is a system that has been tested and developed when attention to the environment was still a secondary issue.

This ensures that Toyota cars are truly designed to have a low impact, unlike other initiatives that often seem like mere marketing campaigns designed to protect the value of the brand.

Going into the details of the initiatives that Toyota carries out in terms of recycling, two types of procedures can be seen:

- Reuse or Downcycling when components are reused without transforming them or as components where lower technical qualities are required.
- Recycling intended as the processing of components to obtain raw material to be reused in various ways.

When it comes to the reuse of used parts, there are many components that have a low level of wear and can, after being overhauled, be reused on new cars or sold as replacement parts.

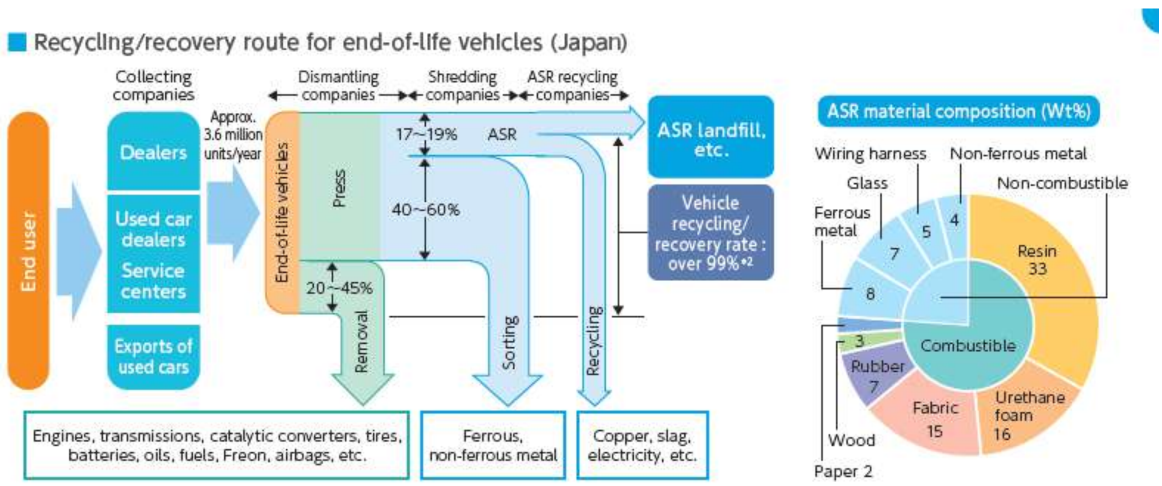
This happens for the gearbox, in fact Toyota in its hybrid cars only mounts the CVT automatic transmission (continuously variable gearbox) which is subject to very low wear as it is composed of a very small number of parts.

Depending on the conditions, the battery pack of electric cars can be recycled (will be explained later) or be subjected to down cycling.

Since 2014 the batteries recovered from disused cars are inspected, if the level of efficiency is still high the batteries are resold as used components; if the efficiency level is not low enough to be recycled, but not high enough to be used in cars, they are modified and inserted into charging stations.

Figure 80: Battery storage system[128]

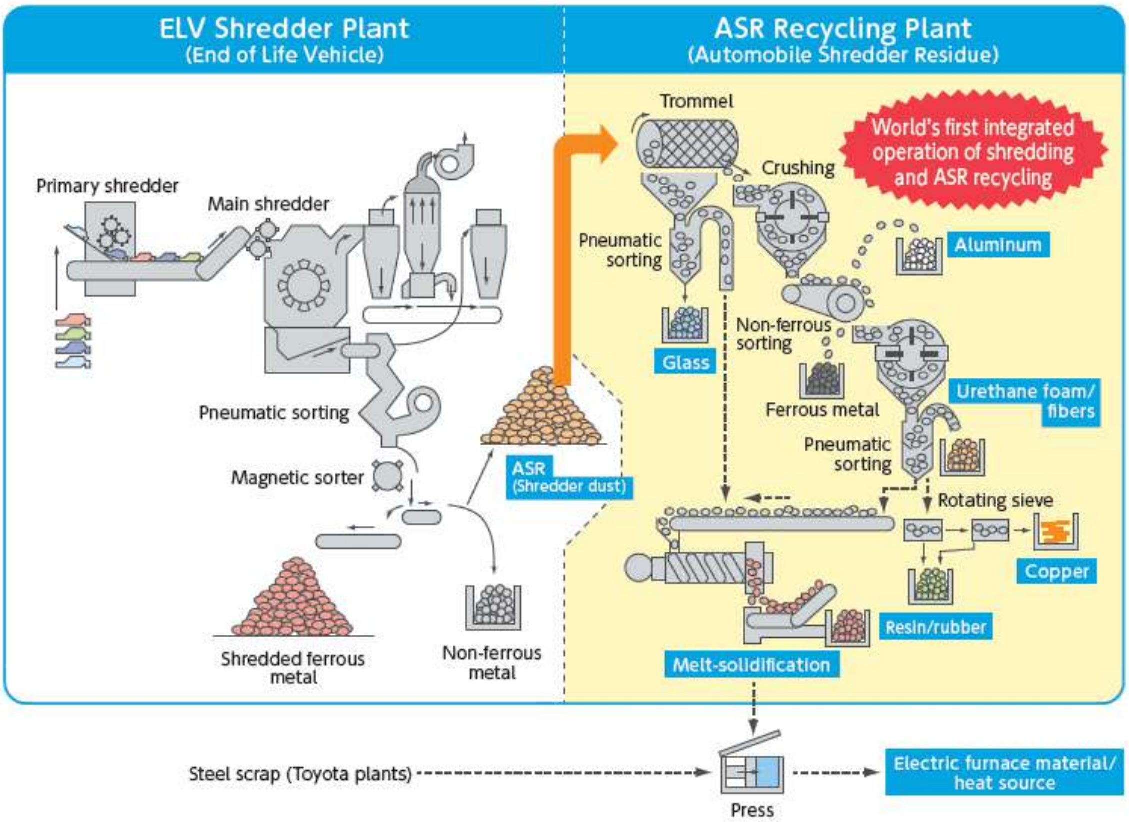
Toyota also re-uses batteries in various pilot projects in order to test new ways of reusing discarded components, for example in 2014 a partnership was made with Yellowstone National Park, where 208 batteries of 85 KWh were used as accumulators of energy obtained with the use of solar panels.
As for recycling, in 1993 Toyota began collaborating with Toyota Metal Co. with the aim of developing technologies for recycling.
Recycling requires dividing the parts based on the material on which various processes are carried out with the aim of bringing the components to the state of raw material which can be reused as a material for the production of components or as a source of energy.



From the graph above you can see the percentages with which the various components are reused or recycled in Japan, while the graph below shows the management of the

[128] Toyota, Vehicle Recycling, 2017, pag 20

components in order to reduce them to raw material ready for remanufacture or use as an energy source.



For example, Toyota since 2014 has implemented methodologies to be able to transform bumpers into pellets and then reuse them as raw material, this previously was not feasible due to technical limitations.

Thanks to this development, the company in 15 months was able to recycle 88,000 pounds which correspond to about 39,000 kg of material that was previously not recyclable.

The quality of these transformations is so high that the company is working to achieve bumper-to-bumper recycling.

This circularity has already been achieved even in the case of such a complex and important component as batteries. Since 2010, the battery-to-battery project has been implemented, with the aim of using disused nickel batteries for total recycling and converting them into new batteries. Toyota was the first company in the world to succeed in this conversion.

As far as lithium batteries are concerned, this circularity has not yet been achieved, but the company is trying to develop the necessary technologies.

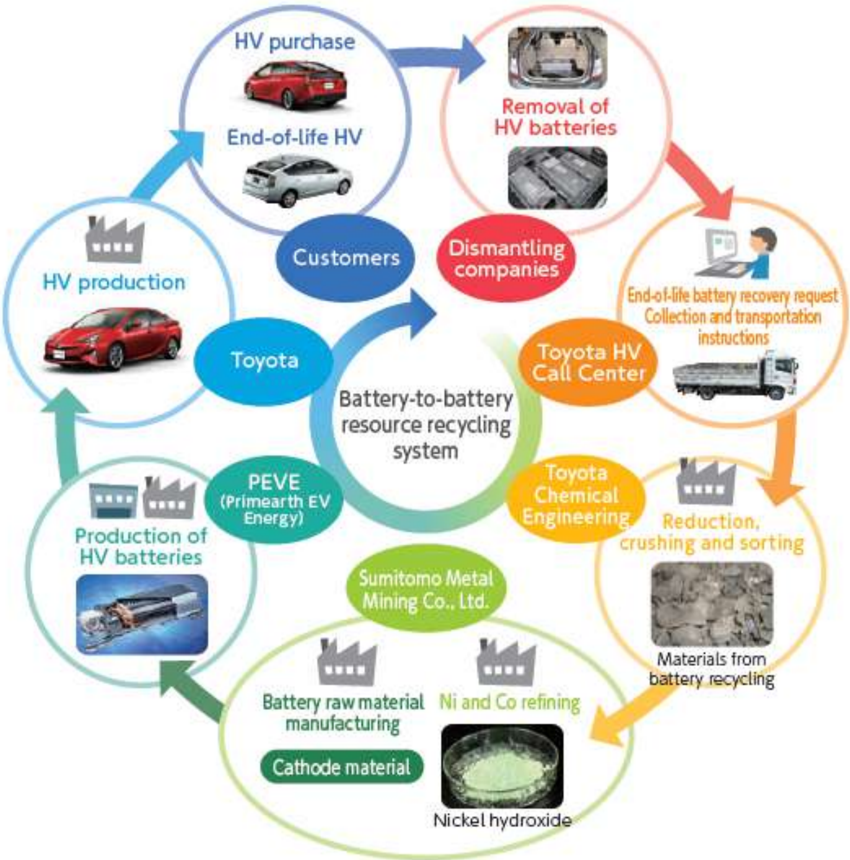


Figure 61: Battery-to-Battery scheme[129]

Toyota is also using circularity to reduce the use of rare chemical elements in the magnets and fuel-cell batteries used in the hydrogen-powered Mirai.

The magnets used in electric motors contain two rare chemical elements, neodyum and dysprosium. Toyota is trying to reduce the use of these elements thanks to a partnership with a specialized company, but in the meantime is limiting demand by implementing circular recycling.

The increase in demand is therefore attributable only to the increase in the market share of electric cars but not to the number of total cars produced, as the material for a new car is obtained from each disused car.

The same happens for the metals needed to build the Fuel-cell stack, which are recycled due to their rarity to reduce total demand.

[129] Toyota, Vehicle Recycling, 2017, pag 19

Figure 82: Magnets and Fuel-cell stack Recycling scheme

Looking at all these projects carried out by Toyota, it can be seen that one of the main qualities of this company is to always be ahead of its time and to develop its products with extreme foresight, taking into account the phases of disposal and recycling of vehicles.
his aspect is evident in the Toyota Mirai. The car itself is an extremely avant-garde project, which for now does not yet have a high diffusion, but, despite this, the company has already planned the disposal phases in detail, which makes it clear how much the environmental aspect is taken into consideration.
From the graph below you can see the flow chart planned for disposal, which leads to the Fuel-cell Recycling scheme mentioned above and the recycling of hydrogen storage tanks, for which the Japanese company is already testing programmes in Europe, in which the carbon in the tanks is recycled through partner companies with whom agreements have already been signed.[130]

[130] Toyota, Vehicle Recycling, 2017, pag 17

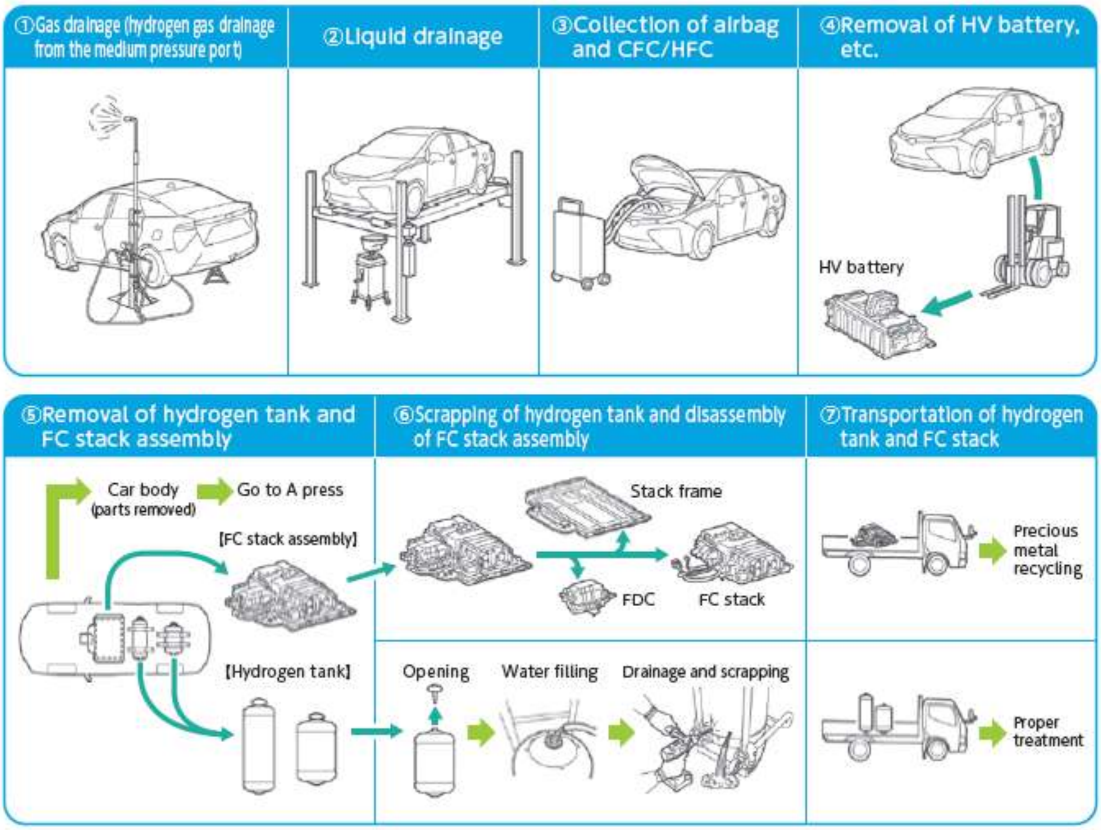


Figure 83: MIRAI dismalting operations

The materials that, on the other hand, cannot be recycled according to a logic of circularity, are instead reused according to other methods, plastic resins for example are used together with carbon additives in metal foundries.

These resins were considered complex to recycle and had too low a calorific value to be used to melt metals. In 2005, Toyota, in partnership with the Alchi Steel Corporation, succeeded in finding a formula for using a mixture of coal and resin.

This has led to a reduction in the use of coal and at the same time to recycling plastic resins that otherwise would have become waste to be crammed into landfills.

Other plastics and materials find recycling in other industries as filler materials, such as crystals and tires

In the photo below you can see a diagram that summarizes how the various components of a Toyota Prius Full Hybrid Plug-in are recycled or reused and a summary diagram that can visually summarise the flows behind the above recycling strategies.

Figure 84: Prius recycling scheme

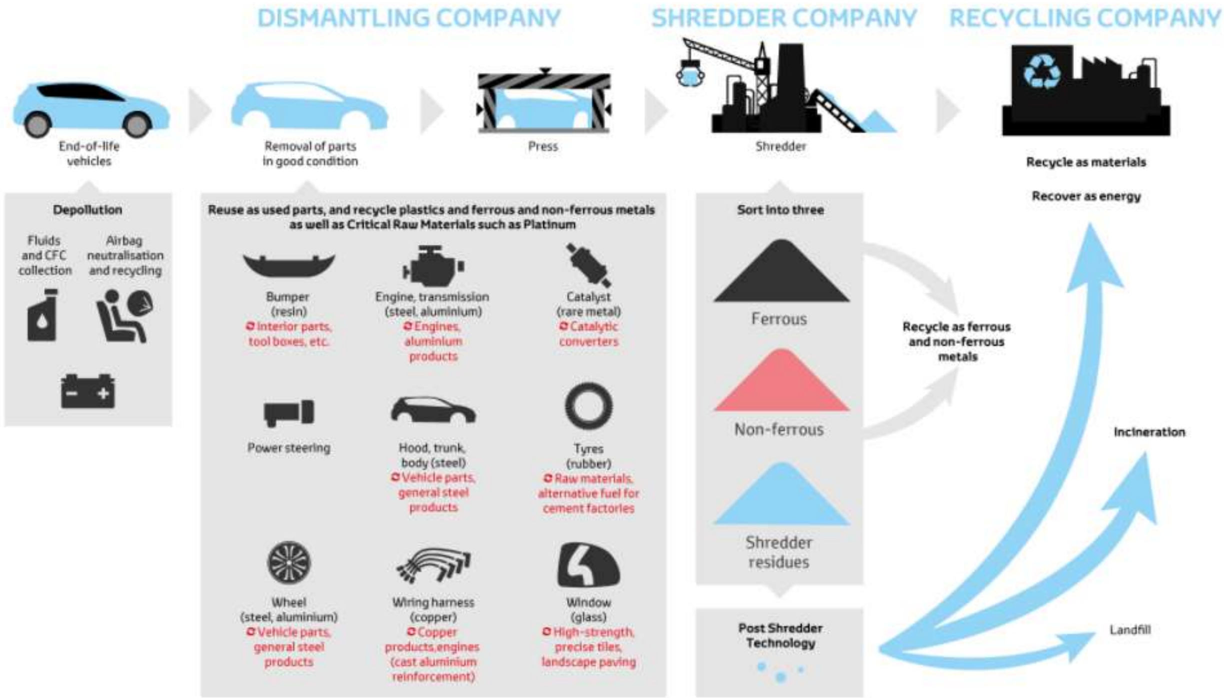


Figure 85: End of Life Vehicle (ELV) Recycling Process

5.3.4 Toyota Environmental Challenge

The initiatives explained in the previous two paragraphs are part of a larger project implemented by Toyota called the "Toyota Environmental Challenge 2050"[131], a project announced in 2015 which includes six sub-goals.

Figure 86: Toyota enviromental Challenge 2050

The topics discussed in the preceding paragraphs are part of the "Challenge of Achieving Zero", as we have seen how the company is trying to propose models with an increasingly low environmental impact for cars, and the MIRAI is currently the model that comes closest.

In this section we will try to explain exactly what the objectives are behind the topics discussed above and behind the "Net positive impact Challenge".

In addition to the targets to be achieved by 2050, in 2018 the company also set itself interim milestones to be reached by 2030, which should help to adjust the targets in relation to the context.

[131] https://www.toyota-europe.com/world-of-toyota/feel/environment/environmental-challenge-2050

Challenge 1: New Zero CO2 Emissions

Toyota has planned that in order to achieve zero emissions by 2050, they will have to sell at least 5.5 million electric vehicles by 2030, of which at least 1 million will be zero emission vehicles (BEVs, FCEVs).

Furthermore, by 2025 every car that will be present in the price lists must have at least one electrified version. This is not at all obvious as Toyota also sells freight vehicles and cars developed for off-road, two contexts in which the electric is still struggling to achieve sufficiently high performance

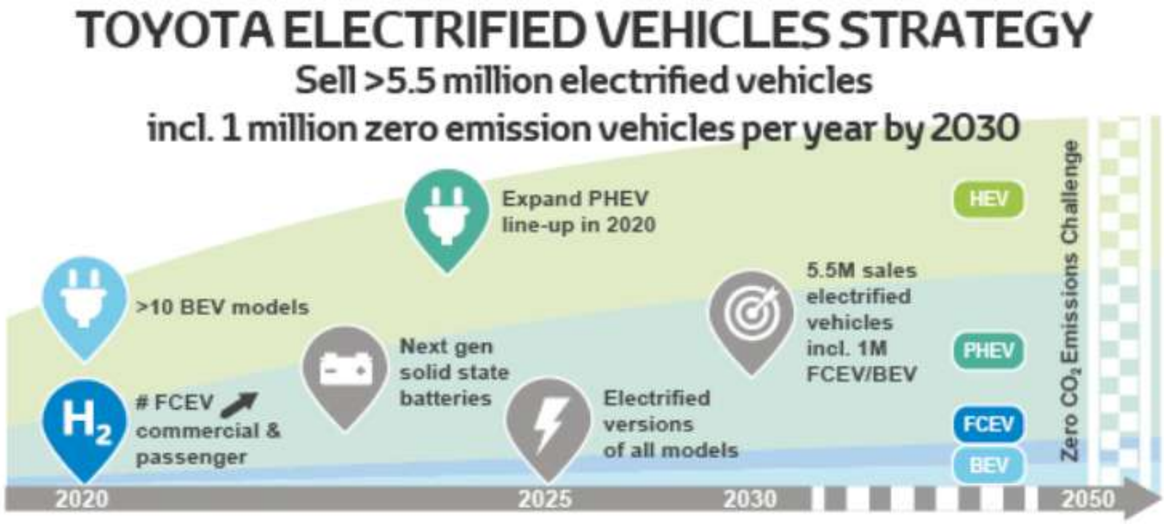


Figure 87: step towards the goal

In order to achieve these goals, huge investments have been made in the development of new technologies. Recently, the automotive industry has been surprised by the fact that Toyota is ready to market the first solid-state batteries by the end of this year.

These batteries, unlike liquid lithium-ion batteries, have a higher density, i.e. more energy expressed for the same weight, which would make it possible to fit more powerful batteries in cars with the same amount of space.

According to reports from the press, the solid state battery that appears to be on the market will have a range of 500km and a recharge time of few minutes.

However, it is speculated that the company has accelerated the development of this technology, which is contrary to what the president of Toyota said, to slow down the development of electric cars and push other companies to invest in hydrogen.
This is because this new technology is already protected by around 1,000 patents, creating an extremely complex development area for other companies, which could start to consider developing hydrogen-powered cars.
Toyota believes so strongly in fuel-cell technology that the second generation of the MIRAI has now been unveiled, showing just how much the company believes in the project. In fact, the first MIRAI sold fewer than a thousand cars commercially because the infrastructure needed to refuel it is only available in a few areas of the world.
Nevertheless, the company is continuing to develop the project, and to contribute to infrastructure development and technology adoption by supporting various institutional projects.
In Paris, for example, a taxi company has made a joint venture with Hype, sending 100 Mirai, which should grow to ten thousand by 2024.
This is helping to give a huge boost to the construction of the infrastructure network, which in Paris already boasts three filling stations and is expected to grow to 20 by 2024.[132]

[132]https://www.bloomberg.com/news/articles/2021-01-19/toyota-backed-paris-venture-targets-10-000-hydrogen-cars-by-2024

Figure 88: MIRAI taxi in Paris

Other projects have been developed with the London police, who have been supplied with 11 Mirai and the Berlin police, who have four Mirai in regular use.

Challenge 2: Life cycle zero CO2 emissions

In order to be able to produce cars that emit zero emissions over their entire life cycle, the company, in addition to the Challenge 1, tries to design cars made from raw materials whose production does not emit CO2, and the cars are designed with a view to reducing the number of components.
In addition, where no special mechanical qualities are required, bio-materials are used to simplify the recycling and disposal process.
By 2030, CO2 emissions will have to be reduced by 25% over the entire life cycle compared to 2013 levels.

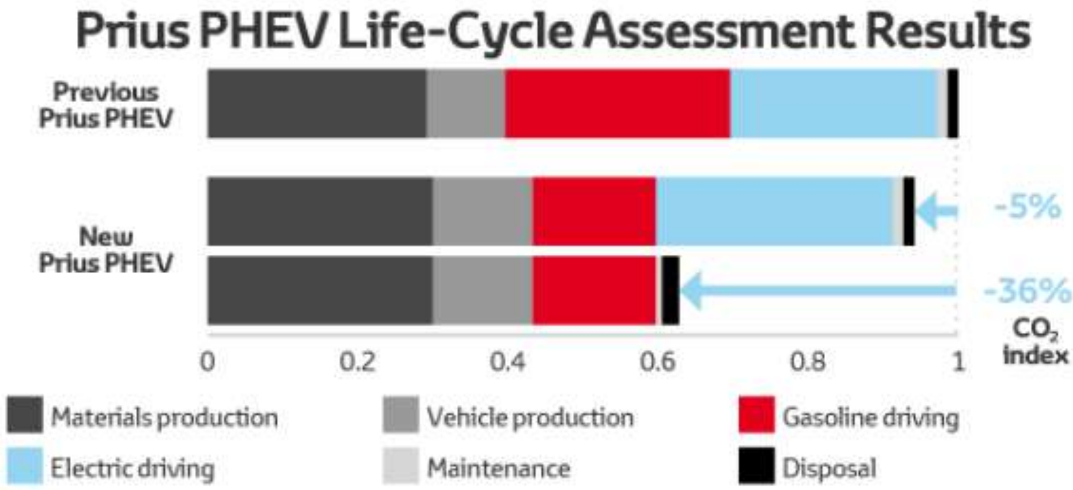


Figure 89: Emission reduction new prius

The new Prius, for example, has 5% lower emissions, which would be 36% lower if the electricity came from renewable sources, but this, as explained in chapter 2, is only achievable through institutional efforts.

Challenge 3: Plant Zero CO2 Emissions

To reduce CO2 emissions, the Japanese company is working hard to rationalise its production processes and facilities so that they can become carbon neutral by 2050.
The intermediate step that has been set by Toyota is to reduce emissions by 35% by 2030 compared to the levels measured in 2013.

The initiatives being developed are varied, one of the processes that has been identified as having the greatest environmental impact is steam production.
Two production plants, Toyota Motor UK Burnaston (TMUK) and Toyota Motor Manufacturing Turkey (TMMT), where steam is used in different processes, were studied and it was found that replacing these processes with other methods that do not require the use of steam could save 8% to 33% energy.
After these evaluations the two plants were converted to steamless. [133]

[133]https://www.toyota-europe.com/world-of-toyota/feel/environment/environmental-challenge-2050/challenge-3

Further energy savings come from the architectural development of the plants, e.g. the new French production facility (TMMF) is designed to be small, which also requires the design of appropriate workflows.
Storage warehouses, for example, are up to 10 times smaller than automotive standards, and this is achieved by lean supply methods that do not require high storage volumes.
In addition, a high level of insulation and the use of the best lighting technology has been provided.
This has led to a 57% reduction in energy used compared to 2002 levels.
Huge investments are also being made to implement renewable energy infrastructure, for example Toyota Motor Manufacturing UK, which has one of the largest photovoltaic plants in the UK, is able to produce enough energy to make seven thousand cars and twenty-two thousand engines a year.

Figure 90: photovoltaic system Toyota Motor Manufacturing UK

Another architectural solution was adopted in the Valenciennes factory where the Yaris is produced: a 410 square metre metal cladding was installed on the south wall, which heats the air between the wall structure and the panel, which is forced into the ventilation ducts in order to heat the area where the plastic components are moulded.
This is an interesting solution that can greatly reduce the use of electricity for heating, with minimal investment compared to the benefits obtained.

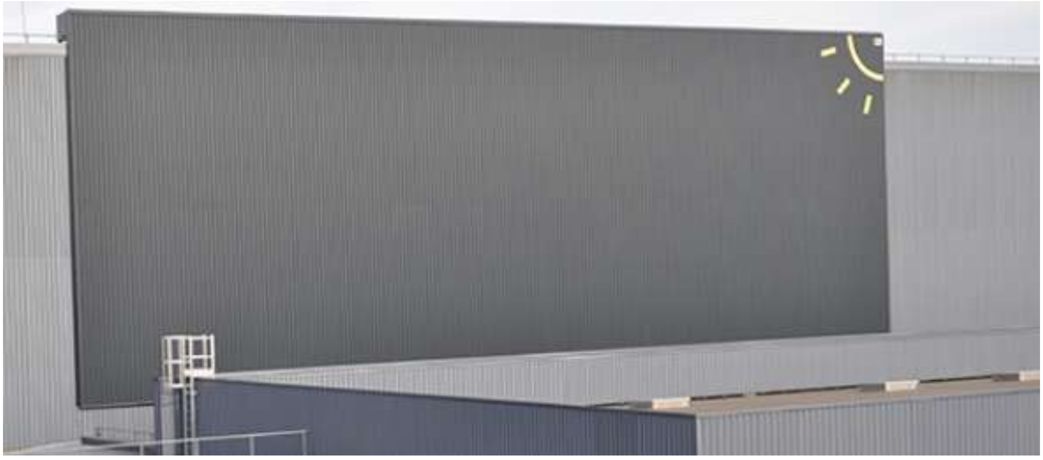


Figure 91: warming metal coating

Another initiative aimed at reducing the CO2 emitted during processing is the one that has been developed at the Japanese Motomachi plant, where a simplified hydrogen dispensing station has been developed.
This station called SimpleFuel produces hydrogen in an electrolytic process using energy from solar panels, which is pressurised and used to power forklifts.
One station can produce up to 9 kg of hydrogen per day, which is enough to power eight forklifts for one day.
This pilot project started in 2018 and after proving its feasibility, the company decided to replicate it in two other plants.

Figure 92: hydrogenl station

Challenge 4: Minimizing and optimizing water usage

Toyota pays close attention to the use and quality of water, as it is aware of how scarce and vital it is as a resource.

By 2030, the company has focused on factories in North America, Asia and South Africa with the aim of minimising their use.

Toyota has implemented a pilot project at its TMMF plant to recycle water that has already been used in the manufacturing process, and to do this it was decided to mix the recycled water with rainwater in order to achieve a sufficiently high level of purity.

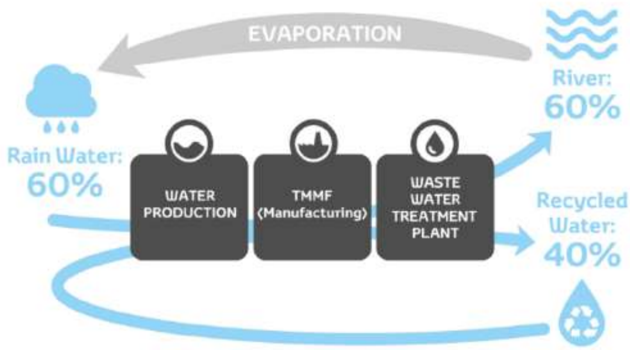


Figure 93: percentages of rainwater use

This was possible through the construction of an artificial basin capable of capturing large quantities of rainwater.

Figure 94: Toyota plant rainwater catchment basin

The focus on water consumption is not only on factories, but also on offices.
The company has established an annual water target per full time employee of 5.5 cubic meters of water, while in 2015 it was 9 cubic meters.
To achieve these goals, a monitoring system has been developed that alerts employees to deviations from normal water consumption in order to stimulate them to be more attentive to their consumption.
In addition, a rainwater recovery system has been developed for use as sanitary wastewater, reducing the use of drinking water by 2400 cubic metres per year.

Challenge 5: Establishing a recycling-based society and system

In order to become a recycling-focused company, Toyota is acting in four areas: the use of eco-friendly materials, the development of durable components, the development of recycling technologies, and the use of as much material from end-of-life cars as possible.
In order to reach this goal in 2050, the company has set itself the intermediate step of creating 30 recycling facilities by 2030.
According to reports from Toyota, in 2019 the company had a 63% lower amount of waste than the industry average, this makes us understand how much Toyota stands out for its attention to these issues and how important it is that buyers in the process of purchase begin to evaluate and reward a virtuosity from which we all benefit.
To achieve these values, the ECO-VAS Ecological Vehicle Assessment System plays an important role. It allows Toyota to predict the life cycle impact of a vehicle from design, production, use and disposal.
This monitoring is done throughout the design, production and prototyping phases and allows the company to have a stimulus that drives continuous research and development of new materials and components. [134]
Toyota pays great attention to the weight of its vehicles, as it is aware that it is crucial in reducing fuel consumption. To reduce weight, all components are evaluated at the design stage to see where weight can be reduced without compromising performance.

[134] https://www.toyota-europe.com/world-of-toyota/feel/environment/better-earth/reduce

This, for example, led to the development of TSOP Toyota Olefin Polymer, an extremely strong and lightweight bio-plastic resin that can be used on both external and internal components and guarantees high recyclability.
Toyota is developing projects and procedures to maximise the level of recycling, and in some pilot projects it has managed to achieve a 95% recyclability level, which has been possible thanks to a design that takes into account the recyclability of the components. [135]
Many of the initiatives concerning this challenge have been dealt with in more detail in the previous section.

Challenge 6: Estabilishing a future society in harmony with nature

Toyota is not only committed to improving its processes and products in order to minimise environmental impact, but is involved in many projects around the world with the aim of directly recovering the damage done by man and industry.
By 2030, the company has set itself the goal of creating 19 "Plants in Harmony with Nature", 12 in Japan and 7 around the world, projects whose aim is to restore balance between man and nature with the help of local communities.
These projects are all related to the AICHI Biodiversity Targets, which is a treaty established by 180 countries during the Convention of Biological Diversity in Aichi Prefecture in 2010, which provides direction in the protection of biodiversity. [136]

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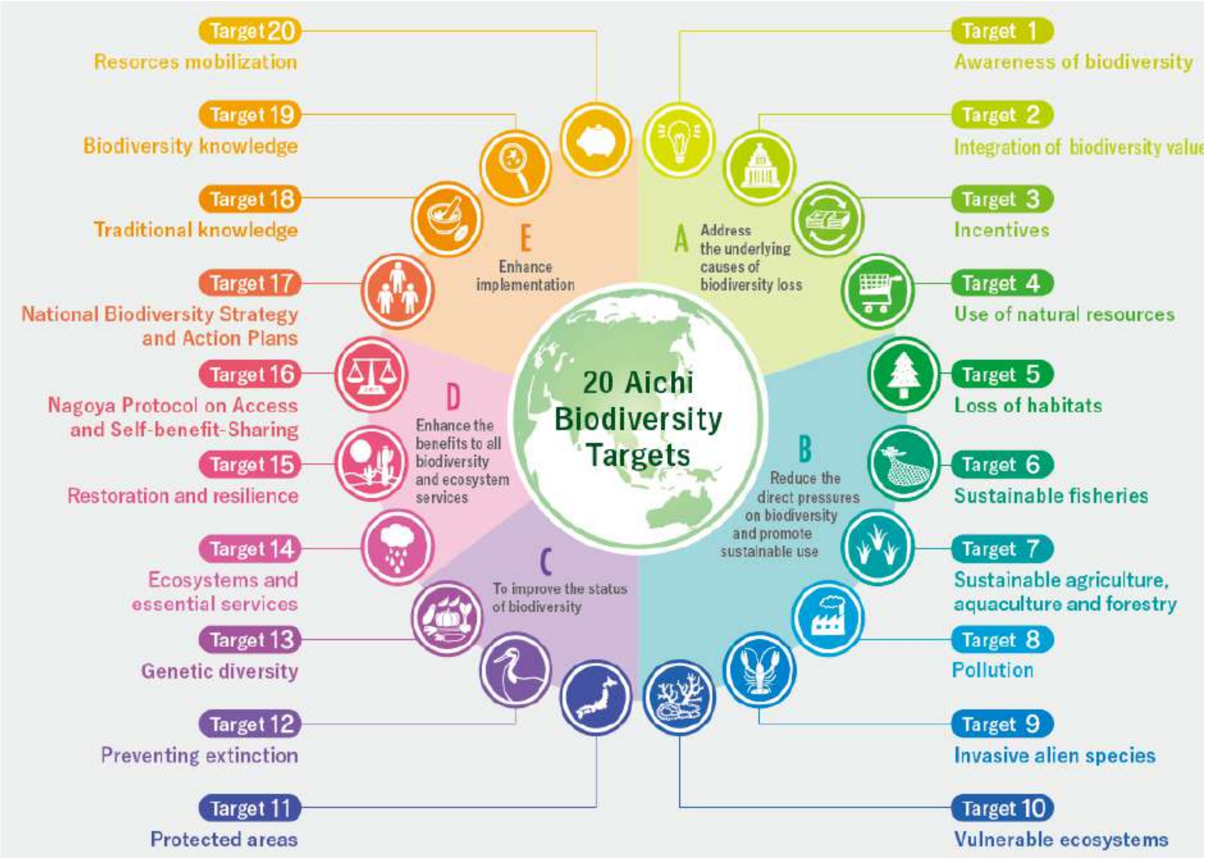
[135] https://www.toyota-europe.com/world-of-toyota/feel/environment/better-earth/recycle
[136] Toyota, All Toyota green project: All Toyota Harmony with nature working, 2016, pag 4



These activities aim to prevent the extinction of endangered animal and plant species, which the International Union for Conservation of Nature (IUCN), with which Toyota cooperates, has determined to be 160,000.

In addition, various activities aim to mitigate the damage resulting from deforestation, Toyota estimates that from 2008 to 2016 it contributed to planting 8.6 million trees worldwide.

Toyota knows that in order to have a decisive impact on our planet, it needs to be supported by the people, who if they do not truly understand the importance and difference of all the initiatives put in place have no reason to prefer Toyota to other brands.

This is why the company also invests in making all these issues known to people, especially children. To do this, in collaboration with the Foundation for Environmental Education (FEE), Toyota created a programme in 2015 in which 665 schools and 30,000 children took part, rising to 77,000 in 2017.

The programme involves children from 6 to 12 years old learning how to explore nature next to their school in order to become more aware of the beauty of biodiversity in a completely new, and not boring, way[137]

[137]https://www.toyota-europe.com/world-of-toyota/feel/environment/environmental-challenge-2050/challenge-6

Conclusions

The last decade, in particular the last few years, is an extremely uncertain period for the automotive industry and for the transport sector in general.

Environmental pressures and the increasingly accentuated and widespread attention to environmental issues have put the automotive sector under the microscope, as it has a major impact on the fate of our planet. The automotive industry is not the only sector responsible for environmental damage, but it is the one that is undergoing the greatest upheaval and must be able to change substantially and radically in a few years to reduce emissions not only from cars but from the whole supply chain. This necessary haste, the result of an evolutionary lag in the industry, is not only accelerating the development of technologies but also creating enormous uncertainty among companies, institutions and buyers.

On the one hand, there are companies that are trying to respond to the electrification trend by including proposals for electric or hybrid vehicles in their price lists, proposals that in some cases are very concrete and rational, as we have seen in the case of Toyota, but the same is true of Tesla.

On the other hand, we see proposals for cars that are nothing more than variations of thermal engine cars supported by very small hybrid engines whose contribution is irrelevant, and the feeling is that they are means that more than represent the awareness of brands with respect to the environmental issue, are only a way of increasing sales thanks to government incentives and marketing strategies to make the customer feel that he is in front of modern brands and attentive to environmental issues.

These choices are the result of the uncertainty and gigantism of automotive companies, beyond the criticism of initiatives that are more commercial than technological, it is also understood how a large and articulated sector such as the automotive one cannot change in a short time and how individual companies before marrying certain evolutionary vectors must be completely sure of the direction in which the future is going, because if this were not the case there would be a risk of mistakes that could lead to the collapse of an entire industry.

It is in this knot to be untied, in these uncertainties, that institutions find their place, tasked with implementing the necessary infrastructures to achieve truly green mobility.

As written in the thesis, car companies, led by some of the more innovative and forward-thinking brands, are trying to develop technologies that can reduce emissions from cars. The problem is that these technologies require infrastructure.

At the institutional level, implementation decisions are also held back by uncertainty, because the investment needed to develop electric or hydrogen car refueling is huge, and institutions are procrastinating to have a clearer and more certain vision of the future in order to make investments that have some benefit.

It seems obvious to think that charging stations for electric cars should be increased, but with a technology that is developing extremely fast, the risk would be to implement infrastructures that would be obsolete in a few years and unable to respond to the energy demand of the market.

For a better understanding, one of the aspects discussed in the thesis concerns the charging time in relation to the type of column and the fact that charging times are strategic because users do not want to wait too long, but also because the shorter the charging time, the lower the number of charging stations needed to meet the demand if the number of electric car owners increases.

This leads institutions to adopt a wait-and-see approach, because it is clear that waiting a few years could mean implementing more durable technologies and thus using resources more intelligently.

The institutional role, however, is also to make the reduction of the environmental impact of new automotive technologies a reality, and this is not just a matter of implementing a network of recharging points (electric or hydrogen), but it means, as we have seen, implementing infrastructures able to produce energy from renewable sources, because only in this way can the reduction of the environmental impact of the automotive sector be maximized.

All this uncertainty has repercussions for the end user, who has a shorter decision-making horizon. So anyone who has to buy a car today has to decide between, on the one hand, extremely interesting new technologies which, however, have limits of autonomy, and, on the other, mature technologies such as combustion engines with their ever-increasing limitations and obsolescence risk.

On the basis of this, there are various lines of thought: some believe that electric cars are the future, while others believe that they are just a mirage.

The truth is that both electric and hydrogen technology are extremely promising but to reduce the environmental impact an overall design and participation of companies, institutions and buyers are required, which is the only way to create the driving force that will lead to the adoption of new technologies.

Also on the basis of these reflections it was decided to treat Toyota as a case study. It was interesting to deepen this company, because the environmental choices it pursues are ahead of its time and could be a path to follow for the entire automotive industry.

The other element that makes it interesting is the way in which it approaches the future, on the one hand, it offers cutting-edge technological solutions such as hydrogen propulsion, but on the other it has a pragmatic approach that aims to solve problems with "contemporary" but immediate solutions.

Think of the full Hybrid plug-in technology: compared to full electric or hydrogen propulsion, full hybrid plug-in technology may not seem very avant-garde or even efficient, using petrol as part of the fuel, but if you analyze it in its cycle of use and results, you can see that it is a transitional way of achieving zero-emission technologies without disrupting the industry and the market

The interesting thing about the full hybrid plug-in is that it looks at the present, at what can be done today to meet future needs, and this is interesting because, leaving aside trends, a pragmatic approach is needed to solve problems.

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