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The EU Green Deal and the Energetic Transition: the impact on the Automotive Industry

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E se capissi che l'amore è un'attitudine, forse la smetto di controllare tutti i tuoi sguardi

E se la scuola insegnasse che dopo un po' quest'abitudine a pensare con gli occhi porta a ciecarti

Contents

Abstract

This document aims at understanding what is the current situation of the automotive industry and how the EU Green Deal and the energy transition is going to affect the equilibriums among countries and how this will impact on the automotive industry. This document starts to analyse what is the European Green Deal Industry Plan and its different policies; in particular, there is a focus on the "fit for 55" package, since it is the most relevant objective that the European Commission has set for 2035 and is already impacting the automotive industry. The second chapter focuses on the impacts of the energetic transition and of the EU Green Deal on the employment in the automotive sector; it aims to understand whether the new mobility solutions will actually increase the opportunities for workers in this sector, or rather lead to less work places due to the substitution of workers by automation and technology solutions. The third chapter investigates the impacts of the energy transition on the global value chain of the automotive industry; several scenarios of introduction of electric mobility are introduced and their impact is studied also depending on the characteristics of the companies involved. The fourth chapter discusses how the energetic transition is going to change the geopolitical equilibriums among countries; it offers a wider view about which countries are expected to increase their relevance and power in the future, the role played by critical materials such as Cobalt and Lithium, and which states will have to face more issues and how all these factors are going to affect the automotive sectors. Finally, the fifth chapter focuses on the adoption of Artificial Intelligence by the automakers, and how this new technology can help these companies to achieve better results not only in terms of productivity but also for what regards the quality of mobility services offered and the increased safety for drivers.

Introduction

The automotive industry is going through major changes in the current years, especially since when the EU Green Deal has been launched. The main objective of the Green Deal is to achieve better results in terms of environmental sustainability also through the adoption of alternative mobility solutions such as the electro mobility to decrease the level of greenhouse gas emissions produced by several industrial sectors, like the automotive one, which one of the most affected by these new rules. Besides environmental sustainability, however, it is important to understand whether this energetic transition is going to be sustainable also under a social perspective. In fact, there is not yet a clear vision whether the introduction of electro mobility as well as other technologies in the automotive sector will be a benefit for the people working in it and also for Europe in general as a country; the technology revolution may lead to a decrease of job places available, and the new ones may require higher skills, meaning that workers have to be trained and receive higher education in order to be able to be fit for future duties. In any case, it is not clear yet, whether the number of jobs created by the energy transition will be enough to compensate the ones that will be lost. The energy transition is a question mark also for the European competitiveness in the automotive sector, among the others: in fact, Europe seems to push particularly towards electrification of its car fleet also because it is an opportunity to rely less on traditional fossil fuels suppliers and on Russia. However, as it appears quite clearly from the reports and from the researches conducted which will be presented later in this document, the production and supply of critical materials necessary for electric vehicles manufacturing is in the hands of very few suppliers, and in particular all of these processes are often controlled by China. This means that the European automotive market, already under threat from Chinese automakers, may face even more issues in the future, for example due to the much lower price of Chinese electric cars with respect to the European ones. Therefore, it is important to investigate also what kind of countermeasures Europe is implementing to dela with this issue, if any, and what this energetic transition means in terms of market and geopolitical power.

Secondary data from past researches and reports have been collected and consulted in order to gather information, and thanks to these resources there was the opportunity to better understand not only the current situation of the automotive sector, but also potential future scenarios and how these scenarios are potentially going to affect the automotive market but also countries' relationships.

Chapter 1: What is the Green Deal?

The European Green Deal is an industry plan launched by the European Commission in December 2019 aimed to decarbonize the European industries, moving from the use of fossil fuels towards renewable energies. This plan originates from the Paris Agreement, when in December 2015 "196 Parties at Cop21 decided to cooperate on a collective effort to keep the global warming below 2°C above pre-industrial levels, trying to limit it to 1.5°C" (United Nations, Climate Change). The Green Deal wants to reach net-zero emissions by 2050 in all the European industries and sectors. As stated by Fetting (2020), it is composed by eight principal key areas:

1. Increasing the EU's Climate Ambition for 2030 and 2050
2. Supplying clean, affordable, secure energy
3. Mobilising industry for a clean and circular economy
4. Building and renovating in an energy and resource efficient way
5. A zero-pollution ambition for a toxic-free environment
6. Preserving and restoring ecosystem and biodiversity
7. Farm to Fork: a fair, healthy and environmental-friendly food system
8. Accelerating the shift to sustainable and smart mobility

The above-mentioned points are summarised in the following figure:

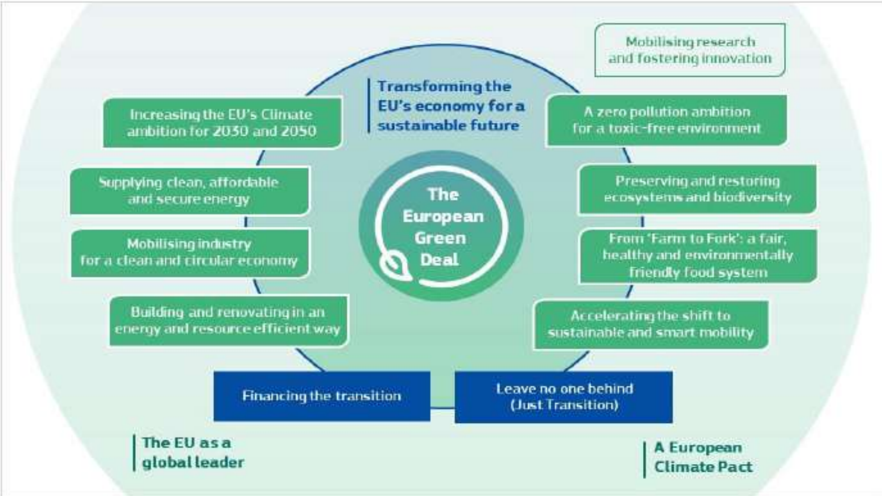

Figure 1: The European Green Deal with its key areas (European Commission, 2019)

In 2018, the EU had decreased its levels of greenhouse gas emissions by 23% with respect to 1990 levels (European Commission, 2019); however, this is not enough to reach carbon neutrality by 2050, and that is why a set of new policies is necessary, since through the current ones only a reduction of 60% in terms of greenhouse gas emissions will be reached in 2050 with respect to 1990 (European Commission). According to the European Commission, at least €1 trillion will be necessary in sustainable investments until 2030 to reach the emissions targets. The money will come in part from the public entities, roughly €500 billion, while the remaining part will be obtained through the investment program "InvestEU" (Fetting, 2020).

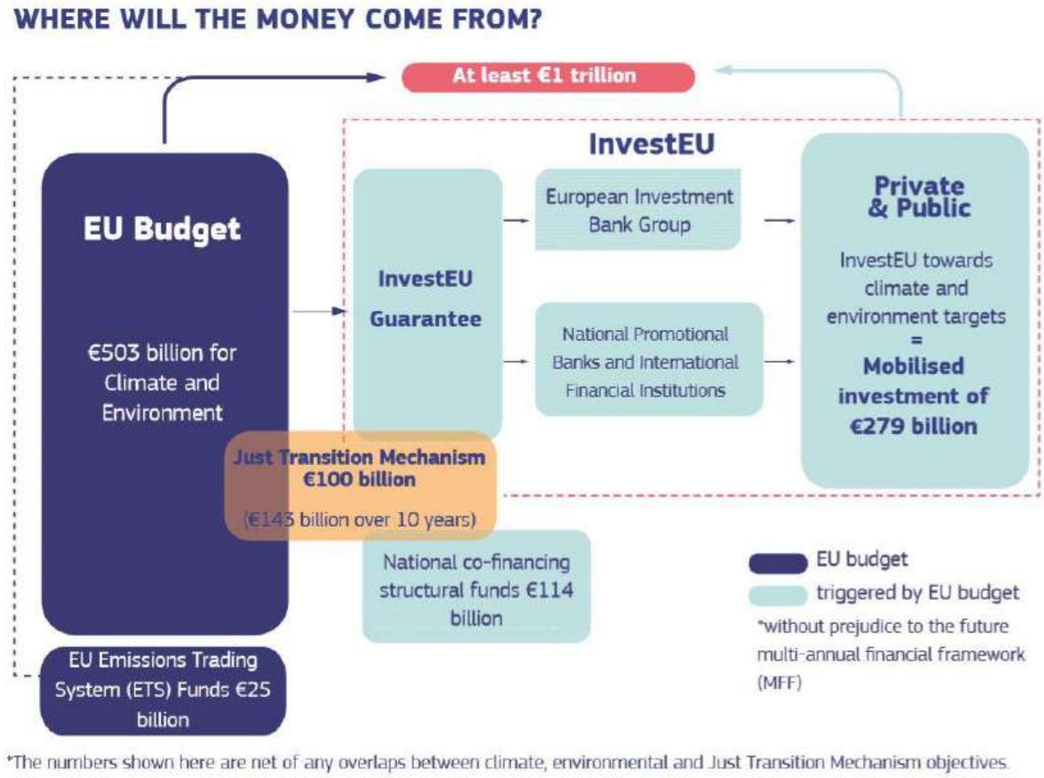

Figure2: The European Green Deal Investment Plan (European Commission, 2020)

An important step towards this direction is the Fit for 55 package which aims at reducing the greenhouse gas emission by 55% in 2030 with respect to the 1990 levels (European Council, 2024; KPMG, 2021). This package comprehends a set of new policies that are going to deeply modify the current European industry infrastructure, going from the energy supply system to one of the most important industrial sectors in Europe, which is the automotive one.

1.1 The "Fit for 55 Package"

In the following list it is possible to analyse in detail the points that are composing the Fit for 55 package:

1. EU emissions trading system (ETS): this system was introduced in 2005; it works according through a monetary payment that firms and companies have to perform to compensate for their greenhouse gas emissions. A cap to these "allowances" that companies buy decreases every year to function as an incentive to reduce the emissions, even though "certain sector that are exposed

to "carbon leakage" get free allowances to support their competitiveness" (Consilium.europe.eu, "fit-for-55-eu-emissions-trading-system", 2024). A new reform wants to reduce the availability of allowances per year, introducing a faster reduction of the cap moving from a current decrease of 2.2% until 2024 to a decrease of 4.3% from 2024 to 2027 and 4.4% from 2028 to 2030. Moreover, additional sectors will be involved in the ETS, such as the maritime transportation one, and a "new self-standing emissions trading system is created for buildings, road transport and fuels…" (European Council, 2024).

2. Social Climate Fund: this fund works to help entities (people with low income or micro businesses) to deal with the rising fossil fuel prices. The Social Climate Fund is financed by the revenues earned from the ETS that countries collect and that can use to help people in need through investments aimed at increasing the energetic efficiency of the buildings, the decarbonization of the heating and cooling systems as well as direct income support in a limited way and for a specific time frame (European Council, 2024).

3. Carbon Border Adjustment Mechanism (CBAM): this tool is used to avoid that industries relocate the production process in countries outside the EU where rules about greenhouse gas emissions are less strict. This mechanism works in parallel with the ETS, that is producers located outside the European Union that want to import in EU countries have to buy CBAM certificates to compensate for the difference in production cost since they did not pay for allowances for the pollution caused. The sectors that at the moment are covered in this mechanism are the ones which involve the production of iron and steel, cement, fertilisers, aluminium, hydrogen, electricity (European Council, 2024).

4. Effort Sharing Regulation (ESR): the European Council has adopted in March 2023 a new target for each member state to reduce the greenhouse gas emissions in those sectors that are not involved in the ETS. The sectors covered are the Road Transport, Agriculture, Buildings, Small Industries and Waste. The objective is to go from decrease of 29% of greenhouse gas emissions in

2030, with respect to 2005 levels, to a reduction of 40% (European Council, 2024). These targets are established taking into account national situation and circumstances and in 2025 may also be modified, if necessary, following the impact that Covid-19 or other events have had on some countries. To reach their targets, member states have some instruments:

- Banking: in case during a year the country emits less than its limit and therefore can use the surplus the following year.
- Borrowing: if a country emits more than what it is allowed to, then it can borrow from the following year allocation.
- Trade: excess allocation can be bought or sold among countries.

Countries may use also some allowances from the ETS to reach their ESR targets and a quantity of credits from the "land use and forestry regulation" (European Council, 2024).

5. Land Use, Land Use Change and Forestry regulation (LULUCF): these set of rules are aimed to "address the carbon footprint of activities related to the conversion, use and management of land and forests for both human and environmental benefits" (European Council, 2024). This regulation was adopted in 2018, with the purpose to compensate "by at least an equivalent amount of removals" the emissions due to the land use and exploitation. By removals, is intended carbon removals, which are the trees that thanks to the photosynthesis process are able to capture CO_2 from the atmosphere. The new target wants to increase the Mt (million tonnes) of CO_2 to be removed from the air moving from the existing target of -225 Mt of CO_2 to -310 Mt of Co2 removed by 2030. The targets will be tailored for each member state according to the past level of carbon removals and to the potential to further increase them. There will be two phases: the first one until 2025 where the regulations will remain mainly the same, instead from 2026 to 2030 there will be the second phase with the new target (European Council, 2024).
6. CO_2 emission limits for new cars and vans: the European Council wants to furtherly increase the restrictions on greenhouse gas emissions produced by

passenger cars and light commercial vehicles. Compared to the 2021 limit of g/km of CO_2 the EU wants to decrease them by 55% for new cars and by 50% for new vans in 2030, while reaching 0 g/km of CO_2 by 2035 onwards (European Council, 2024). This particular point will be furtherly analysed later in the document since the automotive sector is subjected to big changes which will have a huge impact on the industry but not only.

7. Cutting methane emissions in fossil fuels: in May 2023, the EU has adopted new regulations to cut the methane emissions. methane is one of the four greenhouse gases that can be found in the atmosphere. It has a better capacity than CO_2 to capture the heat, meaning that it has "84 times greater global warming potential than CO_2, on a 20-year timescale" (European Council, 2024). The industry sectors that are responsible for the vast majority of methane emissions are the agriculture, energy, waste and biomass burning ones, accounting for the 60% of total methane emissions in the EU (European Council, 2024). The new EU rules involve new processes in measuring and reporting of these emissions, with the use of independent verifiers, constant monitoring by oil and gas companies for leakages or other equipment issues, global monitoring tools to control the emissions of imported fossil fuel and "by limiting the release of methane at energy production plants" (European Council, 2024).
8. Sustainable Transport Fuels: this initiative is aimed to reduce the carbon footprint of aviation and maritime transports, thanks to the ReFuelEU aviation and the FuelEU maritime proposals. According to the European Council, aviation, and maritime transportation account for 14.4% and 13.5% of EU transport emissions. For aviation, the plan is to increase gradually the amount of synthetic fuels in the mix, reaching the 70% in 2050; at the same time the amount of fuel will be only the strictly necessary for the flight to avoid emissions caused by extra weight. Moreover, EU airports will have to "guarantee the necessary infrastructure to deliver, store and refuel" with synthetic fuels (European Council, 2024). The FuelEU maritime proposals will oblige ships weighting more than 5000 gross tonnes (apart from fishing ships)

to adopt a program of introduction of synthetic fuels to reduce to carbon footprint by 80% with respect to the 2020 levels (European Council, 2024).

9. Alternative Fuels Infrastructure (AFIR): this new regulation adopted by the Council in June 2023 aims at creating a reliable infrastructure for any kind of transport, going from the cars to the planes to refuel thanks to alternative sustainable fuels such as hydrogen or liquified methane. A developed recharging stations infrastructure is involved in the AFIR by increasing the presence of charging points on the main roads and in key urban areas. At the same time, also hydrogen refuel stations and liquified methane refuelling points will be implemented and installed on the main roads and in every urban, so to offer an efficient recharging or refuelling service for all the users (European Council, 2024).
10. Renewable energy directive revision: in October 2023 the European Council adopted the new regulation according to which the renewable energy resources should go from 32% to 40% by 2030. This new regulation is part of the RePowerEU plan, which was proposed in May 2022, mainly to respond to the Russia-Ukraine crisis in order to let Europe be more independent from Russian fossil fuels and to have a significant reduction of greenhouse gas emissions caused by the energy sector, which amount for the 75% of total EU emissions (European Council, 2024). This plan has a set of sub-targets for each sector involved:
    - Buildings: the target is to reach 49% of renewable energy.
    - Industry: the target is to increase gradually by 1.6% the mix of renewable energy used year by year from 2022 to 2030.
    - Hydrogen in industry: by 2030, 42% of energy should come from "renewable fuels of non-biological origin".
    - Heating and Cooling: respectively, there should be an increase in renewable energies annually by 0.8% until 2026 and 1.1% until 2030.
    - Transport: in this case, member states can opt either for a reduction of fuel emission intensity of 14.5% by 2030 with respect to 2022 levels or reach at least a share of 29% of renewable energies used in this sector. At the same time, there should be an increase of 5.5% by 2030 in terms of

sustainable fuels, both biofuels and fuels of non-biological origin combined, with at least 1% of the latter type of fuel in the mix (European Council, 2024).

The European Council agreed that member states “will map the areas necessary for national contributions towards the 2030 renewable energy target within 18 months after the entry into force of this directive”.

11. Revision of the Energy Efficiency Directive: this directive is important since using less energy means having less greenhouse gas emissions, reducing the dependence on fossil fuels and having more affordable energy for people. What the EU wants to reach is a decrease of 11.7% of energy use in 2030 with respect to the projections for the same year in 2020. Compared to 2007, the EU was able to reduce the use of energy by 29% on average (European Council, 2024). In 2020 the target was to decrease the energy consumption by 32.5% with respect to 2007 both in terms of primary consumption and for final consumption, while with the revision of the directive the objective is to reach a reduction of 40.6% for primary consumption and 38% for final consumption always with respect to the 2007 levels. The target for primary consumption will be binding for all member states, while the final consumption target is indicative (European Council, 2024). Thanks to this new directive “the annual energy savings target for final energy consumption will gradually increase from 2024 to 2030”, with the objective for member states to reach an average of energy saving of 1.4% per year.
12. Making building in the EU greener: according to the EU Consilium, buildings are responsible for more than one third of the greenhouse gas emissions in Europe, therefore they are a fundamental element to achieve carbon neutrality by 2050. Buildings in Europe account for the 40% of final energy consumption and for the 36% of energy related greenhouse gas emissions (European Consilium, 2024). By 2028, new buildings owned by public bodies will have to be carbon neutral, and the same will be for all the other buildings by 2030. According to this set of new rules, all non-residential buildings will have to have energy consumption “lower than the 16% of the worst performing

buildings" by 2030, and "by 2033 lower than 26% of the worst performing buildings". For what regards residential buildings, the use of primary energy should decrease by at least 16% by 2030 and 20-22% by 2035, with the 55% of energy reduction that should be achieved thanks to renovation of the worst performing buildings (European Consilium, 2024). There are, however, some buildings that are not involved in these measures, such as historical buildings, buildings used for religious activities, stand-alone buildings smaller than $50m^2$, summer cottages and residential buildings with limited time use and energy consumption, buildings owned by armed forces, industrial sites and agricultural buildings. Additionally, solar panels should be installed in every building where it is technically and economically suitable (European Consilium, 2024).

13. Shifting from fossil gas to renewable and low-carbon gases: this new package of rules aims at modify the gas regulation and gas directive approved in 2009. Renewable and low-carbon gasses can be produced from organic sources such as biogas or biomethane or from non-biological renewable sources, by using the electricity, such as renewable hydrogen and synthetic methane (European Consilium, 2024). The low carbon gases are not produced from renewable resources, by during their entire lifecycle they produce 70% less greenhouse gas emissions than gas from fossil resources. The new rules can be divided into four principal points:
    - Creating a market for hydrogen: this includes the creation of a market and infrastructure for the hydrogen, but also the creation of European Network of Network Operators for Hydrogen and a facilitated trade with non-EU countries (European Consilium, 2024).
    - Integrated renewable and low-carbon gases into the gas grid: this means remove the cross-border tariffs, introduce a certification system and common terminology, rules for the quality of gas and increasing the production of biomethane. 2049 will be the last year when it will be possible to enforce fossil gas contracts (European Consilium, 2024).

- Engaging and protecting consumers: it involves the introduction of simpler ways to change energy provider, more transparent bill information and access to smart meters (European Consilium, 2024).
- Increasing security of supply and cooperation: a new plan for electricity, gas and hydrogen networks, certification of storage system operators, more cooperation between EU members and restriction for the import of gas from Russia and Belarus (European Consilium, 2024).

14. Energy Taxation: the Energy Taxation Directive (ETD) is going to be revised by the EU. According to the European Council, the revised directive ensures that the taxation of different energy products reflects their impact on the environment". This means that each product will be taxed depending on how much it pollutes. What will be changed is the structure of the tax rates and there will be a broadening of the taxable base. For what regards the first point, the minimum tax rates will be based on the real energy content and environmental impact, not on the volume, while for what regards the second point, more products will be included in the taxable base. The revisions will have as consequences that the most polluting fuel will be taxed the most, aviation and maritime fuels will be subjected to taxation with a gradual increase of the tax rate; moreover, there will be no distinction between the use of fuels and electricity and there will be a continuous update of minimum rates (European Council, 2024).

To achieve all these goals and the carbon neutrality target, Europe cannot rely only on itself, but it needs the cooperation of other countries, such as those in Africa, but also China, since they are an important resource for energy supply and sustainable solutions. This aspect will be analysed later in the document, while in the following chapter what wants to be investigated is the impact of these new policies in the European automotive sector, what changes will they bring, which challenges and which opportunities.

As has been reported in the previous chapter, the mobility sector is one of those involved in the Fit for 55 package, that is, it has to reduce its emissions by 55% in 2030 with respect to 1990 levels. In Europe, the automotive industry employs 13.8

million people, being the 6.1% of total EU employment and it accounts for the 7% of EU GDP (European Commission, 2021). Europe, has been traditionally one of the most important motor manufacturers, in fact the European automotive sector contributes to generate a surplus of €74 billion thanks to the over 5.6 million vehicles exported per year worldwide (Brown et al., 2021). Automotive manufacturing alone, accounts for the 10.5% of all EU manufacturing jobs involving roughly 3.1 million people (Acea, 2023). As reported by Eurostat data (cit. in Brown et al., 2021) 53% of total EU car manufacturing is located in Germany, 10% in France, 7% in Italy, 6% in Spain and 5% in Sweden.

The energetic transition from internal combustion engine cars (ICE) towards battery electric vehicles (BEVs) is going to affect, and is already affecting, the whole value chain of the industry. More and more vehicles are becoming the product of technology and digitalisation development and less the result of a mechanical research. This mean that the European automotive industry faces several challenges and opportunities for the next decades; some of these regards how the green transition will affect the job market and how it will reshape it. The question to be asked is whether this transition could be considered sustainable not only environmentally but also socially. Another important factor to address is how the demand for raw materials will affect the competitiveness of the European automotive sector: the transition in terms of powertrain does not affect only the engine itself, but also the supply chain that is necessary to obtain the materials needed for the batteries and electric engines manufacturing. The just mentioned point is one of the main reasons why it is possible to observe in the global automotive market, but also in Europe, a set of new brands of OEMs coming from Asia and especially from China; it will be interesting therefore to understand how the EU deals with this situation and what are the policies that it applies to not let European manufacturers lose competitiveness with respect to Chinese ones.

Chapter 2: The new job market in the European Automotive industry

At the end of the previous chapter, it was stated that the European Automotive Industry employs millions of people, both directly and indirectly. This implies that millions of people will be involved somehow in the transition towards electric vehicles. Can this be considered as a positive factor? Will the new industry structure result in new job opportunities or there will be more job losses?

In the image below it can be seen all the jobs that are involved in the EU automotive sector:

Figure 3: "Employment creation in the EU automotive value chain". Available at: Employment - CLEPA – European Association of Automotive Suppliers, accessed on the 19th of June 2024.

As reported by the BMWI 2019 Report (cit. in Brown et al.), a study conducted by the German Ministry of Economics expects that by 2030, the energy transitions towards BEVs will cause a loss of around 40,000 people in car manufacturing only in the Bavaria region, home of Audi and BMW, 35,000 job losses in Baden-Württemberg (Daimler and Porsche) and 25,000 in Niedersachsen (VW). These are the expected data only for Germany, which is the main car manufacturer country in Europe, however also in other European countries the trend is quite similar. The powertrain is the most labour-intensive part in the production of a vehicle and in Europe there are several countries which will be highly affected by the introduction of electric vehicles.

According to The European Association of Automotive Suppliers (CLEPA), in Germany between 2020 and 2040, there will be a total of 122,000 people losing their job due to transition from internal combustion engine, in Italy this would affect more than 66,000 people, in Spain more than 63,000, in Romania almost 50,000 people, in Poland more than 26,000 and in France more than 21,000. A study carried out by the "Jagiellonian University in Krakow suggests that 31% of employment among suppliers (in Poland) depend on internal combustion engine. At the same time, the introduction of BEVs will create new jobs in the same countries where it also caused the job loss for many people; however, the number of new jobs will not compensate the number of job losses. Respectively, in Germany there will be more than 39,000 new jobs related to the powertrain production, in Italy slightly more than 7,000, in Spain more than 37,000, in Romania more than 21,000, in Poland 15,000 and in France 25,600. As can be seen, France is the only country among the ones cited above where apparently the number of jobs created by energy transition in the powertrain manufacturing area is higher than the number of job losses.

Besides the job losses or job creation due to the energetic transition, the European Green Deal is also bringing a change in skills required for the new jobs. For example, in Germany between 2015 and 2019 the employment increased by 10% in R&D (15% for suppliers), 34% in IT and it remained stable with a +2% in manufacturing activities; however, the employment in the latter category is expected to decrease in the next years (CLEPA). In fact, by 2030 the majority of job losses will be among the skilled workers, while roles with higher education profile will be required also during and after the transition (CLEPA).

It is possible to distinguish among four kinds of educational profile of automotive workers:

- Supporting
- Skilled worker (2 years of vocational training)
- Specialist (advanced vocational training/bachelor's degree)
- Expert (4 years higher/ academic education and higher)

According to the BMWK Report (2019), it is true that there has been a trend towards a demand for higher qualified personnel; in fact, the proportion of employees in the German automotive industry with vocational training remained stable since 2012, while the number of employees with a university degree increased from 15% to 20% until 2019, while the proportion of unskilled work personnel by 15%. The constant development of technology therefore leads to a higher demand for highly qualified figures such as engineers, while at the same moment, it means that low-skilled workers are less required, also because of the automatization of the industry and of the production processes. This results in always more issues for low-skilled workers to find new jobs; by consequence the unemployment rate for these figures is six times higher than that of people with vocational training and at the same time they have a higher risk to become long-term unemployed than specialists or experts (BMWK, 2019, p.159). As confirmation of the above-mentioned points, CLEPA reports that "the move towards electrification will lead to a greater demand for engineers with software and digital skills" while at the same time "a decrease in jobs linked to the production of conventional powertrains", with the new drivetrains that require skills not yet available in the labour market.

In the image showed below, it is possible to observe what is the employment trend and the projections for some job figures that are at the moment involved in the car manufacturing processes. It can be seen how the roles that are expected to increase in terms of labour market demand and employment are the most highly qualified ones.

Job impact within production and technical development	Pessimistic assumption	Optimistic assumption
Operative production of vehicles and parts, supporting and executive tasks	-30%	-10%
Supply chain coordinator	-10%	0%
Production coordinators	-10%	0%
Machinery supervisor	-5%	0%
Project managers	-4%	0%
Production planner	-3%	0%
Developer	0%	5%
Electrotechnical worker	0%	10%
Software developer	5%	30%
Data analyst	250%	350%

Figure 4: Job Impact within production and technical development (CLEPA). Available at: Skills dimension - CLEPA – European Association of Automotive Suppliers, accessed on the 19th of June 2024.

The energy transition does have an impact also on the jobs related not to the production or projection of the cars; in fact, vehicles generate employment at more than 1 million dealerships, 360,000 fuel stations, 1 million workshops for maintenance and repair, and for the distribution and sale of spare parts (600,000) (CLEPA). Therefore, it is possible to sustain that roughly 3.2 million people are employed in automotive usage-related activities in Europe. The production of BEVs generates 20% less aftermarket parts with respect to fossil fuel cars and, by consequence, the 1.6 million jobs related to maintenance activities may face a loss of 50% because of the lower number of components that make an electric engine (CLEPA). As stated previously in the chapter, this will result in an increasing demand for electrotechnical and IT or software related maintenance and a decreasing necessity for mechanical operations since parts such as fuel injectors, spark plugs but also brake pads will be no longer used or used in a much less extent. A study of the German ministry of Economics of 2019 reported by the CLEPA "forecasts that employment with vehicle dealers and workshops to decrease between 20% to 24% by 2030 and between 39% and 48% by 2040 due to the electrification and the declining number of vehicles on the road due to new mobility concepts".

To confirm what has been previously stated it possible to affirm that also suppliers will be highly affected by the energetic transition, maybe even more than the automakers; According to Amelang (2021), the suppliers of vehicle parts are much more specialized in the technology that they deliver and have less ability to adapt to the new changes while employing more people than OEMs. Bosch did announce that the company will go through several thousands of jobs cuts due to the decreasing demand for diesel and petrol car (Amelang S, 2021). Also, Continental warned that the new regulations are being introduced too fast, not giving enough time to compensate for employment losses (Amelang S, 2021). CLEPA states that 1.7 million people are directly employed in the supply of automotive parts, and it does insist, together with Bosch, on the issue that to achieve carbon neutrality in the automotive sector, what the new policies should focus on is not the internal combustion engine, but instead the use of fossil fuels, calling for "technology openness" approach toward the problem. According to the VDA (German Association of the Automotive Industry), for example, the synthetic fuels would play a major role in the future (Amelang S); the synthetic fuels are produced thanks to renewable resources and are carbon neutral since to produce them the CO_2 is subtracted from the atmosphere and combined with the hydrogen, which has been separated from the oxygen through a process called electrolysis and through a second step the hydrogen is combined with CO_2 using a catalyst with high pressure (eFuel Alliance, 2022). However, some members of the VDA, such as VW and BMW, seem to have adopted a strategy of only BEVs vehicles (Amelang S).

The energetic transition brings with itself also some other changes regarding the mobility as it was during past decades; in fact, vehicles are always more connected and automated. Also, this aspect brings some impacts in the job's market of the automotive industry; a study carried out by Ecorys in October 2020, commissioned by the European Commission, forecasts four possible scenarios in a time period between 2020 and 2050. It is important to states that these scenarios are the based on the European Commission Reference Scenario, which is "a key analysis tool in the areas of energy, transport and climate actions" (Ecorys, p.55, 2020). Therefore, it is not a forecast but rather it works as a benchmark "against which new policy proposals can be assessed".

2.1 How different scenarios of connected and automated driving are expected to impact on the job market

Scenario 1: fast, private, unrestricted and partially distributed (Maximum uptake). In this case there is maximum penetration "due to a combination of fast technology development and null restriction to the circulation" of connected and automated driving (CAD) (Ecorys, p.24, 2020). It is assumed that in 15 years, so by 2035, the level of autonomous driving will go from a Level 2 to a Level 5. Under this scenario, there would be low cost of ownership for this kind of automated vehicles and a high level of acceptance with limited usage of shared services (Ecorys). It is assumed that since private mobility will continue to be affordable there will not be a high share of population using services like robo-taxi (driverless taxi transporting single passenger or a group of passengers with a common destination), ride sharing or robo-bus (driverless bus without limitations in size or scope), even though, because of the lower cost of labour and because of the low-cost technology of vehicles, these services will be cheaper than the current ones (Ecorys, 2020).

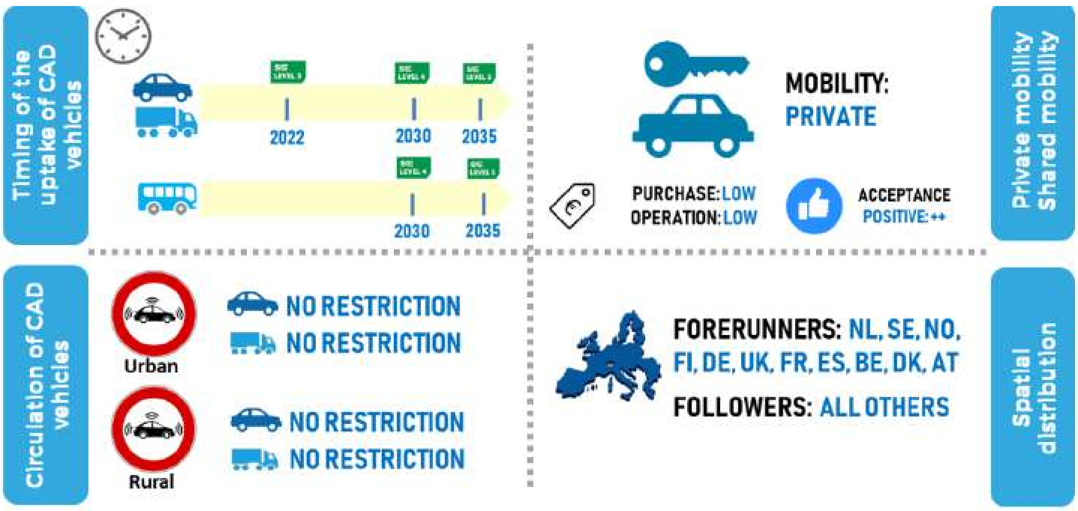

Figure 5: "key assumptions of Scenario 1" (Ecorys, p.25)

Scenario 2: fast, private, restricted and partially distributed (Intermediate uptake). This scenario wants to test what would be the results of the restrictions on the circulation of CAD vehicles. In this scenario, the circulation in urban areas is restricted to monitor “the evolution of mobility demand and preventing any unfavourable impact on travelled distances, trip frequencies and choice allocation on congestion” (Ecorys, p.25). Automated cars are not allowed to circulate in urban areas until 2040 and only after 2045 Level 5 automated vehicles are allowed to do it. Very similarly to Scenario 1, ride sharing services, as well as robo-taxi or robo-buses will be used by a small share of the population.

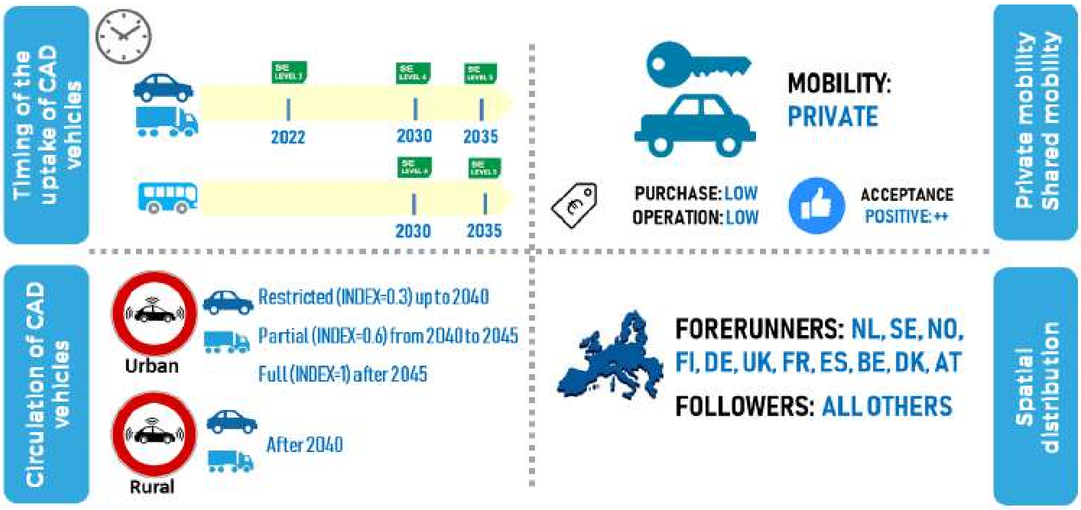

Figure 6: “key assumptions of Scenario 2” (Ecorys, p.26)

Scenario 3: moderate, shared, restricted and with limited distribution (Moderate uptake). In this Scenario the uptake of CAD, and therefore the transition from level 2 automated driving to level 5, will take 20 years and not 15 years like in the previous two Scenarios. The introduction of automated vehicles is slower in this case since it is assumed that the cost of this technology is higher and therefore not every type of customers would be able to buy a vehicle with the CAD technology. Instead, what is growing faster is the share mobility thanks to the new mobility services. At the same time, authorities impose a restriction on the circulation of CAD vehicles, and only after 2045 they can be driven in urban areas (Ecorys, p.27). Since the cost of automated and connected technology is high for private cars and since there would be restriction s on their circulation in urban areas, this means that there will be a higher usage of robo-taxi and robo-busses. Moreover, in this Scenario, forerunners countries are fewer than in the other two scenarios, meaning that many of the other EU countries will have to catch up and recover from the delay (5 years) “due to gaps in terms of investments and infrastructure and technology readiness (Ecorys, p.28)

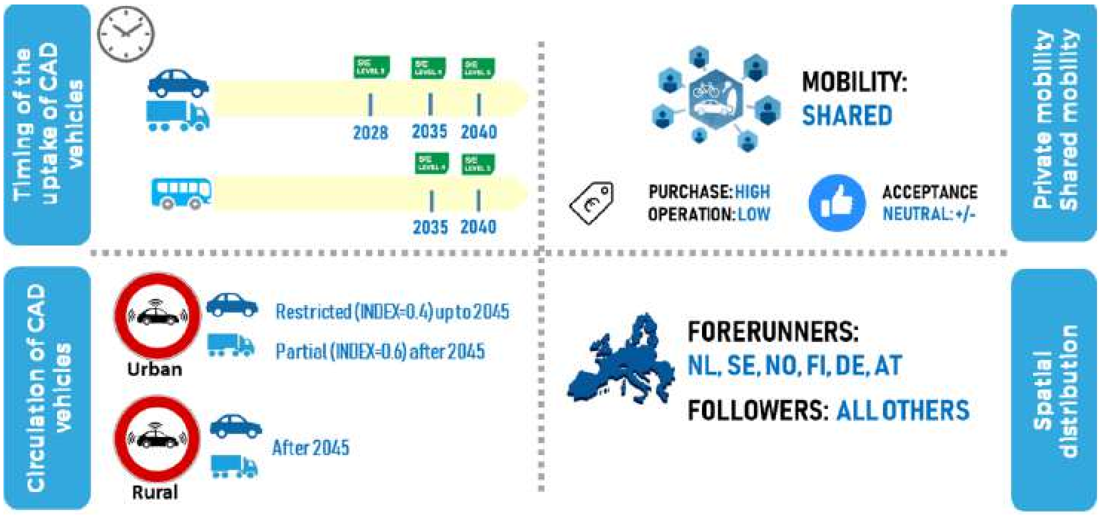

Figure 7: “key assumptions of Scenario 3” (Ecorys, p.28)

Scenario 4: slow, shared, restricted and with limited distribution (Low uptake). This scenario assumes that the transition to level 5 of vehicle automation will be reached in 2045, so 5 years later than in Scenario 3 and 10 later than in Scenario 1 and 2. There is a high cost of production and maintenance of connected and automated vehicles, therefore traditional ones will the ones preferred by the population (Ecorys, p.29). The low uptake of automated vehicles is also caused by restrictions on their circulation imposed by governments and national authorities. Similarly to Scenario 3, there is a reduction of labor costs due to driverless vehicles, which fosters the uptake of ride sharing mobility solutions, such as robo-bus and robo-taxi; ride sharing will be incentivised also thanks to the absence of restriction of circulation in both rural and urban areas (Ecorys, p.29).

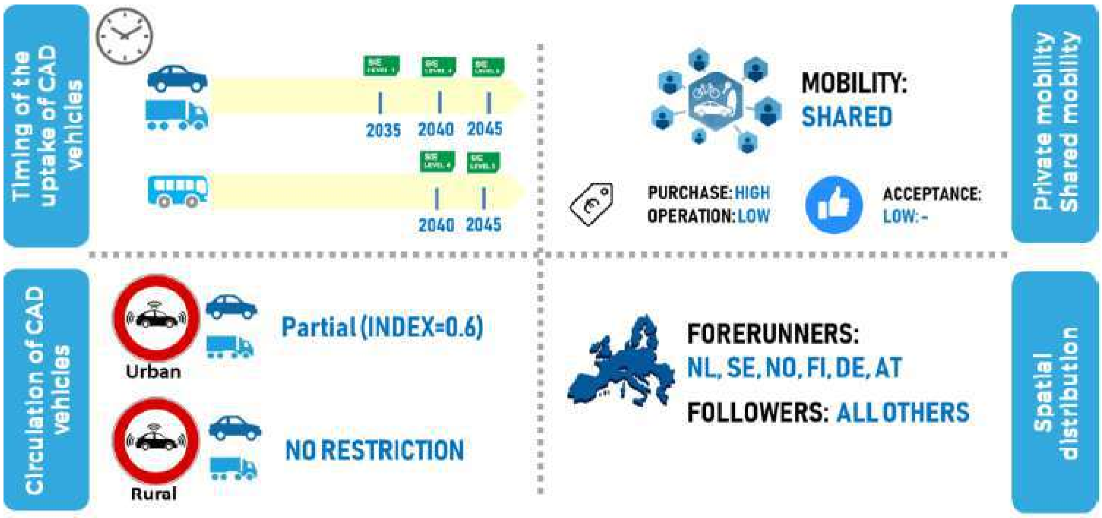

Figure 8: "key assumptions of Scenario 4" (Ecorys, p.29)

To distinguish and analyse these scenarios is important to understand what could be the possible developments of the job market in the automotive sector due also to the advent of these new technologies.

According to the results presented in the Ecorys report, it is expected that there will be "significant employment declines in transport services driver employment" (Ecorys, p.39, 2020). In any case, there are several areas directly or indirectly involved in the automotive industry that will go through changes in the coming years also because of the automated and connected driving systems:

In the passenger transport services, the introduction of automated driving makes the employment decrease "because of job losses in bus and taxi services" (Ecorys, p.39, 2020). In Scenario 3 there would be a loss of 12.5% while in Scenario 4 it would be of 7.4% with respect to 2020 levels. In Scenario 1 and 2, instead, automated driving takes place especially in private mobility, resulting in a lower job loss in bus and taxi employment, respectively 2.1% and 4.1% loss over 2020 levels (Ecorys, p.39).

Freight transport services face an initial growth in demand for employment due to an increase in transport demand; however, the introduction of automated driving means that these vehicles are cheaper since they do not need drivers. Employment levels decrease by 52% in Scenario 1 with respect to 2020 levels and by 58% in Scenario 2. However, following Scenario 4 assumptions, it is possible to cover the amount of job losses (Ecorys, p.39).

As expected, IT jobs are expected to grow significantly since, for example, “stewards will be on automated vehicles to provide customer service” (Ecorys, p.40).

Manufacturing is instead characterized by a constant decline in terms of employment while at the same time the sector will benefit from greater productivity, even though some of this employment decrease will be counterbalanced by the introduction of CAD-relevant sectors which will require further employment (Ecorys, p.40).

2.2 Studies supporting a positive impact of the energetic transition on the job market

There are also some other studies and researches which sustain a different thesis, that is that the energetic transition will not be an issue for the employment in the automotive sector and that enough new work places will be created to counterbalance the effect of job loss due to the energetic transition.

In “Shifting Gears in Auto Manufacturing” (Daniel Küpper, Kristian Kuhlmann, Kazutoshi Tominaga, Aakash Arora, and Jan Schlageter, 2020) Boston Consulting Group conducted a study regarding the effect of how the shift in the automotive value chain will affect the employment in the sector. The thesis states that the BEV manufacturing is not less labor intensive than ICEV manufacturing. For example, even though BEVs do not require the assembly of a fuel piping or an exhaust system, they “require manufacturing of high voltage wiring converters and inverters, installing, motor-charging units and connecting battery-cooling tubes” (Küpper, et al., 2020, p.6). Moreover, some BEVs have an additional front trunk, involving more steps in the assembly line and in general the BEV manufacturing process requires greater attention in quality control.

BEVs do have fewer components than the ICEVs, however, component manufacturing of BEV engines involves very high labour-intensive processes; for example, making wiring harnesses alone takes about 10 hours of manual work against three to assemble an engine (Küpper, et al., 2020, p.9). Again, "cell manufacturing alone adds about 8 percentage points in vehicle hours per BEV, relative to the ICE baseline today" (Küpper, et al., 2020, p.10).

The Boston Consulting Group report assumes that two main possible scenarios may realize in the coming years, depending on how the OEMs will manage the production process of the BEV powertrains and all the electric components: if OEMs will opt for the outsourcing of all the electronic components, then they will have to face a reduction in labor hours per vehicle of 7%. Instead, if OEMs will produce all powertrain and power electronics components in-house, then they will have an increase in labor hours equal to 7% with respect to the employment levels assumed in the BCG study (Küpper, et al., 2020, p.11). At the moment, the trend is the one of the first scenario, with most of the auto manufacturers deciding to outsource battery cells and power electronics (Küpper, et al.).

It is worth to underline how, even in this last research document of the Boston Consulting Group, what comes out in its conclusion is that "the labor needs of manufacturers will shrink over the long term, as the industry moves toward pure electrification" (Küpper, et al.). In this study is declared and supported the thesis according to which electric vehicles are as labour-intensive as the internal combustion engine vehicles; however, in the same document (Küpper, et al.) it is stated that the transition towards electric vehicles will have as a consequence the "shift of much of the value of BEVs to large Asian players already dominant in the area of battery cell manufacturing" (Küpper, et al., p.12). This means that automakers will have to take several considerations regarding the management of their workforces; that is, they will have to understand which employees can be requalified […], internally transferred or let go" (Küpper, et al., p.12). Training of current employees would be a fundamental asset that automakers should deploy in order to keep in their companies as many employees as possible.

These statements play an important role in the general understanding of the future of the automotive employment in Europe since, starting from a thesis where it was stated that electric vehicles are not less labour-intensive than their ICE counterparts, it ends up to say that the real impact of the green transition on the job market is very far from clear. In fact, even if the transition to full electric vehicles is not less labour-intensive than internal combustion engine vehicles, there is a problem regarding where the new jobs will be reallocated. In fact, as has been stated previously, the trend is that many steps of the supply chain and of the manufacturing of vehicles parts will be shifted in Asia, leaving several European employees with few alternatives. Some of them may also go through a process of "training on the job" or other programs able to make them competitive again in the job market, but many of the new jobs that are necessary more and more nowadays require academic skills and a background that are not socially or economically affordable for everyone, leading to an unemployment issue that governments will have to manage. At the same time, as reported previously in the document, the general trend towards connected and digitalized driving but also the digitalization in all the supply chain steps and in the production processes, will lead to the entire European automotive industry to need less employees than in the current situation.

For what regards the re-skilling of the workforce, there are some examples of automakers trying to follow this path. Major OEMs have started to establish relationships with schools and universities especially in centre and eastern Europe to be sure to prepare their future workers with the necessary skills, such as Skoda in Czechia, VW is Slovakia or Audi in Hungary, however the main driver for this type of actions is to assure competitiveness to the companies and not ensuring a jus transition (John Szabo´ and Peter Newell, Driving towards a just transition? The case of the European car industry, 2024). Moreover, not every company in the automotive value chain has the necessary resources to invest in re-skilling workers; in fact, first should be made a clear distinction between large and small companies, with the formers able put resources in re-skilling workers while the same cannot be said for the others (John Szabo´ and Peter Newell, 2024). In any case, always according the analysis carried out by Szabo´ and Newell, re-skilling cannot compensate the number of job losses caused by the energetic transition and they make also a distinction between core countries, like Germany, and semi-periphery countries, like Poland, with the firsts able to capture "most of the value added processes with the state being able to channel support into research and innovation, while automation allows the core to capture some formerly labor intensive activities". Of course, this would be a problem for countries with less economic resources, that is for the east European ones, since they have to deal with a shortage of labor demand and at the same time they have to invest resources to re-skill workers. Some of the semi-periphery countries have started some strategies to counteract this effect, by for example establishing a battery industry; this action may offset some of the negative employment effects caused by the energetic transition, but the issue is that these countries compete against each other to attract workforce and investments, "nullifying the ambition of a just transition that would allow all EU members to prosper" (John Szabo´ and Peter Newell, 2024, p.8).

However, there are also other studies a part from the Boston Consulting Group one which sustain the fact that the introduction of battery electric vehicles will bring many job opportunities, even more than the ones offered by internal combustion engine cars. Pek, Concas, Skogberg, Mathieu and Breiteig (2018) affirm that "by 2030 a total of nearly 200.000 permanent jobs would be created" (p.3) thanks to the transition towards electrification, assuming an uptake of plug-in vehicles equal to 35% of new passenger car sales in 2030. Pek et al. recall also the research carried out by the Fraunhofer Institute commissioned by major automakers in Germany; in this research it is stated that out of 210,000 jobs 75.000 will be lost in the automotive Germany industry from 2017 to 2030. However, this statement was answered by saying that "only 27% of these job losses can be attributed to the rise of electromobility, with the remaining losses being a consequence of productivity gains" (The European Association of Electrical Contractors, 2018*,* p.6). Again, the Fraunhofer study assumes that 40% of the new passenger car sales in 2030 will be electric, but this is higher than the forecasts of the European Commission projections and that battery manufacturing will take place outside of Europe, even though many "carmakers are likely to source cells close to manufacturing sites for electric cars" (p.6).

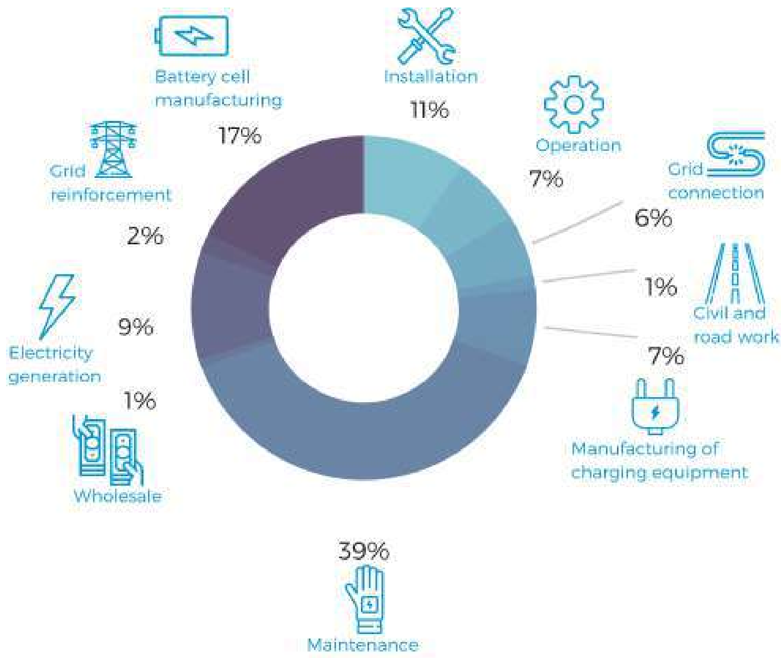

Figure 9: "A breakdown of the 200,000 jobs created thanks to electric transportation", (The European Association of Electrical Contractors, 2018).

In the above-mentioned graph, is possible to see how the new jobs created will be distributed among the several sectors in the value chain by 2030. Below is possible to understand in more depth which kind of sectors will bring most of the new jobs by 2030:

- Maintenance: the reference is the maintenance of the chargers which is considered to be "the most job intensive segment on the electromobility value chain" (Pek et al., p.10). 77,000 new jobs will be created, accounting for the 39% of all new jobs by 2030.
- Battery cell manufacturing: 34,800 new jobs, that is 17% of total new jobs due to electrification will be created in this sector also thanks to the installation of gigafactories in Europe.
- Installation: installation of electric vehicles charges. It could create 21,400 new jobs, accounting for the 11% of new jobs by 2030.
- Electricity generation: it involves the production of additional electricity due to the consumption of electric cars and it may involve 18,700 new jobs, accounting for 9% of total new jobs by 2030.

- Operation of the charging points: it includes metering, billing, and smart charging in order to cover the interactions of the chargers with the users and the grid", generating 14,000 new jobs and accounting for the 7% of all new jobs.
- Manufacturing of the charging equipment: this sector, as the previous one, may also account for the 7% of new jobs, creating more than 14,000 workplaces.
- Grid connection: it is the process of connecting an EV charger to the grid to power electric vehicles. It may create 11,500 new jobs for 6% of total new jobs in 2030.
- Grid reinforcement: it includes grid upgrades and extensions necessary since more EVs are consuming further electricity from the grid; this sector is expected to create around 4,000 new jobs.
- Civil and road work: "it covers the ground works necessary for the subsequent installation and connection of EV chargers" and it would account for 1% of new jobs created, that is 2,400 new workplaces.
- Wholesales: this segment involves the steps needed to bring the electrical material from manufacturers to final customers and it would account for 1,600 new jobs by 2030.

As can be seen by reading all the previously reported queries and researches, is not that clear what is going to be the future of employment in the automotive sector in Europe. In cases like this one is very important to understand the source of the information not because there is the risk of that those resources are unreliable, but because in many cases these researches and studies are commissioned by unobjective parties, which try to shed light on the points that are more convenient for their sector and, more in particular, for their business. Therefore, is important to be aware of this aspect and to read what is the reported in the documents with a critical eye.

An instrument to have a good perspective on what are the current results of the energy transition is to analyse what is happening in the European automotive sectors in terms of employment. It is curious to see how Volkswagen, one of the major supporters towards electric transition of the automotive, is having several issues in terms of market competitiveness and employment due to electric cars. In fact, one of the main reasons of the raise of these new environmental policies it is because of the famous “diesel-gate” case in 2015, which involved the car manufacturer due to manipulation of emissions data of its four-cylinder engines (Aichner, Coletti, Jacob and Wilken, 2020). In order to improve its brand image VW pushed a lot towards electrification, but now is having competitiveness issues since how was stated by the CEO of VW brand cars, Thomas Shafer, Volkswagen is struggling to be competitive in the sales of electric vehicles against leaders of the EVs segment, such as Tesla and the Chinese BYD (Johnson, 2023). VW already introduced a cost-cutting programme in June 2023, with the aim to save 10 billion euros by 2026, involving major layoffs from the companies, even though, at least in Europe where labor unions are present, options as partial or early retirement are offered (Johnson, 2023). Stellantis too is another major OEM affected by low electric vehicles demand problems that in the end result in layoffs; as reported by Automotive News Europe (2024), “Stellantis plans 2,250 temporary layoffs at Italian Mirafiori Plant”, affecting workers building the electric Fiat 500 and the Maserati Models.

To conclude what has been analysed in this chapter, it is possible to say that there is no a clear direction where the energy transition in the automotive sector is going to; it is hard to say whether electric vehicles will create more job opportunities than what are currently available. Can the energetic transition be considered sustainable not only environmentally but also socially? To have a clear view of the matter one should not focus only on the employment effects of electric vehicles, as was shown in this chapter, but also on the entire value chain starting from how and where the raw materials necessary for example to produce batteries are obtained. There are, in fact, many concerns regarding child labor and slavery working conditions in African countries such as Congo generally approved or not considered as relevant matters also by European institutions (Sovacool, 2021), or again waste disposal processes that heavily pollute the environment close to the mining areas, bringing several healthy issues to the people living nearby those places (Mrozik, Ali Rajaeifar, Heidrich and Christensen, 2021). However, these issues are out from the scope of the research of this document, which in this chapter analyses the social sustainability of the European Green Deal only under an employment perspective and only at a European level, even though its effects are much broader.

In the next chapter will be analysed the effects of the Green Deal on the European automotive industry, how the supply chain is going to be affected, what kind of opportunities and challenges traditional OEMs have to face due to these changes and how their competitiveness on the market is affected be the introduction of this new technology which brings with itself new car manufacturers from Asian countries.

Chapter 3: How the EU Green Deal affects the global value chain of the European automotive industry

The introduction of these new technologies, such as the electric mobility, but also, as reported in the previous chapter, connectivity and autonomous driving, have increased the importance of software, data and electronics (Brown et al., 2021). At the same time, a consequence of this transition has been the lowering of the barriers to entry in the market, increasing the competition in the automotive market. In fact, are especially US and Chinese companies who have significant financial resources to invest in these technologies, at the expenses of European ones (Brown et al., 2021).

The change in the value chain of the automotive industry does not affect the automakers only, but there is a list of several shareholders, as reported by HRSS CPAs, such as suppliers, dealerships, technology providers, R&D institutions, governments and regulatory bodies, financial institutions, consumers, energy providers, environmental and sustainability institutions.

In "The Future of Automotive Value Chain: 2025 and beyond", a study conducted by Deloitte in 2017, four potential scenarios of the automotive value chain have been depicted by looking at several possible drivers, that can have both a direct and an indirect impact on the global value chain; these drivers are then grouped into the areas of social change, technology advancement, economic shifts, environmental trends and political developments (Deloitte, 2017). These drivers were also analysed according to their degree of certainty or uncertainty and their impact on the car manufacturers value chain. Is it possible to see a summary of these elements in the figure reported below:

Figure 10: clusters of identified drivers, (Deloitte, "The Future of the Automotive Value Chain: 2025 and beyond", 2017, p.15)

Scenario 1: in this scenario, electromobility, autonomous driving, connected services and charging infrastructure have completely taken over the market. But how does the value chain structure changes? OEMs put massive R&D effort to develop battery technology, while at the same time they sign several strategic alliances with IT companies specialized in the field of autonomous driving, connected services and big data analytics. The relationship with suppliers is changing, since there is a horizontal extension of them, because car companies are looking for different services which are more linked to connectivity, softwares and analytics applications. Also, car companies have to deal with suppliers in a much more dynamic environment, as agility in R&D and decision-making periods are faster than previously (Deloitte, 2017, p.27).

Scenario 2: traditional manufacturers are able to still be competitive against new entrants from IT companies. That is, there is not a big change in the automotive value chain, most of the R&D is to develop efficient internal combustion engines, new materials and "product innovation such as driver assistance systems to preserve unique features" (Deloitte, 2017, p.30). Powertrain production is more complex since there are both traditional engines but also alternative ones. The car manufacturers have still a strong bargaining power against their suppliers since there are not big changes in terms of new technologies and players in the market.

Scenario 3: in this situation, the general interest towards the automotive sectors has declined, however, autonomous driving has become a reality which brings new entrants in the sector which have been able to master the integration of informatics and mechanical engineering. As result, the traditional car manufacturers suffer also because of the loss of brand attractiveness and brand value (Deloitte, 2017, p.32). The R&D is characterized mainly by cost reduction in production, while robotization in manufacturing processes is maximized. The bargaining power of suppliers is increased after new partnerships between these suppliers and the new mobility services providers, meaning that car manufacturers may face an increase of 14% in procurement costs. Car companies have to insource and create alliances with other OEMs (Deloitte, 2017, p.34)

Scenario 4: "cars have become software-based high-tech products with standardized interfaces comparable to today's smartphones" (Deloitte, p.35). IT companies now play a crucial role in the market since they "have captured the mobility and data management service business" (Deloitte, p.35). In this situation, R&D is aimed mainly at developing system interfaces to remain the dominant platform. In general, it has become more complex, with car companies pushing for hardware improvements, while new players from IT companies aim at software developments. At the same time, bargaining power of car companies against suppliers has decreased, therefore they have to invest in relationships with software and analytics providers (Deloitte, p.37).

As has been stated in the previous paragraphs, the automotive industry is facing big changes in the value chain due to the introduction of digitalization, connected driving and electromobility. The electromobility has some serious implications for what regard the raw materials necessary to produce battery packages, which are the powertrain of BEV cars. In particular, the production of these lithium-ion batteries involves many materials such as Nickel, Cobalt, Aluminium, Magnesium, Copper, Silicon, Magnesium and others (Rajaeifar, Ghadimi, Raugei, Wu and Heidrich, 2022). As affirmed by Rajaeifar et al. (cited in Olivetti et al., 2017), an issue that regards the supply chain of these materials is caused by the absence of a clear projection of the demand for BEVs, leading to uncertainty in the supply estimation of battery materials. Moreover, since the industry is dealing with a new and very complex technology "the technological skills, innovation, and knowledge available to suppliers of this component can afford them significant status within the framework of vehicle production chains" (Ramos and Ruiz-Galvez, 2024, p.2). Currently, the production of batteries for electric cars is concentrated in Asia, as affirmed by Ramos and Ruiz-Galvez (cited in Gerocs & Pinkasz, 2019); in fact, companies such as BYD, AESC, Envision, Panasonic and Samsung SDI, are the ones who hold most of the market share in the supply of electric batteries worldwide (Ramos and Ruiz-Galvez, 2024). Several sustainable mobility supply firms develop technologies that require a high level of know-how, which traditional OEMs do not have, and some of these technologies are developed in industries outside the automotive one, such as energy management or recycling of materials, making it difficult for traditional car manufacturers to participate or to influence in some way the new technologies brought to the market (Ramos and Ruiz-Galvez, 2024, cited in Sturgeon et al., 2008).

What has been highly affected by the energetic transition is the cooperation that has always characterized the industry with the traditional players. Ramos and Ruiz-Galvez conducted a study on the relationship between sustainable mobility suppliers and traditional OEMs taking into account the Spanish automotive industry. The results show that the decision power of sustainable mobility firms with respect to traditional ones is increased within the global value chain of the automotive industry. In particular, what changes most significantly within the new value chain, is the price. This means that "sustainable mobility suppliers have greater power to set the price of the supplied product or technologies than traditional component suppliers" (Ramos and Ruiz-

Galvez, 2024, p.5), making the authors think that there is no exchange of information about the component cost structure. Moreover, traditional OEMs, therefore, have no negotiation power in setting the prices. Another factor that changes significantly with the arrival of these new sustainable mobility suppliers is the product design; in fact, "the sustainable mobility suppliers have not resulted from the vertical disintegration of the OEMs" and automakers have no knowledge of these new technologies, making them unable to influence the product design (Ramos and Ruiz-Galvez, 2024, p.5). Location is another element that changed a lot with these new suppliers able to decide where do produce based on technology factors, so that they no longer have to link their location based on where the buyers are, as was happening with traditional suppliers (cited in Turienzo and Lampon, 2022). In fact, traditionally the production processes in the automotive industry have always been quite fragmented under a geographic perspective, with car manufacturer companies outsourcing these processes to the suppliers, as affirmed by Turienzo and Lampon (cited in Ponte et al., 2019). The relocation processes that have characterized the automotive value chain until recent years was fostered by the "operational flexibility for internationally transferring the resources of the multinationals that dominate the sector" (Turienzo and Lampon, 2022, p.5446). However, the increase in production costs and the implementation of new technologies associated to the electric mobility led to an increase in the relevance of products and activities not related to the traditional ones (cited in Pütz et al., 2019). Therefore, there is an increase in the weight of innovation and development in the value creation processes; in fact, "some automotive companies are focusing their innovation activity on emergent technologies such as connectivity, automation and electrification of vehicles, to the detriment of traditional product or production process innovation" (Turienzo and Lampon, 2022, p. 5447). All these factors deeply influence the location of production and innovation activities, with car companies who locate their facilities in developed countries to minimize intellectual property violations (cited in Gray et al., 2017); moreover, as affirmed by Turienzo and Lampon, the production processes for automotive companies is moving from off-shoring to reshoring, which is affected not only by economic factors but also by relationships between social capital, trust, commitment, social or political issues (cited in Tajpour et al., 2021). All these new elements above mentioned, are therefore gaining relevance in the production process and in the value chain of the automotive industry with respect to the labor cost. In fact, Tier-1 suppliers have changed the way they decide where to establish their facilities and production areas: usually they were located close the OEMs but the increasing importance of keeping costs low made the suppliers switch towards areas where the labor cost is quite low, since the OEMs to be competitive need to optimize costs (Turienzo and Lampon, 2022). After the introduction of electromobility, Tier-1 suppliers have "detected a niche of activity linked to the research and development (R&D) of electronic and software associated to new mobility" (Turienzo and Lampon, 2022, p.5449). Legislation is an important element that suppliers have to take into account to decide about the location of their R&D sites and to protect their innovations; however, legislation is not the only thing that they look for to protect their improvements and products, but they also try to avoid vertical disintegration to avoid or decrease as much as possible the risk to lose their knowledge (Turienzo and Lampon, 2022). Tier-1 suppliers have become aware of the necessity of high skilled personnel, and so they have located their development centres close to universities. "Tier-1 suppliers fund research with the universities through the creation of specific chairs or through research contracts with leading research groups. Moreover, they participate in master's degrees and courses by providing their researchers as lecturers and by recruiting students through scholarship programs or internship contracts in these companies" (Turienzo and Lampon, 2022, p.5449). It can be stated therefore, that suppliers and new mobility companies have acquired significant decision-making power in location and relocation processes (Turienzo and Lampon, 2022).

At the same time, there is a decrease in the dependence of component suppliers on buyers with respect to traditional suppliers, since the firsts operate also in industries outside the automotive one, and they provide technologies that are quite recent, meaning that there is not a high availability of suppliers offering those products to the car manufacturers (Ramos and Ruiz-Galvez, 2024). Finally, they found also that the performance of sustainable component suppliers is higher than the one of traditional suppliers because they are positioned on a higher supply level, being practically a Tier-1 supplier (Ramos and Ruiz-Galvez, 2024).

Below is possible to observe the data of the beforementioned information:

Descriptive statistics of variables.

Variable	Type of firm	Mean	Min.	Max.	S.D.
Decision power	Traditional components firms	1.78	1.0	2.6	0.335
	Sustainable mobility firms	2.38	1.5	3.0	0.279
Price	Traditional components firms	1.68	1.0	1.0	0.574
	Sustainable mobility firms	2.44	2.0	3.0	0.506
Quality conditions	Traditional components firms	1.55	1.0	3.0	0.671
	Sustainable mobility firms	1.85	1.0	3.0	0.534
Product design	Traditional components firms	1.55	1.0	3.0	0.624
	Sustainable mobility firms	2.59	2.0	3.0	0.501
Process specifications	Traditional components firms	2.44	1.0	3.0	0.647
	Sustainable mobility firms	2.52	1.0	3.0	0.643
Location	Traditional components firms	1.69	1.0	3.0	0.788
	Sustainable mobility firms	2.48	1.0	3.0	0.643
Dependence	Traditional components firms	62.18	8.00	100.00	27.928
	Sustainable mobility firms	23.56	5.00	85.00	20.476
Performance	Traditional components firms	36.33	9.96	71.10	11.245
	Sustainable mobility firms	60.74	13.99	95.92	23.073
Supply level	Traditional components firms	2.2	1	4	0.99
	Sustainable mobility firms	1.3	1	3	0.55

Table 1: *Descriptive statistics of variables* (Ramos and Ruiz-Galvez, 2024, p.6)

The transition towards electrification has increased the peace of modularization of production in the automotive industry, leading to standardization and homologation of the final product. This increases the competition among "assembly plants for the awarding of new models by a group's parent company, as the plants now operate with relatively flexible production infrastructure in terms of product variety" (Ramos and Ruiz-Galvez, 2024, p.9). Again, the electric transition creates some issues to the traditional suppliers who deal with manufacturing of parts related to combustion vehicles, while at the same time it fosters the entry of new actors which provide battery related components. The automotive value chain has been characterized for many years by high market and product maturity, fragmentation and overcapacity (Schwabe, 2020). In this kind of environment, OEMs are able to increase their competitiveness more thanks to cost reduction than through entering in new markets or investing into new technologies. As Schwabe affirms, "OEMs designed more and more sophisticated and technically complex automobiles over time (demanding an increasingly complex network of suppliers and logistics) the automobile as a product fundamentally remained the same for over a century" (Schwabe, 2020, p.3); the automotive sector has been characterized mainly by incremental improvements opposed to disruptive innovation. Therefore, the automobile sector has always been featured with established relationships among car manufacturers and suppliers, with little space for new entrants. Traditionally, car manufacturers have always exercised a high degree of control over their suppliers, through sheer volume and purchasing power. Schwabe sustains that the type of relationship that has always characterized the OEMs and suppliers one, can be classified as "captive" (cited in Gereffi et al., 2005); "In these networks, small suppliers are transactionally dependent on much larger buyers. Suppliers face significant switching costs [to other buyers or sectors] and are, therefore, 'captive'" (cited in Gereffi et al., 2005). The buyers, in this case the OEMs, have a high decision power on the products provided by the suppliers, therefore is very difficult for them to improve their position in the value chain.

However, as stated previously in the chapter, the energetic transition is bringing some changes under this aspect among the others; in fact, BEVs will make the majority of the automotive value chain redundant. For example, all the parts necessary for an internal combustion engine will no longer be necessary, as well as the drivetrain and the exhaust. This is a huge risk that suppliers will have to face since they may have high switching costs to other products or market segments (Schwabe, 2020).

3.1 How the energetic transition is impacting on companies according to their nature

Schwabe conducted a series of interviews to German automotive suppliers, five companies delivering single components (C1 to C5) and two providing integrated systems (S1 and S2), in order to understand how they are affected by the energy transition; it is important to underline that all these companies are exclusively suppliers operating in the automotive sector, with the exception of C3 which is involved also in the aircraft sector and that "four out of the seven interviewed companies are part of a larger corporate group (C1, C5, S1 and S2). Two of the interviewed companies were located in Germany, but part of a foreign owned structure (S2 and C5)" (Schwabe, 2020, p.160).

In the table below is possible to have a summarised view of the participants to the interview, their product portfolio, their clients, the revenues share affected by the introduction of electromobility and the intensity of competition that they face in the current market:

ID*	Size (employees)	Product portfolio	Clients	Revenue share affected by electromobility	Intensity of competition in current market**
C1	500–1000	Iron cast product with and without coating	Automotive OEMs	0% (if product is adapted)	High and low, depending on product configuration
C2	> 1000–10.000	Iron cast products	Automotive OEMs	100%	Low
C3	> 1000–10.000	Aluminium and other non-ferrous products	Automotive OEMs and other industrial sectors	5–10%	Medium and low, depending on product
C4	500–1000	Steel components for drivetrain and engine	Automotive OEMs, system suppliers	98%	High
C5	> 1000–10.00	Steel components for drivetrain, engine and axis	Automotive OEMs, system suppliers, company internal	52%	High
S1	> 10.000	Auto parts and -systems for engine, ventilation, drivetrain	Automotive OEMs	Not quantifyable, estimated medium risk	Medium
S2	> 10.000	Auto parts and -systems for tubing and cooling	Automotive OEMs	Not quantifyable, estimated medium risk	Medium

* ID of the interviewed company (C = component supplier, S = system supplier).

** High: large number of competitors globally, intense cost pressure; medium: limited number of competitors, product innovation relevant; low: few to no competitors worldwide, unique selling point.

Table 2: *List of interviewed automotive suppliers* (Schwabe, 2020, p.161)

C2 and C4 company expressed high concerns regarding the advent of electromobility since they deliver components strictly related to the internal combustion engines. That is the reason why these two companies are highly investing in new strategies to make them more dependent for the traditional technologies supplied; in any case, C2 company, expects that only a part of the current revenues can be replaced by new markets. C5 company, instead expressed a more neutral judice regarding electromobility, since it is less dependent on internal combustion engines or drivetrain than the previous two companies, however it manifested the desire to build up the capacity for electric vehicle components (Schwabe, 2020).

However, four of the interviewed companies said that they had a positive opinion about the electromobility for their business. These companies are the component suppliers C1 and C3 and both the system suppliers S1 and S2; the system suppliers do not have a business strictly dependent on traditional vehicles even though they require huge investments to develop systems for electric vehicles, while the component suppliers in this case are able to adapt their product to suit electric vehicle necessities (Schwabe, 2020).

Among the interviewed supplier companies, there was a general consensus about the future production levels of forging and foundry industries, which is expected to decrease in the long-term, with one company expecting that 50% of the current (2020) level of production of German foundry sector will be affected by the advent of electromobility. In the short-term, however, the production demand for iron cast products "is expected to increase due to higher mid-term demand in hybrid vehicles" (Schuman, 2020, cited in Schlegel und Partner GmbH and IMU, 2018, 31), while in the long term there will be a steep decline in demand for engine parts.

One can understand from these interviews and from the opinion of the supply companies, that the impact of the electromobility will depend a lot on the degree of product specialization of these companies, whether they are strictly linked first of all to one sector only, and if they are able to develop their products to adapt them to electric vehicles necessities.

ID	Strategy	Measures	Risk	Risk mitigation measure	Advantage
C1	Product upgrade	• Invest over 10 million EUR in R&D and production capacity for product upgrade that can be used for electric vehicles (and also high-end vehicles with combustion engine)			• Low dependency on combustion engine parts • Part of larger company group • Upgraded product technically advanced, facing low competition
C2	Product- and market diversification	• Establish new marketing team to acquire delivery contracts outside of automotive (such as agricultural, construction and special purpose machinery) • Adapt planning and administrative processes for lower volumes and higher flexibility	• Other sectors already highly competitive • Expected market decline for established product • Difficulty to obtain bank loans	• Engage external consultant to develop perspective on three potential target markets and internal restructuring • Increasingly flexible work contracts (e.g. with time limitation) • Increasingly finance new investments from internal cash flow	• No investments in new or adapted production capacity needed • Currently good market situation
C3	New product offering	• Establish an innovation-team that is tasked with making reliable market forecasts and developing product strategies • Co-developing customized battery boxes with clients • Investing in new production facilities for customized battery boxes (ca. 100 million EUR)	• Highly uncertain market forecast for customized battery boxes	• Client will potentially cover part of the necessary investment	• Low dependency on combustion engine parts • New product potentially highly competitive
C4	Product- and market diversification	• Explore possibilities of producing components for electric vehicles with existing capacities • Explore possibilities to deliver products from the current portfolio to other sectors (such as agricultural and construction machinery, railway, aeroplanes) • Explore possibilities to deliver vehicle parts that do not depend on the engine type	• Market potential for electric vehicle parts uncertain • Other sectors for existing portfolio relatively small • Markets for other auto parts highly competitive	• Engage external consultant to facilitate innovation workshops and provide the foundation for future investment decisions	• Currently good market situation
C5	New product offering	• Small scale investment in the adaption of production capacities for electric vehicle component	• Uncertain market demand	• Small scale production capacity for electric vehicle component that may be gradually expanded	• Medium dependency on combustion engine parts • Part of larger company group • Currently good market situation
S1	New product offering	• Invest significant resources in R&D for new product (system for electric engine and battery management)	• Market uptake for electric vehicle systems uncertain	• Dedicate internal team that is exclusively tasked with exploring electric vehicle market developments	• Diverse product portfolio and sufficient resources to manage market transition • Products for conventional vehicles will be needed for the foreseeable future
S2	New product offering	• Establish new division for electric mobility (including R&D, quality control and sales) to develop systems that are customized for electric vehicles	• Market uptake for electric vehicle systems uncertain	• In some cases the client covers cost for prototypes	• Existing product adaptable for electric vehicles

Table 3: *Strategic measures of interviewed automotive suppliers* (Schwabe, 2020, p.163)

In the table presented above is possible to understand what are the strategic measures and risk reduction activities that the supply companies previously mentioned are currently or are planning to undertake.

Companies C2 and C4 highly depend on the market for combustion engines and they expect to:

- Deliver their products also to other markets, even though they may be highly competitive and the companies may face a decline in production volumes.
- Deliver products to the automotive market that is not linked to the internal combustion engines, potentially facing high competition depending on the product that they produce.
- Deliver new products for electric vehicles; also in this case there is huge competition to deal with.

Companies C1, C3 and C5 do not follow an explicit strategy for the electromobility since the new technology does not represent a risk for their business, but instead, they view it as an opportunity to improve their competitive position in the automotive sector. S1 and S2 companies too faces a very low risk in the short-term; the reason is that they deliver products which are not closely tied to client demand and design requirements (Schwabe, 2020).

As can be seen thanks to the information reported, there is not a distinctive and common strategy that company follows in order to cope with the new requirements due to the introduction of electric mobility; however, there are some aspects that are common for everyone (Schwabe, 2020):

- All the strategic approaches are aimed at expanding company's internal capacities, which involves investments in production machinery, product related R&D and the formation of entirely new departments for market analysis and marketing.
- The interviewed companies, with the exception of C2 and C4 companies, expect to add some components or system solutions dedicated to electric mobility maintaining the current automotive production network. "These

companies are likely to face only minor disruptions (for example in the form of temporarily higher investment burdens) or even profit from the transition towards electric vehicles (Schwabe, 2020, p.163).

- Members of steel production and forging industry have started since 2013 an initiative where they present their own product upgrades, especially weight reduction, to OEMs clients in regular workshops; this is done in order to improve their bargaining position towards the OEMs, however, this strategy may work only "if the added value of component weight reductions offsets the reduced degree of cost-control which would result from the increased competitive position of the product supplier" (Schwabe, 2020, p.163).

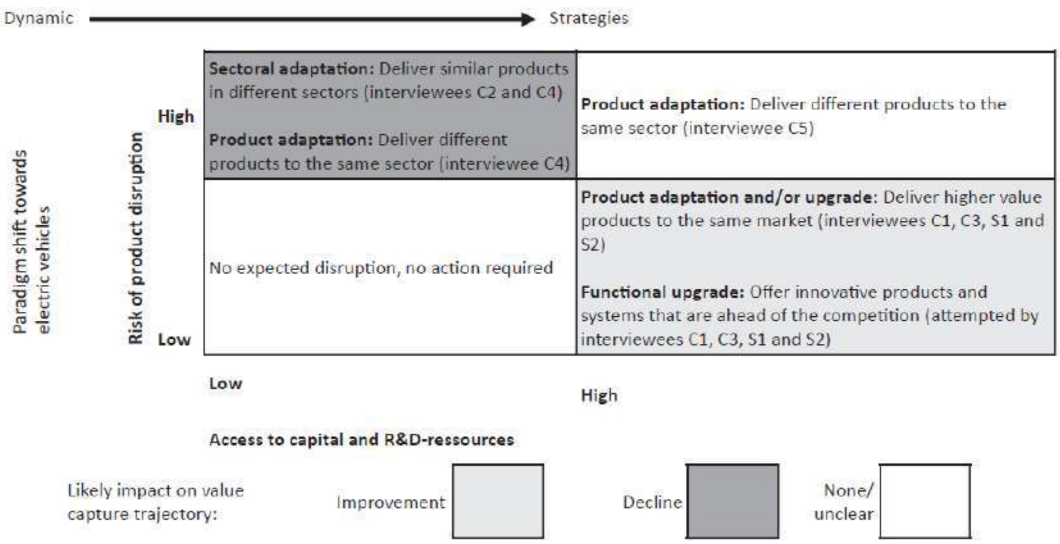

Table 4: *Viable strategic options based on degree of product risk and access to resources* (Schwabe, 2020, p.165)

In the table presented above it is possible to observe what are the possibilities of improvement or decline of company's value capture trajectory based on the risk of product disruption and the access to capital and R&D-resources. Schwabe affirms that according to Pavlinek and Ženka, value capture involves several elements such as reinvested profit for the benefit of the company or a subsidiary, the accumulation of expertise or technical innovation. Profitability is a way to measure value capture, but other indicator may be more appropriate on a firm level, such as capital investments in R&D or in product upgrades and employee wages (Schwabe, 2020).

3.2 The role of Chips and Semiconductors

A fundamental player which gained massive importance and relevance with the introduction of the electromobility are the chips and semiconductors. The semiconductors are included in the engine control, cruise control, power seats and windows, airbags, automatic braking systems, and entertainment systems (Ramani, Ghosh and Sodhi, 2022). That is, the increase in digitalization and electrification of vehicles led to an increase in the needs for semiconductors, however, it can be shown how, this fundamental component in the automotive value chain, is in the hands of very few suppliers. The industry of semiconductors is highly capital intensive (Ramani, Ghosh and Sodhi, 2022), with very high investments needed, therefore it presents high-cost barriers, but also "extensive human capital and learning by doing" (Ramani, Ghosh and Sodhi, 2022). A very important aspect about the semiconductor industry is how the information sharing among the companies works, which is significantly different with respect to other industries involved also in the automotive one, such as the steel industry. As affirmed by Appleyard (1996), the pace and nature of technological innovations is a factor which highly influences the information sharing within the industries and it is one of the reasons why exist different patterns of knowledge sharing. Appleyard cites von Hippel to sustain that in industries with rapid technological changes the knowledge sharing is almost non-existent; "new innovations often qualify for patent protection and the associated monopoly rents. In slower-paced industries, such as the steel industry, technological change is characterized by the accumulation of numerous incremental improvements over a long-time horizon, thus limiting profitable patenting opportunities" (Appleyard, 1996, p.141). Therefore, it can be finally stated that the semiconductor industry is characterized by active patenting, large R&D expenditures and price changes, which reflect the frequent introduction of new production processes and products, leading to a lower knowledge sharing among companies than in slower paced industries (Appleyard, 1996).A curious result from the research carried out by Appleyard, is that in the semiconductor industry, on average, technologists from other companies ranked fourth as source of knowledge behind colleagues within the respondent's company, journal, books and presentations at companies, while in the steel industry the colleagues at other companies ranked second.

But why it is important to understand the nature of the semiconductor industry with respect to the automotive value chain? The reason is that, as stated previously, these components are gaining more and more relevance, and therefore also their suppliers are gaining massive relevance in the value chain. The semiconductor industry has only few major players, which include NVIDIA, Qualcomm, Samsung Electronics and TSMC; however, even among these companies, there is a certain level of market concentration in the automotive industry, with TSMC accounting for 92% of the world's most advanced chip production and 60% of the less advanced chips (Ramani, Ghosh and Sodhi, 2022). Besides market concentration, there is also a certain degree of geographical concentration, with 80% of chip manufacturing taking place in Japan, China, South Korea and Taiwan, with US accounting for the 10-12% of global chip manufacturing (Ramani, Ghosh and Sodhi, 2022). All these elements show that the OEMs have to deal with a small number of suppliers, which have a high bargaining power since they own precious know-how necessary for electromobility. The famous semiconductor crisis happened in 2020 and its effects on the supply for the automotive industry is an example of how much these components are important for nowadays vehicles.

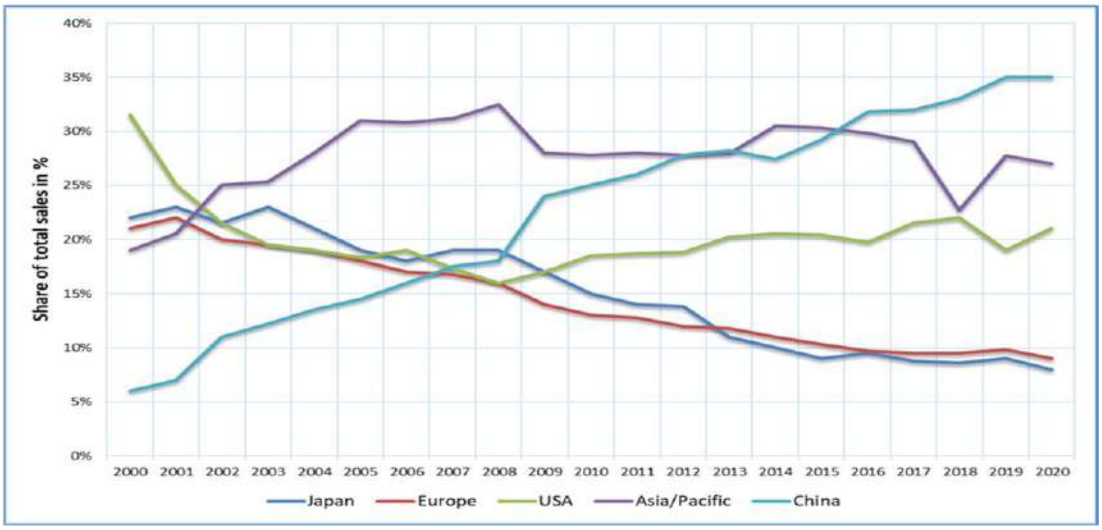

Figure 11: *Development of market share in semiconductor sales* (Frieske, B. and Stieler, S., 2022, p.4)

Above is possible to see the market share in the semiconductor industry detained by several continents and countries and how it changed over the time. As expected, the demand for semiconductors will continue to grow in the future because of the higher requirements for digital and networked functions in the vehicles (Frieske, B. and Stieler, S., 2022). The value share of semiconductors increased from 330€ to 690€ "material value for plug-in hybrids or purely electric-battery vehicles against the background of electrified drive components alone" (Frieske, B. and Stieler, S., 2022, p.7). According to Roland Berger report, the cost of electronic components for a typical premium vehicle will rise from $3145 in 2019 to 7030$ in 2025, as can be seen in the graph reported below:

Graph 1: *Share of Semiconductors content of typical electronics bill of materials,* Roland Berger (2020)

Classic Tier 1 automotive suppliers have to face several changes due to the increase demand for semiconductors, with software companies taking the place of the traditional automotive suppliers in the automotive sector and with the traditional suppliers having to switch and to reposition themselves into electronics and software integration, having to deal with significant competition in the sector (Roland Berger, 2020).

To understand how important are these components for electrified vehicles and for their functionalities, it is interesting to analyse what has been the impact of the shortage of semiconductors soon after the Covid-19 period on the automakers. Chip manufacturers were already operating and producing at full capacity, and could not meet the additional demand placed by the suppliers of automakers, so several auto manufacturers had to close plants at a worldwide level (Ramani et al., 2022). Of course, because of the increase of the demand, there was also an increase in the price of chips, together with an increase in shipping costs, and consequently in the price of all the vehicle models interested by this issue; for example, customers from the US faced in an increase in retail prices even equal to 5000$ (Ramani et al., 2022). The shortage of semiconductors led to several problems also under a labour perspective, causing worker layoffs and furloughs; in fact, chip production requires highly skilled workers, but the pandemic impacted with the availability of these workers at the plants, making auto manufacturers reduce their production too, therefore cutting down shift hours or going through layoffs. Finally, the end consumer was impacted by these issues, since automakers could only produce some type of models, limiting the customers' possibility of choice; the limited stock availability increased then the demand for used cars, leading a price growth also for those vehicles (Ramani et al., 2022). It can be understood that chips and semiconductors are a fundamental element for future mobility and to achieve the objectives that Europe wants to reach through the European Green Deal, but how does Europe perform regarding this technology?

According to Ciani and Nardo (2022) there is not a country which can be considered completely autonomous in every single step of the global value chain to produce semiconductors. Again "Supply chain data confirms that EU companies in semiconductors strongly rely on suppliers and/or customers headquartered outside the EU. […] on average, almost 80% of suppliers to European firms operating in the semiconductor industry are headquartered outside the EU" (Ciani and Nardo, 2022, p.6). Eu is a net importer of several semiconductor devices, mostly from China, but also Taiwan and South Korea. From 2007 to 2019, European countries increased their reliance on foreign suppliers through backword integration, but at the same time they also increased their connections with the rest of the world through forward integration, with Germany accounting for the one third, among EU member states, of total global value chain integration in Europe (Ciani and Nardo, 2022, p.13). In any case, the role of China significantly increased also for Europe, going from more than 30% to more than 50% in 2019 and 2020 as imports from trade partners outside the EU. In the figure reported below is it possible to observe from which countries the EU imports semiconductor devices the most and how the trend changed over the years; as can be seen, China is the most prominent country being by far the biggest exporter for Europe.

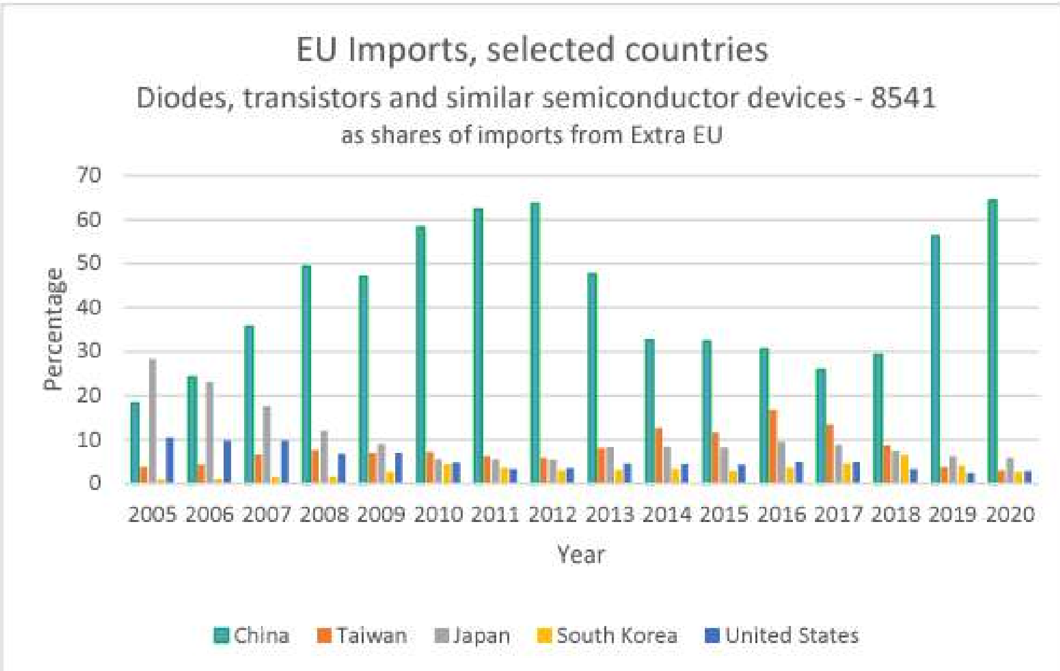

Figure 12: *Diodes, transistors, and similar semiconductor devices. EU imports by trade partner,* (Ciani and Nardo, 2022, p.17)

There are also some EU companies which produce semiconductors, such as STM and NXP, but where do they buy the inputs that they use for production? This is a question that Ciani and Nardo asked themselves, and they obtained the following information: on average, nearly 80% of the suppliers of the European firms operating in semiconductors are headquartered outside of the EU (Ciani and Nardo, 2022, p.29,30).

Considering the number of firms producing semiconductors as contractors for other firms, EU investors account for a very small share of turnover in this segment, which is instead dominated by Asian companies (Ciani and Nardo, 2022).

3.3 The increasing presence of Asian OEMs in the automotive market

As can be understood from what has been reported in the chapter, semiconductors are a very important factor that is going to deeply change the automotive sector in the coming years; at the same time, this kind of technology is highly resource demanding and has significant environmental costs. 90% of the total manufacturing capacity is in Taiwan (Favino, C., 2024), with TSMC (Taiwan Semiconductor Manufacturing Co.) using 6% of island's total power and producing approximately 15 million tons of carbon in 2020, against the 13 million of Samsung and the 3 million of Intel (Favino, C., 2024). Semiconductor production requires a lot of water since it is necessary a ultrapure water, leading to a high consume of it, overall, the semiconductor industry consumes about 10% of Taiwan's water; it is not a case that between 2020 and 2021 Taiwan experienced (Favino, C). Since there is a high need of resources, it is easy to understand that many countries, especially those that want to achieve or maintain a competitive position within this new set up going towards energy transition have to invest a lot in these new technologies, such as semiconductors but also battery development and raw materials for what regards the automotive industry. China is one of those countries that are, strangely, lagging behind in in the semiconductors sector; in fact, in this area China economy is dependent on the rest of the world (Thomas, C., 2021). However, China is a country who is investing a lot not only in direct industries or production processes, but also on the control of raw material supply chain by means of geopolitical interventions with key companies in Africa or Asia. This aspect is going to be investigated in the next chapter, since it involves several geopolitical issues that are happening nowadays and that are having important effects also on the European automotive sector.

In fact, in Europe several new brands from the East are entering the market helped also by the different trade agreements and the low taxes on imports (Muñoz-Vieira, 2024). However, even though the offer from Chinese brands is high, the same cannot be said for the demand of these brands, since in December 2023, from 24 Chinese brands available, only 9 registered more than 1000 units (Muñoz-Vieira, 2024). At the beginning of 2000s and in the 1990s, the European market witnessed a significant increase of Asian OEM's. as Jato sustains in its report, "after years of learning from the European consumer, they finally produced competitive products designed for the consumer there. They localised the production and became a strong alternative to the European mainstream brands" (Jato, 2024). After the Japanese brands, Korean ones arrived, following their predecessors' path and achieving a prominent position in the European market thanks to the quality and wide range of products. In the most recent period, the Chinese brands are increasing their market share going from 1% of 2019 to 10% of 2023 among the Asian car brand composition in Europe (Jato, 2024). In general, the market share in Europe in 2023 was spread with 24% for Asian brands, however, the made in Asia cars accounted for the 13% of the market share and the vehicles made in Asia by Asian brands made up the 11% of the total (Jato). As reported by Jato, "In China, there were 491,000 Chinese made cars registered in Europe, of which 65% were made by Chinese brands. This country is a popular destination of foreign investment and a big export hub: Tesla, Dacia, Volvo, Mini, BMW, Polestar import Chinese made models". All these Asian brands have different strengths which help them to achieve a competitive position in the European market; Japanese brands, such as Toyota, have a strong position thanks to the hybrid engines, in fact they accounted for the 84% of Asian cars registration with this technology in Europe. Korean brands have a significant market share within the plug-in hybrid (PHEV) solution, with 47% of the Asian mix in Europe, while Chinese brands have a good market share for full electric vehicles, with 39% of the Asian mix. In the figure below is possible to understand in which segment, both in terms of engine type but also of body type:

Figure 13: Asian car brands market share in BEV, PHEV and HEV segment and SUV segment in 2023 (Jato, 2024, https://www.jato.com/resources/news-and-insights/asian-car-brands-continue-to-grow-in-the-european-car-market)

Currently, the Chinese brands have still not acquired a dominant position in the European market, with 2.5% of the total cars registered, and with 72% of this 2.5% registered by MG only. However, in the pure electric car segment, China is ahead of Europe and US since they have more resources, a bigger local market with economy of scale and, most importantly, they own a significant part of the supply chain for battery production (Jato, 2024). Chinese electric cars are particularly competitive with respect to Japanese, Koreans, American and European ones because of their lower retail price. In fact, the average retail price of a Chinese electric car in Europe during January was 30% than the average price of European competitors (Jato). The reasons are mainly conductible to the lower labor costs at home, more economy of scale and to the control over the supply chain of battery production.

To counteract the increased competitiveness of Chinese car brands, the European Union has introduced trade tariffs, on top of an already existent 10% duty, on all Chinese imports related to battery electric vehicles making no difference whether it is a Chinese produced and branded car or if it is a model from a European brand manufactured in China (Bonini, 2024). In particular, there will be an individual duty of 17.4% for BYD cars, 19.9% for Geely, and 37.6% for SAIC; a part from these brands, there are other cooperating non-sampled companies that on average will face a 20.8% trade tariff and other non-cooperating non-sampled companies which will face a 37.6% of trade tariff (Bonini, 2024). The tariffs will remain for four months until early November 2024, and after that date it should be reached a mutually agreed solution. Anyway, the European Commission found public subsidies along the entire BEV value chain and therefore the Chinese battery electric vehicles increased their market share from 3.9% in 2020 to the current 25% (Bonini, 2024). If no agreement will be reached by November 2024, the provisional measures could become permanent and imposed for five years.

In the previous paragraphs it has been analysed how some companies already present in the global value chain of the automotive sector are going to be affected by the introduction of electromobility and what are the strategies that they plan to follow to cope with these new challenges; further data also report that the introduction of the European Green Deal regulation is going to deeply affect the entire European automotive sector, since the energetic transition is fostering the entrance in the market of new competitors, such as the Chinese ones who can exploit their direct access on the raw materials needed to produce batteries for electric vehicles. The European Union has recently introduced some economic measures to make European and traditional manufacturers more competitive with respect to the Chinese ones, but it is not sure whether this could be considered as the final solution for this new scenario. It is sure, however, that the energetic transition happening in the western world is causing major changes in the geopolitical asset at a worldwide level, with some countries hardly investing for the control and management of raw materials to gain a strong and competitive position. Therefore, it is interesting to analyse what the European Green Deal is causing at a worldwide level, how the relationships among countries are changing and what this means for the automotive sector.

Chapter 4: The geopolitical aspect of the European Green Deal and the energetic transition

The European Green Deal is going to deeply affect the geopolitical structure and geopolitical relation of European with respect to the other countries. As reported by Leonard, M., J.Pisani-Ferry, J. Shapiro, S. Tagliapietra and G. Wolff (2021), this structural change will impact on the European trade and investment pattern, with some countries such as Norway, Russia and Algeria losing important export markets; moreover, through the energy transition Europe will be more dependent on imports of products and raw materials used for clean technologies and clean energy and again Europe may risk to lose competitiveness if European firms start to follow regulation-related cost but foreign competitors do not follow them (Leonard, M., 2021); “if the EU attempts to limit this loss and avoid carbon leakage by imposing tariffs on carbon-rich imports, it risks being accused of distorting international trade” (Leonard, M. et al., 2021). So, the European Green Deal may have some effects also on the global energy market, being Europe the second largest net importer of oil after Asia Pacific, by depressing oil prices; in this case, Saudi Arabi and Iraq would get an advantage since they are able to produce oil at a relatively cheap price with respect other oil producers (Leonard, M. et al., 2021).

In general, it is possible to affirm that countries with both cheap capital and constant innovation will be the ones winning the clean energy revolution (Bordoff, J. and O’Sullivan, M., p.72). One source of dominance without any doubt can be considered the ability to set standards for clean energy; in fact, a company or a country able to set global standards for what regards the technology considered to be the most efficient one or able to establish norms of engagement, can benefit from a competitive advantage (Bordoff, J. and O’Sullivan, M., p.72). For example, “Australia, Chile, Japan, and Saudi Arabia have emerged as early adopters in trading low-carbon hydrogen and ammonia across borders and thus may be able to set infrastructure standards and certification norms for those fuel sources, giving their favoured technologies and equipment an edge” (Bordoff, J. and O’Sullivan, M., p.72). Of course, in this case is very important also the control of the technologies used to manage data and optimize electric grids or to manage customer demand, since the ones who will be able to set the standard will have the opportunity to export compatible domestic systems but also to get data from those system and gain important information (Bordoff, J. and O’Sullivan, M., p.72). A second source of dominance of the energetic transition, as stated more than once previously in this document, is the control of the supply chain of raw materials such as rare earths, cobalt, nickel and copper. Nowadays, the supply of all these raw materials is in the hand of very few parties, in particular China controls the supply of rare earths, the Democratic Republic of Congo the supply of cobalt and Australia half of the supply of lithium; it is interesting to notice that the three largest oil producers, Russia, United States and Saudi Arabia, account for not more than the 10% of the world's total oil production (Bordoff, J. and O'Sullivan, M., p.74).

In any case, it is crucial that the European Green Deal is applied in someway also in foreign countries, both because if that would not be the case, as stated previously, European firms may face a reduction in competitiveness but also under an environmental perspective it would make no point; in fact, Europe accounts for less than 10% of global greenhouse gas emissions (Leonard, M. et al., 2021), meaning that the Green Deal would have little to non-effect at a worldwide level if the old continent would adopt all the regulations to reduce general pollution, but would not be followed by the rest of the world. Russia is a country that is expected to benefit from the European Green Deal since a coal-to-gas switch is necessary for Europe to cut energy emissions, and Russia has big reserves of gas (Leonard, M. et al., 2021).

As it has been deeply analysed in the previous chapters and paragraphs, electrification will be the key to achieve the objectives for carbon neutrality; this means that Europe might have to rely on imports of solar and wind electricity from close countries such as the Middle-East and the North Africa (Leonard, M. et al., 2021). The European Green Deal may create some new energy security risks for what regards the supply of renewable energy, especially for what regards the supply and import of minerals and materials with few or no substitutes necessary for the manufacturing of solar panels, wind turbines, batteries for electric vehicles and fuel cells (Leonard, M. et al., 2021).

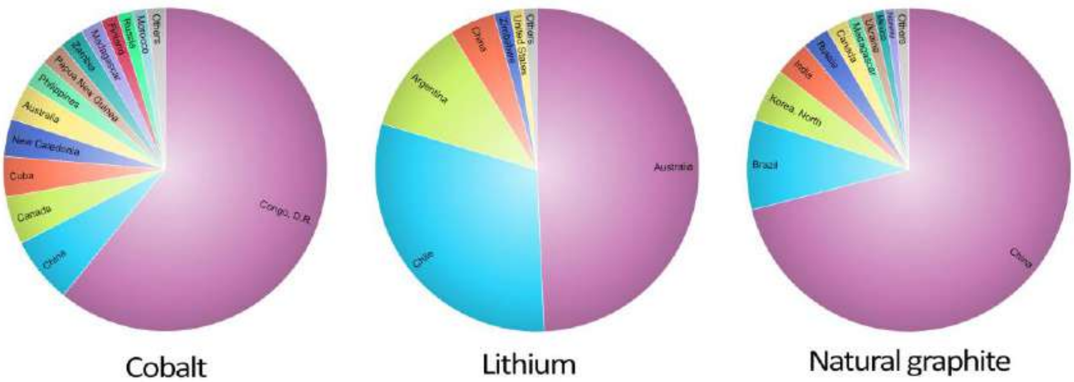

Figure 14: *Global mine production output shares for cobalt, lithium and natural graphite per country* (RMIS, 2019).

As can be seen in the figure reported above, some of the key materials necessary for the electromobility are located in specific geographic areas with high market concentration. The Democratic Republic of Congo accounts for more than 70% of mined cobalt supply at a worldwide level and China controls the refined cobalt sector with a market share of 67% in 2019 (World Bank, 2021, p.5). Furthermore, eight of the 14 largest cobalt miners in DRC are Chinese owned, accounting for half of the Congo mined cobalt output. The exploitation of the Congolese soil starts back to when the World Bank urged the Congolese to lease its mining and industrial assets to other countries after the decline in the very early 2000s of the public enterprise Gécamines, which is a Congolese company working in the field of minerals mining (Rubbers, B. 2020 and https://www.gecamines.cd/). During the years there have been several mining projects and different shareholders investing or divesting in the country, however, it has been few years that the Chinese central State-Owned Enterprise (SOEs) has begun to stabilize its presence in the DRC, by signing mining contracts with the Congolese government (Rubbers, B. 2020). Before 1990s, China was a small producer and an exporter of low value rare earths, while after the country became a global leading producer and exporter and achieved almost a monopoly on the control over the rare earths supply chain (Mancheri, Sprecher, Bailey, Ge and Tukker, 2018). Since the 2008 crisis, China has intensified its presence in the Congolese country, with many projects previously managed by private global companies that have been acquired by Chinese government, Chinese private companies or mixed enterprises (Rubbers, B. 2020).

As cited by Boafo, Obodai, Stemn and Nkrumah (2024), the International Energy Agency, from 2017 to 2022 the demand for lithium tripled, while the one for cobalt and nickel raised respectively by 70% and 40%; at the same time, the market size of critical minerals doubled in 2022, reaching £320 billion (cited in International Energy Agency, 2023). The demand for critical materials is expected to increase significantly, by doubling in 2030 and quadrupling in 2050, always according to the International Energy Agency. In 2023, the increase in investments in new minerals supply, such as copper, cobalt, nickel and lithium, was smaller than in 2022 when the market grew by 30%, but in any case, it had an increase of 10%; China reached the record of $10 billion in the first half of 2023 of spending for acquisition of oversea mines (International Energy Agency, 2023). In general, exploration spending grew by 15% in 2023, with Canada and Australia leading the way, followed by Africa (International Energy Agency, 2024). In the figure reported below it is possible to see that among the critical minerals for the energetic transition, lithium and copper are the most exposed ones for what regards the risk of supply and volume risk, while cobalt, rare earths, graphite and nickel have higher geopolitical risks.

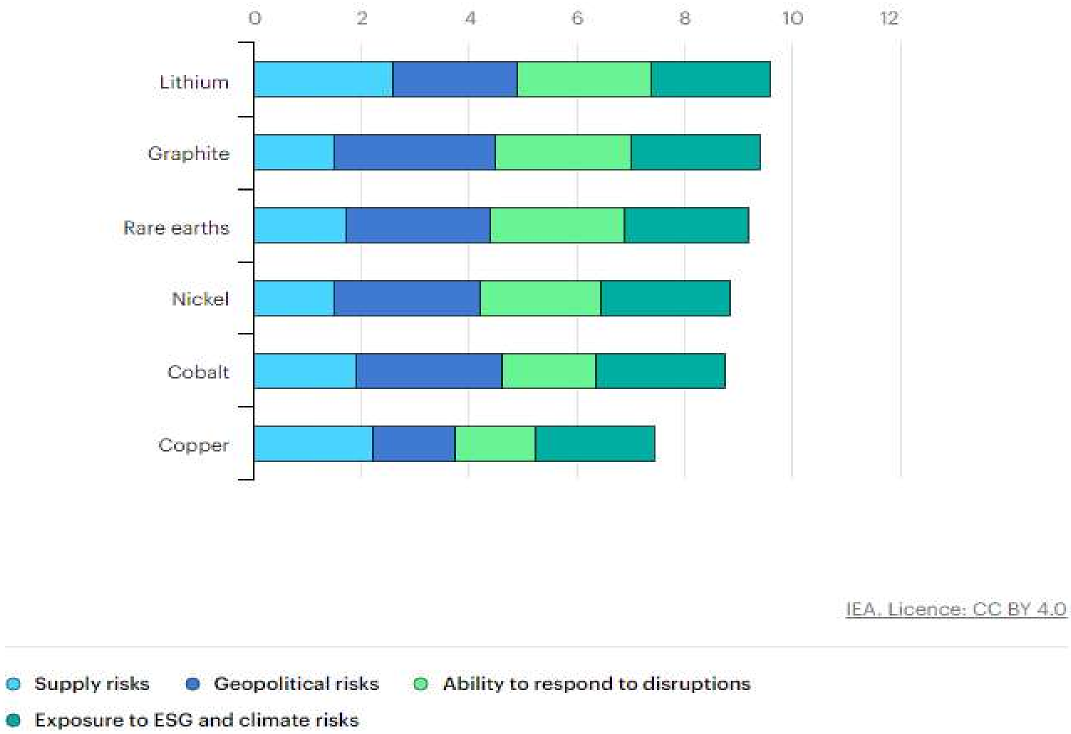

Figure 15: *Clean energy transition risk score for key energy transition minerals* (IEA, 2024).

4.1 What is the current and expected situation of critical materials necessary for automotive energetic transition?

4.1.1 Copper

Copper is the only critical material that is present and necessary for every kind of clean energy, BEVs, solar PV (photovoltaics) and electricity networks because of its characteristics: electronic conductivity, longevity, ductility and corrosion resistance (International Energy Agency, 2024, p.110). The demand for copper is highly influenced by the increase of electromobility, since the material is fundamental element for EVs' lithium batteries production but it is used also in the EV motors. Copper is used also for electricity networks and constructions, but its demand from EVs is expected to experience an increase from 2% in 2023 to 12% in 2050 according to the APS scenario and 13% according to the NZE one (International Energy Agency, 2024, p.110). The supply of copper is particularly concentrated, with the share of the top three producers accounting for the 47% of total copper production in 2023; Chile is the biggest producer, accounting for a quarter of global supply, even though its share it is declining to make space for the DRC, which since 2015 has doubled its supply levels overtaking Peru (International Energy Agency, 2024, p.112). Moreover, Chile is the world's largest supplier of copper but it produces only 8% of world refined copper, which means that over half of the Chilean copper is exported for refining, mainly to China, which has increased its copper imports by 60% since 2012; at the same time, the export of refined copper from China is decreased by 20% over the same period because of the decline in production from solvent extraction electrowinning mines and because of several environmental concerns which led to the closing of smelters in Chile (International Energy Agency, 2024, p.113). According to the projections of the IEA, China will continue to dominate the supply of copper, providing half of global refine copper from 2030 onwards, creating major dependency and vulnerability for the supplied countries and industries. American Latin countries could develop their refining process to foster a greater diversification of suppliers, however they do face some difficulties related to high labour and energy costs as well as high environmental concerns regarding the operation processes (International Energy Agency, 2024, p.114). In the figure 16, presented below, is possible to observe the actual distribution in terms of from where geographically the copper is mined the most and which are the countries who control the most the supply of copper, since these two elements do not match necessarily, as stated previously in the paragraph:

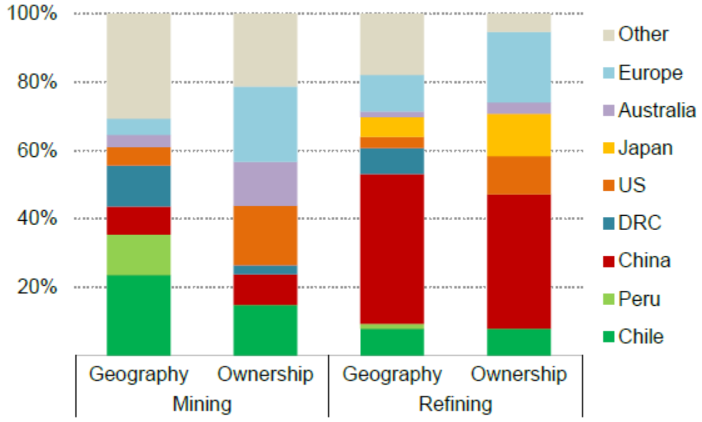

Figure 16: *Copper mining and refining by geography vs. ownership, 2023* (International Energy Agency, 2024, p.114).

4.1.2 Cobalt

Cobalt is another critical material that has a very high importance, since it is and it will be the reason for several geopolitical issues also; it is expected that the EVs demand for cobalt will at least triple by 2040 with respect to the current levels (International Energy Agency, 2024, p.157). It is true that alternative battery solutions with low cobalt or with no cobalt are being developed as an alternative to cobalt-intensive ones, but it will take a lot of time for these new solutions to be commercialized, and in particular, batteries for electric vehicles will be the technology that will push the use of this material the most in the medium and long term (International Energy Agency, 2024, p.157). The Democratic Republic of Congo (DRC) is the number one supplier of Cobalt at a global level; in the long term the existing mine sin DRC are likely to reduce their supply or to diminish due to declining quality and higher production costs, leading to a decrease equal to 15% with respect to nowadays supply levels (International Energy Agency, 2024, p.160). Even though Congo still has very high-grade resources, there is also another country who is emerging as a powerful cobalt supplier; it is located in Asia and it is Indonesia. Indonesia has become the second largest cobalt supplier, since its production rose by 20 times in the last four years after some government policies which banned the export of nickel and it attracted many investments in domestic nickel-cobalt processing operations (International Energy Agency, 2024, p.160).

Because of the low prices, mining projects for cobalt extraction are facing several issues, since companies are forced to look for further fundings to carry out their business production processes. Moreover, Cobalt refining is mostly concentrated in one single country, which is China. China is responsible for more than 75% of cobalt supply refining and this share it is expected to remain the same at least until 2040, with Finland and Japan accounting respectively for 9% and 3% (International Energy Agency, 2024, p.162). Of course, this concentration of supply in hands of very few countries, if not just one, brings with itself some risks; there are, in fact some cases where the Congolese government has suspended some mining projects, such as the China-based CMOC's TFM, which is the second largest cobalt mine (International Energy Agency, 2024, p.164).

4.1.3 Graphite

Graphite is a material that is necessary for the energetic transition as well, and its demand is growing especially because of higher batteries production (IAE, 2024, p.169). In fact, the electric vehicles industry emerges as the main consumer of this material, with 60% of total demand, but this material is expected to be exploited even more also for other uses in the field of electronics (IAE, 2024, p.170). For the EV batteries, the use of graphite is expected to have a slight decrease of graphite demand from 2040-onwards to make place to other materials such as silicon, which is already present in graphite anodes, but to a much less extent than graphite (IAE, 2024, p.170). However, graphite will be used still for a long time, not only because those alternative solutions will take time to be used in large scale, but also because it will be increasingly exploited also for other scopes, such as electric arc furnaces, to reduce the emission caused by the steel production ((IAE, 2024, p.170).

As it is happening for other critical materials for the energetic transition, most battery producers are dependent on China for graphite anodes; in fact, even though "sizeable natural graphite anode capacities exist outside of China, they depend almost entirely on refined graphite supply from China and exhibit low utilisation rates" (IAE, 2024, p.172). Currently, the mining of natural graphite is dominated by China, which accounts for the 80% of global production; this share is expected to decrease to 70% after 2030 because of new countries entering the market as graphite suppliers, such as Mozambique and Madagascar (IAE, 2024, p.172). The refining process of natural graphite brings with itself some major issues about market concentration, as other critical materials: in fact, China detains the 99% of the global market of spherical graphite, which is a refined of the natural graphite. Some other countries are investing in projects for graphite refining, like Canada, US and Sweden, and the share of China in spherical graphite supply is expected to fall to 85% in 2030 and to 80% in 2040 (IAE, 2024, p.173). Natural graphite has some constraints regarding its supply, therefore synthetic graphite production is increasing its share in batteries; however, also the production of this type of graphite is very concentrated, and it is always China to control most of it (IAE, 2024, p.173). In recent years, the production of synthetic graphite for battery use is increased from 0% to 40% of total synthetic graphite supply and it is expected to rise util 55% by 2040 (IAE, 2024, p.173). In the figure reported below it is showed the trend of the exploitation of both natural and synthetic graphite in batteries:

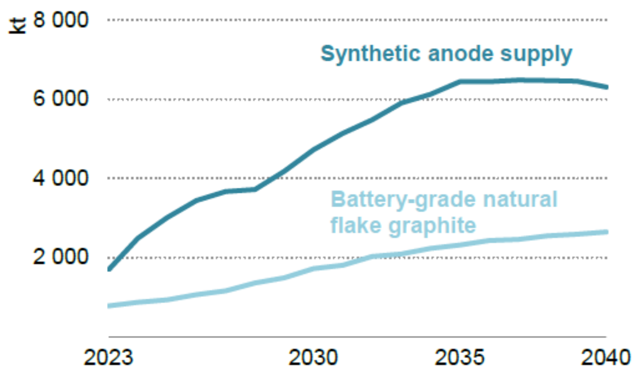

Figure 17: *Use of mined natural and synthetic graphite in batteries* (IEA, 2024, p.173).

Under an environmental perspective, the extraction and conversion of synthetic graphite involves significant higher greenhouse gas emissions with respect to natural graphite, since it involves an electricity-intensive process which relies on fossil resources (IEA, 2024, p.175). As stated previously, China accounts for the vast majority of existing and planned synthetic graphite production capacity and the country has also established a system of export licenses for graphite since December 2023 (IEA, 2024, p.175).

4.1.4 Rare earth elements

As for all the other critical materials, rare earths demand is driven by EV motors and also by wind turbines; as stated by the IEA (2024), the rare earths are a set of 17 nearly indistinguishable silverly-white soft materials. Rare earth elements are usually classified into light rare earths (LREE) and heavy rare earths (HREE). The demand for rare earth elements (REE) is nearly doubled between 2015 and 2023, driven by the electric vehicles sales and wind turbine deployments to meet climate objectives; the share of demand from EV motors rising from 7% in 2023 to nearly 30% in 2050 (IEA, 2024, p. 180).

For what regards the supply of REE, these materials are the ones experiencing the highest geographical concentration for the refining process among all the critical materials that are necessary for the energetic transition (IEA; 2024, p.181). The level of geographical concentration is the same as cobalt and natural graphite for mining, with top three producers for mining of magnet REE accounting for the 85% of total production and China alone accounted for the 62% of global mined production (IEA, 2024, p.182). The story is not that different for what regards the refining of rare earth elements, with China representing the 92% of global refine output (IEA, 2024, p.182). The supply of REE is expected to increase from today's levels by 44% in 2030 and by 52% in 2040, with the dominance of the top three suppliers going from 85% of total production to 81%; China is expected to decline its share of supply reaching the 77% by 2030 (IEA, 2024, p.182). However, the production and extraction of REE causes the dispersion of radioactive elements and only China, with other very few countries, seems the only one to have the infrastructure and the willingness to build solutions for the storage of these radioactive by-products (IEA, 2024, p.182). Moreover, only few mines are operating at scale outside China and Myanmar; there is one operating in the US, one in Australia, one in Vietnam and Brazil, but even though there are newly announced projects it may take them at least 8 years to be as competitive as Chinese ones (IEA, 2024, p.182).

Other rare earths producers outside of China, such as “Australia-based Lynas Rare Earths Limited and US-based MP Materials Corp., are clamping down on costs to offset a sharp drop in prices and weak Chinese demand” (IEA, 2024, p.188). The industry expects that export credit agencies will continue to support rare earths producers outside China, but anyway China will still be a strong driver of rare earths demand, as demonstrates the overtake of the Chinese BYD car company to Tesla as the top selling electric vehicles maker in 2023 (IEA, 2024, p.188).

There are mainly two kinds of magnets made from REE; one is called bonded magnets and it is exploited mainly for electronics or smaller motors, while the other type is named sintered magnets, used mostly in traction motors for EVs and wind turbines (IEA, 2024, p.189). A part from China, only two facilities in Japan are known to produce sintered magnets at industrial scale, even though nowadays OEMs are not willing to pay the premium price of around 30$ to 50$ per vehicle deriving from the energy costs and trade taxes for magnets made outside of China (IEA, 2024, p.189).

4.1.5 Lithium

In the clean energy transition, lithium is the material that is facing the fastest growth in demand. In particular, the demand is highly influenced by the uptake of electric vehicles since lithium is a perfect candidate for high energy density batteries, even though this material is used for many different scopes, such as ceramics or lubricants (IEA, 2024, p.127). The EV industry contributes to about 90% of future lithium growth between today and 2050 according in the APS scenario; in fact, even though some alternative technologies such as sodium-ion batteries and vanadium flow batteries in low range vehicles are gaining some relevance, they do not significantly alter the prospect for what regards the lithium demand in climate driven scenarios (IEA, 2024, p.127).

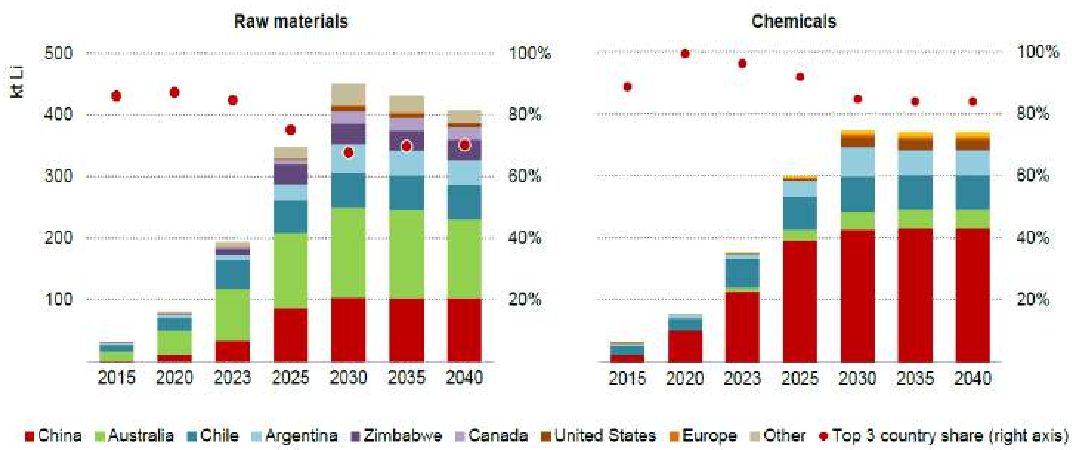

Figure 18: *Lithium raw materials and chemical production from operating and announced projects in the base case* (IEA, 2024, p.128)

As for all the other materials previously discussed, China dominates the refining processes of critical materials also in this occasion; in fact, even though the biggest lithium producer is Australia, most of it is exported to China for refining (IEA, 2024, p.129). Moreover, China is the largest consumer of lithium and the country is putting significant efforts in order to develop domestic supplies with investments in domestic mines from downstream manufacturers, such as CATL (IEA, 2024, p.129). According to some projections of the International Energy Agency, in fact, China will become the world's second largest lithium producer from 2025 overtaking Chile and it has already increased its share of global lithium mining from the 6% of 2016 to the 17% of 2023 (IEA, 2024, p.129). Traditionally, it has been Latin America the major supplier of lithium with Chile's Salar de Atacama, but there are some growing interests in Argentina which is attracting more than 80% of future capital investments for lithium in Latin America, with investors from the US and Australia, Europe, China and Korea (IEA, 2024, p.130). In Africa, lithium is a recent phenomenon, with production in Africa which is recently increased and also additional industrial capacities are planned in Zimbabwe, Ethiopia, Namibia, DRC and Ghana. (IEA, 2024, p.130).

Currently, China dominates the refining of hard rock ore, from domestic resources but also through the refining of most of the lithium mined from hard rock oversea, from Africa and Australia. By 2030 it is still expected that the top three country share of lithium production will remain close to 98%, with Argentina, Chile and China being part of these countries (IEA, 2024, p.130). Since the importance of lithium is definitely increasing with the energetic transition, investments are becoming critical to keep pace with the constant demand growth. However, "recent price volatility may lead to short-term supply responses discouraging investments for new supplies" (IEA, 2024, p.134). Operating cost is a factor that is causing several considerations in production suspension decisions, but it is not the only factor, in fact there are risks that the current low price environment may reduce investments in lithium projects, including those that may offer better ESG performance which would affect medium to long term supply (IEA, 2024, p.134).

In the long term there are still concerns regarding the geographical concentration of manufacturing and refining processes as well as the ownership concentration (IEA, 2024, p.135). China is achieving some progresses researching new deposits and promoting domestic mining activities; in fact, even though the geological perspective puts China in a disadvantageous situation, the new deposits under development may change the current scenario (IEA, 2024, p.135). At the same time, China has the ownership of most domestic ventures as well as major interests in Australian, Argentinian and African companies (IEA, 2024, p.135).

4.1.6 Other key materials

Besides all the materials that have been cited and discussed previously, there are also others which will be fundamental for the energetic transition and therefore also for the future of the automotive industry.

Aluminium is one of those elements and its demand is driven primarily by solar PV and EVs; moreover, the transmission requirements are arising due to the increasing electricity demand and this, together with renewable energy penetration are expected to increase the use of aluminium conductor steel-reinforced cables (IEA, 2024, p.194). Like many others, also this material is highly dependent on China considering the supply side, since "drought risks in the southwestern Chinese province of Yunnan pose significant near-term potential for supply volatility and elevated prices" (IEA, 2024, p.194).

Manganese demand is growing significantly because of the increase of demand of electric vehicles batteries and yet again, the supply of this material is highly dominated by China (IEA, 2024, p.195).

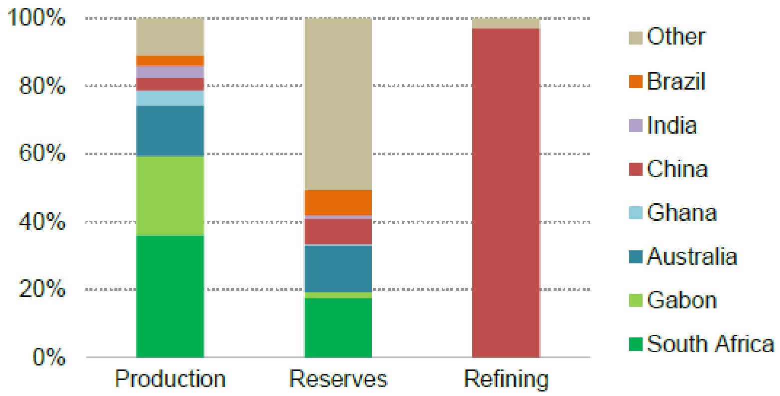

Figure 19: *Geographical distribution of manganese production and reserves* (IEA, 2024, p.196).

In figure 19 is highly visible how the supply of manganese is concentrated almost fully in China. Currently the demand for manganese is driven mainly by steel, since it is a key component of steel alloys, however, the share of manganese exploitation for EVs is set to increase significantly following the energetic transition (IEA, 2024, p.196). According to several scenarios and projections reported by the International Energy Agency, the demand of manganese is expected to be at least 16 times higher than today's levels due to the major deployment of battery electric vehicles. Mined manganese production is therefore, highly concentrated with the top three countries producing three-quarters of global supply (IEA, 2024, p.197). Africa is the largest producer with 35% of production, followed by Gabon with a quarter and Australia with 15%; of course, this concentration of production brings with itself several issues related to the supply of the material like it happened in Gabon with a decrease of supply of 13% from 2022 to 2023 after a military coupe (IEA, 2024, p.197). There is, in any case, a potential for diversification: indeed, also China and Brazil hold significant reserves, accounting for the 15% together, however, what is critical for the supply of manganese is the supply of high-purity manganese which is required for battery chemistries (IEA, 2024, p.197). The supply of this kind of manganese is fundamental for the manufacturing of electric batteries and it is problematic since only 1% of global supply is suitable for batteries production (IEA, 2024, p.197). Following the trend of all the other critical materials, it is China that dominates the global supply of battery-grade manganese supply with the 97%, as showed in figure 19. Therefore, "the total dominance of China in the supply of high-purity manganese sulphates today is a major risk alone, making supply highly vulnerable to sudden changes in policy, geopolitics or supply shocks" (IEA, 2024, p.197).

Silicon is another material which has seen two main phases of demand growth, the first one with the introduction and commercialization of solar PV, while the second one with the growing use of silicon in the battery industry (IEA, 2024, p.198). Recently, technological gains and advancements are deducing pressure on silicon resources, while for EV batteries, manufacturers which are adding small quantities of silicon in anodes are facing some issues such as swelling during the charging period (IEA, 2024, p.198). For what regards the supply side "China's share of solar-grade silicon grew from 27% in 2010 to over 80% today. The current price context and local energy prices are adding pressure on European solar-grade polysilicon manufacturers, with some capacities closing down" (IEA,2024, p.199).

Other materials such as platinum group materials are less relevant in the energetic transition for the automotive industry; some of those materials present in the platinum group, will either decrease because of the uptake of EVs or increase their presence because of the same reason (IEA, 2024, p. 201). For example, rhodium and palladium are decreasing because of the lower demand for internal combustion engines emission catalysts, which represent the 90% of rhodium demand and 80% of palladium demand (IEA, 2024, p.201).

In Figure 20, presented below, it is possible to have a clear and summarised view about what are the several risks that each of the main critical materials discussed above carry with itself:

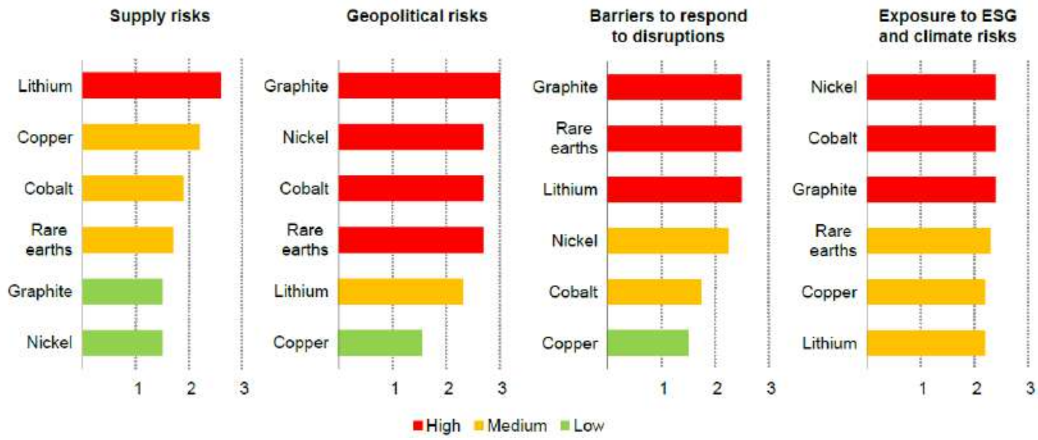

Figure 20: *Risk score by category and mineral* (IEA, 2024, p.213).

As can be seen, there are several categories with materials having from low to high risk; the category where the materials reported appear to have major issues and a greater level of risk is the geopolitical one, therefore it is worth to furtherly analyse this aspect in order to understand what are the consequences of the green transition not only on the automotive industry, but on the whole world structures in terms of economic and territorial power.

4.2 Geopolitical consequences of the energetic transition

Energy transition has deeply changed the action path of geopolitics in the traditional energy era. In fact, the geopolitical game in the new energy era mainly focuses on capital and technology control (Yang, Xia and Qian, 2023, p.686). The scarcity, as well as the "non-renewability, and new geographical dependence on critical materials such as rare earth elements cobalt, and silicon, required for the development of renewable energy sources, become principal reasons for geopolitical games" (Yang, Xia and Qian, 2023, p.686). Moreover, the technology costs of renewable energy resources, intermittency and infrastructure management are key market factors that will definitely shape the new energy geopolitics; for example, renewable energy is mainly transported through the energy grid, a factor that strengthens the interdependence among different countries and regions (Yang, Xia and Qian, 2023, p.686). It is expected that regional conflicts in traditional energy-rich areas, such as the Middle East will be greatly alleviated; however, "geopolitical games between China and the United States as well as between China and Europe around new energy technology, infrastructure, and international investment will become more and more prominent. Countries with critical materials for new energy development may become the focus of new energy geopolitics" (Yang, Xia and Qian, 2023, p.687).

Energy has always been a relevant element in shaping global geopolitics, determining great powers, alliances and war results (Hafner and Tagliaperta, 2020, p.xv). World War I started a new era with oil assuming the role of the main source of energy influencing world equilibriums; in fact, the control of oil resources was the casus belli for several wars in the 20th century, and it was the case, for example, of the 1967-1970 Biafran War, the 1980-88 Iran-Iraq war, the 1990-91 Gulf War, the Iraq War from 2003 to 2011 and the ongoing conflict in Niger Delta since 2004 (Hafner and Tagliaperta, 2020, p.xv). In September 1960 the OPEC (Organization of Petroleum Exporting Countries) was established in Baghdad with the participation of five countries: Venezuela, Saudi Arabia, Kuwait, Iraq and Iran. The aim of this organization was to reach an agreement among its members regarding the oil price to avoid price wars, this by coordinating their production and export policies; however, this organization has also very important geopolitical aspects, in fact it was used as a powerful instrument during the Yom Kippur War, also known as the Arab-Israeli War in October 1973 Hafner and Tagliaperta, 2020, p.xv). In this occasion, "Arab members of OPEC imposed an embargo against the United States, the Netherlands, Portugal and South Africa in retaliation of their support to Israel" (Hafner and Tagliaperta, 2020, p.xv). This operation resulted in a growth of oil prices, as well as oil shortages, causing inflation on the western countries.

This is only one of the many occasions where issues were caused by oil since the 20th century; the issue related to energy security has created two main camps of experts who believe that the energy transition will either increase or decrease the probability and severity of conflicts (Yang, Xia and Qian, 2023, p.688):

- The "increasing conflicts" camp affirms that even though the extensive use of new energy may end the oil wars, it may also cause international economic conflicts in the form of trade wars (cited in Freeman, 2017). Moreover, if the energy transition occurs under conditions of sustained high energy demand, this may lead to situations of energy security vulnerability similar to the ones that characterise traditional energy supplies, such as supply interruptions or geopolitical turmoil (cited in Capellan-Perez *et al.*, 2017). The access to technologies and critical materials required for new energy power generation, distribution, or storage forms a new geopolitical dependence on countries that own these materials, which may lead to new types of conflicts and geopolitical instability (cited in (Hurd *et al.*, 2012; Exner *et al.*, 2015; Habib *et al.*, 2016).

- The "reducing conflicts" camp, instead, sustains that "geopolitical conflicts caused by the scarcity of traditional energy resources will be obsolete in the new energy era" (Yang, Xia and Qian, 2023, p.689). Since energy resources are abundant and not concentrated in few countries, the energy transition will improve its energy accessibility and independence (cited in Francés *et al.*, 2013; Månsson *et al.*, 2015; Escribano, 2019). Moreover, it is stated that "new energy sources have lower density and more uniform geographical distribution, which makes it more difficult to control and cut down new energy supply or manipulate new energy prices" (Yang, Xia and Qian, 2023, p.689). Due to the geographical distribution and technological characteristics of new energy, few countries have triggered conflicts and created geopolitical motives to control it, leading to fairer energy distribution and economic development, reducing geopolitical tensions (cited in Peters, 2003; Tsao *et al.*, 2017).

By now it is clear that oil is no longer the only source of energy, especially nowadays that the world is going towards renewable energies. As it was showed in the previous sections of the document, it is still not clear weather renewable energies will bring the same geopolitical results and consequences of fossil fuels. In particular, Europe has to face several industrial risks related to new technologies, low-carbon technologies value chains, access to markets and tenders, assets such as investments and shareholdings in companies operating in electricity, gas, digital technologies, data-processing and data, cybersecurity, information and image (M.-A. Eyl-Mazzega and C. Mathieu, 2020, p.36). The EU will have to take further actions in order to foster both demand and competitive supply of low-carbon solutions by confronting emerging and established countries such as China and the US (M.-A. Eyl-Mazzega and C. Mathieu, 2020, p.36).

China has defined a "Made in China 2025" strategy, with the aim to dominate and master the energy technologies and as it has been showed by previous data, the country was able and is currently increasing its market relevance and its dominant position in the energetic transition. China, moreover, benefits from its big domestic market which provides economy of scale while competition among state groups is weak (M.-A. Eyl-Mazzega and C. Mathieu, 2020, p.36). There have been also several mistakes of the European Union and some of its Member States, by transferring polluting industries to China and by accepting forced technologies transfers; at the same time, China's state companies have unparalleled investment capacities and are making major investments and acquisitions abroad, especially in Europe ((M.-A. Eyl-Mazzega and C. Mathieu, 2020, p.37).

In most countries, electricity accounts for the 20-30% of total final energy consumption, with Sweden and Norway having electrification rates greater than 40% and according to IRENA, the global demand for electricity will increase by almost 220% between now and 2050 (IRENA, 2024, p.39). In Figure 21 reported below it is possible to observe that some countries have high rates of imported electricity, and this could result also in a lack of domestic production capacity and political instability (IRENA, 2024, p.39).

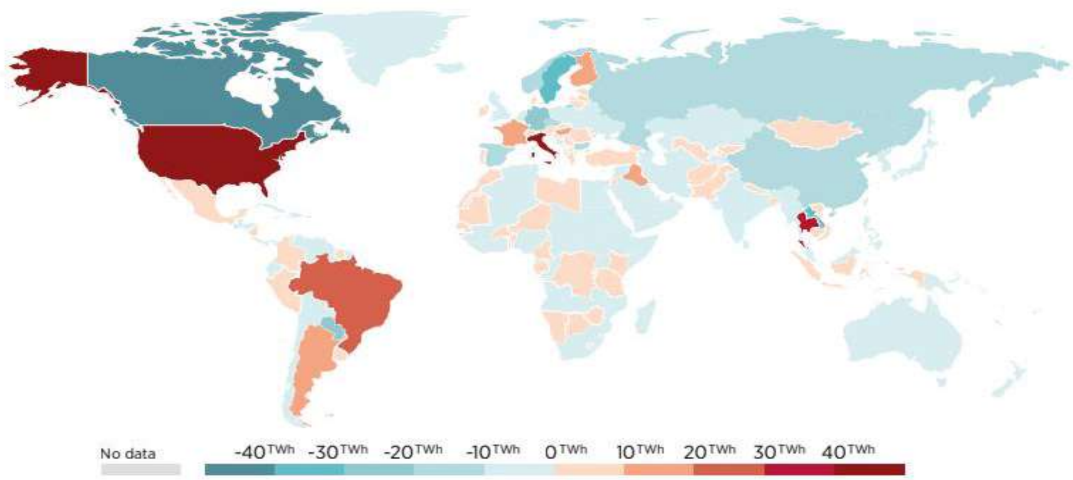

Figure 21: *Net electricity imports in 2022* (Our World in Data, 2023)

"One of the primary challenges in interconnecting grids is synchronisation, a task that involves aligning the frequencies of every generation facility in the connected systems" (IRENA, 2024, p.40). Connecting national grids may cause also shared problems such as "cross-border cascading outages. An issue in one part of the grid, such as a plant failure, could cause a change in frequency to ripple throughout the entire network" (IRENA, 2024, p.40). Another example of interconnected grids' risks are also the deliberate disruptions; even though cuts in electricity exports are rare, a recent example is Russia cutting the exports to Finland in May 2022 over disputes related to sanctions that affected payments, resulting in Finland losing 10% of its electricity supply (IRENA, 2024, p.41). The impacts of these kind of circumstances can be limited as long as importing countries maintain proper capacity margins and significant capability to reduce demand during emergencies; however, "the fact remains that the effects of a cross-border electricity disruption are different from those of an oil or gas disruption" (IRENA, 2024, p.41). The reasons behind this are several: because electricity imports are grid-bound, their loss can be made up only to the extent the existing grid allows, while "electricity is difficult to store in significant volumes and for long time periods. Therefore, non-delivered amounts of electricity would probably require the curtailment of energy-generating capacities" and finally as reported by IRENA, electricity has to be sold and consumed the instant it is produced, so the effects of an export boycott would be immediate and could have significant economic and social effects (cited in Lilliestam and Ellenbeck, 2011).

The geopolitical effects and the geostrategic significance of developing new energy resources is not a recent field of study, but already back in the 1970s-1980s American scholars and experts emphasized a lot the geopolitical aspect and the importance of new energy to the American energy security system (Yang, Xia and Qian, 2023, p.687). For example, "in 1980, the California Academy of Sciences submitted a report to the Federal Emergency Management Agency, which stated that the American energy system (fuel and electricity) was extremely vulnerable, as it relied on energy imports, and was overly centralised, […]. It was argued that the de-centralized new energy could reduce national vulnerability and the possibility of war by replacing fragile centralised traditional energy (CAS, 1980)" (Yang, Xia and Qian, 2023, p.687).

4.2.1 China's role in the energetic transition

As it was showed in the previous paragraph, China is one of those countries who is assuming a crucial role in the supply of critical materials for the energetic transition. Back in 1978, the country an economy worthing half of the Italian one; currently, China's economy is the second largest in the world, with a GDP which grew 24 times from 1978 to 2017 (Meidan, 2020, p.75). The driver of this huge GDP growth can be found in the enormous demand for energy, which increased from under 400 million tones oil equivalent (toe) in 1978 to 3.27 billion toe in 2018 (Meidan, 2020, p.75).

Nowadays, China has achieved a dominant position as global refiner for critical materials, by processing over half of all lithium, cobalt, graphite and rare earth elements (IEA, 2024, p.63). However, a part from graphite and rare earth elements, China is not a major mining centre for the other materials, meaning that the security of supply of these materials is a critical concern for China as well (IEA, 2024, p.63). Therefore, China invested a lot into the mining sector, both at a domestic and international level; as a result of this, in 2023 China's investments in the metal and mining sector reached 19.4 billion USD, an increase equal to 160% with respect to 2022 (IEA, 2024, p.63). Out of the seven lithium assets in Africa that are expected to start production in 2027, five have at least a 50% Chinese equity ownership(IEA, 2024, p.63); one of the most important projects was the Arcadia project in Zimbabwe, but China has invested and took ownership of mining projects also in Latin America, where the Chinese CATL won a bid in 2023 to develop Bolivia's resource of lithium, and in Argentina, where the Chinese mining major Zijin Mining acquired the Canadian Neo Lithium to access an important lithium project (IEA, 2024, p.63). Chinese companies do also control nickel mining in Indonesia, which is the world's largest supplier of nickel; in 2024, majority Chinese-owned producers supply over 80% of Indonesia's battery nickel output (IEA, 2024, p.63).

Because of the size of the country and, also thanks to the domestic energetic demand, Chinese companies are becoming more and more global (Meidan, 2020, p.83). However, while these companies have helped to reduce cost, some researchers suggest that they face issues in developing global products and competing in terms of innovation (Meidan, 2020, p.83). Notwithstanding this issues that the country is facing, it is undoubtful that China is changing the geopolitical assets and country relations because of its massive investments in the energy sector; that was the cause of a trade war between US and China. In 2019 "Officials in the US administration including Vice President Mike Pence and Secretary of State, Mike Pompeo have issued increasingly hawkish speeches regarding China's economic statecraft and accusing it of becoming increasingly aggressive and destabilising" (Meidan, 2020, p.86). In fact, before China, it was US to dominate the production of and distribution of REEs but ceded the supremacy in this field to China because of legal constraints on radioactive elements (Hua Fan, Omura and Roca, 2023, p.1) As reported by Hua Fan et al., "Its monopoly on REEs originated from its need for nation-building, its territorial politics with the then Union of Soviet Socialist Republics, and its atomic aspirations (cited in Kilinger, 2017). Of course, what helped significantly China is the low labor cost and its low environmental standards which kept the price of REE exports very low with respect to the competition. Moreover, China has apparently two main strategic objectives in developing its REE industry: "it wants to ensure that it can meet its internal demand for REEs at cheaper costs than the cost it attaches to its exports, and it wants to continue to provide international corporations access to China by allowing them to relocate and keep their production units in China" (Hua Fan, Omura and Roca, 2023, p.2). According to Hua Fan et al. studies, the trade of rare earth elements is highly influenced by the geopolitical risk and that China's dominance of the entire REE supply chain poses a risk to the continuity of many industries that rely on these critical inputs (Hua Fan, Omura and Roca, 2023, p.9). Moreover, the channels through which China's policies can impact the West's production and supply chains include squeezing competitor margins, discouraging recycling, and eroding the need for strategic stockpiles (cited in Ferreira and Critelli, 2022).

Further studies always conducted by Hua Fan et al., use a new index variable that measures the geopolitical risk (GPR) and its impact on the trade and price of rare earth materials; this index was developed by Caldara and Iacoviello (2022), and it constructed using text-search algorithms that count the number of geopolitical-risk-related articles from major American and international newspapers 14 during a time-period […]. This number is then divided by the overall number of news articles to measure geopolitical uncertainty (Hua Fan, Omura and Roca, 2023, p.6). Through their studies they found that "the REE trade is strongly influenced by geopolitical risk and that China's dominance of the entire REE supply chain poses a risk to the continuity of many industries that rely on these critical inputs" (Hua Fan, Omura and Roca, 2023, p.9). Ferreira and Critelli (2022), summarizes that "the channels through which China's policies can impact the West's production and supply chains include squeezing competitor margins, discouraging recycling, and eroding the need for strategic stockpiles" (Hua Fan, Omura and Roca, 2023, p.9).

In 2020, China's REE production accounted for the 58% of the total (cited in U.S. Geological Survey, 2021), and to reduce the supply risk, countries are striving to find new REE resources and develop related technologies (Zhang, Wang, Tang and Guo, 2022). In Figure 22 it is possible to understand how the export of REEs material is distributed at a worldwide level in 2020; China, US, Germany and Japan are the countries who export the biggest amount of rare earths (Zhang et al., 2022, p.6).

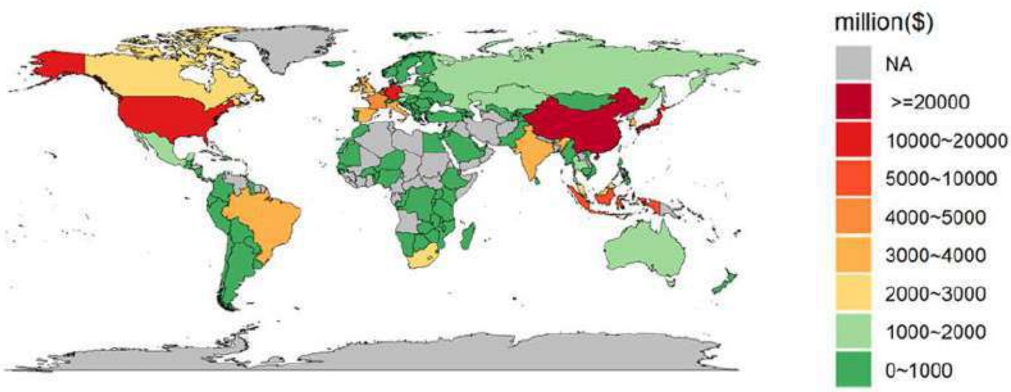

Figure 22: *Global rare earth products export value in 2020* (Zhang et al., 2022, p.6).

The trend of REE trade competition network shows that from 1996 to 2020 it increased significantly the competition between exporter countries, meaning that "the RE export market was expanding and more competitive relations were formed between exporters" (Zhang et al., 2022, p.8). It has to be said that most of the 17 rare earth materials are not geologically rare, but they are expensive and polluting to mine and produce, leading the US to limit production and allowing China to rise predominance over rare earth production since the 1990s (Meidan, 2020, p.87). Even though some efforts are being made by competitors, for example by creating cobalt-free batteries, China was able to improve its geopolitical standing in several aspects (Meidan, 2020, p.87). In fact, "by producing more of its own energy, China is reducing its reliance on fuel imports and the risks of energy disruption which could put a brake on its economic ambitions" (Meidan, 2020, p.87). Moreover, China's investments along the BRI, could profoundly shape the geopolitics of energy; the US has shaped and safeguarded fossil fuels trading routes, while China could shape power networks going forward (Meidan, 2020, p.87).

Since the early 2000s, China's emergence as a global economic power and energy consumer has changed the geopolitical landscape of oil and gas, however, Beijing was aware of the strategic vulnerabilities associated with its strong dependence on imports and therefore it has supported and funded several projects in order to turn Chinese in global leaders in the technologies for the energy transition (Meidan, 2020, p.88). More recently, China was particularly worried about the so called "Malacca Dilemma", which is the narrow strait leading past Singapore and into the South China Sea (Yergin, 2020, p.2). In fact, in 2017 China became the world's largest oil importer, with 80% of these imports passing through the Strait of Malacca, "which is a narrow stretch of water between the Indonesian island of Sumatra and the Malay Peninsula and with Singapore, a major US ally […], located at the mouth of the strait's eastern opening, making the Strait of Malacca a natural strategic chokepoint" (Khan, A. 2022).

Figure 23: *The Strait of Malacca and the Indonesian archipelago* (Khan, A. 2022)

As can be seen in Figure 23, the Strait of Malacca can easily be blocked by a rival nation, making much more problematic the import of energy resources for China (Khan, A. 2022). Even though China has deeply invested in alternative solutions for its imports, like for example the economic corridor going from the city of Kashgar, passing through Pakistan and reaching the port of Gwadar on the Arabi Sea, the country will still be highly dependent on the Malacca Strait (Khan, A. 2022).

That is why China is pushing and investing so much in new energy resources, and how it was showed in the previous paragraphs, the country is achieving a dominant position in the supply of all the critical materials necessary for the green transition. In fact, as reported by Gong, X. (2022), China is trying to transform its leadership in developing renewable energies and in building global energy interconnections into a geopolitical leverage, by integrating its dominance in the renewable energy sector into national security strategies to achieve an advantageous position in geopolitical competition for power (cited in O'Sullivan et al.). It is expected that China will ultimately transform its economic predominance into a political leverage and will impose its political ideas on other states (Gong, X., 2022, p.6); thanks to the big investments in Central Asia, China was able to take the place of Russia as the leading economic presence, in the Region. In fact, according to several researches reported by Gong, X. (2022), through the BRI energy cooperation, China will be able to control regional energy distribution by playing a key role in investments on oil and gas pipelines, power grids and storage facilities. In the end, the electricity interdependence led by China will help the country to exercise its influence over Central Asia, South Asia and the Middle East (Gong, X., 2022, p.6). China's power investments in Laos may also represent examples of how host states are captured by China; in fact, there are increasing hydropower projects in Laos and this source of energy could be particularly important to the energy security of Laos because the state's electricity supply almost entirely relies on power generated by water (Gong, X., 2022, p.7). This implies that the energy security of Laos could be extremely dependent on China. In a broader sense, it is possible for China to include Laos in its regional economic orbit by leveraging hydropower projects there (Gong, X., 2022, p.7). Because of these projects, Laos has improved its economic performance and thus the state needs to adjust its behaviour to meet China's interests, especially when the state has been in debt to China (Gong, X., 2022, p.7).

Some G7 countries have launched bilateral development initiatives that aim to reduce the economic dependence of emerging markets and developing countries on China (Bian, L. et al., 2024, p.14); For example, as reported by Bian, L. et al., (2024) "the Partnership for Resilient and Inclusive Supply-Chain Enhancement was announced in 2023 by G7 finance ministers to address vulnerabilities resulting from the high geographical concentration of supply chains. Following the launch of the Build Back Better World initiative by the US, the creation of the Indo-Pacific Economic Framework for Prosperity (IPEF) supports sustainable and resilient economic growth in ASEAN countries, including through strengthening the resilience of regional supply chains in the 14 IPEF member countries, comprising Australia, Brunei, Fiji, India, Indonesia, Japan, Republic of Korea, Malaysia, New Zealand, Philippines, Singapore, Thailand, Vietnam and the US" (cited in Asia Society Policy Institute, 2023). In general, Asiatic countries are performing better than other emerging markets in catching up with frontier value added manufacturing (Bian, L. et al., 2024, p.14) mainly because of the high value of inflows from foreign direct investments driven by investments in infrastructure for information and communication (ICT), enhanced skills, R&D, and a conducive business climate (Bian, L. et al., 2024, p.17).

To conclude the paragraph on the role of China in the energetic transition, it can be clearly defined that the country will be one of the most important players in the upcoming years, thanks to its huge investments for mining and refining activities of critical materials necessary, among the other things, for the production of the components of electric vehicles. In fact, "China already dominates in lithium, the necessary ingredient for batteries for electric cars. Though lithium is mined in a number of countries, China stands atop the entire supply chain, with over 80% of the world's battery manufacturing capacity. And a world that turns increasingly to solar power will run largely on goods made in China. China's solar manufacturing juggernaut has driven down solar costs dramatically over the past decade, with China now the source of almost 70% of the world's solar panels" (Yergin, 2020, p.3). It seems therefore that the European Green Deal is going to advantage Chinese global energy strategy and its geopolitical power, making the European continent dependent on Chinese resources; this may seem not a wise decision taken by the European council, since one of the aims of this package of directives is to achieve a certain level of independence from Russians and Arabians energy resources, but with this new industrial plan Europe appears to become dependent on Chinese resources, letting the country also to easily enter the European automotive market with competitive advantages in terms of price with respect of competition because of the vats control over the supply of critical materials. It is interesting, therefore, to analyse what can be the role of Europe in this new energy industry, with changing geopolitical and trade powers and equilibriums to understand whether there are more opportunities than risk for the old continent.

4.2.2 Europe position in the energy transition and its geopolitical role

As anticipated at the end of the previous paragraph, the energy transition will reduce the European dependence on fossil fuels imports, but at the same time it will create new dependencies on key inputs for clean energy technologies (Giuli, M., and Oberthür, S. 2023, p.152). As reported by Giuli, M., and Oberthür, S. in fact, in the EU public discourse, analogies are increasingly being made between the risks associated with reliance on CEMs (Critical energy Materials) and those linked to oil and gas dependence (cited in (Simon 2018 and Breton 2022). It was found that the past literature put very low attention on the implications of the EUs climate priorities and policies for its position in the geopolitics of energy, focusing, instead, mainly on the case of natural gas, where relations between the EU and Russia, a major supplier, have been highly contested (Giuli, M., and Oberthür, S. 2023, p.153). Moreover, this literature has not elaborated on what the European and global clean energy transition will mean for the EU′s overall position in the geopolitics of energy compared to the still dominant fossil fuel-based system (Giuli, M., and Oberthür, S. 2023, p.153).

First, what should be taken into account is the country's level of external dependence, which is commonly measured as the share of consumption met by imports (Giuli, M., and Oberthür, S. 2023, p.155). The level of external dependence, as well as the level of concentration of supply, may cause political problems depending on the partnership quality (cited in Månsson et al. 2014). Three aspects should be considered when dealing with relationship with key energy suppliers:

first, the level of institutionalisation of the EU's general relationship with key suppliers it is supposed to shape the geopolitical risk linked to the energy dependence: a dense or even hierarchical institutionalisation of the relationship may constrain the suppliers' ability to politically instrumentalise external energy dependence (Giuli, M., and Oberthür, S. 2023, p.155). Second, the nature of the political systems of major supplier countries is another element which profoundly affects the relationships with them; hence, authoritarian countries might be more prone than democratic systems to politically instrumentalise the EUs energy dependence, as they have greater political control of their economy (Giuli, M., and Oberthür, S. 2023, p.155 and cited in Charokopos and Dagoumas 2018) and are more likely to have a tense political relationship with the EU, which is a democratic system that values the rule of law. Third, the ability of large suppliers to instrumentalise energy interdependence can be expected to vary with the more general distribution of economic power resources as indicated by market size. Specifically, the EU may exploit its market size to balance any asymmetric interdependence in the energy field (Giuli, M., and Oberthür, S. 2023, p.155) (cited in Damro 2012).

Also, the material features of the energy materials affect the sensitivity of importers to supply disruption; in fact, the effect of similar disruptions depends on the general economic relevance of the goods concerned, since the disruption of certain energy goods only affects specific parts of the economy, the disruption of other goods may pose a systemic risk by triggering a cascading of events across the whole economy (Giuli, M., and Oberthür, S. 2023, p.155). Not only, the sensitivity to supply disruption varies depending on the quantitative level of demand for and on the techno physical properties of energy materials, which affects their logistical flexibility (Giuli, M., and Oberthür, S. 2023, p.155).

For what regards the vulnerability dimension reported by Giuli, M., and Oberthür, S., they sustain that a country or an actor can shape its vulnerability by implementing appropriate policies and measures (cited in Keohane and Nye 1977). They continue to affirm that several policies options to address vulnerability on the supply and demand side can be identified (cited in Stirling 2010 and Dannreuther 2017):

1) Import substitution, meaning the replacement of imports with domestic sourcing to reduce external dependence;
2) Diversification of supply to reduce supply concentration or raise the share of suppliers with institutional and political relations with Europe;
3) Stockpiling of imported material in order to face the impact of potential supply disruptions and the necessity to access materials on foreign markets in times of scarcity or high prices;
4) Efforts to further institutionalize and develop relations with key supplier countries to reduce the risk of geopolitical instrumentalization of energy and interdependence;
5) Demand-side measures, such as support for research and innovation, to enhance material efficiency, recycling or material substitution as a means of reducing the need for imports.

In Table 5 it is possible to have an overview of the indicators used to assess the sensitivity and vulnerability dimensions of interdependence in energy geopolitics. In fact, while factors can be analysed individually, a full appraisal of interdependence requires all factors to be looked at together, taking into account the manifold trade-offs and interactions (Giuli, M., and Oberthür, S. 2023, p.156).

Interdependence dimension	Indicator	Measure
Sensitivity	*External dependence*	Imports as share of domestic consumption Supply concentration
	Partnership quality	Institutionalisation of relationship Political systems of suppliers Market size of suppliers
	Material features	Degree of impact of supply disruption Logistical flexibility
Vulnerability	*Import substitution* *Diversification* *Stockpiling* *Institutionalisation* *Demand-side measures*	Record and prospects of relevant policy measures

Table 5: *Analytical framework: key aspects of energy interdependence* (Giuli, M., and Oberthür, S. 2023, p.156).

Continuing their analysis, Giuli and Oberthür sustain that the level of external dependence regarding CEMs is at least as high as for fossil fuels; in fact, while Europe relies on imports for about 90% of its gas consumption, 97% of crude oil consumption, and 69% of its coal consumption in 2019, the corresponding rate exceeds the 70% for most of the critical materials, with the only exception of hydrogen (Giuli, M., and Oberthür, S. 2023, p.158). The concentration of external EU suppliers is even higher, however, for CEMs than for fossil fuels, since the "aggregate supply concentration index" (ASCI) for fossil fuels in 2019 ranged from 10 (coal) to 17 (natural gas), it exceeded 30 – a critical threshold, according to the EU – for many CEMs between 2012 and 2020" (Giuli, M., and Oberthür, S. 2023, p.158). The prospect regarding the supply of critical materials is much more varied than the one of fossil fuels; on the one hand, in fact, "a large share of these materials reserves (including lithium, natural graphite, borates and copper) are located in countries that nurture highly institutionalised relations with the EU and/or possess democratic governance systems (including Chile, Norway, Australia, Turkey and others)" (Giuli, M., and Oberthür, S. 2023, p.158). On the other hand, however, some material reserves, such as rare earth materials and cobalt, are concentrate din countries with autocratic or hybrid political systems and a low institutionalisation of relations with the EU (Giuli, M., and Oberthür, S. 2023, p.158). In fact, as it was reported several times in the previous paragraphs, China controls the supply of most of these materials, and the EU's dependence on REEs supply from China seems to be quite problematic.

The CEMs' material features suggest that the EU is less sensitive to supply disruptions than in the case of fossil fuels, since, as reported by Giuli and Oberthür, the consequences of a supply disruption of CEMs would be limited to specific sectors and economic activities without affecting the regular functioning of an energy system (cited in (Krane and Idel, 2021). Moreover, "given the diversity of suppliers of the different CEMs, it is highly unlikely that the supply of all or a large part of CEMs would be disrupted at the same time (Giuli, M., and Oberthür, S. 2023, p.160). The impact of supply disruptions is further mitigated by the fact that many CEMs can be substituted (so far with particular difficulty: lithium and REEs), even if at the expense of a reduced performance and higher costs" (Giuli, M., and Oberthür, S. 2023, p.160).

It has to be noted, however, that as Giuli and Oberthür report, rare earths and lithium are very difficult at the moment to be substituted, and they are key materials for the energy transition in general and in particular for the transition in the automotive sector, since how it was discussed in the previous paragraphs, these materials are fundamental for the production of batteries for electric vehicles. The two authors continue to affirm that with respect to fossil fuels, there is a greater logistical flexibility of several CEMs being it a result of the lower sensitivity of the lower supply disruptions; in fact, "Since import volumes are limited and many CEMs are solid rather than gaseous, the effects of potential supply disruptions can be mitigated through stockpiling (Giuli, M., and Oberthür, S. 2023, p.160).

Analysing the EU vulnerability for the supply and demand of these critical materials, Giuli and Oberthür sustain that the possibility of import substitution by increasing the domestic production of CEMs is limited at the same level of fossil fuels. In fact, in Europe the endowments of critical materials are as low as the ones regarding conventional fossil fuels reserves (Giuli, M., and Oberthür, S. 2023, p.160). Moreover, because of several barriers such as issues related to regulatory style (cited in Barteková and Kemp, 2016), national permitting procedures (cited in Schüler et al., 2018; Regueiro and Alonso-Jimenez, 2021) and the lack of public acceptance of mining activities (European Commission 2020b), it is expected that the domestic production of most of the critical materials will decrease in the period between 2020 and 2050 (cited in KU Leuven and Eurometaux, 2022) (Giuli, M., and Oberthür, S. 2023, p.160).

As reported in the previous paragraphs in this document, also Giuli and Oberthür sustain that the production capacity of clean energy products faces substantial challenges. In particular, the Eu possesses a more limited capacity for industrial policy than its main competitors (Giuli, M., and Oberthür, S. 2023, p.160). With a growing geopolitical and geoeconomic competition both US, and particularly China, have mobilised substantial state support to bolster domestic clean energy value chains; by contrast, the EU lacks capabilities in industrial policies and "the support and incentives from the EU and its member states are still at an embryonic stage and have focused on networking and information-sharing initiatives" (Giuli, M., and Oberthür, S. 2023, p.161). However, options for a diversification of imports seem to be more significant;

according to Giuli and Oberthür, while the concentration of reserves imposes limits, there is scope to diversify supply, as CEM reserves are generally less concentrated than current supplies. Because of this, the diversification of supply of minerals is established as an EU objective (cited in European Commission 2020e) and the Commission has underlined that "the EU is currently negotiating Free Trade Agreements with a number of important countries from a raw material perspective" (cited in European Commission 2020e, 15) (Giuli, M., and Oberthür, S. 2023, p.161). Stockpiling it is expected to be easier for CEMs than for fossil fuels; in fact, "quantities are significantly lower, and the transport and storage of mostly solid CEMs do not require complex infrastructure", with the exception of hydrogen that may present technical storage challenges similar to those associated with natural gas (Giuli, M., and Oberthür, S. 2023, p.161).

Europe has also the opportunity to establish significant partnerships with key suppliers of critical element materials; in fact, even though the Europe success in building close partnerships with suppliers of fossil fuels was limited, there is a good basis for developing closer relationships with several potential large CEM suppliers such as Australia, South Africa, the US or the Mercosur area (Giuli, M., and Oberthür, S. 2023, p.161). "Europe has already has already signed memoranda of understanding on CEMs with Canada, Ukraine, Kazakhstan and Namibia" (Giuli, M., and Oberthür, S. 2023, p.161). These agreements seem to be more promising than agreements with fossil fuels suppliers mainly for three reasons:

1) "Several prospective CEM suppliers are already close EU partners";
2) "In most prospective partner countries, CEM extraction and exports play a much smaller role in the economy than oil and gas do in petrostates";
3) "The EU has common external policy instruments at its disposal, such as trade and development policies (cited in European Commission 2019). It has already pushed for the removal of constraints on CRM exports in the accession protocols of the World Trade Organization and in trade agreements with key suppliers" (Giuli, M., and Oberthür, S. 2023, p.162).

Giuli and Oberthür sustain that while reduction in fossil fuels demand did not lead to a reduction in external energy dependence, "most CEMs are generally recyclable and substitutable, which can be enhanced through regulation, financial support, and research and innovation". Currently recycling rates for CEMs do vary significantly (cited in Joint Research Centre 2022), and in particular, rare-earth materials are very difficult to recycle as the relevant end products contain very small amounts and mixtures with other metals change over time (cited in Jowitt et al., 2018) (Giuli, M., and Oberthür, S. 2023, p.162). However, as reported by Giuli and Oberthür, "with appropriate policy support, recycling rates of raw materials used in batteries in Europe may reach 50-60 per cent, 10-30 per cent for wind turbines by 2040 (cited in Rizos and Righetti 2022) and significantly higher rates by 2050" (cited in KU Leuven and Eurometaux 2022).

Battery recycling, for example, has been made a priority area in the Circular Economy Action Plan (cited in European Commission, 2020); "the European Parliament and the Council reached a provisional agreement on the Battery Regulation, foreseen to take recovery rates to 90-95 per cent by 2025 and 2030 for cobalt, nickel and copper, and to 50 per cent by 2027 and 80 per cent by 2031 for lithium" (Giuli, M., and Oberthür, S. 2023, p.162).

To conclude the paragraph regarding the European position in this new energy system, according to Giuli and Oberthür, the continent is going to improve its position in the geopolitics of energy; in fact, "while still significant, future clean energy-related international dependencies are likely to be an order of magnitude less than current fossil fuel-related dependencies" (Giuli, M., and Oberthür, S. 2023, p.163). The EU sensitivity to critical energy material supply disruptions is less sensitive than in the case of fossil fuels since "while the EU is at least as dependent on external supplies of CEMs as it is on fossil fuels, a significant part of the supply of (raw) CEMs can be sourced from non-authoritarian countries with which the EU has close trade relationships [...]" (Giuli, M., and Oberthür, S. 2023, p.163). The vulnerability to supply disruptions remains in any case quite high for Europe, even though it has the possibility to reduce it thanks to the several policies options at its disposal; the EU can diversify supplies and foster closer relations with supplier countries (Giuli, M., and

Oberthür, S. 2023, p.163). The supply of rare earth materials and hydrogen could be more problematic to manage with respect to other critical materials since REE supply is dominated almost entirely by China while hydrogen supply is logistically challenging (Giuli, M., and Oberthür, S. 2023, p.163).

Therefore, important challenges remain for the EU since “its ability to shape outcomes will also depend on its response to broader geopolitical developments and challenges”. The mastering of clean energy technology is an element that will bring important implications, increasing geopolitical contestations and implying a growing appetite for interventionist industrial policies, where the EU has comparatively limited capacities. This is particularly relevant since CEMs are not only imported by Europe as raw products but also in refined form and in components of clean energy products, with China holding a very strong position (Giuli, M., and Oberthür, S. 2023, p.163).

Chapter 5: how can the AI help the European automotive industry to increase its market competitiveness

The three industrial revolutions deeply changed the way manufacturing of goods is conducted, going from complete manual production “to producing those operating machines and finally mass production of goods using organized production and assembly lines” (Kamran et al., 2022, p.4207). However, with the ever-advancing technology and man desire to achieve maximum comfort, it becomes inevitable to develop systems capable of completely replacing humans and completing a task independently; this led to the development of artificial intelligence (AI), which consists in machine or software programs that possess the ability to think, understand and to make decisions (Kamran et al., 2022, p.4207).

One of the industries that will be profoundly changed is the automotive one, which will be transformed with the employment of more sophisticated AI systems. However, differently from other sectors; in fact, also the designing work and several aftersales services have great potential for applying AI (Kamran et al., 2022, p.4208). Sophisticated AI systems can forecast future happenings of certain events up to a certain degree and based exactly on the level of sophistication, AI can be broadly classified into four categories (Kamran et al., 2022, p.4208):

1) Reactive AI: that is the most straightforward AI system capable of providing expected output based on the type of input supplied; such AI systems always give the same output for identical inputs and they are not capable of learning and evolving by observing and analysing the actions or experiences of the past;
2) Limited Memory AI: this is the most common type of AI used nowadays, and it can learn from past experiences or actions and change the output accordingly. This kind of AI is used in driverless cars where it enables the vehicle to map the surroundings by observing the speed and direction of other vehicles and objects present around it. Limited memory AI is the most suitable for self-driving cars because it can retain the information for a limited time-period and after the car has crossed that part of the road the data surrounding objects are lost and new data can be learned;
3) Theory of mind AI: this type of AI is considered truly intelligent and it is capable of performing human-like tasks like making decisions depending on the surrounding. It is capable of perceiving emotions and adjust its behaviour accordingly. This type of AI is used in robots that can interact with humans like any other human being;
4) Self-aware AI: this is the most sophisticated type of AI and it is still only a theoretical concept; technology, it is not far from its development, however, at the moment, there are no hardware or softwares to develop such highly sophisticated AI.

According to a McKinsey report conducted by Matthias Breunig, Matthias Kässer, Heinz Klein, and Jan Paul Stein, over the next two decades, artificial intelligence will enable autonomous vehicles to become mainstream; "the McKinsey Global Institute has found that robotics and AI technologies such as machine learning have advanced to the point where it would be possible to automate at least 30% of activities in about 60% of occupations in both the United States and Germany" (Breunig et al., p.1). McKinsey continues to sustain that the artificial intelligence will improve different areas in the auto manufacturing sector:

1) Less equipment failure: in fact, AI-based algorithms can digest masses of data from vibration sensors and other sources, detect anomalies, separate errors

from background noise, diagnose the problem, and predict if a breakdown is likely or imminent. The impact it is expected to result in a 20% increase in equipment availability, up to 25% lower inspection costs and up to 10% lower total annual maintenance costs (Breunig et al., p.3);

2) More productive employees through robot-human collaboration. Greater computing power and better algorithms will lead to the development of flexible non special purpose robots that can collaborate with humans while reacting to changes in their environment with less configuration. The impact will be that collaborative robots will simplify factory design by reducing the need for robot only areas, and since instructing these robots will be simpler, companies will save money on development and deployment costs (Breunig et al., p.3);
3) Fewer quality problems: quality control is often performed by human workers and therefore this method is more prone to errors, while being also relatively slow. Also automated methods can break down due to numerous variables in the test environment, while AI-enabled visuals QC (quality control) can filter out several issues to focus on defects only; this AI system can learn constantly to improve its analysis based on feedback. This has a positive impact in the way that Ai-based machines can detect defects up to 90% more accurately than humans; insights from AI-based quality testing can also be used to analyse root causes of defects and improve overall production processes (Breunig et al., p.3);
4) Leaner supply chains: accurate forecasting is fundamental to achieve a close match between demand and supply, but traditional forecasting and replacement systems can face several issues related to the big amount of data that they have to manage and to the increasing number of influencing factors. AI system can be exploited to meet these challenges by using machine learning to produce more accurate demand forecasts since AI-powered supply chains have the flexibility to adapt and respond to changes in the product mix or unforeseen events. As stated in the McKinsey report, "AI will allow fully automated self-adjusting systems to make supply-chain management decisions autonomously, adjusting routes and volumes to meet predicted demand spikes". The potential impact of AI-based forecasting systems is expected to result in a reduction of

forecasting errors by 30 to 50% and it could also reduce inventories by 20 to 50%, leading to a cascade of cost savings by eliminating the transport, warehousing and supply-chain administration of unneeded goods (Breunig et al., p.4);

5) Smarter project management: AI-based methodologies can improve R&D project prioritization and increase performance within individual projects, thus liberating budgets and raising overall efficiency (Breunig et al., p.4);
6) Improved business support functions: AI has high potential to automate tasks such as IT or finance that are already supported by computer systems. For example, "on an IT service desk, codified problem-solving strategies and knowledge (such as server configuration) can be fed into an AI system so it can automatically combine individual pieces of knowledge to build a tailor-made problem-resolution process". Its potential impacts are expected to result in 30% of automation rates within business support functions; for what regards the IT service-desk automation, a degree of automation equal to 90% is possible to achieve. Together with automation there would be greater accuracy and consistency, increased scalability and speed (Breunig et al., p.5).

5.1 How can AI affect the automotive sector and the employment?

According to the ACEA report, "Artificial Intelligence in the automobile industry", artificial intelligence is a key technology for the automobile industry. Currently, AI is being implemented in automotive manufacturing, including design, s upply chain, production, and post-production (ACEA, 2020, p. 24). How can be understood from what has been reported until now, AI is increasingly being applied in automobiles, with autonomous driving being the most well-known example, but it is used also in safety features for vehicles, comfort functions, Advanced driver Assistance Systems (ADAS), warning and driver risk assessments systems, connectivity systems and infotainment systems among the others (ACEA, 2020, p. 24).

AI technology can contribute to increase the level of safety for vehicles, drivers and roads and as acknowledged by the European Commission, connected and automated vehicles can improve road safety by reducing fatality rates in incidents (ACEA, 2020, p.29). Through driver monitoring, road safety will be enhanced;

“recognition/identification, detection of distraction or drowsiness of the driver, systems to alert the driver, etc can all be based on, or improved by, AI technology” (ACEA, 2020, p. 29). AI technology can also improve traffic fluidity by optimizing routes and detecting parking spots; at the same time, gain in terms of driving comfort also can be expected: in fact, “thanks to data processed through sensors and fed into algorithms, both speed and manoeuvring can be adapted to provide smoother navigation in different types of driving situations” (ACEA, 2020, p. 30). Moreover, AI will increase safety in heavy-duty commercial vehicles and it will make logistical flows more efficient together with a greater accessibility, affordability and greater offer (ACEA, 2020, p. 30).

ACEA suggests that Europe should take a take a balanced and sector-based approach to AI; that is, one that ensures that the EU automotive industry and its supply chain – as well as the wider EU industry – is well placed in the global race for competitiveness and is able to preserve its innovation power (ACEA, 2020, p.6). to achieve this, it is not viable a “cross-sectoral horizontal AI initiative to address the way in which automotive products are developed, tested, produced and put on the market”. Therefore, ACEA recommends that European policymakers should refrain from adopting a “one-size-fits-all” approach deal with the challenges posed by the AI (ACEA, 2020, p.6).

In the figure reported below it is possible to see where the AI can be applied in the automotive sector:

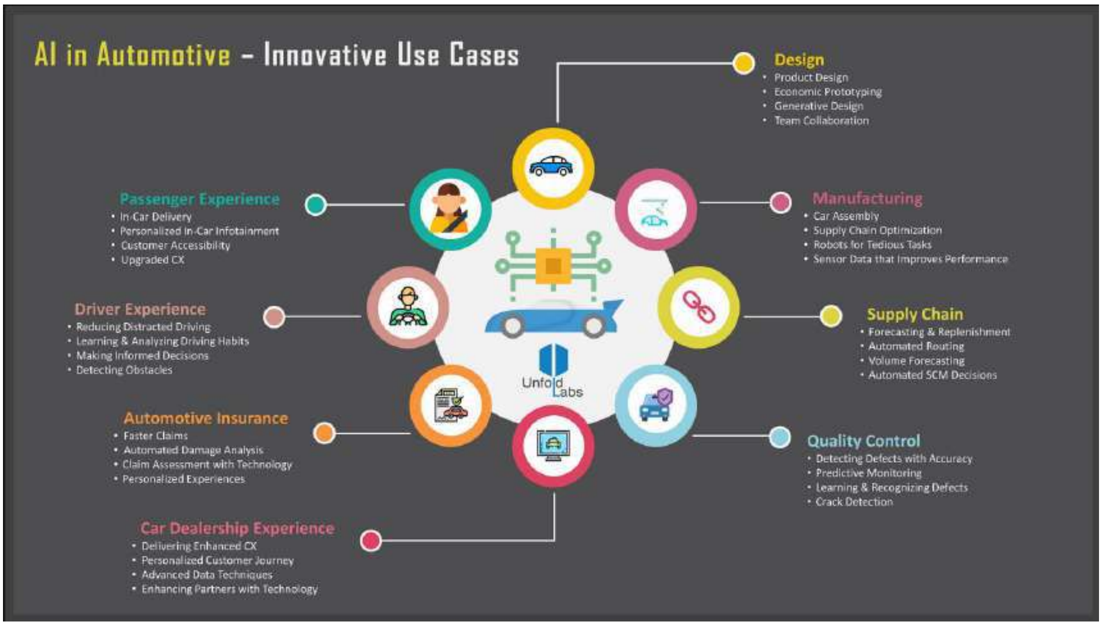

Figure 24: *AI in Automotive – Innovative Use Cases* (CMC Global Company, 2023)

Developments in AI, autonomous technologies as well as the emergence of the Internet of Things (IOT) and robotics are associated with a set of risks that have to be seriously addressed to establish a trustworthy technology (ACEA, 2020, p.14). These risks have been reported by the European Commission White Paper on Artificial Intelligence; in fact, as it is stated, "While AI can do much good, including by making products and processes safer, it can also do harm. This harm might be both material (safety and health of individuals, including loss of life, damage to property) and immaterial (loss of privacy, limitations to the right of freedom of expression, human dignity, discrimination for instance in access to employment), and can relate to a wide variety of risks" (European Commission, 2020, p.10). Citizens and legal entities will increasingly be subject to actions and decisions taken by or with the assistance of AI systems, which may sometimes be difficult to understand and to effectively challenge where necessary (European Commission, 2020, p.11).

In order to face all of these problems, an extensive body of existing EU product safety and liability legislation, including sector-specific rules, further complemented by national legislation, is relevant and potentially applicable to a number of emerging AI applications (European Commission, 2020, p.13).

But as stated previously, AI based technology systems can help significantly the automotive manufacturing, being a complementary role in what is called “smart manufacturing”, in a set of five technologies, namely digital twins, additive manufacturing, AI-based monitoring and inspection system, human-robot collaboration, and advanced technology for supply chain (Lee et al., 2023, p.95). Figure 25 shows the role and relationships of these five technologies:

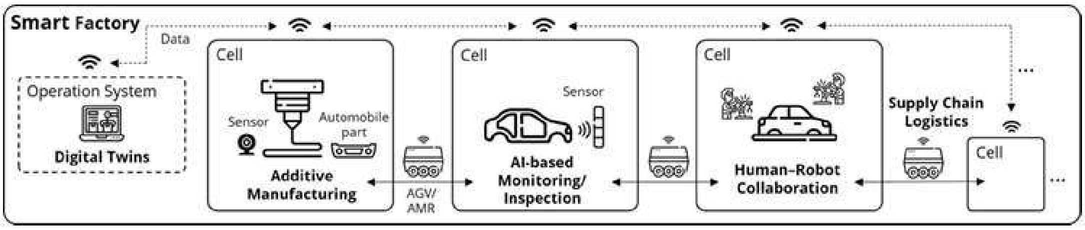

Figure 25: *Overview of the roles and relationships among five technologies for a smart factory* (Lee et al., 2023)

Focusing on what has been defined as AI-based Monitoring and Inspection System, they are used to check and improve the design completeness of parts as well as assembled and finished vehicles (lee et al., 2023, p.98). In most of the Additive Manufacturing processes (AM), often known as 3D printings, trial and error method is still used in order to determine the ideal process window parameters, such as laser power, scanning speed, powder flow rate and hatch spacing, to produce fully dense and defect-free parts (Lee et al., 2023, p. 98). However, “Even when the same process parameters are used, there are still variances in part quality. The heat accumulation and buildup of residual stress can result in defects such as porosities, cracking, and geometric distortions” (Lee et al., 2023, p. 98). “Extensive research has been reported on vision-based porosity predictions, and acoustic-based monitoring for AM utilizing the state-of-the-art AI techniques” (Lee et al., 2023, p. 98). For example, vision information can be used directly to predict porosities, using supervised machine learning (ML) or unsupervised ML approaches. “Another example is surface monitoring using laser line scanning, where the laser triangulation method is used to produce 3D point cloud data of part surface. The surface waviness and geometric distortions can be captured in-process and dimension deviations can be corrected to avoid further deterioration of part quality" (Lee et al., 2023, p. 98).

AI-enabled monitoring can be used also for online and incremental learning, in fact "the state-of-the-art vision and acoustic based in-situ monitoring could achieve high defect prediction accuracy by employing cutting-edge deep learning techniques" (Lee et al., 2023, p. 98). To ensure good performance and reliability when applying to different materials, equipment, or process settings, the models must be re-trained and re-optimized, which is costly and time consuming (Lee et al., 2023, p. 98).

Much of the automobile production process has been automated but the final assembly automation rate is still only 5%; in order to increase the automation rate a collaborative robot (Cobot), known as Human-Robot collaboration has been introduced (Lee et al., 2023, p.99). The scope of Cobot is to assist humans in the assembly or disassembly of components welding, grinding, inspection, as well as a safety control and this type of technology is the most accepted and recognized one in the industry (Lee et al., 2023, p.99).

As can be understood, Cobot technology is already present in the market and "it conducts physical Human-Robot Interaction (pHRI) in a shared environment and effectively takes down the barriers that separate humans and robots" (Lee et al., 2023, p.99). There is also a different technology called Mobile Robotics (MR), which has been used for logistics and loading without pHRI for long time. However, the HRC is fundamental in the vehicles business since it relies heavily on operators since "it not only handles heavy objects continually, freeing workers of manual labor and lowering the need for personnel but it may also be assigned to dangerous and repetitive tasks to reduce the chance of repetitive strain and accidental harm" (Lee et al., 2023, p.99).

Also digitalization and automation of supply chain and logistics are requisite for an automobile smart factory. In particular, "a seamless and flexible inbound logistics system is crucial to enable flexible and resilient production systems in future manufacturing" (Lee et al., 2023, p.99). Automated guided vehicles (AGVs) are the main component of autonomous warehouse system since they can change logistics companies' practices such as picking and loading. For example, Michael Henke et al., proposed an alternative use of AGVs introducing a concept of infrastructure-less logistics; they "addressed that the logistics system did not require investment for infrastructure such as warehouses. Instead, they suggested that innovative and modular systems that were easily set up and dismantled did not adopted. By using the innovative AGVs, loading jobs in warehouses can be dealt with efficiently without scaling up the space size. This is because the vehicles can calculate automatically a new inbound logistics route when the information about load carriers or storage location changes" (Lee et al., 2023, p.99).

Decentralized control system in production and logistics is another technology keyword for future supply chain management. In fact, "the decentralized machine intelligence enables autonomous responses, such as job rescheduling in the context of critical system conditions. For autonomous supply-chain networks, simulation software is utilized to predict disruptions on the transport routes and to select an optimal alternative" (Lee et al., 2023, p.99). As reported by Lee et al., based on the existing literature, five smart factories levels have been identified as fundamental to facilitate smart manufacturing systems in the automotive industry; these five levels are defined as digitalization, connectivity, predictability and analysis, optimization and cognitive and self-recognition and autonomous:

- the first level, the digitalization one, is to gather and convert production data and information into digital platforms (Lee et al., 2023, p.100);
- the connectivity level means connecting and integrating data into a single source and by using the data collected real time monitoring can be feasible in a production system (Lee et al., 2023, p.100);
- the predictability of the third level is instead exploited to predict failures and issues avoiding setbacks as much as possible (Lee et al., 2023, p.100);
- the optimization in level four is aimed at maximize the utilization while minimizing costs, time and inventorying by using cognitive algorithms and prescriptive analysis (Lee et al., 2023, p.100);

- the fifth level deals with the AI-driven fully automated factory. Decisions and control can be conducted without an intervention of engineers (Lee et al., 2023, p.100).

Figure 26 shows the selected keywords and descriptions to materialize smart factories depending on the levels:

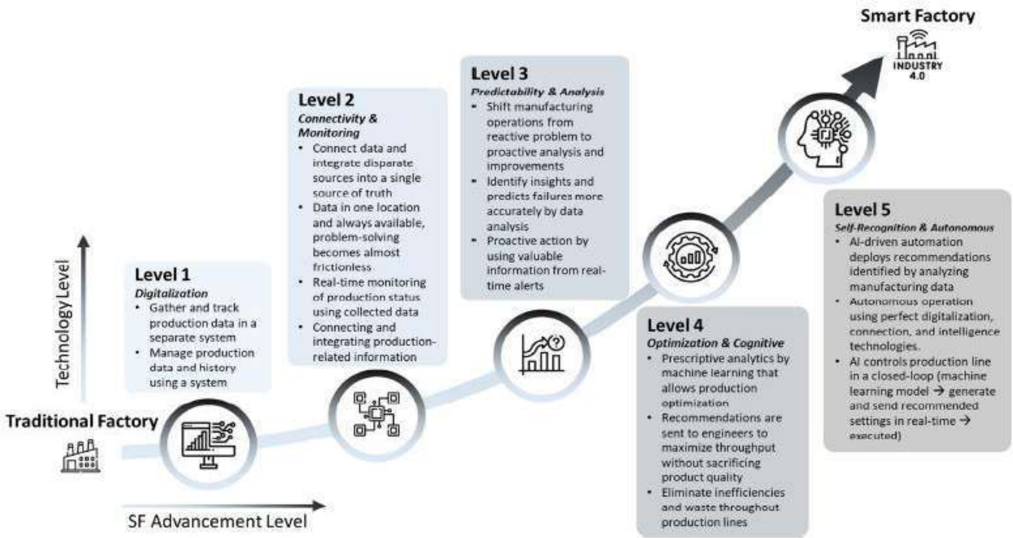

Figure 26: *Details on SF operational characteristics, necessary technologies, and application cases* (Lee et al., 2023, p.100).

Artificial intelligence is also a key element that can help OEMs to improve the sustainability of their supply chain management; in fact, as sustained by Dumitrascu O., Dumitrascu M., and Dobrotaˇ, by using data mining, "the relationship between certain problems that appear in the supply chain management of every company and specific KPIs can be identified" (Dumitrascu O., Dumitrascu M., and Dobrotaˇ, D., 2020, p.1). According to their research result, they suggest that "every company should measure the five most relevant KPIs of every subsystem" and that by measuring these KPIs there will be an improvement "in the supply chain management performance by taking actions in order to avoid future problems, improve existing processes and provide better risk assessment, quicker risk communication, improve risk management and increase the sustainability of the system" (Dumitrascu O., Dumitrascu M., and Dobrotaˇ, D., 2020, p.14). Among the most important problems that have been noted during the research, "communication issues, such as deficient communication, poor inter-departmental communication, deficient client communication, high focus on reduced costs, untrained workforce and lack of workforce, undefined procedures and documentation and delayed deliveries" particularly stand out, and they are the root cause for several problems that appear in the supply chain management (Dumitrascu O., Dumitrascu M., and Dobrotaˇ, D., 2020, p.14). To validate the relationship and influence between KPIs and some problems identified in the supply chain management system, "the multilayer perceptron (MLP) artificial intelligence algorithm of data mining is used, developing a mathematical model based on neural networks" (Dumitrascu O., Dumitrascu M., and Dobrotaˇ, D., 2020, p.15). In fact, thanks to this algorithm, "the top selected KPIs are linked to certain specified problems, a fact that validates, also, the hypothesis of the research, through which every KPI is linked to a specific problem of the supply chain management system". Therefore, thanks to the usage of this algorithm, it is possible to predict which KPI should be able to predict which KPI should be used following the identified problems within the organisation (Dumitrascu O., Dumitrascu M., and Dobrotaˇ, D., 2020, p.15). Finally, "the need to analyse the top five most relevant KPIs for every SCM subsystem is identified as a future research direction in order to allow the learning algorithm to obtain a brief overview for the most important KPIs linked to the selected problems appearing within an organisation" (Dumitrascu O., Dumitrascu M., and Dobrotaˇ, D., 2020, p.16).

Therefore, an integrated information flow can be achieved in order to generate the top KPIs that an organization should use based on the input data in the graphical user interface, which codes the values to allow the neural network to provide the needed KPIs into a dashboard as a KPI-monitoring system (Dumitrascu O., Dumitrascu M., and Dobrotaˇ, D., 2020, p.16).

Artificial intelligence is going to sensibly affect also the employment in the automotive industry, since "the production of AI is a labour-intensive process, which particularly needs the little-qualified, inconspicuous and low-paid contribution of "micro-workers" who annotate, tag, label, correct and sort the data that help to train and test smart solutions" (Tubaro, P., Casilli, A., 2019, p.333). In fact, according to the analysis carried out by Tubaro and Casilli, production processes for AI will be highly labour-intensive and it will rely not only on highly qualified engineers, but also on the less visible contribution of little qualified, low-paid people who toil to ensure the "last mile" (cited in Gray and Sury, 2017). As reported by Tubaro and Casilli, "this inconspicuous, low-profile human activity behind AI is known as "microwork", a notion that encompasses a range of small, fragmented tasks performed remotely online by large numbers of providers. Such tasks consist, for example, in identifying objects on a photograph, sorting items in a list, answering simple questions, transcribing or copying short texts, or adding labels to images" (Tubaro, P., Casilli, A., 2019, p.334).

This kind of micro-workers are recruited through dedicated platforms and they act as intermediaries in two-sided markets where clients are AI or data-hungry companies on one side and the workers on the other one. Usually, they are not employed but independent contractors paid by piece-rate, with varying levels of activity and engagement (Tubaro, P., Casilli, A., 2019, p.334). Many of these workers come from countries with emerging economies such as India, Indonesia and the Philippines, "and a recent surge in participation from crisis-affected areas such as Venezuela (cited in Schmidt, 2019).

The automotive industry has become one of the largest clients of digital data-related micro-working services, notably for the development of autonomous vehicles and of connected cars (Tubaro, P., Casilli, A., 2019, p.335), and this result is showed by the fact that micro-tasks integrated in long supply chains is no longer limited only to digital industries, but it reached out also core economic sectors, where major tech companies such as Google and Uber now compete with established car manufacturers worldwide (Tubaro, P., Casilli, A., 2019, p.335). Currently, AI solutions for the automotive industry rely on machine learning; that means that algorithmic models are developed and that they are intended to learn a solution based on data, without that solution being explicitly programmed. In recent years, in autonomous vehicles, machine learning has been widely adopted "even for simple rule-based behaviours such as "slow down if a pedestrian crosses the street" requires recognizing a pedestrian, a trivial task for humans, an extremely complex one for a computer" (Tubaro, P., Casilli, A., 2019, p.339). In order to achieve these results, "machine learning algorithms need not only large sets of images of pedestrians, but also labels that tell them what these images are whether they show pedestrians at all, how many of them, where precisely they are positioned in the picture, among the other things" (Tubaro, P., Casilli, A., 2019, p.339). This is the moment when the micro-workers enter the scene; in fact, platforms send those images to their online micro-task executors, who identify and label everything that can be seen in every image. This type of job is very huge because the machine can only learn from large amounts of data, and it would be tedious and lengthy to annotate if just one or few workers were in charge, therefore platforms "fragment these large batches into many short, quick-to-do tasks, and allocate them to many providers, each of whom will do just one or few" (Tubaro, P., Casilli, A., 2019, p.339). The type of tasks that autonomous vehicles producers outsource to micro-workers are mainly image classification, object detection or tagging, landmark detection and semantic segmentation (Tubaro, P., Casilli, A., 2019, p.340).

The micro-work phase is not considered to be a passing phase; in fact, even though one may think that "because algorithms "learn", they will grow better and better even at tasks such as labelling, tagging and segmenting images, or categorizing audio datafiles" (Tubaro, P., Casilli, A., 2019, p.341). However, challenges have not disappeared, but companies now "need customized resources, want to tackle nuances and details, and demand a very high level of precision especially in the automotive sector, where a mistake might be fatal" (Tubaro, P., Casilli, A., 2019, p.342). In fact, the huge variety of scenes and situations in which vehicles can find themselves is a reason "why there is a continuing need for new training data that cover, for example, different lighting and weather conditions at different times of the day and year, as well as road circulation modifications due to construction, special events or accidents" (Tubaro, P., Casilli, A., 2019, p.342). Moreover, another reason why human input will still be needed even with better and better AI solutions is the necessity to check the accuracy of those solutions. It can be said, therefore, that micro-work is not expected to disappear in the incoming years, and with the development of AI solutions; what is changing is the type of tasks offered, and a general shift from more general to more specialized platforms (Tubaro, P., Casilli, A., 2019, p.342).

The AI market in the automotive industry is expected to grow in the incoming years, as reported also by Precedence Research in figure 27:

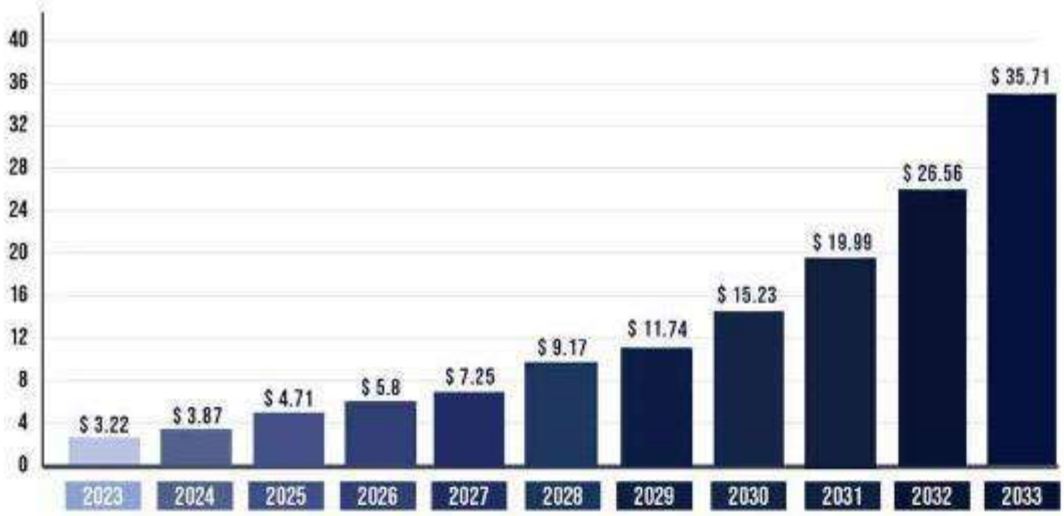

Figure 27: *Automotive Artificial Intelligence market size from 2023 to 2033 in USD Billion* (Precedence Research, 2023).

To conclude the chapter on the Artificial Intelligence presence and development in the automotive industry, "automotive companies are looking to boost their AI capabilities and implementations by investing in startups" (Capgemini, 2019, p.10). These investments are focused on areas where they want to build an economy of scale and stay competitive, including the customer/driver experience and the mobility services. From 2018 to 2019 the investments of OEMs in AI-led startups increased by 60% (Capgemini, 2019). However, as affirmed by Dr. Christian Müller, senior researcher at DFKI (the German Research Centre for Artificial Intelligence), which is a public-private partnership for research on AI, the "European organizations, and the German automakers in particular, are trying to overcome the slower pace of adoption of disruptive technologies. It is harder for them owing to regulations, greater costs of operation, and a mindset of following well defined processes. Despite this, over a longer time horizon, I believe that their process-oriented approach might yield them greater dividends from AI" (Capgemini, 2019, p.13).

Always according to the Capgemini report, large automotive manufacturers can boost their operating profits by up to 16% by deploying AI at scale. In order to effectively scale AI, automakers should focus on some specific aspects (Capgemini, 2019, p.21):

- Focus on high-benefit use cases: for high-benefit use cases it is intended those cases that offer an above average benefit level for their function (Capgemini, 2019, p.21);
- Put in place strong AI governance: it is important "to put in place governance frameworks that allow them to accelerate progress, because they are able prioritize AI investments, secure support from top management, and align the expert resources needed" (Capgemini, 2019, p.22);
- Invest more: scaling AI use cases requires significant resources, ranging from skills to software and these skills and expertise are highly concentrated in innovation hotbeds and cities with a thriving startup ecosystem. A solution for automotive firms would be to acquire AI start-ups (Capgemini, 2019, p.23);
- Hire AI expertise and proactively upskill their employees: "this proactive strategy is critical to building the skills necessary to drive long-term competitive advantage. It can also unlock a performance boost, with our recent research showing that those organizations with scaled upskilling programs report higher levels of workforce productivity" (Capgemini, 2019, p.24);
- Develop the maturity of enterprise IT and data practices: the better performing companies have more mature IT and data practices, harmonizing data collected from a variety of sources, upgrading traditional IT systems to successfully integrate AI (Capgemini, 2019, p.25).

Conclusions

After the study of the documents consulted to write this thesis is possible to have a clearer view of the aspects discussed previously. As can be understood thanks to the European Council documents and directives, the EU has set some very challenging objectives to reach in 2035 and in 2050. The impact of these interventions is not completely defined nonetheless, especially depending on the aspect which is analysed. It appears that the effects of the energy transition on the job market of the automotive sector is not clear; in fact, depending on the resources consulted, and on who commissioned the research, the results change. While most of the documents sustain that the number of new jobs created will not be sufficient to compensate the ones lost due to the energy transition and the EU Green Deal, a minority of documents state instead that the number of new jobs will be equal if not higher than the ones currently available. It is not a topic of debate however, that employees need to be re-skilled and retrained in order to meet the future market demand and that, in general, companies will need always more prepared and highly skilled workers; whether this aspect can be considered sustainable under a social perspective deserves further attention and studies. The energetic transition does not affect the workers only, but the entire global value chain of the automotive sector; this means that companies along the supply chain will have to undergo to several changes according to their nature; in fact, some companies may have more issues in changing themselves and adapt to the new market requirements. This is especially the case for small companies, since they have less resources to invest to change their structure and production processes. Moreover, the energetic transition is particularly a problem for companies who have their business mainly or completely linked to the automotive sector and even worst to the internal combustion engines. Finally, the advent of electric mobility leads to a greater importance of software, data and electronics, weakening the competitive position of Europe since are especially USA and China to have the financial resources necessary to invest in these technologies. A very important aspect of the energy transition that has been analysed is the new geopolitical equilibriums that will come out as consequence. In fact, several countries, especially in Africa and Latina America, are gaining importance and relevance in this new scenario. This aspect should be furtherly studied since there are not many documents and reports addressing the impact of these measures aimed at fostering the advent of electric cars on the competitive position of Europe. It is well known that, several critical materials are necessary to sustain the development of electric mobility, and that the supply and refining of these materials is sensibly controlled by China and very few other countries; so, the question is, if Europe wanted to free itself from its dependence on Russia natural gas and from supply of fossil fuels, has it been a wise decision to entrust its mobility future to only one energetic resource? For sure this topic deserves more in-depth studies. Finally, the AI role in the automotive industry is studied; the increased use and exploitation of this technology it is expected to bring several advantages for the industry sector. Greater productivity, leaner supply chains, less equipment failures and fewer quality problems are only few among the benefits brought by the AI. While AI seems to bring several advantages to car companies, the result that this technology may have on the employment is not that clear yet. It is possible to assume that the changes to the employment trend due to the introduction of AI will follow the ones caused by the introduction of electric mobility, since the two technologies often go together. The documents consulted for this thesis sustain that AI production processes will be highly intensive and therefore there will be the necessity of employees to achieve the desired the results; however, the kind of employees that will be mainly employed are "little-qualified, inconspicuous and low-paid contribution of "micro-workers"" coming especially from countries such as Indonesia, Philippines and India. Therefore, the question that may arise from this information is whether the introduction of the AI will be beneficial for the people working, in this case, in the automotive sector. In fact, it appears to be a gap since electro mobility and the use of AI seem to require especially either a very high skilled workforce or very low-income and low-skilled workers; what about all the workers in the middle, like for example the middle or low-skilled workers in Europe? Can Europe be certain that reskilling will be the ultimate solution for them and that most of these work places will be actually replaced by the new coming jobs? This question still does not have any clear answer, and it would be very important and interesting to get more precise and independent information so to continue to assess the impact of the European Green Deal, an industry plan which will bring many opportunities to the EU but also some issues that have to be solved to let the Green Deal be sustainable both environmentally but also socially.

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