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The Transition to E-Mobility and the Labour Market

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ABSTRACT

The transition from ICE vehicles to E-Mobility entails a vastity of socio-economic implications. This paper will focus primarily on the consequences this shift might have in the labour force and the automotive industry. To do so it will take into consideration several reports and articles published by international organizations, renowned consultancy agencies and scholars. After a brief introduction on the main features and processes of the transition, this paper will turn to an overview of the Environmental, Economic and Social impacts of the EV transition. The environmental aspect is the main driver of such electric transition. The purpose is to lower the transport sector's environmental footprint. The economic and social impacts of the transition are several. The paper will focus on the future of work in the automotive industry, a topic which comprises both economic and social aspects. In particular, it will take into consideration the main industry sectors and job families affected. It will then present the major trends within these sectors and the overall net impact of job development in the coming years. Last but not least this paper will discuss the employment movement and job transitions that will take place across industries.

Table of Contents

List of Figures

1 Introduction

Today's world is facing an unprecedented conundrum, namely that of conciliating human development with the environment. The origins of such issue may be traced back to rather recent contemporary history. The industrial revolutions of the 19^{th} century ignited the processes of development that shape the modern world. These innovations were based on environmentally threatening means, particularly fossil fuels, which still play a pivotal role today. Fossil fuels have been the backbone of energy production and transport since the 1800s.

Only in recent decades have humans acknowledged the unsustainable consequences of such kind of growth on the planet we inhabit. The first steps forward were made in the 1970s, specifically in 1972 at the UN Conference on the Human Environment held in Stockholm. It was on this occasion that the concept of sustainable development received its first major international recognition. Sustainable development may literally mean "development that can be continued either indefinitely or for the given time period" (Mensah, 2019). Some years later it was more emphatically defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Development, World Commission on Environment and Development, 1987). This idea of development gained growing relevance as the years passed. The global arena was becoming more and more aware of the need to conciliate economic growth with Earth's ecosystems. Today it is impossible to set them apart, as universally stated by the 17 UN Sustainable Development Goals set for 2030. The scientific community increasingly highlighted the harmful environmental consequences of unrestrained economic growth, the most notable of which is climate change, among several.

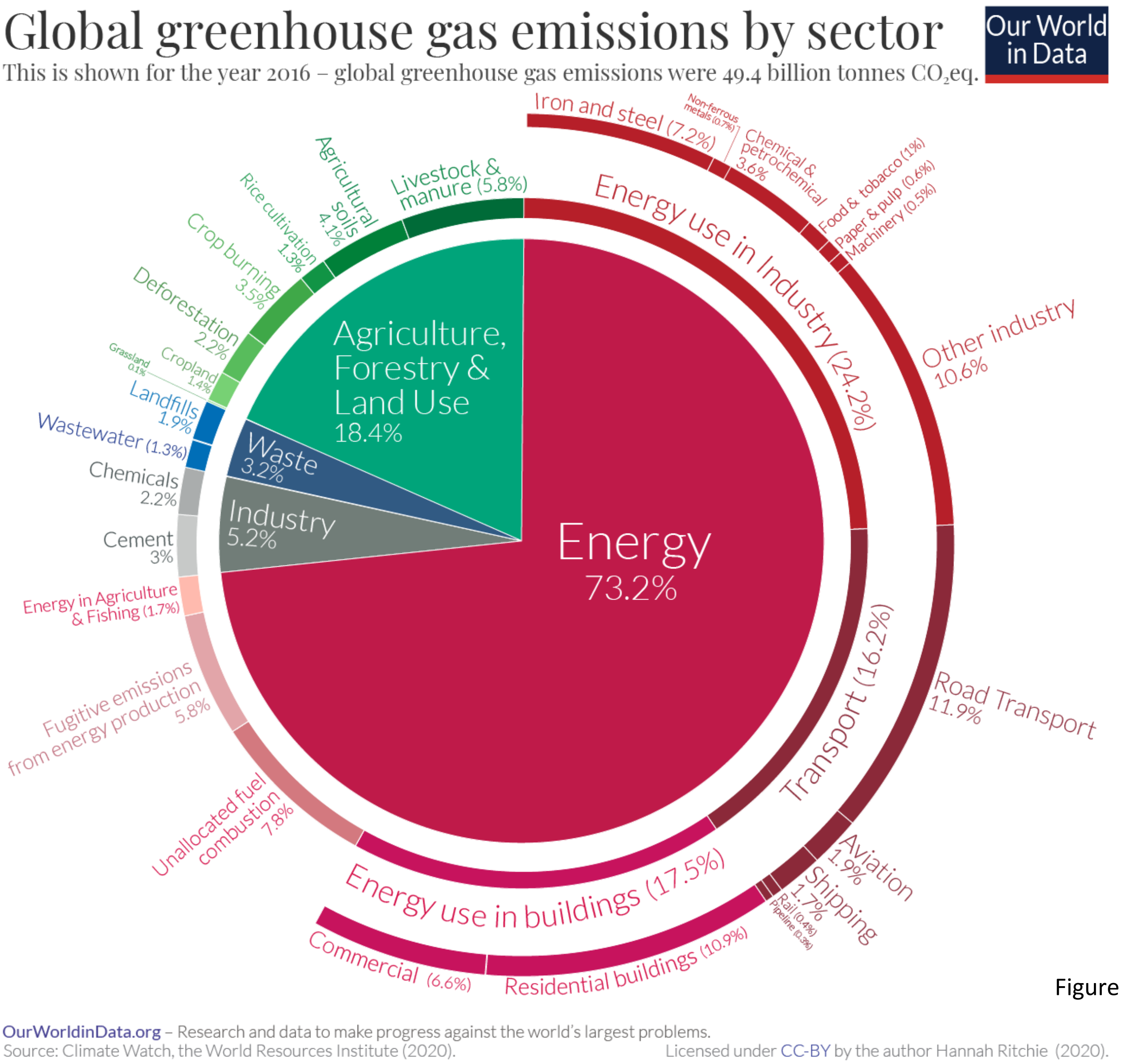


Figure 1

This phenomenon is triggered by unsustainable emissions of greenhouse gases (GHG), such as carbon dioxide, methane, and nitrous oxide. These gases trap heat inside of Earth's atmosphere, causing hotter temperatures, more severe meteorological conditions, droughts, a rising sea level, loss of biodiversity and several other correlated effects. The combustion of fossil fuels is by far the largest contributor to global climate change. Over 75 per cent of global greenhouse gasses emissions are due to fossil fuels. Furthermore, fossil fuels account for nearly 90 per cent of all carbon dioxide emissions (United Nations, 2023). Many sectors of human activity are responsible, to varying degrees, for global greenhouse emissions and use of fossil fuels (see Figure 1). As of 2016, the energy sector accounts for 73.2 per cent of global GHG emissions, followed by agriculture (with forestry and land use) at 18.4 per cent, Industry (chemicals and cement) at 5.2 per cent and waste at 3.2 per cent (Ritchie, Roser, & Rosado, 2020). The energy sector, which is the one that burdens the most our biosphere, includes 3 sub-groups: energy use in industries, energy use in buildings, and transport. Each of these subgroups are also divided into sub sections. What stands out, among more than a dozen sub-sections, is the load of emissions hold by road transport. In fact, it accounts for almost 12 per cent of global GHG emissions. Among all the single contributing sectors, road transport is the largest component shown in the 2016 pie chart above.

Transport is therefore one of the main drivers of climate change, due to its huge volume of emissions. 60 per cent of road transport emissions come from regular passenger travel vehicles such as cars, motorcycles, and buses. The rest is due to road freight (lorries and trucks) (Ritchie, Roser, & Rosado, 2020). The centrality of transport in the achievement of a sustainable future was first acknowledged at the historical 1992 United Nation's Earth summit in Rio de Janeiro. It never left the international agenda since. Transport sustainability is now one of the top priorities within the UN SDGs. It cuts across "several SDGs and targets, especially those related to food security, health, energy, economic growth, infrastructure, and cities and human settlements" (United Nations, 2023). It is particularly relevant for the 11th SDG, which is making "cities and human settlements inclusive, safe, resilient and sustainable" (United Nations, 2023). In fact, fossil-fuelled vehicles not only contribute to greenhouse emissions and global climate change, but also to local air pollution, which is correlated to health conditions such as heart diseases, lung diseases and cancer ((Health Effects Institute, 2010) cited in (Briceno-Garmendia, Qiao, & Foster, 2022)).

It is in this context that the transition to electric mobility comes into play. Electric mobility offers a technological feasible solution to polluting fossil-fuelled means of transport. Electric vehicles (EVs), as opposed to vehicles that are equipped with an internal combustion engine (ICE), do not directly emit GHGs that harm our biosphere. "This means that, if we could electrify the whole road transport sector, and transition to a fully decarbonized electricity mix, we could feasibly reduce global emissions by 11.9%." (Ritchie, Roser, & Rosado, 2020). This is certainly ambitious, but it emphasizes the scope and impact that sustainable transport would have on our planet's well-being. The automotive future is believed to be electric for 3 main reasons (McKinsey Center for Future Mobility, 2021). First, national and international policy choices are introducing incentives to accelerate the transition to electric mobility. Second, consumer awareness is converging towards alternative and sustainable mobility ways. Finally, automotive industries are supplying increasingly new technology as time goes by, making the cost for EVs go down and attracting more and more investments. The electric mobility sector has attracted more than 100 billion dollars in just over a year, from early 2020 to mid-2021, and over 400 billion dollars over the last decade (McKinsey Center for Future Mobility, 2021). Coherently with the amount of investment flows that have been injected in the sector in the last years, combined with those which are programmed for the following years, the largest automotive markets are expected to go electric by 2035 (McKinsey Center for Future Mobility, 2021). The spread of electric mobility may be in its initial phases but shows a huge potential and an "irresistible momentum" (McKinsey Quarterly, 2021). The transition is unfolding in many high-income countries, but it is believed to gather increasing momentum also in less developed countries in the years to come(Briceno-Garmendia, Qiao, & Foster, 2022)The magnitude and variety of effects that the electric transition will bring along are still uncertain, but most certainly enormous and all-encompassing.

The aim of this dissertation is to present some of the various implications that electric mobility entails today, with an outlook into the future. The scope and size of the mobility phenomenon requires a selection of subject matters in order to be dealt with in the present paper. The focus will in fact be set on the consequences this transition might have on the labour force and the automotive industry. To do so it will take into consideration several reports and articles published by international organizations, renowned consultancy agencies and scholars.

The discussion will unfold as follows. The subsequent section will provide the reader with a cross-cutting overview of the environmental, economic, and social impacts of electric mobility, treating the latter as a developmental issue throughout the discussion. In the 3rd section the focus will then turn more specifically to the future of work in the automotive industry. In particular, it will first examine the main industry sectors and job families affected. Secondly, it will illustrate the major trends within the industry over the coming years and the net impact of job development given by the EV transition. Thirdly and finally, it will briefly describe the transitions and shifts of employed persons happening across the automotive industry. The 4th and last section will be devoted to the conclusion.

2 Electric Mobility as a Development Issue

2.1 Environmental Impacts

The spread of electric mobility will set countries on a development path which will bring along environmental, economic, and social effects. The discussion will start from the environmental aspects.

The world as a whole is under pressure to put a hold on climate change. The Paris Agreement of 2015 legally binds 196 countries to climate commitments. The paramount of which is to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels, and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" (United Nations, 2015). In fact, the UN's Intergovernmental Panel on Climate Change suggests that the crossing of the 1.5°C limit would unleash extremely severe climate consequences, which may turn out to be unbearable for humankind (Allen, et al., 2018). On the opposite, climate science indicates that if these temperature parameters are respected, the most catastrophic impacts of climate change could be prevented (Hannon, Krishnan, Patel, & Sahdev, 2022). Climate change may be slowed down by the reduction of global greenhouse gas emissions, as we saw in the introduction.

Transport accounts for a large share of GHGs emissions. The transport sector is the only major sector whose greenhouse emissions have steadily risen during the past decade (2010-2019) (Briceno-Garmendia, Qiao, & Foster, 2022). Furthermore, road transport alone is the source of almost 12 per cent of global emissions as shown in Figure 1. Electric mobility is seen as an important part of the solution, as "en -route emissions immediately go down" (Straubinger, Verhoef, & de Groot, 2022) , conversely to petrol and diesel vehicles which produce harmful exhaust fumes. Today's increasingly ambitious policies to promote EVs are driven by the possibility of lowering the transport sector's environmental footprint (Briceno-Garmendia, Qiao, & Foster, 2022). There is more. Electric mobility could also have a great impact on local air pollution. The use of EVs might increase considerably the air quality of crowded urban areas, with positive effects on the people's well-being.

2.1.1 Net impact of Electric Vehicles on Europe's future emissions

A study conducted by the European Environment Agency in 2016 assesses the effectiveness that electric vehicles would have in lowering future emissions in the European area. The need for sustainable road transport is given by its potential to decarbonize future road transport and reduce air pollution. It is in fact quite common for many European cities to not meet the air quality standards set by the EU and the World Health Organization (WHO) (European Environment Agency, 2016).

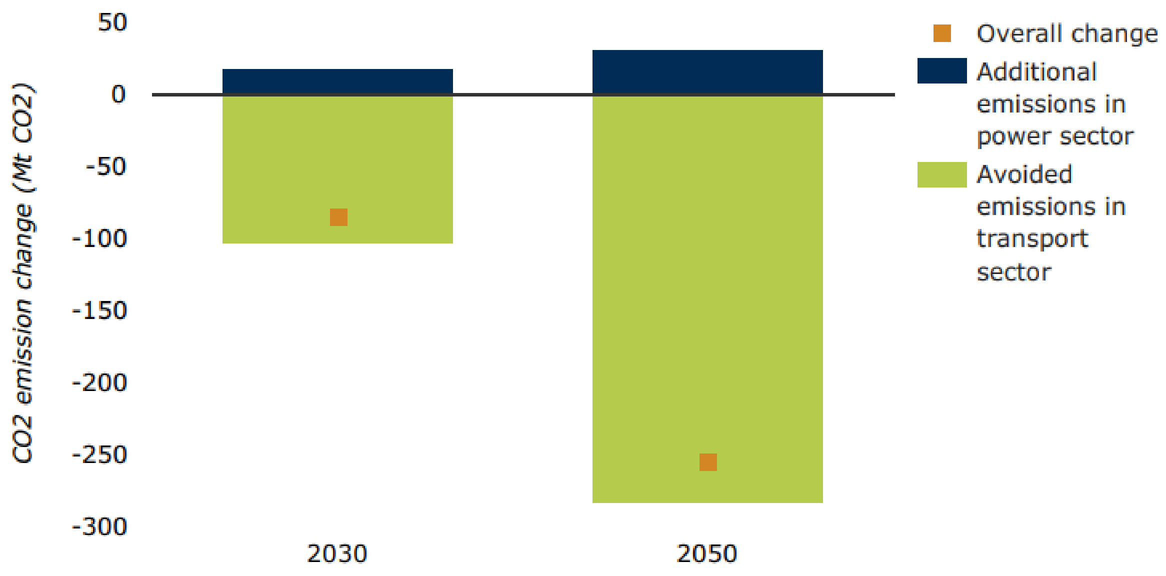
The case considered two possible development scenarios of electric mobility. The first more conservative scenario assumes that in 2050 electric cars will have a 50 per cent share over the entire EU members car fleet. The second more progressive scenario assumes an electric car fleet share of 80 per cent by 2050.

An increase in electric vehicles entails a first issue: an increase in energy demand. The high rates of electric vehicle ownership expected in future decades will have to be corresponded by an increase in power generation. The share of electricity consumption due to electric vehicles will grow considerably. It was approximately 0.03 per cent in 2014. It is expected to reach 3-4 per cent by 2030 and 9.5 per cent by 2050 if taking into consideration the more progressive scenario mentioned previously. The 9.5 per cent electricity share represents an on average prediction. The EU member states will face a varying share of EV electricity demand depending on the number of vehicles anticipated in each country. The range is expected to vary between 3 per cent and 25 per cent. Luxemburg for example is expected to have a 25 per cent EV energy demand share over the total electricity demand in 2050. Bulgaria on the contrary is expected to have a 3 per cent EV energy demand share.

Along with the increase of energy demand, there will be a matter of infrastructure, as "this additional energy needs to be integrated into the grid infrastructure across Europe" (European Environment Agency, 2016). In the short term, presumably until 2030, such matter will be bounded and marginally significant. In the longer 2050 term, the extra energy produced will have a considerable impact on power systems in Europe. For some countries with a weak network infrastructure the mobility transition may become a major challenge.

In order to assess the actual beneficial impact of non-polluting electric vehicles, the extra emissions caused by additional energy demand must be considered. A 30 per cent share of electric vehicles in 2030 will result in fewer greenhouse gas emissions and air pollutants in the road transport sector. In particular it will provoke a reduction of roughly 100 Mega tons (Mt) of carbon dioxide by 2030. Even more significant is the effect of an 80% share of electric vehicles in 2050, where almost 300 Mt of carbon dioxide emissions could be avoided. These potential beneficial effects will be mitigated by the additional emissions produced in the power sector in order to fuel such an electric mobility transition with energy. Nevertheless, "the avoided CO_2 emissions in

Figure 2 **Future changes in CO_2 emissions in the energy and road transport sectors**



Note:
Assuming a 30 % share of electric vehicles in the EU-28 in 2030 and an 80 % share in 2050.

Data sources: Öko-Institut e.V.. Electric mobility in Europe — Future impact on the emissions and the energy system

the road transport sector outweigh the higher emissions from electricity generation" (European Environment Agency, 2016). Figure 2 shows the future changes in carbon dioxide emissions in the energy and road transport sectors. The graph highlights the positive net impact of electric mobility on climate and on the environment. In 2030 a net reduction of 100 Mt CO2 could take place. In 2050 the net reduction could amount to 255 Mt CO2. This results from the positive difference between the avoided emissions in the transport sector minus the additional emissions of the power sector. The first accounting for almost 300Mt and the latter for little less than 50 Mt of CO2.

Electric mobility may also play a relevant role in the reduction of air pollutants. The scenario considered above, with an electric car fleet share of 80 per cent by 2050, also evaluates the reductions of direct exhaust emissions of nitrogen oxides (NOx), particulate matter (PM) and sulphur dioxide (SO2). Each pollutant is believed to face a reduction of more than 80 per cent, compared to 2010 recordings of road transport. However, as for the carbon dioxide emissions analysed above, some considerations must be made (European Environment Agency, 2016). The reduction of nitrogen oxides and particulate matter will be partially countered by additional emissions coming from the energy production sector. This offset will be limited and account for 1 per cent of NOx and 3 per cent of PM. The net reduction for these pollutants remains therefore highly positive. Sulphur dioxide presents a different situation. Road transport already accounts marginally for this kind of emission. The main source of SO2 is the burning of fossil fuels by power plants and other industrial facilities (EPA, 2023). The reduction made in the road transport sector will be overwhelmed by the additional SO2 emissions produced in the use of coal in power generation. The excess is believed to be by a factor of 5 (European Environment Agency, 2016). Sulphur dioxide emissions will then need to be addressed with further action. Nevertheless, there are some overarching aspects to be considered when discussing air pollutants in the road transport sector and the power generation sector. The impact of air pollutants on air quality and human health largely depends on the location, intensity, and type of emission sources (European Environment Agency, 2016). Road transport emissions usually take place in urban areas, where there is a high population density, and at ground level. This exposes a large share of the population to harmful air pollutants, affecting their well-being. On the opposite, power generation emissions usually take place in non-urban areas, with limited population density. This exposes a smaller component of the population to polluted air. A shift of air polluting emissions from road transport to the power generation sector may therefore be beneficial for health.

This assessment highlights a very positive environmental potential of the electric mobility transition. EVs offer a solution to considerably lower overall carbon dioxide emissions and improve air quality, especially in urban areas. The electric transition poses some relevant challenges to the energy sector. Additional electricity demand will come along with the transition, coupled with further infrastructural needs. The replacement of traditional ICE vehicles with EVs will reduce road transport emissions, but the extent to which it will help the environment as a whole depends considerably on the energy sources used to charge vehicles. Electricity sources have highly different environmental impacts depending on whether they are renewable, nuclear, or fossil-fuelled. The cleaner the energy source, the greater the impact of EVs in helping the planet escape climate doom. It is crucial for the electric mobility transition that road transport and the energy sector become closely interconnected. Policy choices and investments should be tightly coordinated across the two areas of interest. Furthermore, along with electric vehicles and renewable energy sources, in order to achieve a greener economy consumers should make a responsible use of transport.

2.2 Economic Impacts

The discussion now turns to the main economic impacts brought along by the electric mobility transition.

The automotive industry is one of the most important worldwide. The International Labour Organization Secretary-General defined the automotive industry as the “industry of industries” (International Labour Organization, 2021, p. 6). The global automotive manufacturing market was worth around 2.86 trillion US dollars in 2021. In the same year 57 million units of passenger cars were produced and around 66.7 million units were sold (Carlier, 2023). The main producers of motor vehicles worldwide are China, the USA, Japan, India, South Korea, and Germany, which is the first European country appearing on the list of major producers. Mexico, Brazil, and Spain complete the top ten global producers table (OICA, 2021).

Electric mobility presents itself as an epochal transformation for the industry. Automobile manufacturers have been building internal combustion engines for more than a century. Only in recent years have electric vehicles taken a relevant part into the scene. Furthermore, as stated in the previous sections, EVs are expected to take the upper hand in the transport sector in the coming decades.

Electrification will cause major changes in the whole automotive supply chain (McKinsey Center for Future Mobility, 2021). EVs present highly significant structural differences compared to ICE vehicles. First of all, EVs contain considerably fewer and simpler parts (Mönnig, Schneemann, Weber, Zika, & Helmrich, 2019). In fact, the drivetrain in a traditional vehicle contains more than 2’000 moving parts, compared to an EV drivetrain which contains only around 20 moving components (Raftery, 2018). EVs, other than obviously not requiring an internal combustion engine, are also not equipped with any of the following ICE vehicle components: fuel piping, exhaust system, propeller shaft, fuel tank, gearbox, alternator, and starter. These omissions are coupled with the insertion of several new key pieces that make an electric vehicle operational. EVs require an electric traction motor, a battery module, high voltage wiring, DC/DC & DC/AC converters, and a power electronics controller. These are the main differentiators between EVs and ICEVs (Boston Consulting Group, 2021).

These considerable structural differences have several implications. In order to appreciate the magnitude of the transformation it is worth mentioning that critical components for electrification, such as the ones revealed above, are expected to make up to around 52 per cent of the total automotive components market by 2030 (McKinsey Center for Future Mobility, 2021). Furthermore, a successful electric mobility transition will mean a steady rise in the demand for raw materials necessary to produce the new EV components mentioned (Briceno-Garmendia, Qiao, & Foster, 2022). It is also relevant to keep in mind that all supply chains in the automotive industry are characterized by an overarching length, complexity, and international reach (World Bank & International Association of Public Transport, 2018)

The following sub-sections will take into consideration some of the main impacts that the electric mobility shift will have on supply chains and market forces for automotive components. In particular, it will first consider battery supply chains, secondly the fossil fuel market, thirdly the future of the fuelling business, and lastly the automotive aftermarket.

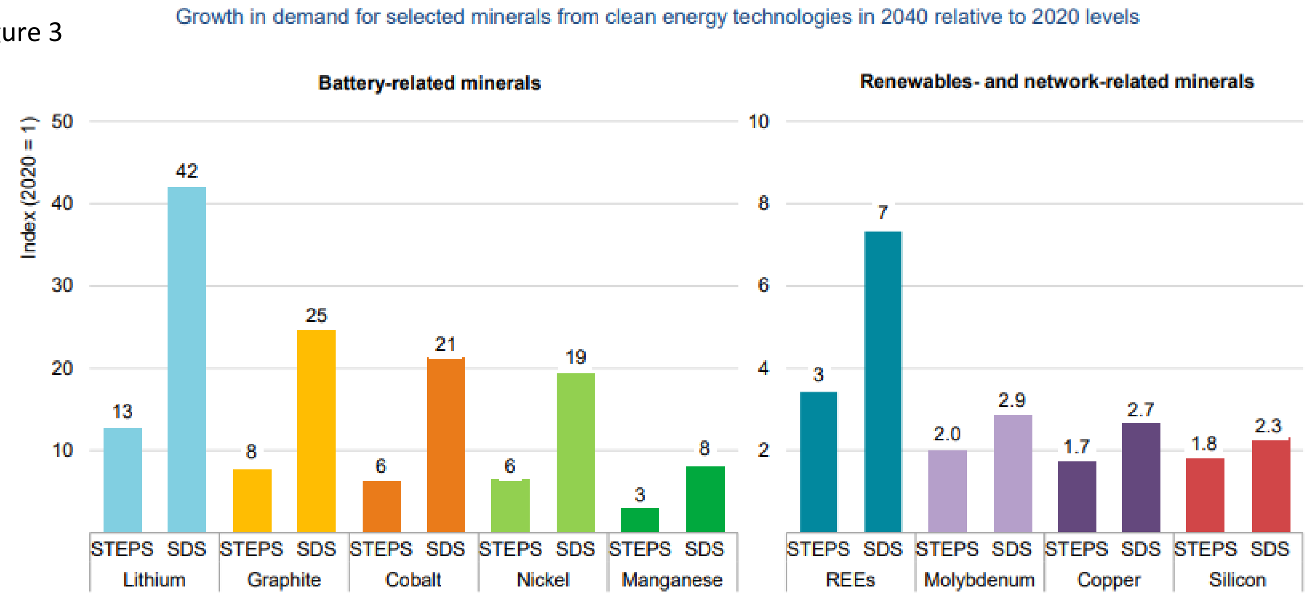
2.2.1 Supply Chains for Batteries

This section has the aim to highlight the main economic effects that the rise of electric mobility will have over the supply chain for EV batteries. The demand for battery-related minerals will reach unprecedented levels over the next few decades. This anticipated increase in demand is expected to be met with sufficient reserves of raw materials, not putting on hold the transition to electric mobility. However, the battery supply chain presents some other relevant issues to be considered. First, raw materials can be found in only a limited number of countries around the world. This condition gives single countries prominent roles in the automotive market, with possible global consequences. Second, most of the largest deposits of minerals are located in developing countries. This circumstance poses further problems related to equality, human rights violations, job safety and child labour. It is appropriate to conclude that the most critical component of the battery supply chain is the mining of raw materials. Other parts of the supply chain may be deemed as less problematic (Briceno-Garmendia, Qiao, & Foster, 2022). This can be considered as unsurprising. In many parts of the world, extractive industries have left a legacy of "environmental degradation, adverse impacts to public health, marginalized communities and workers, and biodiversity damage" (Sovacool, et al., 2020, p. 30). These problematics may be offset by the recycling of EV batteries. The increase in circularity is in fact expected to bring along considerable positive impacts for the decarbonization, stability and ethical responsibilities along the battery supply chain. Such activity is expected to create a value of $95 billion per year by 2040 (Breiter, Linder, Schuldt, Siccardo, & Vekic, 2023).

The battery module is the technical component that supplies the electric motor with energy, allowing it to move the vehicle. EVs use lithium-ion batteries, which are composed of battery cells. The latter account for roughly 2/3 of the battery's total weight. These units, other than lithium, contain a considerable number of minerals. These include nickel, cobalt, manganese, graphite, and copper. The amount of each mineral depends on the kind of lithium-ion battery produced (Argonne National Laboratory, 2020).

In order for the electric mobility transition to happen, such minerals must be extracted from the earth's soil at an increasing rate. In 2021 the International Energy Agency developed some projections that predict the demand for critical minerals in the clean energy transition over the coming decades (see Figure 3).

Figure 3



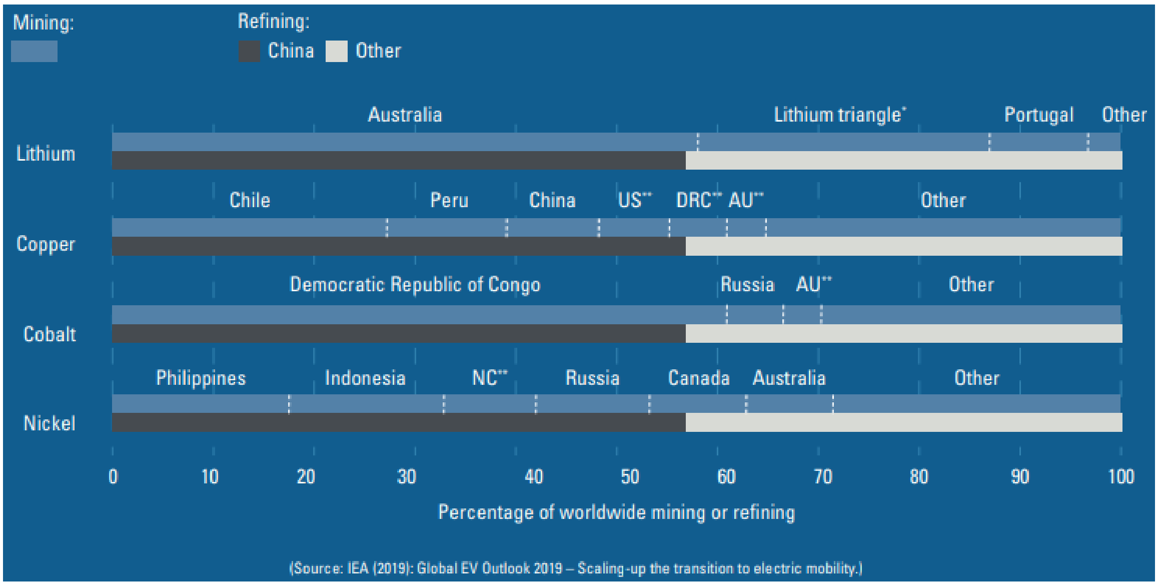
The prediction above considers two scenarios. The first being the Stated Policies Scenario (STEPS) and the second being the Sustainable Development Scenario (SDS). The first appears to be more conservative and considers minimal improvement. On the contrary, the second scenario appears to be more progressive and with modest improvement. This double approach is due to the subject's considerable uncertainty, the latter being caused both by the varying stringency of climate policies and the possible technology development pathways. The graph on the right considers minerals used for clean energy in general. The graph on the left, which is the most relevant for this discussion, considers more specific minerals. Namely, all those minerals eagerly required for battery production. The baseline year considered to assess the increase in mineral demand is 2020, which is compared to the 2040 predicted level.

The 2040 projection shows an incredibly sharp increase of raw material demand compared to the 2020 levels. All 5 battery-related minerals are expected to at least exceed the 2020 levels by a factor of three, in both the conservative STEP scenario and the progressive SD scenario. In two decades, the lithium demand will reach levels 13 times higher than those of 2020. Or a shockingly 42 times higher if we consider the SDS. Similar outcomes are expected from graphite, cobalt, nickel, and manganese demand. Graphite demand will grow between 8 and 25 times its original state. Cobalt between 6 and 21 times. Nickel between 6 and 19 times. Manganese between 3 and 8 times. Furthermore, clean energy technologies are expected to emerge as the majoritarian drive in the demand for three of the 5 minerals considered above (International Energy Agency, 2021). In 2040 clean energy technologies will hold a demand share of 80 per cent for lithium, more than 60 per cent for cobalt, and 60 per cent for nickel (SD scenario).

It is crucial to establish whether global reserves and resources can be considered adequate to satisfy such a steep demand increase. In 2020, the German National Organization for Hydrogen and Fuel Cell Technology (NOW GmbH) published a report regarding the availability of raw essential materials for batteries. Specifically, it considered lithium, cobalt, and nickel. For each of these minerals it shows that the increasing demand will be met with sufficient resources. The study therefore concludes that the availability of raw materials is not a fundamental obstacle to electric mobility (NOW, 2020).

Nevertheless, battery production and the extraction of its key minerals present some relevant issues. First of all, reserves of key raw materials are concentrated in very few countries. The democratic Republic of

Figure 4



(Source: IEA (2019): Global EV Outlook 2019 – Scaling-up the transition to electric mobility.)

Congo (DRC), for example, accounted for about 60 per cent of the global cobalt extraction in 2019. Similarly, South Africa and Brazil jointly hold 60 per cent of the world's reserves of manganese (Briceno-Garmendia, Qiao, & Foster, 2022). The previous graph gives a more complete picture of the main mining countries for lithium, copper, cobalt, and nickel (see Figure 4). The majority of the lithium extracted comes from Australia (AU), followed by the "lithium triangle", which includes Argentina, Chile, and Bolivia. Copper presents a slightly more diversified extraction scenario, with Chile being the main extractor, followed by Peru, China, the US, the DRC. Cobalt extraction as mentioned earlier is dominated by the DRC, followed by minoritarian countries such as Russia and AU. Nickel, similarly to copper, presents a diversified extraction scheme. The Philippines, Indonesia, New Caledonia, Russia, Canada, and AU each hold a mining share of roughly 10 per cent. These levels of raw material concentration have global repercussions (Briceno-Garmendia, Qiao, & Foster, 2022), burdening few countries both with significant challenges and opportunities. It is worth highlighting China's prominent role in the refining process of the critical minerals considered. China accounts for over 50 per cent of refining for every single battery related mineral considered in Figure 4. This situation allows China to have a massive influence over the market for raw materials (NOW, 2020).

Most of the countries mentioned in the mining extraction schemes above belong to the Global South. These countries present poor governance, weak environmental policy, and weak social safeguards (Briceno-Garmendia, Qiao, & Foster, 2022). The mining expansion taking place in such developing countries determines an increase in conflicts and injustices around industrial mining operations (Prause & Dietza, 2022). The most critical circumstances may be found in the DRC and the so-called lithium triangle. In 2016 Amnesty International estimated a number of 110,000-150,000 artisanal miners working in the DRC's cobalt mines. The DRC has been unable over the years to protect these workers from human rights abuses, unhealthy working conditions and grant sufficient safety standards. Child labour is also a significant phenomenon. Local DRC workers often find themselves in open conflict over the DRC's largest cobalt mine, namely the Tenke Fungurume Mine (TFM), which is now run by the Chinese company China Molybdenum. Artisanal miners demand fair access to mining sites, to industrial jobs in cobalt mining and to better working conditions. Similar situations can be encountered for lithium mining in Chile and copper mining in Peru (Prause & Dietza, 2022). Unrestrained mineral extraction seriously risks to severe the economic and social conditions of workers within institutionally weak developing countries.

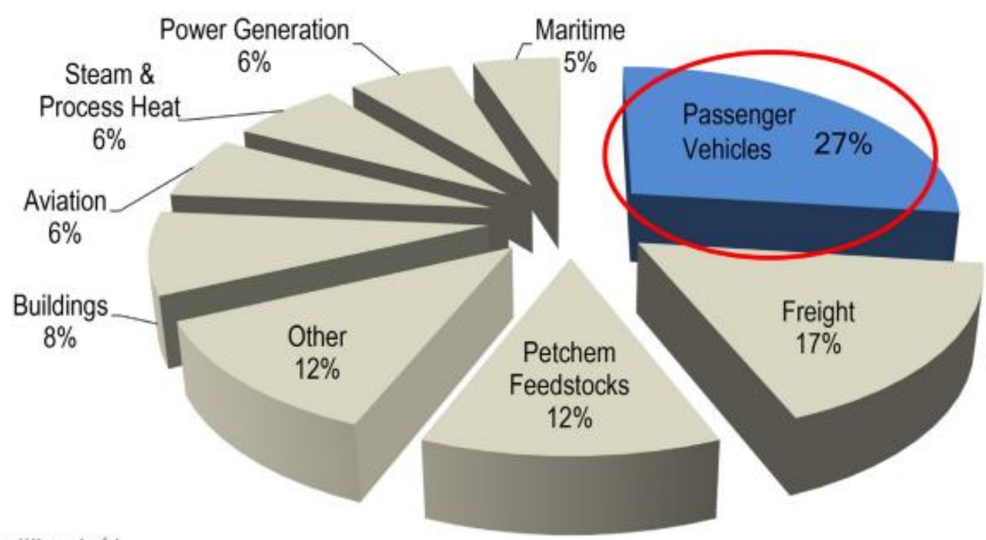
Recycling may offer a solution to these issues. Battery recycling presents itself as a key opportunity to develop a "stable, resilient, efficient, and sustainable supply chain" (Breiter, Linder, Schuldt, Siccardo, & Vekic, 2023, p. 2). In fact, among the main factors driving EV battery recycling there are the needs for supply-chain stability, supply chain decarbonization, and the reaching of ethical targets. Other factors include technological progress, regulatory incentives, and regulatory pressures (Breiter, Linder, Schuldt, Siccardo, & Vekic, 2023). As for supply chain stability, locally recycled batteries offer original equipment manufacturers (OEMs) and cell producers raw material at steady prices. As for decarbonization, recycled battery materials bear four times less carbon-emissions than newly extracted materials. This makes the recycled material footprint per kilowatt-hour (kWh) lower by 28 per cent, compared to the one of virgin raw materials (Breiter, Linder, Schuldt, Siccardo, & Vekic, 2023). These data highlight the potential contribution that battery recycling may bring along in order to accomplish a more sustainable and circular supply chain. As mentioned above, recycling may also foster the reaching of ethical targets. The reuse of batteries minimizes the social and environmental impacts of mining (Briceno-Garmendia, Qiao, & Foster, 2022). In fact, as discussed in the previous paragraph, high demand for raw materials in mineral-rich developing countries and conflict regions may exacerbate local working conditions and inequality. Domestic recycling may prevent the formation of an intense demand for battery-related minerals in such socially vulnerable countries (Breiter, Linder, Schuldt, Siccardo, & Vekic, 2023). To conclude, it is critical for the successful outcome of the electric transition to create sustainable supply chains. This will not allow battery materials "to remain a critical bottleneck for electrification" (Breiter, Linder, Schuldt, Siccardo, & Vekic, 2023, p. 9), and will offer a less impactful source for supplies.

2.2.2 Fossil Fuel Demand

The attention will now turn to the impacts of electric mobility over the antagonist market for fossil fuels, in particular oil, which is the most relevant to the automotive industry.

In electric vehicles, electricity stored in batteries replaces oil as a transport fuel. This key feature allows EVs to not emit any on-road emissions. Oil, and its derivatives, have been the main fuels in the automotive industry since its origins. However, oil is used in many other sectors other than the transport one. Figure 5 below, built upon International Energy Agency data (2017)and available on Kah's paper (2018), gives a complete picture of global oil demand across sectors.

Figure 5 Global oil demand by sector (% share, 2016)



Basis 94 million b/d
Source: International Energy Agency 2017 World Energy Outlook

Passenger vehicles account for a considerable part of global oil demand, namely 27 per cent. But many other sectors are responsible for its request. Freight, aviation, and petrochemical feedstock for example respectively hold 17, 6, and 12 per cent shares of oil demand. These circumstances highlight the need to make some considerations when making predictions about the future of oil demand globally.

The electric mobility transition is expected to reduce oil demand only modestly over the next 10 to 15 years (Hensley, Knupfer, & and, 2018). This situation may be explained by taking into consideration some underlying factors. Kah (2018) identified two underlying drivers that might explain the initially counterintuitive trend of oil demand in the following decades. These are the ongoing global population growth and global economic growth. Population growth and economic growth determine an increase in oil demand for all the sectors mentioned in the graph above, including the passenger vehicle oil demand. In fact, population growth entails a larger vehicle fleet, including a larger number of oil-demanding ICE vehicles. Global economic growth determines a higher income, the number of cars people can purchase and how much use they make of them. Even if oil demand in the passenger vehicle sector were to decline, this decrease could be offset by the demand growth in sectors such as aviation, petrochemical, and freight transport (Kah, 2018).

When taking into consideration a longer term the situation changes. The rates of population growth and economic growth are declining (Kah, 2018). The shrinking of these underlying drivers for oil demand might allow the electric mobility transition to make a consistent impact over oil demand. The graph below, taken from the most recent World Energy Outlook Report (International Energy Agency, 2022), shows the oil demand trends over the next three decades.

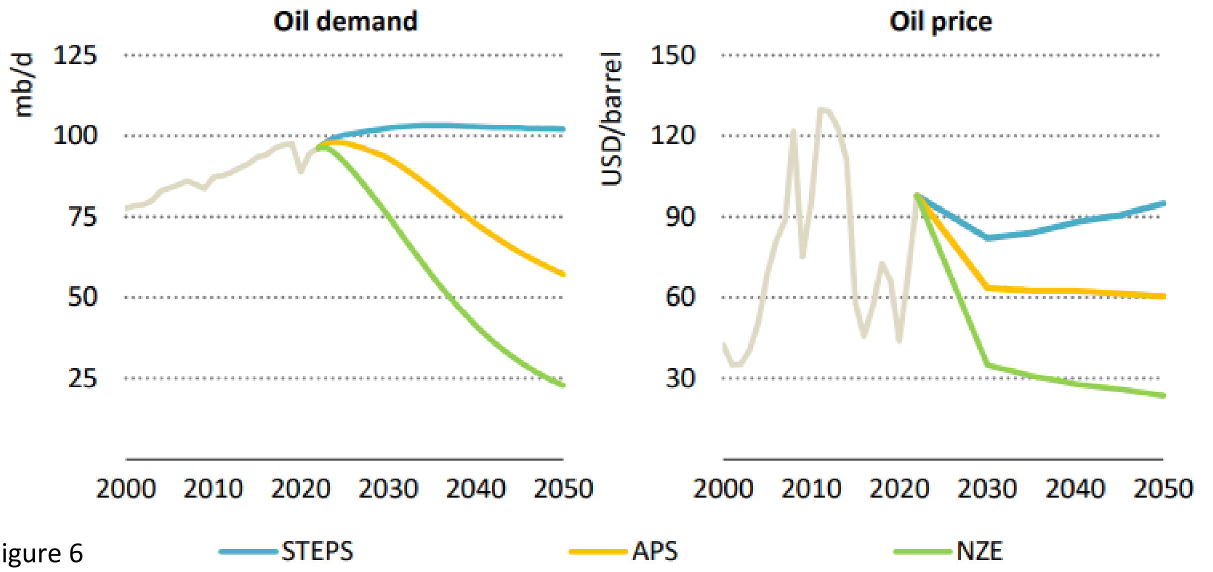


Figure 6

The graph considers three scenarios. The stated policies scenario (STEPS) shows a peak in the mid-2030s and then a slow decline up to 2050. The initial growth recorded in this scenario is due to increased use of oil for aviation, shipping, petrochemical feedstock, and freight. The later decline is caused by the declining oil use in other sectors, particularly passenger vehicles, buildings, and power generation (International Energy Agency, 2022). The announced pledges scenario (APS) entails tighter policy actions. In fact, the oil demand peak is expected for the mid-2020s. Demand then starts dropping up to 2050, falling by about 40 per cent between 2030 and 2050. The sectors mainly accountable for this reduction are passenger cars, road freight and industry. Petrochemical feedstock is one of the few sectors that are expected to register a rise in oil demand (International Energy Agency, 2022). The net zero emissions by 2050 scenario (NZE), which is the most ambitious and challenging to pursue, never returns to pre-pandemic levels and therefore does not predict a demand peak in the coming years. Demand is expected to fall by 2.5 per cent up to 2030, and then by 6 per cent from 2030 to 2050. Road transport is given a significant role. This scenario assumes that no ICE cars are sold after 2035 and almost every truck after 2040 runs on electricity or hydrogen (International Energy Agency, 2022). The three scenarios considered all highlight a decrease of oil demand in the long term, in contrast to what described for the short term previously. Furthermore, all these scenarios consider the road transport sector as a key driver for the reduction of oil demand. This is due to the future electrification that mobility will most likely go through.

It is worth mentioning the effect that a decreased oil demand might bring along for sensible economic actors. In fact, "once EVs eventually start to reduce oil demand, public revenue could decline in oil producing countries" (Briceno-

Garmendia, Qiao, & Foster, 2022, p. 14). Oil producing countries in Latin America, North Africa, Sub-Saharan Africa, and the Middle East are vulnerable to possible income losses brought along by a decreased oil demand. These fossil fuel-dependent countries (FFDCs) should pursue strategic action in order to deal with the potential impacts of a low-carbon transition (Peszko, et al., 2020).

This section described the path that oil demand is expected to take both in the short term and in a longer one. A short-term analysis highlights a steady oil demand, unaffected by the ongoing electric transition in the transport sector. This may be explained by the only partial share that the passenger vehicle sector holds in total global oil demand. Furthermore, some crucial underlying trends were highlighted. Namely population growth and economic growth. These factors determine a rise in the fossil fuel demand market for the remaining sectors. The long-term approach highlighted something different. Oil demand is expected to decrease over the next three decades. The IEA considers three development scenarios with varying degrees of climate action. In all of them, the role played by the transport sector is underlined and how it contributes to the lowering of future oil demand. It is appropriate to conclude that the transition to electric mobility will eventually reduce oil demand affecting the global fossil fuel market.

2.2.3 The Fuelling Business

Electric vehicles are fuelled differently from ICE vehicles. EVs run on batteries. These batteries have a fixed capacity and are able to run the vehicle for a certain number of miles. Before the batteries completely run out, the vehicle has to be connected to a charging point. Depending on the type of vehicle and the charging speed of the station, the EV will have to stay parked for some time. On the opposite, ICE re-fuelling is practically immediate compared to EVs. Ordinary gas stations do not provide the fuelling infrastructure needed to support an electric transition. In fact, the transition to electric mobility is expected to change the business model of the fuelling infrastructure (Briceno-Garmendia, Qiao, & Foster, 2022).

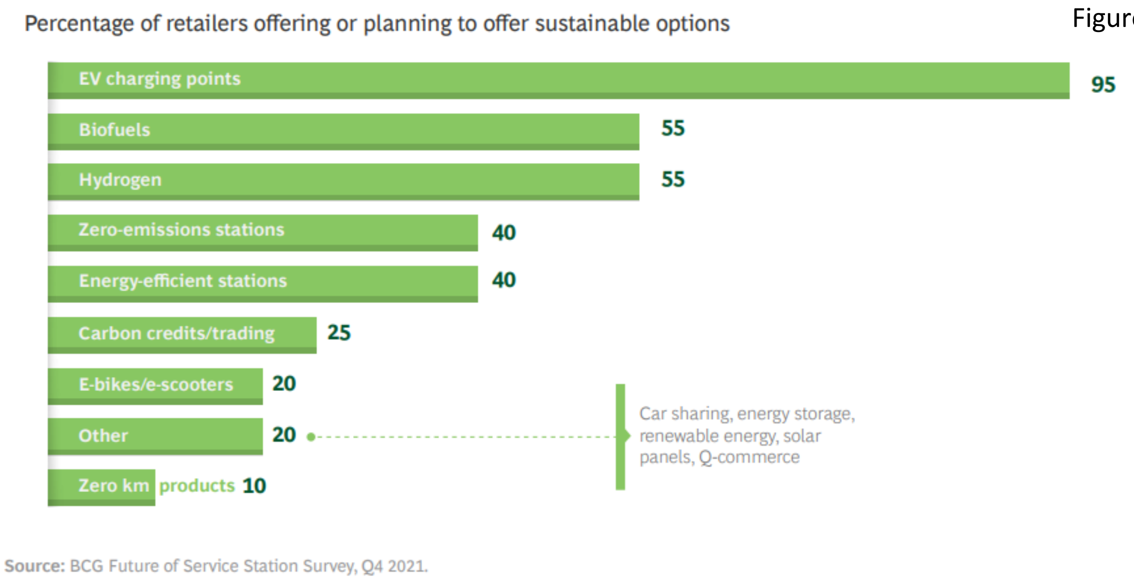
The growing pace of the EV transition not only will decrease sales of petroleum-based fuel in the coming future, but it also pressures the expansion of the charging infrastructure (Rubeis, Groves, Bonaccorsi, & Portera, 2022). The expansion is in fact already underway. In 2017 the IEA globally recorded just over 100 thousand fast public chargers and 330 thousand slow public chargers. In 2021 the numbers rose to nearly 570 thousand fast public chargers and 1.2 million slow public chargers. Furthermore, only in 2021 the number of charging points went up by nearly 40 per cent (International Energy Agency, 2022). It is relevant to make a broad distinction between EV chargers. Chargers can be private or publicly accessible. Private chargers are located at residences or workplaces. They range from 3 to 22 kilowatts (kW) of power. As of today, this is the primary means of EV charging. Publicly accessible chargers present different characteristics. They can be found in urban areas or along highways. On average they deliver more power than private chargers, namely between 11 and 350 kW. Public infrastructure is required in order for EV drivers to endeavour on long-distance journeys. They are also necessary for those EV owners that lack a private charger.

The electric mobility momentum can be sustained only if met with sufficient access to charging infrastructure. In 2021 the sales for EV vehicles more than doubled bringing the total car fleet at 16.5 million (International Energy Agency, 2022). The adequacy of such infrastructure may in fact be assessed by considering the EV-per-charger ratio and the charger power-per-EV ratio, expressed in kilowatts (kW). For example, in 2014, the European Union advised member states to supply one public charger per every 10 electric light-duty vehicles. This was set as a 2020 objective (The European Parliament and the Council, 2014). As of 2021 the ratio stands at 14. As for the power-per-EV ratio it suggested 1kW per battery electric vehicle (BEV) and 0.66 kW per plug-in-hybrid vehicle (PHEV). Globally, the charging infrastructure is taking shape. In 2021 the worldwide average was of 10 EVs per charger and 2.4 kW per EV (International Energy Agency, 2022).

The fuel retail business is entering a new era. Several major trends may be identified as factors of change. Not all of them are linked to electric mobility. The change of consumer behaviour brought along by COVID-19 is one of them. The emerge of biofuels, the exploring of the hydrogen alternative and the expansion of digital technologies may also all be considered (Rubeis, Groves, Bonaccorsi, & Portera, 2022). Nevertheless, the EV transition plays a prominent role in this evolution. The rise in EV sales and the usage shift from ICE to EV are clear trends. Furthermore, EVs, along with biofuels and hydrogen, can be placed in a wider trend of sustainable transport. It is in fact obvious that sustainability is taking root at in increasing pace in today's societies. More stringent emissions regulations are enacted, consumer awareness is growing, and the cost of carbon credits is rising. These trends highlight the need for fuel retailers and oil companies to respond. "Every fuel retailer in the world needs to prepare for a different future-and one that unfolds at different speeds across markets" (Rubeis, Groves, Bonaccorsi, & Portera, 2022, p. 4).

Fuel retailers have three main development opportunities to modernize their stations. These are the capitalization of their real estate, the transformation of their convenience store, and mostly important to this discussion, the modernizing of the pump through alternative fuel offerings. Companies have the business opportunity to upgrade their offerings and equip gas stations with EV charging stations and other alternative fuels. This is a fine opportunity, as the demand for charging points is rising (Rubeis, Groves, Bonaccorsi, & Portera, 2022). Figure 7 below shows the of retailers that are planning to or are already offering these kinds of solutions. These results are in response to share the following survey questions: "Do you have a strategy in place to serve EVs and alternative-fuelled vehicles?", and "Which of the following products are you offering or planning to offer?".

Figure 7

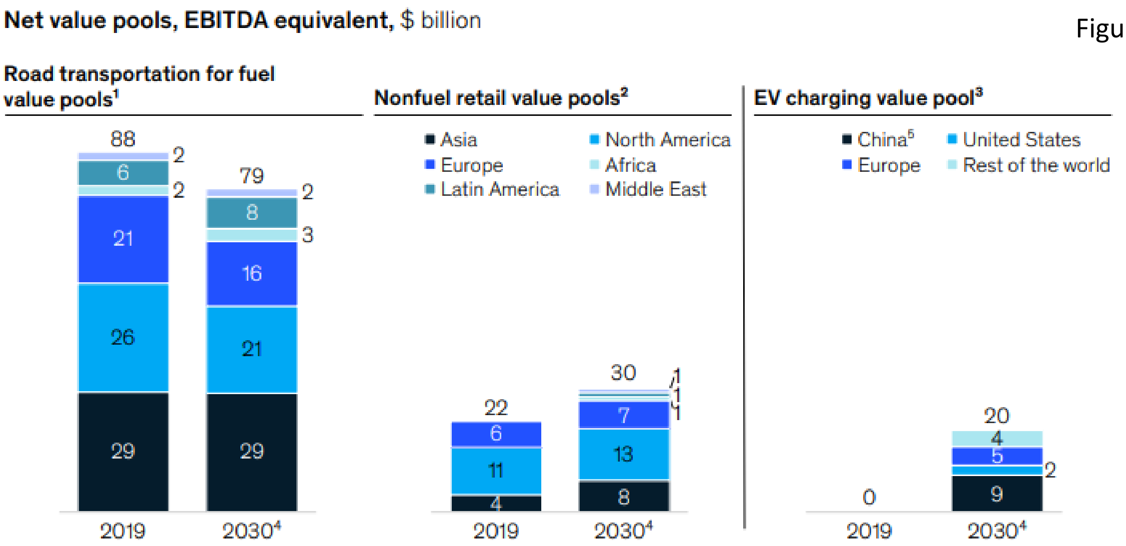


EV charging points stand out as the dominant product that retailers are planning or already offer among the vast selection of sustainable options. 95 per cent of respondents indicated this choice. EV infrastructure is then followed by biofuels and hydrogen at a 55 per cent answer rate. The graph also shows the incidence of other sustainable products in the survey such as zero-emissions stations, energy efficient stations, carbon credits, e-bikes, and e-scooters.

It is clear that almost all retailers are considering upgrading their services with charging points, if they have not already done so. This choice appears to be certainly reasonable when considering the prospect of e-mobility in the fuelling business.

The global value pool for fuel retail is expected to decrease from $87 billion in 2019 to $79 billion in 2030. This is due to efficiency improvements, emissions regulations, the rise of e-mobility and shared mobility mostly in North America and Europe. This decline however is expected to be offset by gains in nonfuel retail and EV-charging. E-mobility is in fact considered an emerging value pool. In 2021 the estimated value pool for EV charging in the fuel retail business was worth less than $0.1 billion. By 2030 it is expected to reach a value of $20 billion if met with a high level of capital-expenditure investment in infrastructure (Bau, et al., 2021). This scenario is illustrated in Figure 8.

Figure 8



Note: Figures may not sum exactly, because of rounding.
[1]Includes B2C (passenger vehicles and 2/3 wheelers) and B2B (passenger-vehicle fleets, light commercial vehicles, buses, and trucks).
[2]Includes forecourt convenience and car wash.
[3]This is a nascent and uncertain market requiring significant investment and its eventual value could differ significantly from this projection; use cases included are home, work, destination, fleet, and on-the-go charging, but not two wheelers.
[4]2030 projections are based on the McKinsey Muted Virus Recovery scenario.
[5]Assuming no cap on tariffs for public charging, allowing private players to set tariffs.
Source: McKinsey Energy Insights Value Pool model

The bars on the left indicate the overall loss of value of road transportation for fuel value pools. As shown in the composition of the bar, degrowth does not take place everywhere. Asia and the Middle East are expected to maintain the same value. Latin America and Africa will experience a growth. North America and Europe will register a decrease. The overall degrowth will be offset by gains in the nonfuel retail value pools as shown in the middle bars. The growth is expected to be from $22 billion to $30 billion in that specific value pool. On the right, the bars show how the EV charging value pool will grow from almost null to $20 billion as mentioned earlier. The ground is still nevertheless uncertain. “Any large-scale investment in EV charging would need to be justified by attractive prospects for profitability, along with sufficient EV penetration to allow charging stations to be operated above utilization thresholds and earn back the capital expenditures invested" (Bau, et al., 2021, p. 7). For these reasons EV charging may present strong variations across different markets and locations. The biggest opportunities appear to lie in China, the European Union, and some areas of the United States, such as California.

This sub-section aimed at describing the effects that the electric mobility transition will bring along to the fuel retail business. The pace of this transition requires a strong infrastructure to support it. Traditional gas station facilities need to provide services that were not required in the past. The availability of charging points and their diffusion is key for the successful outcome of e-mobility. A survey conducted in 2021 confirms that almost all businesses are aware of such infrastructural need and are planning to meet it. In the following years the retail fuel business will suffer a decline due to a decreasing purchase of fuel. Even so, EV charging will offset such degrowth and add extra value to the sector, offering an interesting business opportunity.

2.2.4 The Automotive Aftermarket

The automotive aftermarket is a key sector of the automotive industry. The approximate revenue in 2015 stood at around $760 billion. This amount accounted for around 20 per cent of total automotive revenues. (Breitschwerdt, Cornet, Kempf, Michor, & Schmidt, 2017) The aftermarket sector includes automotive services and parts businesses. The service business refers to maintenance and repair of vehicles. The parts business includes retail and sale of vehicle components. This sub-section aims at highlighting the effects brought along by the electric mobility transition in the aftermarket sector. In particular, the focus will be set on automotive maintenance.

The overall automotive aftermarket is expected to grow in the following years. A McKinsey analysis published in 2017 (Breitschwerdt, Cornet, Kempf, Michor, & Schmidt, 2017), shown in Figure 9, compares the size of the market in 2017 and 2030. The study predicts a 3 per cent per annum (p.a.) growth, that will increase the market size from $803 billion in 2017 to $1,196 billion in 2030. In both circumstances the largest shares of the market are hold by Europe and North America. They respectively have a compounded average growth rate (CAGR) of 1.5 and 1.7 per cent. These values are relatively low when compared to other regions around the world. Asia is predicted to be the

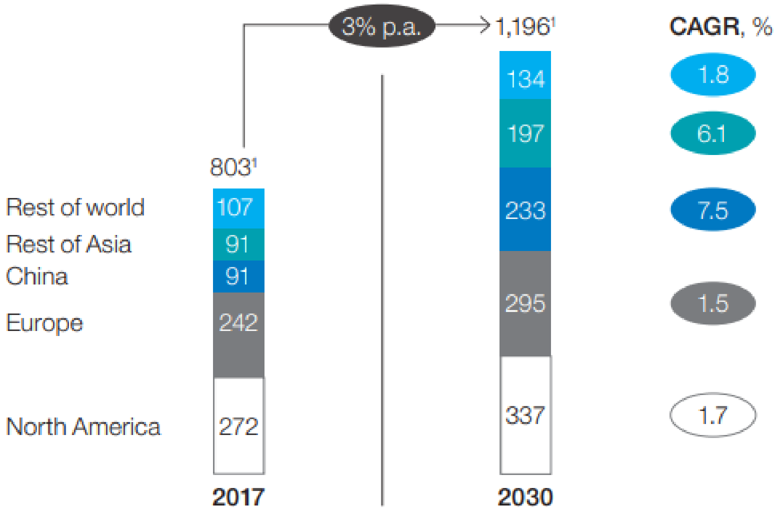


Figure 9

main driver of growth in the market. China alone will register a 7.5 CAGR. The rest of Asia will reach a 6.1 per cent CAGR.

The predictions described above are the outcome of some underlying trends. Shared mobility for example is considered to be one of the growing factors. This is due to its need for encreased annual meintenance, given a larger on average use of shared vehicles. However, the market's overall growth will be offset by some disrupting factors. In fact, some trends will have "strong and opposing influences on the development of this market and the distribution of value across players" (Breitschwerdt, Cornet, Kempf, Michor, & Schmidt, 2017, p. 14). The spread of autonomous vehicles for example will exponentially decrease the resources spent on crash repairs by up to 90 per cent in 2030. Electric vehicles will also play a consistent role in the market's offset. EVs require much lower maintenance expenses compared to traditional ICE vehicles, to which the discussion will now turn.

The expansion of electric vehicles will limit the automotive aftermarket's growth. This is because EVs are expected to bear much less maintenance costs than traditional vehicles. This claim is due to the strucural differences that exist among electric power trains and ICEs. (Briceno-Garmendia, Qiao, & Foster, 2022) As mentioned earlier in this paper, electric motors have very few moving components, namely around 20. ICEs have roughly 2000 moving parts. This exposes ICE vehicles to higher levels of deterioration when compared to EVs. Furthermore, EVs do not require fluid changes (Plungis, 2020). A study conducted in 2020 empirically compares the meintenance costs of electric vehicles, plug-in-hybrid vehicles and internal combustion vehicles (Harto, 2020). The results are shown in the two tables below (Figure 10 and Figure 11).

Figure 10 Estimated Per-Mile Repair and Maintenance Costs by Powertrain

Powertrain Type	0-50K Miles	50K-100K Miles	100K-200K Miles	Lifetime Average
BEV	$0.012	$0.028	$0.043[13]	$0.031
PHEV	$0.021	$0.031	$0.033[5]	$0.030
ICE	$0.028	$0.060	$0.079	$0.061

Figure 11 Lifetime Maintenance Costs by Powertrain[14]

Powertrain Type	Lifetime Maintenance and Repair Cost	Lifetime Savings vs. ICE
ICE	$9,200	
BEV	$4,600	$4,600
PHEV	$4,600	$4,600

The first table takes into consideration the estimated per-mile repair and maintenance costs of BEVs, PHEVs and ICEVs. The estimated cost-per-mile is divided into three ranges. On the right the lifetime average is also shown. In all three distance ranges BEVs and PHEVs powertrains register much lower per-mile costs than ICEVs. In fact, the lifetime per-mile average repair and maintenance cost for BEVs PHEVs is shown to be approximately half of the cost for ICE vehicles. Namely $0.031 for BEVs, $0.030 for PHEVs, and $0.061 for ICEVs. The second table uses the same data to put such costs in a consumers' context. The three types of powertrains are compared on total lifetime maintenance and repair costs. ICE vehicles will usually cost $9200 during their lifetime, which is double of what BEVs and PHEVs will need. The column on the right simply states that EV and PHEV owners will save $4600 compared to ICEV owners. These data highlight the impact that the transition to electric mobility will have in bounding the growth of the automotive aftermarket for maintenance.

This sub-section sought to highlight the effect of the electric transition over the automotive aftermarket, with a special focus on the maintenance sector. The discussion first started with taking into consideration the path that the market is expected to take in the following decade. The market is in fact expected to grow. This growth will not take place homogenously, as Asia is expected to be the main driver. Nevertheless, Europe and North America will still hold the majority of the market volume. The market's growth will however be bounded by some disrupting trends. EVs in particular, because of their operational differences, bear reduced maintenance and repair costs than ICE vehicles. This was empirically assessed by taking into consideration a relevant study published in 2020 by Harto. As a matter of fact, BE and PHE vehicles cost half of what an ICE vehicle would for maintenance and repairs over its lifetime. As the transition to electric mobility unfolds, reduced maintenance will limit the market's ability to grow.

3 The Future of Work in the Automotive Industry

The discussion now turns to the social impacts that electric mobility will bring along in the coming years.

The transition to electric mobility is a major technological shift for human societies, as emphasized several times in this paper. The previous sections have highlighted some of the main environmental and economic consequences caused by such change. Social impact is the last dimension to be considered.

This section will deal with the paramount social concern linked to the rise of electric vehicles, namely employment. Only in Europe, as of 2021, the automotive industry and its adjacent sectors included more than 5.65 million employees (Boston Consulting Group, 2021). Furthermore, the European Automobile Manufacturers Association (ACEA) estimates that the automotive sector accounts for 7 per cent of total EU jobs, with more than 13 million Europeans being directly or indirectly employed thanks to the industry (2022). Globally, the broader automotive industry accounts for around 34 million workers, employed across the passenger car value chain (Hannon, Krishnan, Patel, & Sahdev, 2022).

"The global automotive industry had already been at a turning point prior to the pandemic, due to the digitalization of road transport systems and the shift to carbon-neutral mobility" (International Labour Organization, 2021, p. 10). This statement by the ILO highlights the revolution which is gaining pace in the automotive sector. Green mobility, coupled with digitalization and technological advances will considerably alter the automotive scenario in the coming years.

In particular, the substantial operational and structural differences between ICE vehicles and electric vehicles will have disruptive effects over employment in the sector. It is worth reminding that electric cars are less complex and labour-intensive to assemble. They have a lower number of components. Consistent job losses are expected to take place due to the decreasing production volume of ICE-powered vehicles. Combustion-engineering personnel will no longer be required as before. The same is expected to happen for maintenance and servicing, where EVs require less attention than ICEVs, as saw in the previous sections. Nevertheless, other job opportunities are expected to flourish. The fields of battery manufacture and electric motors will come to the rise (Thielmann, et al., 2020). These opportunities however "would not be like-for-like replacements of old jobs, and workers would not be able to transition automatically or spontaneously" (International Labour Organization, 2021, p. 11) This new kind of mobility entails new competences and new skills. Workers will need to be upskilled and reskilled in order to cope with the ongoing transformation. Several car parts suppliers are already taking action in this direction. Bosch for example, which is Europe's largest car parts supplier, in 2022 announced the spending of €2 billion in order to retrain part of its working force (Miller, 2022). Digitalization, and the prominent role played by in-vehicle software, increases the demand for digital talents. Similarly, EVs will require engineers with electrical and battery chemistry competences. "All in all, the changes to the automotive workforce are likely to be as extensive as the changes coming to the vehicles they manufacture" (Hagermann, Heuss, & Weerda, 2021, p. 9).

Despite the expansion of the new working fields mentioned, the net impact of the electric mobility transition over employment does not seem particularly promising. Several studies expect a net loss of jobs, or rather a stationary development of employment in the industry as a whole. Very few predictions forecast overall increases in occupation for the sector (Thielmann, et al., 2020). The impacts may be much more severe when considering specific sectors within the industry.

The following subsections will deal with the several aspects related to the future of work in the automotive industry. In particular, the focus will be set on the impact that the transition to electric mobility will bring along in Europe. This choice may be justified by the fact that the transformation is not happening at the same pace around the globe (International Labour Organization, 2021). The automotive industry is global and interconnected, but electric mobility will take root at different times in different regions in the world, depending on the countries' backgrounds and expectations. Europe, along with China and the USA, is a key region in the ongoing transition (International Energy Agency, 2023). Europe, together with China, is expected to lead the way in electric vehicle sales by 2030 (Adeola, et al., 2023). The limited scope of this paper also does not allow a broader analysis of the matter.

The discussion will continue along these lines. First, it will provide an overview of the industry sectors and job families that will be taken into consideration. Secondly, it will describe the major ongoing trends within these sectors. Thirdly, it will discuss the overall net impact of electric mobility over job development. Thirdly and lastly, the discussion will briefly turn to the employment movement and job transitions that will take place across the automotive sector.

3.1 The relevant Industry Sectors and Job Families

It is relevant to for this discussion to identify and categorize the economic sectors and job families that will be taken into consideration along the rest of the analysis. This is a complex task given the reach and complexity that characterizes the automotive industry. Such an industry has "an important multiplier effect in the economy" (European Commission, 2023) due to its links to adjacent sectors. This multiplier effect is in line with the size of the turnover it generated. In fact, the industry accounts for over 7 per cent of the European Union's GDP (European Commission, 2023).

A detailed report published by the Boston Consulting Group in 2021 outlines the various components that make up the automotive industry in Europe. The scheme considered is shown in Figure 12. The values illustrated refer to 2020, and take into consideration the European Union member states, the UK and Norway.

Figure 12

Total number of jobs in Europe 2020 [in K]

Industry cluster[1]		Engineering	Procurement	Production/ Service Ops.	Sales	Other	Total 2020	
Core automotive	OEMs	119	33	759	65	108	1,084	19%
	ICE-focused suppliers	123	28	427	28	59	666	12%
	Non-ICE suppliers	380	80	1,554	92	180	2,286	40%
	Maintenance & Repair	10	51	835	71	51	1,019	18%
Adjacent industries	Equipment & Services	97	22	238	47	35	439	8%
	Energy production	7	1	34	1	5	49	1%
	Energy infrastructure	2	1	16	1	2	22	0%
	Material recycling	9	9	54	9	9	90	2%
		748 (13%)	225 (4%)	3,917 (69%)	316 (6%)	449 (8%)	5,654	

Job category[2]

1. Based on 26 industries
2. Based on 31 jobs families
Source: EuroStat; BCG

The column on the left lists eight industry clusters. These clusters are divided into two larger groups. The top four clusters are labelled as "core automotive" industry clusters. These are activities that can be directly and indisputably linked to the automotive sector. Namely, original equipment manufacturers (OEMs), ICE-focused suppliers, non-ICE suppliers, maintenance & repairs. On the contrary, the lower four industry clusters showed are defined as "adjacent", due to their indirect relation to vehicles. These include equipment & services, energy production, energy infrastructure and material recycling. The broadening of the analysis to adjacent sectors is what makes the report distinctive. The consideration of such industry clusters allows the assessment of job development to be much more comprehensive (Kuhlmann, et al., 2021). This approach is in line with the multiplier effect that characterizes the automotive industry, as mentioned earlier.

The industry clusters are the synthesis and grouping of 26 industries overall. The non-ICE supplier cluster for example includes up to nine industries. Similarly, the energy production and energy infrastructure adjacent clusters respectively include five and four industries. This information highlights the scope of the analysis and the complexity of the automotive sector overall.

The top row in the table lists five major job categories. These are engineering, procurement, production & service operations, sales, and other remaining occupations. The automotive industry clusters considered in the previous paragraph clearly include several different kinds of employment. These are represented by the five job categories. These distinctions are relevant as the shift towards electric vehicles is expected to affect different job categories to varying degrees (Kuhlmann, et al., 2021).

As for the industry clusters, the job categories are the outcome of a grouping of 31 job families. The engineering, production & service, and sales families take into consideration almost ten different professions each. Procurement includes five.

The table gives an insightful overall picture of the automotive sector. The total number of employees across the eight industry clusters and five job families amounts to 5.654 million. Unsurprisingly, the core industries hold the largest shares of employment. The non-ICE cluster holds 40 per cent of the total, followed by OEMs with 19 per cent, Maintenance & repair at 18 per cent and ICE-focused suppliers at 12 per cent. The core clusters total over 5 million workers and 89 per cent of jobs in the scenario considered. The adjacent industries present considerably lower numbers, as it may be expected. Equipment & services hold an 8 per cent share of workers, followed by material recycling at 2 per cent, energy production at 1 per cent and energy infrastructure with a share close to 0 per cent. The automotive workers in the adjacent clusters sum up to 600 thousand, which accounts for around 11 per cent of the total. The five job categories also present much variation between each other. Production & services holds by far the largest share. Across the eight industry clusters, such job category amounts for 69 per cent of workers, explicitly almost 4 million jobs. The other categories follow at a distance. Engineering with 13 per cent, or 748 thousand. Sales at 6 per cent, or 316 thousand. Procurement at 4 per cent, or 225 thousand. The residual category of mixed occupations holds 8 per cent, or 449 thousand.

The eight industry clusters on the left, joint with the five categories on the top, create a grid which can describe more accurately job distribution in the industry. In fact, the intersection between the eight rows on the left and the five columns on the top creates sets of working force. The largest sets appear to be along the production & services (P&S) column when intersected with the four core industry clusters. For example, when P&S crosses the non-ICE suppliers row it shows a considerable set of 1.554 million workers. Similarly, when crossed with the maintenance & repair industry, it creates a set of 835 thousand employees. Other considerable sets can be found along the engineering column when crossed by core industry clusters.

It is worth mentioning some overarching data not showed in the table above. Of the almost 5.7 million jobs involved in the automotive industries, 68 per cent are located in only six European countries. Germany alone holds 1.7 million employees. The UK and France follow at 0.5 million. Italy and Poland at 0.4 million. Lastly Spain at 0.3 million. The remaining 1.8 million workers are scattered across the region (Boston Consulting Group, 2021). These data show the rather high geographical concentration of the industry in Europe.

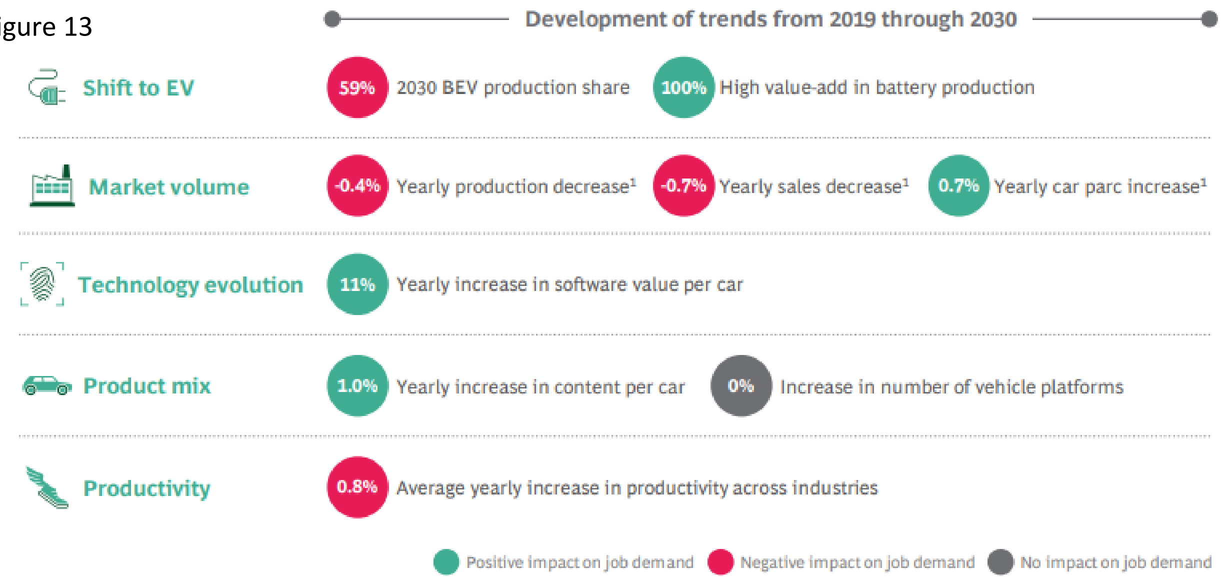
This section aimed at providing a satisfying overview of employment in Europe’s automotive industry. In order to do so, a considerable amount of classification and categorization was required. The discussion considered an analysis published by the Boston Consulting Group as a main reference. This study provides an all-encompassing view of the matter. In fact, other than taking into consideration the traditional automotive activity sectors, it also includes into the inquiry the indirectly related and adjacent industries. Furthermore, the data refer to 2020. This allows for an up-to-date overall picture. The insights found in this section will be the basis for the ongoing discussion in the subsequent sections of this paper.

3.2 Major Trends in the Automotive Industry

This section will be dedicated to the major trends that are expected to disrupt employment in the automotive industry over the coming decade. The trends that will be analysed present varying degrees of connection to the ongoing transition to electric mobility. These factors will be pivotal for the evaluation of the electric mobility transition over employment in 2030. The next section, devoted to the net impact of EVs over job development, will in fact draw conclusions based on these disrupting trends.

The report published by the Boston Consulting group in 2021 highlighted the presence of five major trends driving job changes in Europe throughout the decade. These are shown in Figure 13 below. The data take into consideration 2019 as the baseline year, and 2030 as the end year.

Figure 13



1. 2019 as baseline year.
BEV = battery electric vehicle
Source: Eurostat; IHS Markit; BCG

Along with the transition to electric vehicles, other four trends are considered. Namely market volume, technology evolution, product mix and productivity. The graph shows that the shift to electric mobility will have both negative and positive impacts on job demand. The negative side, shown in red, states that by 2030, 59 per cent of automotive production will be devoted to BEVs (battery-electric vehicles). Furthermore, BEV production is expected to grow by 37 per cent year over year. It is considered as a negative aspect, due to the labour effort required to produce BEVs, which is lower than the one for ICE vehicles. Nevertheless, this trend also holds a positive impact. The battery manufacturing forecast shows a 100 per cent value-add (Boston Consulting Group, 2021). The process of battery production may present itself as an opportunity. In fact, the new battery components needed exclusively for EVs may result in potential additional employment (Küpper, Kuhlmann, Tominaga, Arora, & Jan, 2020).

Market volume is the second trend considered. This is shown to bear two types of impact due to three different elements. The first is yearly production, which is seen as having a negative impact. The production volume of the European automotive industry suffered a heavy decline in 2020 due to the COVID-19 pandemic. Vehicle production passed from 17.7 million units in 2019 to 13.6 million in 2020. This decrease in expected to be offset by a gradual recovery up to 2025, reaching 17.2 million cars produced. After that year though, the predictions state that the year over year (y-o-y) production volume will decrease by 0.4 per cent. This will bring the yearly production in 2030 to be 3.9 per cent less than in 2019. Namely, 17.1 million units in 2030 compared to the 17.7 million of 2019 (Boston Consulting Group, 2021). The overall production of cars is obviously considered to be a significant driver of employment. If production goes down, the labour demand will follow (Kuhlmann, et al., 2021). The second negative element to be considered is sales volume. The forecast for vehicles sales presents similarities to the production one. Vehicle sales suffered a heavy drop in 2020, registering 13.5 million sales, compared to the 17.7 million of 2020. The sales volume is expected to grow up to 16.4 million by 2025. After that, sales will suffer a slight y-o-y decrease of 0.7 per cent. In 2030 sales will amount to 16.3 million, 7.7 per cent less than 2019 (Boston Consulting Group, 2021). This outcome is believed to be caused by the European market's considerable saturation (Kuhlmann, et al., 2021). The third and last element related to the market volume trend is car parc. The car parc is the total number of registered vehicles within a region. Europe's car parc is expected to grow by 0.7 per cent y-o-y. It is supposed to reach 343 million units by 2030, 8.4 per cent more than 2019. This increase is rather moderate when compared to previous years. This is linked to the consistent decline in sales considered previously (Kuhlmann, et al., 2021).

The third trend shown in the graph is technology evolution. As mentioned in the introduction to this chapter, digitalization and technological improvements will affect the industry. These include tools such as assistant driving, autonomous driving, and connectivity. In particular, the software value per single vehicle will register a sharp increase. Starting from $329 in 2020, the value of software in a vehicle is estimated to grow by 11 per cent every year. It will reach $615 in 2025, and $900 in 2030 (Boston Consulting Group, 2021). This steep increase in software per unit will increase the job demand for software engineers. This is the main reason why the technological evolution is deemed as positive trend over employment in the automotive industry (Kuhlmann, et al., 2021).

Another positive trend to consider is product mix. This term refers to the share that various vehicle categories have in the production output. Three categories may be identified, based on the cost of content per car. The first is entry, with a content per car below $30 thousand. The second is mid, with a content ranging from 30 thousand to 50 thousand. The third is premium, with a content of more than 50 thousand. The mid and premium car categories are expected to grow, while the entry category is expected to decrease its share in the production mix. This phenomenon will cause the cost of the average content per car to grow. Specifically, it is expected to grow by 1 per cent y-o-y. This trend will take the average content per car from 43.1 thousand in 2012, to 51.7 thousand in 2028. It is worth mentioning, as shown in the graph, that the product portfolio will remain basically unchanged. This means that the number of vehicle types will remain rather constant, and that the job demand for development engineers will follow (Boston Consulting Group, 2021).

The last trend to take into account is productivity. The automotive industry is expected to go through a raise in productivity values. As shown in Figure 13, the productivity increase is projected to be of 0.8 per cent y-o-y. These results stem from a weighted average of the gross value added per employee in the automotive industries (Boston Consulting Group, 2021). The most relevant productivity gains may be registered in the manufacture of batteries & accumulators, and the charging infrastructure. This increase of productivity in the automotive sector will be mainly promoted by the spread of digitization and automation across the industry over the next decade (Kuhlmann, et al., 2021).

The five trends contemplated above were industry specific. It is worth mentioning the presence of two overarching trends which are not included in the scheme considered so far. These are retirement and fluctuation. By 2030, 20 per cent or 1.2 million automotive workers will retire. Clearly, this will cause a considerable amount of employee movement in the industry. Similarly, fluctuation of employees will cause some degree of employee movement. The weighted average fluctuation factor is estimated to be at 1.9 per cent y-o-y.

This section had the aim to describe and analyse the trends that will affect the automotive industry over the coming decade. The discussion was supported with the aid of a 2021 report by the Boston Consulting Group. This detailed study identifies five major industry specific trends that will impact the employment scenario. The shift to electric vehicles is one of them. The other four trends nevertheless present some degree of relation to such transition, as explained above. The factors identified in these paragraphs will result as pivotal for the next stage. The following section will in fact be dedicated to the net impact of such trends over job development, and which differences the 2030 scenario has to offer.

3.3 The Net Impact on Job Development

As anticipated, this section will be dedicated to the net impact of the electric mobility transition over the development of total jobs in the automotive industry. The five trends considered in the previous section will guide the analysis, as the 2030 scenario that will be presented originates from these factors. In fact, the five trends will act in combination, affecting the overall amount of job opportunities. The first prediction that will be taken into consideration will be the one by the Boston Consulting Group (BCG) published in 2021, also used in previous sections. This report will also allow the discussion to include some specific information on the changes that the trends will bring along in specific industry clusters and job families. The discussion will then continue by contemplating other relevant studies on the same topic. Some conclusions will be drawn, highlighting potential outcome similarities or discrepancies across case studies.

The discussion will start by taking into consideration the model developed by the BCG (Kuhlmann, et al., 2021).Figure 14, shown in the next page, shows the impact of the industry specific trends over the number of employees up to 2030.

The starting number of jobs in 2019 is of 5.65 million. Over the decade, up to 2030, the five trends are expected to maintain the number of jobs almost constant. In fact, the 2030 forecast shows 5.615 million available jobs. The net impact, computed as the difference between the 2019 value and 2030 value, registers a loss of roughly 35 thousand jobs. This a rather moderate number when compared to the total amount. Namely, less than 1 per cent. It is appropriate to conclude that “the shift to EV will have only a minor net impact on jobs, leaving the total number of

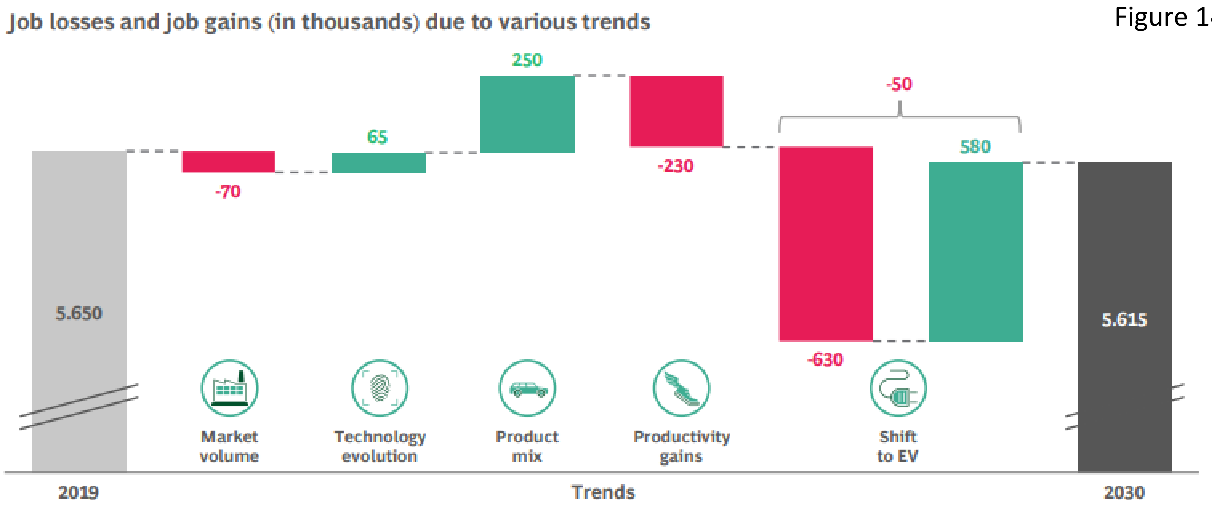


Figure 14

Source: BCG

jobs in the affected industries largely unchanged in 2030 compared with 2019" (Kuhlmann, et al., 2021, p. 6). Nevertheless, this picture does not give a profound insight of the changes taking place in the automotive sector. It is only a net numerical evaluation of the trends involved. It shows which trends will have positive or negative impacts and with what intensity, using the number of job positions gained or lost as measurement. It is for these reasons that the discussion will continue by contextualizing these trends in specific industry clusters and job families. This approach will hopefully cast much more light on the actual effects of the electric mobility transition over net employment.

3.3.1 The Trends within Industry Clusters and Job Categories

The discussion will continue by taking into consideration industry clusters and job categories. In particular, how each of these entities interact with all of the trends specified above. The figure below presents the expected automotive landscape across industry clusters and job categories for 2030. The values are compared to the original table shown at page 28. Therefore, they are assessed on the basis of the determined 2020 amounts. The core automotive industry clusters will be the first to be analysed.

Figure 15

Total number of jobs in Europe 2030 [in K] and relative change to 2020

	Industry cluster[1]	Engineering	Procurement	Production/ Service Ops.	Sales	Other	Total 2030	
Core automotive	OEMs	146 22%	27 -18%	527 -31%	57 -12%	108	865 -20%	-5%
	ICE-focused suppliers	62 -50%	13 -53%	236 -45%	17 -41%	58	385 -42%	
	Non-ICE suppliers	423 12%	86 8%	1,747 12%	89 -4%	179	2,524 10%	
	Maintenance & Repair	10	53	854	73	52	1,042	
Adjacent industries	Equipment & Services	96	28 28%	254 7%	41 -12%	33	453	34%
	Energy production	19 161%	2	78 128%	1	11	112 128%	
	Energy infrastructure	14 545%	9	96 507%	12	10	140 543%	
	Material recycling	9	10 9%	57	12 31%	9	97	
		779 4%	228 2%	3,849	302 -4%	461	5,619	

Job category[2]

1. Based on 26 industries
2. Based on 31 jobs families
Source: EuroStat; BCG

Higher job demand compared to 2020 · Lower job demand compared to 2020 · Nearly constant job demand compared to 2020

25

OEMs will register a consistent loss in job opportunities. The decrease amounts to a total of 219 thousand or -20 per cent, when compared to 2020. All five trends play a role in this outcome. Three of them hold a negative impact. The most relevant in this case is the change brought by the shift to EVs. OEM labour requirements for EVs are lower than the ones for ICEVs, due to their structural differences. In particular, the amount of labour hours required per EV are lower than the ones for an ICEV. This aspect single-handedly drops occupation in the industry sector by 166 thousand jobs. Productivity is the second negative trend to consider in the industry cluster. Productivity and efficiency are expected to grow in the future, as mentioned before in this paper. This will cause a 51 thousand job reduction. Such trend can be verified by taking into account the many reduction programs announced by OEMs worldwide (Boston Consulting Group, 2021, p. 29). The third negative trend is market volume. It is clear that a reduced production volume in the coming decade will decrease job demand and employment. The actual amount is believed to be of 35 thousand jobs. The three negative trends in the OEMs cluster sum up to a loss of more than 250 thousand workers. This considerable drop is marginally countered by two positive trends. 29 thousand jobs are expected to be created by the technology evolution. As already stated, the software in cars is expected to grow. This will lead to an increase of demand for software engineers in the sector. Product mix will also play a role. It is expected to boost 4 thousand jobs due to a rise in vehicle portfolio and vehicle complexity.

ICE-focused suppliers will register both the strongest employment percentage loss and numerical loss across all the eight clusters. The values are respectively 42 per cent and 281 thousand. This might not come as a surprise. The EV will gradually gain dominance in the automotive industry. ICE components will be demanded at a decreasing rate. Also, as for the OEMs case, the component labour requirements in the ICE-focused industry for BEVs are less than for ICEVs (Boston Consulting Group, 2021, p. 35). In fact, the EV shift trend alone will cause a decrease of 274 thousand jobs in the industry cluster. Both the market volume and productivity trend will play a negative role too. The first will cause a decline of 25 thousand jobs due to its declining nature throughout the decade. The second will cause a 29 thousand decrease due to its increase throughout the same period. The only positive trend registered in this cluster will be associated to product mix. The rising of vehicle complexity will bring about 47 thousand new jobs.

Non-ICE suppliers will register a consistent employment boost. The net growth will amount to 238 thousand new jobs, or 10 per cent more than in 2020. The largest part will be played by the EV shift. This is coherent with the definition of non-ICE focused supplier. The spread of EV vehicles will drive an increase in battery manufacture and electric motors. In fact, the battery tier labour requirements for BEVs are clearly superior to the ones for ICE vehicles, which do not bear such components. Furthermore, cell production alone has the potential to create up to 60 thousand new jobs (Boston Consulting Group, 2021, p. 37-38). Product mix will also bring along job opportunities, namely of around 173 thousand. This is due to the rising in vehicle complexity and variety. The last positive trend to be considered is technology evolution. The increase in electrical and electronics software will bring along 36 thousand new jobs. The negative trends regard productivity and market volume, as always so far. They present the same reasons as the ones explained for ICE-focused suppliers. The values are however different. The productivity factor will decrease employment by 132 thousand. The Market volume one by 76 thousand.

The maintenance & repair cluster will not register consistent changes as for the number of employees. Only two trends will come into play, and will have opposing effects. When the market volume trend was discussed in the previous section, its description included a rise in the European car parc. Such an increase in registered vehicles is expected to boost jobs by 85 thousand in the maintenance industry cluster. The shift to EV however will almost totally counter this growth. As said when discussing the evolution of the automotive aftermarket, EVs bear less maintenance costs and efforts. This will cause a 60 thousand loss in repair shop employees. The net job impact on the cluster is a slight 24 thousand increase (Boston Consulting Group, 2021, p. 42).

As it may be deduced from the data in Figure 15, and the discussion so far, the four core industry clusters will suffer overall losses. Specifically, when putting the four together, the job loss will be of 5 per cent compared to the value of 2020. The situation will be much different for the adjacent clusters, to which the examination will now turn.

Equipment & services is the first adjacent industry cluster to consider. Four trends will come into play, although with moderate momentum. The shift to EVs and product mix will bring along slight positive impacts. The first will increase equipment demands for battery manufacturing and electric motors factories. The expected increase amounts to 13 thousand jobs. The second is estimated to create 26 thousand new positions, due to an increase in vehicle complexity. The market volume and the productivity factor will respectively decrease employment by 15 and 10 thousand. The reasons are still a decreasing production trend and an efficiency increase. All things considered, the count will be of 14 thousand new jobs.

The energy production industry will register an important employment increase. This appears to be caused by only one trend, namely the shift to EVs. When discussing the environmental impacts of the electric transition in section 1.1, it was already clear that such a shift will cause an increase in energy demand. Electric vehicles run on electricity-fuelled batteries. In order for the transition to the place, the increasing energy demand has to be met with further power generation. Further power generation entails a larger working force. The extension of the energy production industry will bring along a 63 thousand job expansion by 2030. In particular, EV energy production jobs will grow by 41 per cent y-o-y (Boston Consulting Group, 2021, p. 47). This will take the overall number of energy production workers from 49 thousand to 112 thousand in just a decade. The percentage increase is a shocking 128 per cent.

The energy infrastructure will register an even sharper increase than the one seen for energy production. When discussing the fuelling business in section 2.2.3, the analysis highlighted the infrastructural change brought along by the expansion of electric cars. The traditional fuel infrastructure will face a reduction over the years, due to a declining purchase of conventional fuel. On the contrary, charging points are on a steep rise. The consistent growth in the charging infrastructure required for EVs will increase related manufacturing and maintenance jobs. This transformation will inject 118 thousand new jobs into the energy infrastructure sector. The expected y-o-y growth rate for charging infrastructure employment is expected to be of 38 per cent (Boston Consulting Group, 2021, p. 50). In fact, the 2030 employment percentage change is a shocking 543. In 2030 the industry will account for 140 thousand workers, against the 22 thousand of 2020. It is reasonable to say that the shift to EV will generate a considerable opportunity in this sector.

Less intense will be the change in the material recycling industry cluster, as shown in the table used as reference (Figure 15). The three trends involved are all expected to have moderate intensities. Material recycling employment will suffer slight reductions due to a decreasing sales volume in the industry. The prediction suggests a 5 thousand job loss due to this market volume trend. Similarly, a rising productivity will cause the loss of 8 thousand positions. On the contrary, the transition to EVs will foster employment in such sector. As mentioned in the 2.2.1 section when dealing with battery supply chains, EV battery recycling is a rising phenomenon. Other than contributing to the solution of issues such as supply stability and decarbonization, it offers a thriving business opportunity. The transition to electric mobility will increase the volume of recyclable battery material. This is expected to increase the sector's occupation by 20 thousand positions. The overall job impact is therefore an increase of 7 thousand. It is relevant to mention the efforts made by policymakers in order to foster battery recycling. The example that may be used for Europe regards the 2018 directive on batteries and accumulators (The European parliament and the Council, 2018). Nevertheless, such legislation still lacks specific references to EV battery types (Boston Consulting Group, 2021, p. 52).

As anticipated, the adjacent automotive industry clusters present consistent employment increases. The most noticeable are the ones found in energy infrastructure and energy production. As opposed to the core industry clusters, the adjacent ones register a high overall increase. The average percentage increase across the latter four is of 34 per cent. Therefore, although the net impact on job development across all clusters is rather constant throughout the decade, "it is equally important to analyse how these jobs are distributed across the different industries and functions" (Kuhlmann, et al., 2021, p. 6). The discussion now briefly turns to the behaviour that the four job categories will assume, also quoted above as "functions".

The engineering category will register a significant increase of 31 thousand jobs, or 4 percentage points compared to 2020. The industry clusters contributing to this positive balance are OEMs, non-ICE suppliers and charging infrastructure. The first two may be respectively justified by the need to develop new BEV vehicles and new BEV components. The third may be linked to the massive increase in planned installations. These three elements add up to 95 thousand new jobs. This amount is offset by the engineering job reduction expected in ICE-focused suppliers. The reduced number of ICE components will take the net impact down by 62 thousand (Boston Consulting Group, 2021, p. 54).

Procurement will remain almost numerically unchanged. Nevertheless, it will go through changes in five different industry clusters. These will even each other out. The sectors on the positive side are non-ICE suppliers, equipment & services and charging infrastructure. Meanwhile, the sectors on the negative side are OEMs and ICE-focused suppliers. The overall alteration is a modest amount of 4 thousand workers, or 2 percentage points (Boston Consulting Group, 2021, p. 55).

Production & services will register a strong reduction. Four industry clusters come into play. OEMs and ICE-focused suppliers will register respectively a loss of 232 and 191 thousand. The reasons are increased labour productivity and reduced demand for ICE components. Growth is expected within non-ICE suppliers and energy infrastructure. The first amounts to almost 200 thousand, while the second to 124 thousand. Such numbers are driven by an increased demand for BEV components and an increase in charging installations (Boston Consulting Group, 2021, p. 56). The net impact stands at -68 thousand. However, the percentage change stands low at 2 per cent. This is due to the huge initial working force of 3.917 million.

The last job category that will be considered is sales. Many variations are expected to be seen for such group across the industry clusters over the coming decade. Such type of employment will decrease in OEMs, ICE-focused suppliers, non-ICE suppliers, and equipment & services. The shift towards online sales will be the paramount factor in such losses. The only industry cluster to register a rise in sales occupations is the energy infrastructure one. The net impact is negative. The job losses in the sales category will amount to 14 thousand. The percentage change is of 4 points.

This sub-section had the aim to provide a profound analysis of the evolution that will take place in reaching the 2030 automotive employment scenario. The discussion started with the comparison of the 2030 table of values with the 2020 one. The five trends described in the 3.2 section guided the assessment through every industry cluster. The changes in each automotive entity were explained through the characteristics of each single trend. The extensive report by the BCG served as a paramount reference throughout all the discussion. This maintained the discourse coherent with what described in the 3.1 and 3.2 sections. In fact, the outline on automotive industry categories and trends provided in those sections was extracted from the same report. The general conclusion that results from the analysis of these data stands as an overall flat development of automotive jobs until 2030. However, this outcome stems from a wide array of changes throughout industry clusters and job categories. Those labour variations come close to compensating each other. The core automotive sectors are the ones expected to suffer the most from the EV transition. On the opposite, the adjacent automotive sectors are projected into a stimulating environment of job opportunities. The discussion then turned to job categories, which will also undergo some degree of change. The engineering set is expected to grow, as for procurement. Sales will be the one to suffer the most. Production & services will remain almost unvaried. The next sub-section will be devoted to the consideration of other relevant studies over the same topic. This will be done in the sake of providing more comprehensive and complete conclusions over the expected evolution of automotive labour.

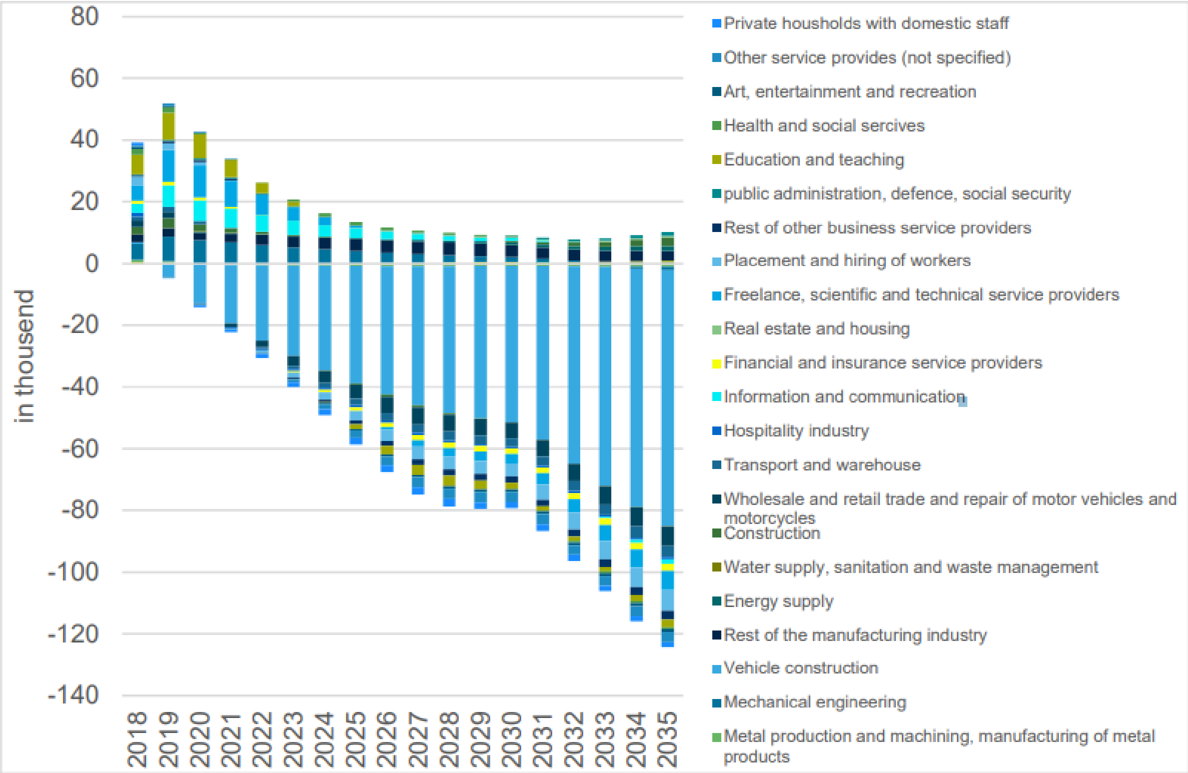
3.3.2 The IAB and McKinsey models

As anticipated, this sub-section will briefly take into consideration two recent studies that deal with the same topic seen above. Namely, job development in the automotive industry. The inclusion of more research in this discussion has the purpose of providing a more complete analysis of the matter. Hopefully, stronger conclusions will follow. The studies considered, as presumed from the title, are a discussion paper by the German Institute for Employment Research (IAB) (Mönnig, Schneemann, Weber, Zika, & Helmrich, 2019) and an article by the McKinsey Quarterly (Hagermann, Heuss, & Weerda, 2021). The IAB research will be the first to be discussed.

In 2019 the IAB developed a model in order to predict the economic and labour consequences that electric mobility will cause over the next 15 years. As opposed to the BCG report, the scope of the analysis is restricted to Germany, Europe’s greatest automotive nation. The projections constructed go forward to 2035. The model is extremely complex, laying on 17 assumptions and 14 quantitative settings. These tools are used in order to apply a scenario comparison technique.

The first relevant finding to consider is the trend assumed by the total number of persons employed in the German automotive industry. This is shown in Figure 16. The graph shows the number of employed persons by economic sectors. The ones relevant to this discussion are those relatable to the automotive industry.

Figure 16 **Number of employed persons in the electromobility scenario vs. the QuBe baseline projection by economic sectors**



Source: QuBe project

The graph highlights a strong macroeconomic effect. The vehicle construction sector will suffer a heavy loss of 83 thousand jobs by 2035. This decrease was expected to move its first steps as soon as 2019, when the study was conducted. Such an early decline is motivated by an increase in productivity, a trend which was also encountered in the BCG report. Other short-term variations can be found in sectors such as mechanical engineering, energy suppliers and the construction industry. Mechanical engineering is expected to benefit due to the investments made in the sector. Energy suppliers will benefit from the electric transition and the linked increase in energy demand, creating new jobs. The construction industry will register an increase in hiring due to the increasing demand for electric infrastructure, necessary for green mobility (Mönnig, Schneemann, Weber, Zika, & Helmrich, 2019, p. 37). These are phenomena which have been encountered more than once in previous sections. Furthermore, they present very similar characteristics to the ones described in the BCG report.

The IAB study also considers employment demand from an occupational point of view. Professions such as mechanical & automotive engineering, technical development, construction of production controls, metal production, machining, and metalworking are all expected to register a decline in labour demand (Mönnig, Schneemann, Weber, Zika, & Helmrich, 2019, p. 37).

The study concludes a future net loss of employment due to electric mobility. The scope of this evaluation includes all economic sectors. In particular, it takes into consideration the balance between employment loss and gains across four different moments. In 2020 the balance was expected to be positive. A surplus of 28 thousand jobs is estimated. In 2025 the balance is negative, with a net loss of 45 thousand. In 2030 and 2035 the net loss exacerbates, reaching 70 thousand and 114 thousand. The electric mobility scenario is initially expected to have an overall positive impact on employment. As it goes on, the balance turns consistently to the negative side. The transition to electric mobility will entail a consistent loss of employment for Germany. An additional 10 per cent of the population will become unemployed (Mönnig, Schneemann, Weber, Zika, & Helmrich, 2019, p. 36). These final results cannot be appropriately compared to the ones found in the BCG report, due to huge variations in the scope of the analysis. This study only considers the German nation. Also, the net job impact is evaluated across all economic sectors, not only the automotive one as for the BCG study. The similarities worth highlighting are the ones registered in the automotive sectors and occupations, as indicated throughout the discussion. The attention will now turn to a study conducted by the McKinsey group.

In 2021 the McKinsey group published an article dealing with future employment levels in the automotive industry worldwide. Similarly to what seen for other case studies, this one identifies several disrupting trends that will shape the future of the sector. All of these factors are placed in relation to the ongoing mobility transition.

The next decade is expected to bring along job losses in manufacturing, marketing & sales and other support functions (Hagermann, Heuss, & Weerda, 2021). The exact loss percentages that each sector will bring to the whole automotive industry are expected to be 14 per cent, 10 per cent and 6 per cent. The 14 per cent loss brought along by the marketing & sales sector is believed to be due to growing digitalization, and an increasing e-commerce. The 10 per cent loss related to the manufacturing business is attributed to the shift to EVs, which is expected to reduce demand in that sector. The other support functions are expected to register a 6 per cent loss due to automation and digitalization. As for marketing & sales, digitalization reduces demand for in-person work.

Nevertheless, some employment gains are expected too. These will partially offset the decrease in employment. A 6 per cent increase in jobs is expected in manufacturing. The increase in software and analytics will cause a higher percentage of vehicle value. Similarly, digitalization and analytical improvements will shift points of sale to advanced online channels, triggering a 2 per cent employment increase in the marketing & sales sector of the automotive industry. A 2 per cent increase will also be witnessed in other supporting functions, due to an increased use of data analytics. All these elements considered, the net impact of electric mobility over the automotive industry amounts to an employment loss ranging from 10 to 25 per cent (Hagermann, Heuss, & Weerda, 2021). This estimate refers to a worldwide evaluation.

This sub-section had the aim to give a provide a wider understanding of electric mobility and its employment impact. Two more studies were considered. One by the IAB, the other by the McKinsey group. The main reference was the report published by the BCG, widely used in previous sections. The purpose was to highlight potential similarities across all of them. This comparison was hindered by the different scopes and techniques used in all three of them. Nevertheless, it is worth underlying the similarities that cut across all the case studies considered so far. First, none of them associated the spread of electric vehicles with a net increase in employment levels. The BCG predicts a slightly negative or flat development trend in Europe up until 2030. The IAB case expects a severe loss of automotive workers. By 2035, 83 thousand automotive jobs are expected to be lost, with very few counterbalancing trends. When considering the whole German economy for the same year, the net loss amounts to 114 thousand jobs. The McKinsey study also predicts a net loss. It is expected to reach between 10 and 25 per cent of the global automotive industry. The second element of similarity are the trends and factors that were considered across all three pieces of research. Trends such as the shift to EVs, digitalization and productivity were present throughout every paper. It is appropriate to conclude that electric mobility is not expected to foster overall employment in the automotive industry. In some of the contexts seen so far, it may bear even more severe consequences. In order to maintain such effects under control, the working force will have to go through some degree of transformation, to which the last section of this chapter will be devoted.

3.4 Movement of Workers

This section will be devoted to the employee movements triggered by electric mobility across the European automotive sector.

The previous sections dealt with the net impact that electric mobility will have on the number of workers. In the case of Europe, the overall number of automotive employees is expected to remain practically unchanged in the coming decade.

As already suggested, this result may hide an underlying phenomenon. Several studies anticipate that major transitions will take place within the working force (Hagermann, Heuss, & Weerda, 2021) (Boston Consulting Group, 2021) (International Labour Organization, 2021). This is because the spread of carbon-neutral mobility and digitalisation will change the skills required from employees (Huitema, 2020). Electrical vehicles need competences largely not yet available. In fact, there is "a huge gap between the future skills needs of the industry and the current workforce" (International Labour Organization, 2021, p. 19). In order to mitigate the disrupting impact of the green mobility shift, the industry needs to adapt and increase training and education (Huitema, 2020). These approaches should not be limited to new entrants. Reskilling should begin by taking into consideration the existing working force.

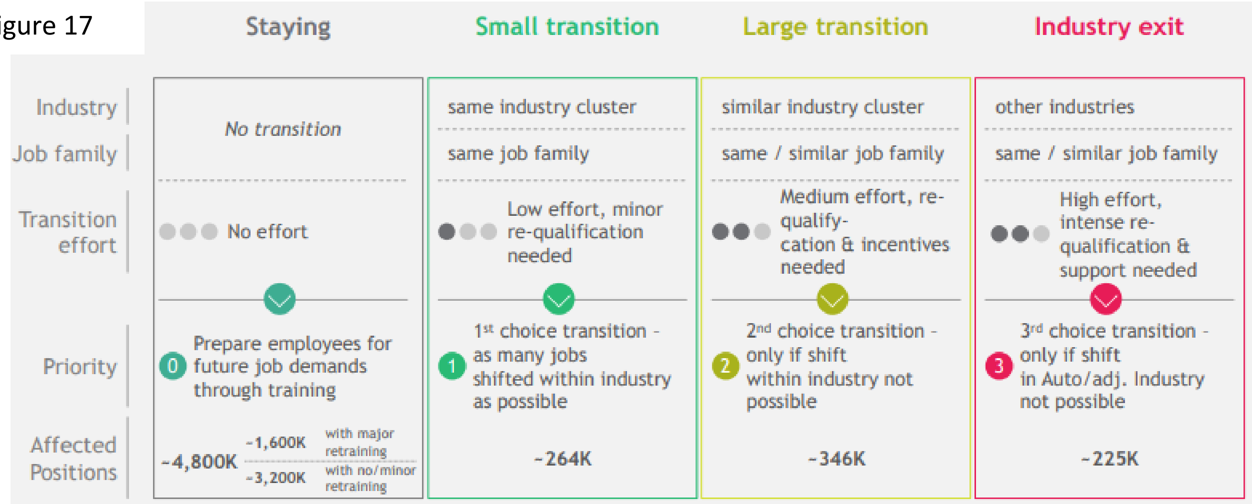
In recent years stakeholders and policy makers have started to take action in such direction. In 2016, the European Commission developed a "New Skills Agenda". This piece of legislation has the aim to "strengthen human capital, employability and competitiveness" (European Commission, 2016, p. 1). It consists of a five-year plan to support individuals and companies in developing appropriate and up to date skill sets (European Commission, 2023). Private interest groups are doing the same. In 2020 the "European Automobile Manufacturers Association", or simply ACEA, launched a program named "Skills Partnership for the Automotive Ecosystem" (Huitema, 2020). European manufacturer Bosch has announced similar policies in order to cope with the ongoing automotive revolution (Miller, 2022). SEAT, owned by the Volkswagen group, invested in personnel training, transforming some of its production operators into software developers (International Labour Organization, 2021, p. 23). These are only some of the many examples that can be found across the automotive industry. The transition to electric mobility and the ongoing automotive revolution require such type of policy.

The discussion will focus on the job transitions across automotive industries and automotive job families. The framework used will be the one set by the 2021 BCG report, already thoroughly described. Such transitions will be determined by the degree of training that jobs will have to go through, to which the discussion now turns.

3.4.1 Training Needs and Job Transitions

The 2021 BCG report categorizes three types of transition, and its corresponding training need (Boston Consulting Group, 2021, p. 61). These are schematically shown in the picture below.

Figure 17



It is worth noticing that the vast majority of the automotive workforce will undergo no transition. The grey box on the left accounts for 4.8 million workers, out of the total 5.6 million expected in 2030. These occupations will maintain their original characteristics.

The first type of transition presents different characteristics. This "small" transition will involve some degree of training and re-qualification. This is due to a slight change in job requirements. This type of on-the-job training is expected to maintain the interested work force in the same job family and same industry cluster. The number of positions affected is estimated to be around 264 thousand.

The second type of transition will entail greater changes. This "large" transition is expected to move the concerned workforce into another industry or job profile. Nevertheless, same degree of similarity with the original profession is maintained. A consistent amount of re-qualification will be required in order to fit the workers into their new positions. Incentives are also expected, in order for such training to take place. This movement is expected to affect around 346 thousand workers.

The third and most challenging type of transition is the "industry exit". 225 thousand workers will have to move to another industry. They will have to develop a new job profile. Such a change will require a high training effort and an intense re-qualification path. An appropriate example of such transition may be the moving of workers from automotive assembly to battery cell production (Kuhlmann, et al., 2021, p. 8). The support needed by such workers will be significant.

Each of these transition types and related training needs will take place in all automotive job families. As saw in section 3.1, these can be categorized as engineering, procurement, production & services, and sales. The discussion will continue by taking into account employment transitions expected to happen in each of these job categories between 2020 and 2030 (Boston Consulting Group, 2021, p. 65-68).

By 2030, 13 per cent of the engineering job category will have undergone some degree of transition. 3.2 per cent of workers will experience a small transition from within the same industry cluster. 3.3 per cent will undergo a more intense shift. They will have to move to other automotive or adjacent industries. Finally, 6.5 per cent of engineers will be drawn from totally different sectors. All the affected jobs will amount to more than 100 thousand.

Procurement positions will be affected even further. By 2030, 15 per cent of the job family will be the result of transitions. 5.6 per cent will undergo a small transition, moving within the same industry cluster. 6 per cent will experience a large transition. The remaining 3.4 per cent will be injected from outside the automotive industry. The total number amounts to 35 thousand.

The production sector will experience transitions of up to 13.7 per cent by the end of the decade. The main transition types will be small and large, with shares of 5.5 and 7.6 per cent respectively. Only 0.6 per cent of 2030 procurement workers will come from other industries. The total amount of shifted workers stands at more than half a million.

The last considerations regard the sales sector. Less than 10 per cent of sales workers will be affected by job transitions by 2030. This is the relatively less affected category. 5.3 per cent of workers will go through a low-intensity transition. 4.3 per cent will experience a larger transition instead. No external transition is expected to happen.

This sub-section had the aim to briefly discuss a key challenge that automotive employers and workers will have to face in the coming future. The transition to electric mobility and related technological trends will alter the skill sets and job requirements across all occupational categories and automotive industries. Such disruption will require a consistent load of training and re-qualification. Three broad types of transition were identified. Their intensity was determined by the amount of training required to adapt employees to their new position. When considering the four main automotive job categories, every single one of them will undergo a significant transition and retraining. By 2030, a total of 835 thousand job positions will be the product of transitions and consequent retraining. This accounts for almost 15 per cent of the total working force expected in the industry in the same year.

4 Conclusion

This dissertation had the aim to emphasize the all-encompassing impact that electric mobility will have over the coming future. To this end, it dealt with the environmental, economic, and social dimension of the issue. The discussion was guided by up-to-date international organizations reports, studies from renowned consultancy agencies and relevant scholarship.

Electric mobility was proven to bear a very high environmental potential. The diffusion of electric passenger vehicles offers a feasible solution to considerably reduce global greenhouse gas emissions and improve urban living conditions. The transition will entail an increase in energy demand and infrastructure. For this reason, it is of paramount importance that the road transport sector and the energy one become closely interconnected. This coordination will be key in order to exploit the full environmental potential of electric mobility. In fact, the source of energy production strongly determines the positive effects of EVs. The cleaner the energy source, the greater the impact of EVs in helping the planet escape from climate doom.

The electrification of vehicles is an epochal transformation for the industry. The profound structural and operational differences among traditional ICE vehicles and EVs will disrupt the whole automotive supply chain and its market forces. In particular this paper considered the battery supply chain, fossil fuel demand, the fuelling business, and the automotive aftermarket. The first will register an unprecedented demand for battery-related minerals, with consequent social and environmental concerns due to mining activities. Electric mobility is also expected to drop oil demand over the next three decades. This will disrupt the global fossil fuel market and its participants. The fuelling business will undergo huge change. The business model and infrastructure of the sector will be completely transformed. The charging infrastructure will take the upper hand. Some degree of change will take place into the automotive aftermarket too. Here, the transition to EVs will bound the market's expected growth. This is due to the reduced maintenance costs that EVs bear, when compared to traditional vehicles.

Finally, the transition to electric mobility will affect the automotive labour market. The total amount of labour across Europe's industry is not expected to register consistent changes over the next decade. The net impact over job development is estimated to be close to zero. The true transformation will take place within and across industry clusters and job families. Here, the EV transition will radically change the employment composition, bringing along consistent job transitions. These movements of workers will be driven by strong changes in skill requirements and competences. A large training effort will be required in order to cope with such shifts.

In conclusion, the diffusion of electric mobility offers a solution to improve the sustainability of human life on Earth, which is today's paramount priority. The road transport sector is an essential element of our societies. This transition will bear many challenges, on both the economic and social side. The labour market will need a large amount of intervention. The impacts will be considerable and will require effective action from all the stakeholders involved. All these difficulties will be justified by the all-embracing end of achieving a more sustainable society. The original purpose of electric mobility.

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Il mondo di oggi sta affrontando un dilemma senza precedenti. Questo consiste nel conciliare lo sviluppo umano con l'ambiente. Le origini di questo problema risalgono alla storia contemporanea. Le rivoluzioni industriali del diciannovesimo secolo stimolarono i processi di sviluppo che contraddistinguono la nostra epoca. Queste innovazioni erano basate su strumenti dannosi per l'ambiente, come i combustibili fossili, che tutt'oggi rivestono un ruolo chiave. I carburanti fossili sono stati la colonna portante della produzione energetica e del trasporto sin dal 1800. L'essere umano è diventato consapevole dell'impatto insostenibile di tale sviluppo solo nella seconda metà del ventesimo secolo.

I primi passi in avanti furono fatti a partire dagli anni 70 del Novecento. In questo periodo il concetto di sviluppo sostenibile iniziò a prendere forma. Di particolare rilevanza sono la conferenza delle Nazioni unite del 1972 a Stoccolma e il resoconto del 1987, conosciuto anche come "Our Common Future". Nei decenni che seguirono crebbe la consapevolezza che una crescita economica smoderata avrebbe portato conseguenze estremamente dannose per l'ambiente. Il fenomeno più rilevante tra queste è sicuramente il cambiamento climatico.

Il fenomeno è dovuto a una enorme quantità di emissioni di gas serra, come anidride carbonica, metano e gli ossidi di azoto. Questi gas intrappolano il calore all'interno dell'atmosfera terrestre. Questo provoca un aumento delle temperature, condizioni metereologiche più estreme, siccità, l'innalzamento del livello del mare, perdita di biodiversità e altri effetti correlati. Oltre il 75 percento dei gas serra prodotti è riconducibile all'uso dei combustibili fossili. Diversi settori economici sono responsabili per tali emissioni. Quello energetico è quello più rilevante. Infatti, detiene una percentuale di emissioni di gas serra del 73.2 percento. All'interno del settore energetico è incluso quello del trasporto. Questo sottogruppo è responsabile individualmente per quasi il 12 percento delle emissioni serra globali.

Il trasporto è quindi uno dei più grandi fattori coinvolti nel riscaldamento climatico. La maggior parte delle emissioni in questo reparto sono dovute a mezzi comuni come macchine, moto e mezzi pubblici. La centralità di questo settore nel raggiungimento di uno sviluppo sostenibile fu riconosciuta per la prima volta nel 1992 alla conferenza delle Nazioni Unite a Rio de Janeiro. Da quel momento non ha mai lasciato l'agenda internazionale. Oggi giorno è inserito tra gli obiettivi per il raggiungimento di un futuro sostenibile da parte delle Nazioni Unite.

La mobilità elettrica ha origine in questo contesto. Questo tipo di tecnologia offre una alternativa ai veicoli equipaggiati con motori a combustione interna, e quindi dannosi per l'ambiente. I veicoli elettrici non emettono nessun tipo di emissione. Il futuro della mobilità sembra andare in questa direzione principalmente per tre ragioni. La prima è le politiche nazionali e internazionali stanno introducendo incentivi per accelerare la transizione. La seconda riguarda il consumatore. I consumatori stanno diventando sempre più consapevoli nell'utilizzare tipi di mobilità sostenibili. La terza ragione riguarda le industrie automobilistiche. Quest'ultime stanno sviluppando tecnologie sempre più invitanti per consumatori e investitori. La transizione elettrica sarà un processo con impatti ambientali, economici e sociali altamente rilevanti. La discussione inizierà con l'aspetto ambientale.

La specie umana ha bisogno di mettere a freno il cambiamento climatico. Uno studio condotto dall'agenzia Europea dell'ambiente nel 2016 dimostra il grande potenziale della mobilità elettrica nel ridurre le emissioni di gas serra. Inoltre, tale transizione aumenterebbe considerabilmente la qualità dell'aria nelle zone urbane. Tuttavia, questo grande beneficio verrà parzialmente ridimensionato a causa di un aumento di richiesta di energia elettrica. Il bilancio rimane tuttavia fortemente positivo. Un aspetto chiave da considerare è la provenienza di tale energia. Più la sorgente è rinnovabile e sostenibile, maggiore sarà la resa ambientale dei veicoli elettrici. La coordinazione tra il settore energetico e quello dei trasporti risulterà fondamentale negli anni a venire.

Gli impatti economici della transizione elettrica sulla filiera automobilistica saranno molteplici. Il primo da considerare sarà la fornitura di minerali per batterie, come cobalto, litio, rame e nickel. La richiesta per tali materiali aumenterà esponenzialmente nei prossimi due decenni. Questo incremento nella domanda sarà corrisposto da un'adeguata fornitura, senza compromettere la riuscita della transizione. La quantità di risorse presenti sul nostro pianeta è in grado di soddisfare tale bisogno. Tuttavia, la fornitura di materie prime per batterie presenta alcune problematiche. La prima riguarda la distribuzione di tali risorse nel mondo. Solo pochi paesi hanno tali risorse nel sottosuolo. Questa condizione mette singoli paesi al centro del mercato automobilistico globale, con possibili ripercussioni. Un secondo problema è la condizione in cui si trovano la maggior parte di tali paesi ricchi di risorse. Questi, infatti, sono principalmente paesi in via di sviluppo. Un aumento delle attività estrattive in questi paesi comporta problematiche di tipo sociale, economico e ambientale. Tra queste il lavoro minorile, varie violazioni dei diritti umani e la sicurezza sul lavoro. Il recupero delle materie prime attraverso il riciclaggio delle batterie potrebbe offrire delle soluzioni a questi problemi legati alla fornitura. Infatti, il riciclaggio di batterie per veicoli elettrici aumenterebbe la stabilità, sostenibilità e responsabilità etica della filiera per veicoli elettrici.

Il secondo impatto economico di rilevanza sarà quello riguardante la richiesta di combustibili fossili. Nel breve termine la transizione elettrica non impatterà la richiesta globale per il petrolio. Questo perché il trasporto su ruota ricopre un ruolo importante ma tuttavia parziale nella domanda globale. Inoltre, l'andamento di alcune variabili come la popolazione mondiale e la crescita economica determinano un aumento della richiesta per petrolio. Nel lungo termine la situazione cambierà. Una volta che quelle due variabili subiranno un rallentamento, la richiesta per il petrolio diminuirà. Nel corso dei prossimi tre decenni tale richiesta è infatti destinata a ridursi. Uno dei fattori determinanti di questa diminuzione sarà la diffusione della mobilità elettrica.

Il terzo impatto economico considerato è quello riguardante il settore dei rifornimenti per veicoli e le infrastrutture di servizio. La transizione elettrica cambierà fortemente la natura di queste attività economiche. I veicoli elettrici necessitano di una vasta infrastruttura per essere utilizzati efficacemente. Le stazioni di servizio tradizionali dovranno fornire servizi non richiesti in passato. La disponibilità di punti di ricarica è fondamentale per il successo della mobilità elettrica. Un sondaggio effettuato nel 2021 conferma che quasi tutti le compagnie del settore sono al corrente di tali bisogni infrastrutturali e stanno pianificando di soddisfarli. Nei prossimi anni il settore del rifornimento per veicoli soffrirà una decrescita dovuta alla diminuzione dell'acquisto di carburanti. Nonostante ciò, i servizi necessari ai veicoli elettrici stimoleranno un'opportunità interessante per le compagnie del settore.

L‘ultimo aspetto economico considerato riguarda il mercato dei ricambi. Le previsioni suggeriscono una crescita di questo settore nei prossimi anni. Tale crescita verrà tuttavia ostacolata dalla diffusione di veicoli elettrici. Quest'ultimi, infatti, necessitano di minore manutenzione e ricambio di componenti. Le motivazioni di tali caratteristiche sono riconducibili alla grande differenza di funzionamento dei veicoli elettrici rispetto a quelli tradizionali. I primi hanno circa 20 componenti in movimento quando in funzione, mentre i secondi più di 2000.

La discussione adesso riguarderà l'impatto sociale che avrà la transizione elettrica. La preoccupazione principale in questo ambito è il mercato del lavoro. L'industria automobilistica garantisce milioni di posti di lavoro a livello mondiale ed Europeo. Questo settore sta attraversando una forte rivoluzione dovuta a fattori come la digitalizzazione e la mobilità elettrica. Avverrà un forte cambiamento nelle competenze e nelle abilità richieste per lavorare in questo settore

Uno studio condotto dal BCG in 2021 in Europa identifica cinque fattori di cambiamento nel mercato automobilistico del lavoro. Questi sono la transizione elettrica, il volume di mercato, l'evoluzione tecnologica, la combinazione dei prodotti, o "product mix", e la produttività. Questo studio inoltre distingue sette sottogruppi industriali e quattro categorie lavorative all'interno dell'intera industria automobilistica europea. I sottogruppi industriali comprendono quattro settori centrali e quattro settori adiacenti. Ogni singolo fattore di cambiamento avrà effetti specifici in ogni sottogruppo industriale e categoria di lavoratori. Il bilancio complessivo di queste variabili lascerà il totale dei lavoratori impiegati nel settore automobilistico praticamente invariato alla fine di questo decennio. Il numero totale di lavoratori tra il 2020 e il 2030 rimarrà quasi invariato.

Questa conclusione nasconde cambiamenti molto più considerevoli che avverranno nelle singole categorie lavorative e sottogruppi industriali. I settori che soffriranno maggiormente per i cambiamenti in atto saranno le attività centrali dell'industria, come i produttori di apparecchiature originali e i fornitori di componenti per motori a scoppio. Nel 2030 i settori centrali dell'industria registreranno una perdita lavorativa complessiva del 5 percento, rispetto al 2020. Al contrario i settori adiacenti dell'industria automobilistica, come la produzione energetica, l'infrastruttura energetica e il riciclaggio di materiali, registreranno una crescita considerevole nelle opportunità di lavoro. I settori limitrofi registreranno complessivamente una crescita considerevole del 34 percento. Per quanto riguarda le quattro categorie lavorative menzionate precedentemente, il gruppo ingegneristico registrerà un aumento notevole, come il settore dell'approvvigionamento, o "procurement". Il numero di lavoratori addetti alla produzione rimarrà pressoché invariato. Al contrario, la categoria dedicata alle vendite subirà una riduzione considerevole.

Un ultimo fenomeno molto rilevante da considerare sarà la transizione di lavoratori tra industrie e categorie lavorative. La mobilità elettrica stimolerà un grande volume di movimenti lavorativi attraverso tutti i settori dell'industria automobilistica. Questo fenomeno è dovuto al cambiamento che la transizione elettrica comporterà in quanto a competenze richieste e abilità necessarie. Molti lavoratori dovranno essere riqualificati e sottoposti ad una intensa formazione. Una grande componente di ogni categoria lavorativa sarà soggetta a transizioni lavorative. Il 13 percento del gruppo ingegneristico dovrà avere a che fare con transizioni lavorative. Similarmente tutte le altre, dove la percentuale non si abbassa sotto al 10 percento per ogni categoria.

Lo scopo di questa tesi era quello di sottolineare il grande impatto che la transizione elettrica avrà nel prossimo futuro. I cambiamenti avverranno attraverso tre dimensioni. Quella ambientale, economica e sociale. La discussione è stata guidata da relazioni da parte di organizzazioni internazionali, società di consulenza internazionali e articoli accademici. La transizione elettrica comporterà molteplici cambiamenti e problematiche. Queste difficoltà saranno giustificate dal raggiungimento di una società più sostenibile. Lo scopo originario dei veicoli elettrici.